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AN INVESTIGATION INTO THE BEHAVIOURAL AND TECHNICAL FACTORS AFFECTING SUCCESS IN THE USE OF NETWORK ANALYSIS IN THE CONSTRUCTION INDUSTRY OF GREAT BRITAIN

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A Doctoral Thesis

submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy of the Loughborough University of Technology June 1973

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CHAPTER 1 INTRODUCTION

Network analysis techniques have been used for planning purposes in the construction industry for over a decade. They have been used with various degrees of success by the client to control the progress of his job, by the architect (or consultant) to plan the design phase of the project, and finally, by the contractor to prepare his pre-tender and contract programmes. This study is concerned about the factors which contribute to higher success in the use of network analysis techniques in contracting organizations.

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The construction industry is of special significance when network analysis applications are considered because it has pioneered the use of network techniques in commercial (rather than military) areas and still is the major user. Apart from this aspect, the British construction industry occupies a large part in the national economy: in 1971 it contributed 7% of the gross national product compared with approximately 5% for the mechanical engineering industry which is the largest manufacturing industry.

The high annual increase in the construction workload — which averaged 4.5% during 1959-1969 — the chronic shortage of labour force and the increased technological complexity of projects bring about a strong need for efficient management methods at all stages of the construction process.

Network analysis was brought into use in the early 1960's and was thought to provide a means of achieving a major advance in the efficiency of the British construction industry. During the next decade it developed with an increasing speed, especially as it became linked to developments in computer technology — including both software and hardware. Today, however, there are signs of some disillusionment and its use is thought by some people to be declining.

Several surveys have been carried out in this country, in Norway, and in the USA, to determine, among other things, the extent to which network analysis is being used in the construction industry and in other industries. The results suggest that network analysis is not used as extensively as one would expect of a technique which has been praised so highly by the great majority of writers on the subject. Discussions with users indicate also that interest is falling off. One author refers to network analysis as a "pseudoevent" and speaks of its "decline". Thus, some commentators characterize the history of the use of network analysis as reaching an enthusiastic boom in the mid 1960's, followed by a plateau and possibly a decline. The aim of this exercise has been to find out the reasons for this disappointing history by means of empirical methods.

There is a remarkable consensus among writers that the basic principles of network analysis are quite sound. There are a number of papers which are critical of the PERT algorithm, but there seems to be no criticism whatsoever of the deterministic approach to network calculations (*). Moreover, the mechanics of constructing a network and calculating the CPM parameters have occupied a large portion of the current and past literature on network analysis.

(*) As it will be reported in a later chapter, no organization in the sample used in this study employed probabilistic networks.

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But no systematic attempt has been made at empirical level to search for a relationship between these various methods of applying network analysis on the one hand and the conventional means of measuring success (namely profitability and efficiency) on the other. A major reason for this is that it is an extremely difficult task to determine the contribution made by any management technique to the overall profitability and/or efficiency of an organization.

It is noted that a number of authors have mentioned the necessity to look into human relations, behavioural aspects and organizational aspects in network applications, albeit in a rather speculative fashion. These attempts to explain success or failure in network applications provide an indication as to the direction an empirical study could take.

The idea behind the approach used in this study is that "success" in network applications — which is difficult to estimate in the conventional terms of profitability — should be viewed as the degree to which the technique is up to the expectation of different people occupying different positions in the organization. The hypothesis has been put forward — and tested by means of questionnaires and interviews — that "success" as defined above, is closely related to a number of factors which include not only the way it is applied, but also the way it is introduced and the environment in which it is used.

Chapter.II (Development of the Hypothesis) describes the efforts made to diagnose the factors likely to affect success in network analysis applications. In Chapter III (Theoretical Background) a detailed explanation is given about the theory behind these factors. Chapter IV (Methodology) indicates how the study was

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conducted. The results of the main field survey and discussion of the findings in the light of the information collected in the feedback survey are given in Chapter V. The last chapter, Chapter VI, contains the conclusions.

CHAPTER II.

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DEVELOPMENT OF THE HYPOTHESIS

1. The construction industry:

"I tell this tale, which is strictly true, just by way of convincing you. How very little, since things were made, Things have altered in the building trade".

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A Truthful Song by Rudyard Kipling. In the same book where Sir Norman Longley quotes these lines by Kipling, Professor Denis Harper (1) states that: ".... the performance of buildings has not improved over the years, and all connected with the design and management of construction are less reliable than they need to be".

This view is also shared by a number of authors (See e.g., 2,3). The construction industry, (i.e., the building <u>and</u> civil engineering industries), is therefore rather conservative when compared with manufacturing industries. It also differs from many other industries in a number of ways. Stone (4) defines construction as "an assembly industry, assembling on site the products of other industries".

The construction industry has the following features: It is one of the most important activities in any economy.

a) In 1971, it contributed 7% of the gross national product compared with 35% for all manufacturing industries (including building materials which are themselves estimated to contribute nearly as much again as the construction industry),
11% for the distributive trades, and 6% for transport. The largest manufacturing industry, mechanical engineering, contributes approximately 5% (5).

- b) In 1971, investment in new building and works accounted for over 50% of total investment (5).
- c) It accounted for 6.5% of the total UK employees in employment in June 1969 (5).
- d) The annual growth rate of new construction averaged 4.5%
 during the ten years between 1959 and 1969 (5). Prospects
 for 1973-74-75 are also estimated to be quite high (6).
- e) Productivity, measured as output per head, has increased at an annual average of 4% over the ten years between 1956 and 1966 (7).
- The net return on capital employed in construction for those public companies which published their reports during 1969 was 15.5% compared with 15.0% for all industrial companies and 13.0% for all companies (5).
- 3. The return on turnover in construction is lower than in other industries (5).

4.

- In 1969, it spent only 0.5% of the value of its output in research (5) which is much lower than for other industries. Because of their larger average size, civil engineering companies are able to do rather more research (e.g., into site organization and planning) than relatively small builders. The results of such work, however, tend to stay with the companies which have done it rather than being gradually disseminated so that the construction industry as a whole could benefit (8).
- 5. The construction industry is sharply divided between design on the one hand (architects, consulting engineers, and quantity surveyors) and production on the other (builders, civil

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engineering contracts, and sub-contractors).

6.

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The Emerson Report (9) and several others (7,8,10,11,12) state that the construction industry does not create a demand for its services and that its capacity is governed by necessity, the level of economic activity and Government policy. Consequently, the amount of work is liable to fluctuate. The Government have a crucial role in determining both demand for the industry's output and its growth prospects, the reasons being that public authorities buy over half its output (5) and because credit policies, investment incentives and general economic measures have a powerful influence on the demand for private housing, industrial and commercial building.

In one of a series of articles on the "Economic Aspects of Building" Ward (13) gives a comprehensive description of possible Government policies to regulate the national economy by means of affecting demand in the construction industry. This "stop and go" policy which has been used time and time again by successive Governments (and which presumably will be used by future Governments) has been largely criticized (8,11) for creating the uncertainty that exists within the industry. A survey by The Builder in 1962 (8) has claimed that it created uncertainty and sapped confidence which discourages building owners from starting new projects, material producers from installing new capacity, good managers and skilled labour from entering the industry; precludes the use of market research and long-term planning; and discourages expansion and adoption of new techniques. But, Lewis & Singh (11) put forward this defense: "However much we may criticise Government, we have to

realise that the task of driving an economy along a precariously balanced path of growth, with inflation, balance of payments problems and bankrupcy on one side, and massive unemployment on the other, is far from easy".

The achievement of economy and higher efficiency in the construction industry is therefore of considerable importance to the industry itself, to the national economy, to clients and to the community. There is no single way of achieving economy however. Rationalisation is necessary at every stage of the construction process including both design and production; and one such stage is production planning with which this study is concerned.

2. Literature survey related to network analysis planning and control:

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Before designing the questionnaire to be used in the survey of a number of contracting organizations, it was found appropriate to review the past and existing literature on network analysis to find out about the evolution, the general characteristics, and the advantages and disadvantages of using this technique. The literature survey which was initiated by a few bibliographies by Bigelow (14), Lerda-Olberg (15), Dooley (16) and a number of other writers is reported in the following sections and in the following chapter.

2.1. Short historical background:

After the publication of the two famous and by now almost classical papers by Malcolm, Roseboom, Clark & Fazar (17), and Kelley & Walker (18) in 1959 the evolution of network analysis techniques did not follow a straight ascending line.

In the early days of its inception, network-based planning techniques were received with great enthusiasm by potential users. Stories of how PERT was successfully employed by the US Navy in the Fleet Ballistic Missile Program (the development of the Polaris Weapon System), of how CPM was successfully used by Du Pont de Nemours (19), and of how much savings in time and cost were achieved in various projects were described in a multitude of papers, articles and textbooks (See e.g., 20,21,22,23). The following years saw the development of a plethora of variations and extensions of the original PERT and CPM, and they were called by acronyms such as: CSPC (Cost and Schedule Planning and Control), PEP (Program Evaluation Procedure), PERT/COST, PERT/TIME, SCANS, PEST, CPS (Critical Path Scheduling), RAMPS (Resource Allocation and Multi-Project Scheduling), GRASP (General Resource Allocation and Scheduling Program), PCS (Project Control System), PMS (Project Management System), MPM (Metra-Potential Method, French), BKN (German), RPS (German), LESS (Least-Cost Estimating and Scheduling), CPA (Critical Path Analysis), SCOPE (Schedule, Cost, Performance), GERT (Graphical Evaluation and Review Technique) to name but a few.

This explosive growth of the literature in the 1960's can partly be attributed to the quick development of the computer technology in both the software and hardware fields, and partly to the over-enthusiastic initial selling of the technique as a panacea to all management problems.

The later parts of the 1960's are marked with a certain amount of discrimination (24,25), disenchantment and disillusionment (24,25,26,27,28). A survey carried out in USA indicates that contrary to what people used to believe not all large companies use network analysis and that only a small percentage of user firms feel that they are very successful in achieving the numerous benefits attributed to the use of these procedures (29). Vazsonyi (30) indicates in his humerous article that this "decline", as he calls it, is partly due to the wrong image — which he later calls a pseudoevent — that was generated by the initiators about the potential benefits of network analysis.

The situation in Great Britain has developed in a very similar pattern to the one described above. It seems that after the enthusiastic approach in the early 1960's, the use of network analysis in construction companies has reached an optimum which is, in fact, far less than what the advocates of this technique would expect. There have been two major surveys in the UK construction industry, one by Wade (31) and one by MacDonald (32) which indicated that 58% and 64% of the companies used some sort of network analysis respectively. At first glance, these percentages may seem to be quite large, but if one considers that the extent to which each company uses these techniques is around 45% (See Chapter V, Section 4.4), then, it will be clear that the value of the work planned with network analysis is not high. Furthermore, the information collected during this research study indicated that there has not been any significant increase in the use of network analysis over the last five years (See Chapter V, Section 4.4).

One of the aims of this research project was therefore to develop an analytical framework which would later be used for an empirical study to find out the reasons for this disappointing history.

2.2. The cost of using network analysis and its effect on profitability:

Part 1, in Appendix C is a review of the literature related to the cost of network analysis as reported by a number of authors. The figures given are in some cases estimates and speculations (22,33,34,35,36); in some cases the result of organized field surveys (37,38,39,40,41); and in some cases the result of cost measurements in individual experimental projects (39,42,43,44,45).

To measure the cost of implementing network analysis in a project is not a very difficult task. The assessment of data processing and network engineering costs are quite straight forward. Appendix C, Part 1 indicates that, apart from a few extreme cases, such as 5% reported by Frambes (46) and 2% reported by Pacaud (43), the cost of

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implementing network analysis seems to vary between 0.10 and 1.00% of the total project cost. Miller (47) reckons that the real amount depends on the degree of planning capability available in the company, on the effectiveness of the organization, and on the amount and quality of network analysis indoctrination given.

But, when a manager or a board of directors is about to decide whether to replace the existing conventional planning system by network analysis, the vital information that is necessary is not cost, but rather a cost/benefit analysis of the new technique. What does the technique cost to install and to operate? What does it offer in return? Do the returns justify the cost? These are the questions that need answering. Part 2 and Part 3 in Appendix C review the time and cost savings reported by various authors. Apart from a few individual examples reported by Pocock (21), there have been no systematic attempts to determine whether the cost of network analysis is justified by the returns. The literature is full of speculations, hearsay, and rumors that network analysis produces considerable savings. The vast majority of authors accept explicitly that these alleged savings very much warrant the use of network analysis techniques. It is generally claimed that the size of intengible benefits such as improved communications, better efficiency, higher confidence, and so forth are in themselves self-evident and large enough to validate the preceding statement. Users in Britain seem to feel the same way because they generally insist that they would not have used network analysis if it were not profitable (48). But none of them is able to quantify the additional benefits obtained. Indeed, a study of planning and programming carried out for the Ministry of Public Buildings and Works (49) state that these

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techniques do not provide the facility to see the cost implications of planning decisions. In a survey of network analysis implementation by large American contractors carried out by Davis (29) it was found that only 13% of the companies in the sample had reported definite cost savings. A number said that they probably made some savings but had no supportive data. The truth of the matter is that it is an extremely difficult task to determine the extent to which a management technique (network analysis or any other management technique) contributes to the profitability of a company. Accountants with whom this issue was discussed stated that the results of such an exercise would be most unreliable because of the multitude of factors influencing overall profitability, and their complex interrelationships.

A brief conclusion to this sub-section is that although some, perhaps most writers and users believe that network analysis contributes positively to the profitability of a company, no-one really knows the extent to which (or whether or not) this is true. But, as the survey by Booz Allen Applied Research Inc. (39) has found out, the cost of using network analysis has not been a major deterrent in its There are also those like Ross (50) who argue that return on use. investment or some similar ratio is not a valid criterion for deciding whether to install a management system, and that some sort of weight should be given to the less tangible benefits in making the decision. So, what is it that prevents this technique from being used extensively? What are the reasons for - not reported, but certainly a large number of -- failures, if it is not cost considerations? The following chapter will give the theoretical background to the analytical framework proposed to understand better the phenomenon created by the use of network analysis.

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2.3. Observations on the literature on network analysis

It is the rule rather than the exception that most of the earlier papers and textbooks on network analysis contain a section describing the advantages of network analysis and sometimes, but seldom, the disadvantages. There seems to be general consensus on the point that network analysis is a much better and advanced technique than conventional bar-charts and that the advantages of using it far outweigh its disadvantages. A review of the literature indicated that the items listed in Appendix D are the most commonly mentioned advantages and disadvantages of network analysis.

It is interesting to note that the most frequently mentioned advantage is the ability of applying "management by exception" by concentrating on critical activities. Moder & Phillips (51) indicate that critical activities account for only 15% of the total number of activities. That means, network analysis would not only reduce considerably the load of the manager, but also would provide the possibility for much better and efficient control.

An underlying feature of the literature on network analysis was found to be its emphasis on the application procedures of the system. The majority of books and articles right until the late 1960's dealt solely with procedural aspects such as; how to draw a network; whether to use arrow or precedence diagrams; how to make the calculations; whether to update the programme or not; how, and with what frequency to update it; how to present the final results; whether to use computer programs or not; etc., etc. Two typical examples of this sort of approach can be seen in a textbook by Lockyer (52) and an article by Nuttall & Jeanes (53). This sort of literature generally recommeds that the user should: 1. Update the programme regularly.

- Avoid too much detail but use the capacity of the technique to have a well detailed programme with sub-networks where appropriate.
 Use a computer program if the size of the network is large enough.
- 4. Use network analysis for planning and for controlling the job.
- 5. Use network analysis on time-limited rather than resource-limited projects.

There are however different opinions on:

- 1. Whether to use arrow or precedence diagrams.
- Whether to present the results in network, bar-chart, or some intermediate compromise form for site use.
- Whether to disclose float values associated with each activity to all site staff members.

These aspects will be described in detail in the following chapter under Section 2, Methods of Application. The point is made in this sub-section that the general literature on network analysis abounds with textbooks, articles and papers which mainly deal with these sorts of procedural characteristics.

It must also be noted, however, that some authors such as Miller (22), Archibald & Villoria (39), Walton (44,54), Reynaud (55) and a number of other writers have mentioned the necessity to look into behavioural, organizational and human relations aspects in network applications, albeit in a rather speculative fashion. The general point of view is that:

 Full support from top management and clear policy statements are necessary.

2. All concerned with network analysis must have a clear understanding

- of what the technique is and of what it can achieve.
- 3. Resistance to change and inertia are always present when a new technique is being introduced.
- 4. The organizational structure necessary for applying network analysis may clash with the existing structure.

A detailed discussion of these aspects is made in the following chapter. For the purpose of this sub-section it will suffice to note that none of the articles, studies, or books mentioning the above-cited observations, has been written as a result of an empirical exercise carried out within an explicit framework. They provide, however, an indication as to the areas an empirical study should cover.

A review of the literature shows therefore that no writer doubts that network analysis is a more useful technique than conventional bar-charts and that the basic principles are sound enough not to require extensive investigation. It also shows that the majority of authors tend to concentrate on methods of applying the technique while only some of them mention the need to take into consideration the behavioural and organizational aspects as well.

3. The case study and the preliminary field survey:

In the early stages of this research project it was decided that the first steps in tackling the problem should involve not only a comprehensive literature survey to determine what has been said about network analysis, but also an initial practical study covering a few companies to determine what users in the industry think of the technique.

With this purpose in mind a contracting organization was approached and access to every member of staff was obtained. The company, had an annual turnover of over £10 million, was a public company, and had subsidiaries in three large cities. They had been using network analysis since 1963 with various degrees of success, and had a clear company policy to plan as many projects as possible by network analysis, but to use computer programs only when required contractually. The managing director, the director in charge of planning and construction, the chief planning engineer, the training officer, a contracts manager, a planning engineer, and two agents were interviewed. The interviews were conducted by means of a loosely designed check-list (See Appendix E, Part 1) which permitted discussion on aspects which were found to be of importance by the person interviewed. As a matter of fact, the very purpose of this exercise was to determine the factors regarded as important by the staff of a user company. The case study is described in detail in Appendix E, The most important findings of this study, worth mentioning, Part 2. have been selected and are reported below:

 Enthusiasm in network analysis was highest in the director in charge of planning and construction, because he was the one who introduced it into the company; it was naturally supported by

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- the planning department, but this support was fairly low in the case of agents. There was even resistance on the part of the contracts manager who was interviewed.
- 2. The fact that the branch visited had been making more profit/ turnover than the other branches (none of whom used network analysis) was attributed by the planning department to the successful use of network analysis. The rest of the respondents with only one exception were more cautious, but nevertheless expressed their belief that network analysis increased profits in some way. The only respondent who did not see any economic justification was the contracts manager.
 - There was an open intra-organizational conflict between the planning department and the contracts managers. While contracts managers saw no benefit at all in network analysis planning, the planning department was seeking more line authority with an open aim of abolishing the office of contracts management and integrating its duties in the person of individual planning engineers in charge of different projects.

3.

 The planning department was not a purely consultative department to site managers; it was very much above the site manager, more in the same level as contracts managers and having a direct reporting link to the director in charge of construction.
 Although training programmes had been run for all the site management staff, people on site were interested only in a barchart. All networks were transformed into bar-charts for site use.
 There was a definite and well defined difference in the attitudes of site management and the planning department towards planning in general and network analysis in particular. Whereas planning

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engineers were quite enthusiastic about network analysis, site managers were only interested in bar-chart transformations. It can be said that network analysis was being used only in the planning department.

Following this study of network analysis usage in a single company, a preliminary survey of a number of companies was undertaken in the light of the information gained in the case study. The loosely structured check-list was this time completed with a number of specific questions for each item, but always in an open, loosely defined form, thus again allowing persons interviewed to express themselves freely on related aspects as well. Appendix F contains a copy of the check-list and of the questions developed for each item during the case study. A synopsis of the replies follows each question.

In the preliminary survey, a total of 31 contracting organizations were approached by a letter to which was attached a one page circular signed by Professor E.G. Trimble (See Appendix G). Of these, 5 did not reply at all, and 5 others wrote back saying that they were not interested. The rest, 21 companies, agreed to co-operate. Later, bearing in mind that this survey would only be a preliminary one and after taking the time factor into consideration, the size of the sample was reduced to 10 companies. Sampling procedures are described in Chapter IV, "Methodology".

The sample for the preliminary survey was formed of 2 civil engineering contractors, 4 building contractors, and 4 building and civil engineering contractors. Annual turnover figures for 1969 ranged from £4.5 million to £56.0 million with an average of £15.7 million. The number of people employed by each company ranged

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from 146 to 10,711 with an average of 3479 employees. Five of these companies were situated in the Midlands, three in the North and two in the London and Southern areas.

A total of 29 people were interviewed in the preliminary survey, with a minimum of 2 persons, one planning engineer and one site manager, in each company. The length of interviews ranged from 30 minute talks with managing directors on aspects of planning policy, to 3 hour interviews with planning engineers about all the details. The overall average was 1 hour 20 minutes.

Two of the 10 companies contacted, did not use network analysis at all. The remaining 8 companies used it in as little as 2-3% of their projects to as large as 99%. The answers to the questions are given in a brief form after each question in Appendix F.

The major points that are worth mentioning and which had considerable effect on the design and compilation of the final questionnaire used in the main field survey, are given below in a brief form:

- Most companies used time and resource analyses by networks. All of them used arrow diagrams, and none of them used multiproject-scheduling, cost optimization (time-cost trade-off), and with the exception of one company, cost analysis.
- 2. Resource analysis was generally carried out manually on a barchart translation of the final network; and it was generally carried out for the entire period of the project. In most cases, this analysis provided the basis for allocating float to activities.
- 3. The majority of companies expressed the view that network analysis was a better technique than bar-charts especially for complex jobs.

Most of them used sub-networks for complex activities and all of them transformed their final results into a bar-chart form mainly for site use. None of them employed time-scaled networks, but some of them tried logic-linked bar-charts.

4. Five of the companies believed that network analysis was economically justifiable whereas the remaining five (who include the two non-user companies) believed it was not. All companies admitted that when network analysis was introduced, they expected a rise in their profits as a direct result. Not only were they not able to say exactly how much network analysis contributed to their profitability, but they had also no idea of how much network analysis cost as a percentage of total project costs. All companies agreed however, that network analysis formed a better basis for claims.

The introduction of network analysis was invariably forced by one interested man in the company. It was not generally initiated by contractual compulsion. The first ever network was computed manually in the majority of companies. At the time of the survey, all companies believed that there would be no increase or reduction in the near future in the extent they were using network analysis.

5.

6. It is with the introduction of network analysis that half of the companies acquired a central planning department. The other half had a planning department already. In the large majority of companies, the planning department had a lateral or consultative authority, could make only minor alterations in the network, but reported directly to top management. Half of the companies believed that the introduction of network analysis had reduced,

to some extent, the site manager's authority. In the large majority of companies, there were no regular internal courses on network analysis, although such courses were run in some of them, from time to time. Staff members ranging from directors to site supervisory staff were also sent to external courses, from time to time. Opinions about whether formal training courses served their purpose were divided. Whereas half of them thought they were useful, the other half restricted their answer to "very moderately useful". Site managements were generally formed of ex-tradesmen as opposed to qualified engineers. Whereas planning engineers believed that with a better qualified site staff they would have got better results in network analysis applications, site managers complained of insufficient site experience in most planning engineers. Although, in the large majority of companies there were no resident planning engineers on site, it was stated that there was continuous contact between the site and the planning department, starting after the award of the contract and continuing through the construction phase. But, time estimates were prepared only by the planning engineer in half of the companies. It was also stated that time estimates given by sub-contractors were in general less correct than those given by planning engineers.

Network analysis was used for forecasting and for control by all companies in the sample. There was no problem of network analysis being integrated with other management techniques, because it was carried out quite independently of any other technique.

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7.

8.

9.

- 10. Updating was generally found to be very cumbersome and timeconsuming but was nevertheless carried out regularly by half of the companies, and when felt necessary by the other half. The initial input for a computer program was generally found to be very complicated and time-consuming. But, loops and overlapping activities presented no problem at the planning phase.
- 11. There was no participation whatsoever on the part of site managements to the decision whether to introduce network analysis or not. In none of the companies, was it stated that, management took proper notice of the problems and requirements of site staff before deciding to introduce network analysis.
- 12. It will be noted that replies to the questions are reported in Appendix F in terms of companies. No differentiation was made among different respondents in the same company and the predominant view was reported to be the view of the company. However, while compiling this information from the transcripts of the interviews it was noted that the inevitable difference of opinion among various respondents did exist, but that these differences were particularly marked between planning engineers and site managers.

4. Need for the study and its objectives:

In Section 1, in this chapter, it has been briefly shown that the construction industry is one of the most important industries in the national economy of the United Kingdom and that attempts to rationalize any aspect of the construction process from the design phase to the handover of the construction to its clients should be welcomed.

Section 2 gives an idea of the evolution and characteristics of network analysis as described by the majority of writers on network analysis. It seems that the use of network analysis has not increased as expected, and indeed, fears of decline are expressed. The majority of writers have tended to concentrate on the application procedures of the technique while only a few made allusion to its behavioural and organizational aspects. There is general agreement that the basic concepts of the technique — such as critical path, float, etc. — are sound. Although no writer is able to quantify the contribution of network analysis to the profitability of a company, its cost does not seem to be a deterrent.

There have been two major surveys of network analysis applications in this country by Wade (31), and by MacDonald (32). The Bureau of Building Marketing Research (56), Frambes (46), Schoderbek (57) and Davis (27,29) in the United States, and the Norwegian Building Research Institute (58) in Norway attempted also to find out the facts about network analysis. It would be fair to say however, that none of the studies mentioned above tried to examine the factors that make network analysis applications more successful in certain organizations than in others. Up to now, there has been no systematic attempt to find out why the use of network analysis has not boomed as anticipated and what makes certain companies stick to network analysis while others reject it. The only exception is Davis (29) who asked top management whether they found network analysis applications in their company successful or not, and then based his analysis on this single subjective assessment of the situation.

One reason why any such study has never been carried out is the sheer impossibility of measuring the effects of network analysis in the conventional terms of profitability and efficiency. It was as late as 1965 when an author — Schoderbek (57) — finally raised the subject of success measurement in network analysis applications. He concluded that the evaluation of success would be extremely difficult to do in any other manner than on the basis of subjective judgement.

The purpose of this study was therefore expressed as follows in the early stages of this project.

- 1. To develop an analytical framework to measure success in network analysis applications which would be based on the subjective assessment of the situation by individuals occupying key positions in the application of network analysis.
 - To determine the most important factors which are likely to affect success in network analysis applications, and to organize them in a quantifiable system.
 - To select a sample of network analysis user companies, to administer questionnaires, and to conduct interviews in order to get the information mentioned in the preceding two items.
 And finally, to analyse statistically the data so obtained in order to find out the relationships that exist between success in using network analysis and the other factors, and interpret
the results.

1.

2.

The contribution of the literature survey, of the case study, and of the preliminary survey towards the final investigation has been of importance. It was during and immediately after the two initial studies that the following were decided with the help of the published literature:

The only way to measure success in network analysis applications is by recording subjective assessments of the situation. It is true that subjective assessment methods have obvious disadvantages and limitations. Faced with the impossibility of measuring network analysis's value in objective terms of contribution to profitability, it was decided that subjective assessment methods provided the most realistic solution to the problem. Supportive information about this aspect is given in Chapter III, Section 1. There are definitely differences of view and opinion between those preparing the network and those actually using it, because they occupy different positions in the management structure and because they have different values and expectations. Top management's views also differ from those of planning and site staff for the same reasons. However, time considerations and difficulties in gaining access to top management forced the author to consider in the final investigation only the two parties most directly involved - the planning engineers and the site managers.

3. The factors which are likely to affect success in network analysis applications are not formed solely of application procedures, but also contain contextual factors (such as the size, specialisation, general policy, expansion trend, etc. of a company), organizational

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factors and factors related to the conditions existing when the technique was introduced. The preliminary studies convinced the author that it would be totally wrong to look into this problem by considering only a few factors most commonly mentioned by the literature. A study of this kind should cover all possible aspects that were shown to be affecting network analysis applications in the preliminary studies.

CHAPTER III THEORETICAL BACKGROUND

1. Success in network analysis applications and the analytical MODEL:

The degree to which a business organization is successful is normally measured by assessing the degree to which it has achieved its objectives. As to what these objectives are and/or should be, there are many different opinions.

According to accountants (See e.g., 59,60,61), profit maximization is and should be the main objective of business organizations. They usually find that "profitability" or "return on capital employed" is a good, convenient yard-stick to measure success.

The concept of profit maximization as a primary objective of business organizations has however, come under increasing and continuous criticism by many economists in the last decade. According to Solomon (62), the concept of profit maximization in its original form was simply "the logical extension of the legal concept of a business entity within a system based on private property rights and freedom of enterprise". In such a system, it was expected that owners would manage their businesses for their own maximum profit. Indeed, Adam Smith (63) states: "I have never known much good done by those who affected to trade for the public good. It is an affectation, indeed, not very common among merchants". Solomon (62) claims however that this "affectation" is quite common nowadays and that it is in fact an integral part of the newer managerial ideology. In this ideology, the owner-manager interested solely in his own gain has been replaced by the professional manager who serves not only the owners' interests, but also those of all parties connected with the

enterprise, including employees, customers, suppliers, the management, etc. In this newer ideology, Anthony (64) indicates that the concept of profit maximization is not a valid assumption to explain either how businessmen actually behave or how they should behave. He believes that, in this context, profit maximization is unrealistic, difficult, inappropriate and immoral. In its place, Solomon (62) suggests service, survival, sales, personal satisfaction, and "satisfactory" profits.

In his discussion of the profit maximization assumption, Koplin (65) proposes that the objective of a firm is maximizing profits and that the objective of managers is utility maximization. For an owner-manager, profit maximization accompanies utility maximization. But, utility maximization by managers does not imply profit maximization by the firm in cases where ownership and management are separated. In such organizations, there are indeed extensive opportunities for managers to increase their returns at the expense of company profits. Moreover, cases of conflict of interest between managers and owners are also quite frequent. For example, Blois (66) explicitly accepts that profit maximization is a firm's shareholders' objective, but not the objective of the firm's management. It seems therefore that Koplin's (65) and Blois's (66) analyses of the profit maximization concept reinforce Anthony's (64) view that in modern, large and public companies this concept is rather unrealistic.

The financial performance of a company is generally measured by a number of economic criteria derived from financial information. Beardsall (67) gives in her "Notes on the Ratios" a good description

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of the most popular criteria. It must be noted that these criteria are all measures of "profitability" and/or "efficiency". But the wisdom of using this sort of performance criteria is questioned by Hunt (68) who in his paper submitted to the seminar organized by ORS & UCL, in 1970, on "Economic and Financial Statistics for Construction Industry Decision-Making", says:

- "At the time of writing, it can be said that in the United Kingdom: a) there is no agreed method for measuring "productivity" in a firm, or group of firms, or at national level,
- b) confusion still exists in the minds of economic specialists and building managements over the meaning of the terms
 "output", "productivity", "productive efficiency",
 - "production", and "profitability", and their significance for measuring the trading performance,
- c) as yet, no uniform bases have been recommended for compiling the cost and financial accounts of construction companies of different types and sizes,
- d) there is much more agreement on the technical and management steps to be taken to raise productivity (as yet undefined), but no indication has been made on how to measure the success achieved in applying the recommended measures; i.e., other than in terms of "profit on capital invested" or "higher wages",
 e) general support is given to the view that productivity cannot however be raised so long as there is continued reluctance to introduce technical changes, and resistance to productivity improvements by all types and sizes of firms."

Furthermore, it has been stated in Chapter II, that the best way to decide whether to switch to a new management technique must

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depend on a cost/benefit analysis taking into consideration all the possible costs and all the tangible and intangible benefits. It is this sort of calculation that ultimately leads to an assessment of the extent to which the technique contributes to the overall profitability of a company. It has also been shown, in the same chapter, that this sort of calculation is not only impractical but also almost impossible. Hunt's ideas (68) seem to reinforce this point of view.

To summarize what has been said in this section: successful companies are assessed by the degree to which they achieve their objectives; the most commonly accepted objective is profit maximization; but profit maximization does not seem to be the main objective in organizations where owners and management are separated; there is confusion about the traditional performance criteria "profitability" and "efficiency"; and finally there seems to be no way of assessing the effect of a new management technique by measuring its impact on profitability. The problem is therefore: how to develop an analytical framework to measure success in network analysis applications by avoiding using the popular criteria mentioned above.

It was in the 1930's that Roethlisberger and Dickson (69) carried out their experiments in the Howthorne factory of the Western Electric Company in the USA. According to Blau & Scott (70) no single research has exerted more influence on the direction taken by students of industrial organization than this study. Urwick & Brech (71) summarize the contributions of these investigations in nine groups, the first ot which reads:

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"The greatest need is for a recognition of all those concerned with the higher responsibilities of industry that management has this large human element in it, that it is primarily social skill. Two consequences follow — the one, the essential role in management of principles and techniques that provide adequately for the motivation and well-being of the working teams; the other, the importance of a sound human approach by every individual manager and supervisor in the exercise of his authority in day to day activities."

A number of studies of job attitude and behaviour - mainly job satisfaction — followed. Brayfield & Rothe (72) developed an index of job satisfaction; Herzberg et al (73) formulated a "two factor theory" of job satisfaction; Porter (74,75,76,77) and Talacchi (78) studied the relationship between job satisfaction and a number of structural characteristics; a good bibliography of studies investigating relationships between job attitudes and behaviour, and properties of organizational structure, is given by Porter & Lawler (79); Lodahl & Kejner (80) developed a method to measure job involvement; Weissenberg & Gruenfeld (81) and Lawler & Hall (82) tried to establish, among other things, whether there is a relationship between job satisfaction and job involvement; Harding & Bottenberg (83), Brayfield & Crockett (84), and Katzell et al (85) investigated relationships between job satisfaction and job performance; Walker (86) and Paul & Robertson (87) studied the problem of repetitive jobs on job satisfaction and the issue of job enlargement.

Locke (88) defines job satisfaction or dissatisfaction as "the perceived relationship between what one wants from one's job

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and what one perceives it as offering or entailing". It is implicit in this definition that job satisfaction covers all aspects of one's job. Some investigators like McClelland et al (89) have argued that satisfaction is a function of the discrepancy between what is perceived and what is expected; and some others like Porter (74), Schaffer (90), and Morse (91) believe that it is a function of the discrepancy between needs and outcomes. Locke (88), on the other hand, suggests that neither of these two definitions are right and that the concept of "value" should be accepted as the factor that determines satisfaction. "A value is that which a man actually seeks to gain and/or keep or considers beneficial. A value presupposes an awareness, at some level, of the object or condition sought. A need does not". But Locke accepts that values and expectations often coincide because "most people value only that which they have some reasonable chance of attaining".

After having carefully examined the literature mentioned above it was decided that the concept of job satisfaction would be most suitable to the study of success in network analysis applications. An extension of this concept which covers one's perceived satisfaction of one single aspect of his job — in this case the use of network analysis — has been found to be a suitable basis on which to build the section of the questionnaire related to success measurement in network analysis applications. In the remaining parts of this document, success in network analysis applications and satisfaction in network analysis applications have been used synonymously, and was defined as the discrepancy between what one expects of the technique and what one achieves.

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Taking into consideration the observations already stated in the preceding chapter and in this section, the following analytical model has been formulated to form the theoretical framework within which the investigation was conducted.



Figure 1. The analytical model

It has been hypothesized that success in network analysis applications — as defined above — is dependent on the way it is applied, on the way it is introduced, and on the environment in which it is used. These have been categorized into five main groups of variables: <u>Methods of Application</u> which deal with the procedural aspects of network analysis such as updating procedures and frequency, determination of the degree of detail, the use of computer programs; <u>Technical Aspects</u> which deal with the shortcomings of the basic

mathematical assumptions such as the β distribution for the activity duration when three time-estimates are used, the normal distribution for the calculation of probabilities, etc.; Methods of Introduction which contain attitudinal and behavioural variables such as perceived changes in status, authority, basic securities, etc. due to the introduction of network analysis, extent of support for network analysis given by different echelons of management, attitudes to training courses, etc.; Organizational Characteristics which provide information about the organizational structure; and finally General Company Characteristics which deal with the context in which network analysis is used, i.e., characteristics like size of company, types of jobs undertaken, expansion policy, etc. The aim was to establish whether there are any statistical relationships between these aspects on the one hand and success in network analysis applications on the other. Possible links with profitability aspects were also intended to be investigated.

Information about the five groups of variables is given in the following five sections. The individual variables included in each group can be seen in Appendix K.

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2. Methods of Application:

The literature abounds with textbooks, articles and papers which investigate various aspects related to the application of network analysis. The general attitude is described in the following sub-section.

a) Programmes must be updated. One of the biggest advantages of using network analysis -possibly in a computerized way- is its
flexibility towards changes that happen during the continuation of the project. The majority of authors agree that updating should be carried out regularly for best results (See e.g., 22,37,44,55,92,93, 94,95). Both major surveys of network analysis in Britain, (31,32)
found that the large majority of contractors did update their programmes regularly.

Only one contractor in the former survey (31), and a few in the later (32), stated that updating was only done when difficulties were encountered. Woodgate (96) supports this view and recommends that users should update their programmes either regularly or irregularly according to existing conditions.

The most popular period recommended as updating frequency seems to be two weeks to one month (See e.g., 45,55,93,94,95,96,97,98). The survey carried out by Wade (31) indicated that updating periods varied between one week and two months, and the survey by MacDonald (32) showed that 25% of the firms which updated regularly, updated their programmes every month. Battersby (38) states that the frequency of updating should depend on the type, the length, and the complexity of the project. Armstrong-Wright (94) claims that it should be set with due consideration to the amount of control required and the type of project. Kennedy et al (45) found in their experiment that updating frequency should be chosen, not only to give time for successive reports to show that significant progress has been made, but also to provide a sensitive indicator when little or no progress has been made. Shaffer et al (36) and O'Brien (33) recommend that projects of shorter duration should be updated more frequently, that lengthy projects should be more frequently updated towards the end, and that updating at the close of fiscal periods may also help to show the company's exact position.

As it will be discussed in a later chapter, it was found out during this research project that there was considerable misunderstanding among site managers as to what updating really means. There is, however, enough consensus in the literature (See e.g., 22, 38,99) that updating should reflect not only actual progress but also future changes.

It has also been reported that site staff complained about changing the programme at every update on the grounds that it was difficult to follow (100), and that consequently it was difficult to get the right sort of feed-back information from site management (101). It must be stressed that while updating is accepted to be one of the major contributions of network analysis towards making better decisions, it is also quite a complicated and tedious process, especially when there are a lot of changes such as variation orders, and when calculations are carried out manually. The extent of change that is necessary at each update is possibly quite considerable in a construction project because the untimely receipt of information and drawings, and the considerable number of variation orders are rather inherent characteristics of the construction industry (See Appendix A). Only the three examples in paragraph 14 of the report

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in Appendix A, are sufficient to guess the tremendous effect that untimely receipt of information can have on a production programme. In the discussion of Wade's paper, Jepson (102) rightly indicates that: "less regard has been paid to the physical difficulties of updating; perhaps simpler networks with relatively large volume of work in the activities reduce the problem".

b) Although one of the main advantages of network analysis is a deeper insight into the problem and a more detailed analysis, too much detail must be avoided. However, everybody seems to agree that well detailed programmes are desirable for better decision-making. For example, Wade (31) reports that 80% of the companies in his sample felt that long range and detailed planning was beneficial, while only 20% felt it was not. However, there is also consensus that too much detail is often a nuisance and causes complications. Lichtenberg (103) sums up the disadvantages of too much detail in four categories:

(i) the cost and time demand for planning,

- (ii) the progressively growing amount of undetected errors,
- (iii) practical problems of current replanning and adjustment, as well as effective control, feedback and information, and
- (iv) the growing difficulties of finding time for an optimization, or at least to choose the best alternative schedule among several possible ones.

There are many suggestions as to what the degree of detail of a network should be. Wiest & Levy (42) think that the network should not be very detailed if it is used only for planning purposes, but that it should be highly detailed if it is used also for controlling the job. Armstrong-Wright's opinion (94) is that not much detail is needed for programmes used for broad policy decisions, while higher detail is necessary for programmes used in day-to-day work. According to a survey carried out by the Bureau of Building Marketing Research (56) most contractors reported that the network diagram should be kept as simple as possible; that too much detail regiments the project, resulting in a state where the contractor is not allowed to use his know-how and experience. Walton (104) finds that the ability to monitor the activities is the prime indicator of the depth of detail required; he distinguishes three levels: Geographical or technical breakdown, functional subdivision, and finer detail. Schmidt (105) claims that the degree to which a network should be detailed depends on the objective of the network, on contractual conditions, on project technology and on the importance of individual events; he also suggets that short-term planning should be well detailed, while there is no necessity for long-term planning to be so well detailed. Finally, Moder & Phillips (51) think that the level of detail depends on accuracy and economy required for the presentation; who will use the network; whether it is feasible to expand an activity into more detail; whether there are different responsibilities in the activity to warrant a split; and on whether the accuracy of the logic or time estimates will be affected by more or less detail.

There has also been an attempt to find the optimum level of detail for a network by considering the magnitude of the variance of each activity duration. This procedure which is called "Successive PERT Planning" has been well described by Lichtenberg (103) and Jensen (106), but is not being used in practice in the British Construction Industry to the best knowledge of the author.

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- c) Calculations must be carried out by means of a computer program if the network size is large enough. Battersby (38) lists the advantages of using computers as:
 - (i) the arithmetic in a large network is tediously repetitive and should not be inflicted on human beings.
 - (ii) a computer gives virtually the perfect result, given the correct input.

(iii) the speed of computation is very high and its cost is low.(iv) many alternative plans can be considered.

- (v) the schedule can be revised easily at short notice.
- (vi) although computers are complicated machines, one need only know how to use them, not how they work.

To these, Archibald & Villoria (39) add the advantages of economy, sorting facilities and legible uniform results.

It seems, however, that there are some problems associated with the use of computers for network calculations.

The most commonly stated problem is the necessity of having a 100% — and no less — exact input. The problem is sometimes referred to as RIRO, for rubbish in rubbish out or GIGO for garbage in garbage out (See e.g., 34,96,107). Campbell & Allwood (108) have found that 5 out of 7 computer bureaux examined made card punching errors, which were detected only because this was an experiment, and which would not otherwise have been detected. This result in itself is proof enough of the seriousness of the situation in this area.

Another problem is that printouts are generally too complicated and difficult to understand by site personnel. Tatham (109) reports that they needed specialists on their sites to interpret computer printouts. Furthermore, if one is not selective enough, there is

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always the danger of being lost among a large pile of printouts.

One of the advantages of using a computer is that calculations are carried out at an extraordinary speed and that consequently updatings and the evaluation of alternative plans should present no time problems. In practice, however, a common complaint is that turn-round time is very long (See e.g., 39,109,110,111). Campbell (112) reports that turn-round times for the 9 computer bureaux approached differed between 1 and 25 days. However good is Barnetson's (107) argument that time is necessary for punching cards, pre-processing and post-processing, it is generally believed that turn-round times nearer the 25 days limit are not acceptable by most users.

Archibald & Villoria (39) add to the above-stated problems the fact that the aura of mystery that surrounds computers increases expectations, Barnetson (107) states that people usually approach computers with many misconceptions and Battersby (38) goes further and believes that many people mistrust computers. McKee (113) and Grant (114) find that for best results in computer applications, people involved should be very well educated in computer procedures and that there should be strong management support. A case study reported by Hedley (115) of the impact of computers on an organization, and a paper by Eason et al (116) examining manager-computer interaction seem to point to the fact that a human problem does exist when computers are used.

Apart from these problems, it is sometimes difficult to get access to the right computer with the right program. It must be stressed that the modification of existing programs or the development of new programs to suit the particular requirements of

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a company can be extremely costly.

Despite all the problems stated in the preceding few paragraphs, the majority of authors agree that if a network is large and complex enough, a computer can be used, indeed should be used, as it becomes more economical. The size of a network, in terms of the number of the constituent activities, is the most commonly used criterion to decide whether or not to use a computer. While Lomax (117) believes that networks having over 150 activities should be computerized, Antill & Woodhead's (35) opinion is that computerization should be considered for networks of 100-200 activities and over. Larkin (118) recommends 250 activities as the limit; and Szuprowicz (40) believes that for networks of 150 activities or over manual calculation will be too slow or inaccurate to keep up with work progress. A research study of network analysis carried out for the Department of the Environment (25) concludes that networks having over 300 activities should be computerized, especially it they need updating every 4 to 8 weeks and if resource analysis also is incorporated into the calculations. Armstrong-Wright (94) agrees that frequent updatings add to the necessity of using computers but sets a lower limit as to the size at 100-150 activities. Williams (119) recommends 200+ activities, but agrees with Stires and Murphy (120) that the complexity of the analysis, as well as the availability and cost of computer processing, should also be considered. Apart from these criteria, Archibald & Villoria (39) think that the importance of the timeliness of reports, the number of people requiring the reports, the necessity for alternative report formats, and the benefits in using cost and resource data should also be taken into consideration before deciding whether to use a computer or not.

We have seen therefore that the use of computers for network calculations has advantages over manual methods but also presents a number of problems (*). It would be fair to say that the large majority of writers state explicitly or implicitly that computers are useful and necessary once a number of criteria are fulfilled. A survey carried out by the Bureau of Building Marketing Research (56) shows furthermore that there is a misconception among user and non-user contracting companies that computers have to be used for getting better results out of network analysis. But Oxley & Poskitt (95) emphasize that although for large projects it is customary to use computers, smaller networks can be calculated by hand. Antill and Woodhead (35) also make sure, unlike many other writers, that manual methods do exist and that they have a number of advantages over computerized methods, such as being more flexible at updates, i.e., the planner can adjust interdependencies if he feels it is necessary whilst the computer cannot. But, by far, the most ardent advocate of manual procedures has been Fondahl (123). He claims that there is a need for manual methods because:

- (i) Smaller companies have no computer, and service bureaux are inconvenient and impractical.
- (ii) Programs are not satisfactory (it must be remembered however that Fondahl wrote this in 1962 and that since then many more advanced programs have been developed).
- (iii) A step by step manual method allows the planner to retain more judgement control in making changes in the input data.

^(*) For a good discussion of the managerial problems associated with computer installations, see Constable (121).

(iv) With the manual approach the introduction of new data is

allowed as the schedule develops.

Fondahl (123) also recognizes that manual methods have a number of disadvantages, but proposes possible measures to minimize them. d) Network analysis must be used not only to plan the job, but

also to control it. This characteristic of networks is accepted in the majority of the literature as one of the main advantages of the technique.

It is generally claimed that network analysis is a good, systematic and logical basis for planning and that it enforces discipline. Furthermore, it makes people more involved in the job. But the other half of the benefit is obtained during the contract period: network analysis enables the manager to manage "by exception", i.e., to take a closer look at critical or nearly critical activities while he can use the rest of the time for other tasks.

A survey carried out among large American contractors (29) showed that organizations which were successful in using network analysis were observed to use it not only for planning but for control as well. A survey carried out in USA in 1965 by the Bureau of Building Marketing Research (56) showed, however, that only half of the contractors in the sample used network analysis for control purposes.

e) Jobs planned by network analysis must be time-limited, i.e.,

the main consideration must be speed.

Barmby (124), for example, believes that network analysis has its principal utility in programmes where time is of essence. Mahoney (125) agrees with this view, but is more specific in stating that network analysis has chances of being of more use in jobs where

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time is more important than economy. In the discussion of Wade's survey (31), Hancock (102) proposes a number of criteria for the "pertability" of a job. One of these criteria is that the job must contain a high proportion of time-bound work as opposed to resourcebound work. Finally, the study of network analysis undertaken for the Department of the Environment (25) fully agrees with Hancock's suggestions.

Opinions on what sort of diagram to use, in what form to present the final results for site use, and how to allocate float in the final schedule, are divided.

 a) Arrow diagrams were the original form of presentation when CPM and PERT were first invented. But, later on, precedence diagrams (or activity on node systems, or circle and link diagrams or box diagrams, etc.) became quite popular. Advantages and disadvantages of using precedence diagrams are given in Appendix B together with the major pieces of work about them.

It is also worth noticing that the two German network analysis systems BKN (126) and RPS (127) are both using precedence diagrams and that the French MPM system (128) which was developed by Roy in 1958 concurrently with PERT is based on activity on node networks. b) As to the final presentation of results, opinions are deeply

divided into two extremes: A number of authors believe that a bar-chart transformation would be more familiar and easier to read and understand by site personnel (See e.g., 22,92,129,130,131,132,133) and by senior management (134). Burgess (92) quotes the results of a field survey carried out by a research team in the University of Manchester Institute of Science and Technology, that only 5% of the sites used networks and that the rest used bar-chart presentations. Some other authors, such as Hale (102), Schmidt (105) and Battersby (38) are categorically against using such transformations. Battersby (38) characterizes them as confessions of failure.

There are also those who settle for a compromise and favour the use of intermediate means of presentation such as time-scaled networks, or logic-linked bar-charts. For example, Mulvaney (135) advocates the use of "Analysis Bar Charting", a system which not only improves presentation but also is more suited to resource analysis than ordinary arrow diagrams. Lowe (136,137) claims that logic-linked bar-charts are the best solution for good presentation. A paper by Miller & Cordiner (138) describes the Cascade Activity Numbering Method, which is later reported by Rist (100) to have been extremely well accepted by site managements over the 6 years they have used it. Britten (139) advocates the use of time-scaled networks and planning frames. And finally, a research study of network analysis carried out for the Department of the Environment (25) recommends that presentation should show some sort of a time-scale. Reynaud (141) agrees with this as long as the network is a large one.

c) Whether float values associated with each activity should be disclosed to all levels of management is also a question which has bothered many a writer. It is argued that float can make people relax, until, in the end, all activities become critical (25) and that in order not to fall into this situation, float values should not be disclosed to certain levels of management. The counterargument is, of course, fairly obvious: management needs all sorts of information, and particularly float values, in order to make better decisions. Coker (140) suggests that the personnel actually

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doing the task should not be told what float exists; their administrators or managers should know more and more detail regarding float the nearer they are to the project manager. In the same book

Trimble (142) suggests a compromise by stating that letting the float be known, but withholding the latest dates, has worked under certain circumstances. The research project carried out for the Department of the Environment (25) concludes however that no-one on site but the site manager should be aware of what float exists at the end of each activity.

3. Technical Aspects:

There have been a plethora of papers published dealing with the theoretical aspects of networking algorithms. Mathematical/statistical algorithms have been developed for every possible situation and the basic assumptions made by the initiators have been questioned. The last issue of the International Abstracts in Operational Research (143) lists 69 items under "Networks/Theoretical".

In this section some brief information will be given about the major studies which examined the original PERT assumptions and their possible consequences.

There are four main assumptions in the PERT (three time estimates, probabilistic network) theory:

- a) The probability distribution governing the length of time to accomplish an activity is assumed to be a β distribution defined over the range from the optimistic time estimate to the pessimistic time estimate.
- b) The standard deviation of this β distribution is assumed to be equal to 1/6 of the range.
- c) When calculating the overall completion time, the model is reduced to a deterministic form, i.e., only means of activity durations are considered and no notice is taken of their variance.
- d) A normal distribution is assumed in the calculations of the probability of finishing on or before the actual completion time.

MacCrimmon & Ryavec (144) have analysed all of these four assumptions and calculated that the first two may yield errors of up to 33% in the mean activity duration and up to 17% in the standard deviation. However, they have determined that these errors are sometimes positive and sometimes negative; that they depend on a number of configurational aspects of the network; and that cancellations are likely to happen so that they are reduced to about 5 to 10% in practice. The same authors found that total errors are likely to be minimal in cases where:

a) There are more activities in series than in parallel.

b) The ranges of activity durations do not differ much.

c) The skewness of activity durations is arbitrary.

d) There is one path through the network that is significantly longer than any other path.

One immediate consequence of these findings is the effect of resource allocation procedures which reduce deterministic completion time by increasing the parallelism of the network. While increasing parallelism decreases completion time, it also reduces the probability of completing on or before the new date. This aspect of resource analysis is claimed to partially offset its advantages (145).

There have also been attempts to get rid of the errors mentioned above by using different activity duration distributions. While MacCrimmon & Ryavec (144) propose a triangular distribution, Murray (146) claims that a I distribution is more convenient to use. On the other hand Jensen (106) and Lichtenberg (103) use the ERLANG function which they claim is a good approximation of the stochastic distribution of the duration of most activities in the construction industry.

Healy (147) had determined that the mechanics of subdividing activities into smaller sub-networks can influence the computed probabilities of accomplishing events on or ahead of their scheduled dates. Another problem that has interested a number of researchers has been the accuracy of subjective time estimates. MacCrimmon & Ryavec (144) found that these can produce errors of up to 33% in the mean and errors of up to 17% in the standard deviation, assuming that each estimate (pessimistic, most likely and optimistic) varies $\pm 10\%$ to 20% from its actual value. King & Wilson (148) have tried to develop mathematical models to improve subjective time estimates. They hypothesized that:

- a) Pre-activity time estimating accuracy improves as the beginning date of the activity approaches, and that
- b) Time estimates made during the progress of an activity improve in relative accuracy as the completion date of the activity appraoches.

But in a later article, King, Wittevrongel & Hezel (149) found however, that such mathematical models based on historical estimating behaviour would be impractical in the day-to-day routine of network calculations.

These are only a few of the multitude of research studies made on this subject. They have been selected because they are quite interesting and because they are directly related to practical applications.

The original intention at the start of this research project was to collect a typical network diagram from every organization in the sample and to examine its configurational characteristics in the light of the information given in this section. The idea was to find out whether typical construction programmes are suitable for this sort of probabilistic calculation or whether they are likely to produce significant errors. But, it so happened that none of the

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user organizations approached used probabilistic networks. Therefore, the idea had to be dropped; but this section has been kept in its briefest form for the sake of completeness.

4. Methods of introduction:

Network analysis, when compared with the well established conventional planning techniques, is a novelty, especially in the construction industry which tends to be slow to accept innovation.

According to Schumpeter (150), innovation is the second step in the process of technical change, the first step being invention, and the third imitation. As to the reasons why innovation occurs, Johnston (151) mentions two early theories that it occurs either as a reaction to the competitive pressure of numbers, and to falling profits, or in large firms enjoying a protected position. Williams (152) suggests however that both pressure and opportunity are necessary for innovation but are not sufficient in themselves.

After an extensive study of the literature Johnston (151) further states that the following factors affect the speed at which an innovation spreads:

- a) Extensive research and development activity.
- b) Purchase and flow of knowledge, i.e., the import of know-how into the organization.
- c) Talent level and distribution, i.e., good quality of scientific, engineering, research, management, administrative, production staffs.
- d) Suitable economic and market structure, i.e., good opportunity for profits, a stable economy, ability to predict risks and available capital.
- e) Investment and availability of financing; the speed at which an innovation spreads and the size of the necessary investment are inversely related to each other.

After the study of a large sample of companies, Mansfield (153,154) agrees with the last factor and adds in his book (155) that there is no significant tendency for the length of time a firm waits before using a new technique to be directly related to its profit trend.

It is not surprising therefore that the construction industry is particularly slow to accept innovation. As a matter of fact, in 1969, the construction industry spent only 0.5% of the value of its output in research (5), which is much lower than for other industries; output prospects have never been stable, as the industry has always been used as a regulator for the national economy; and finally the distribution of knowledge within contracting companies is far from being equal, as the majority of site managements are ex-tradesmen with insufficient formal education.

The level at which a social process occurs is determined by a variety of social and technological pressures of forces acting in opposite directions so as to form a state of equilibrium. A change in this level can be brought about by adding certain forces in the direction desired or by reducing the magnitude of specific opposing forces. It follows therefore that the success of a change depends mainly on the identification of the nature and magnitude of the forces in question. Mann & Neff (156) show with the help of a diagram reproduced below, that a major change goes through three stages: the unfreezing, the moving, and the refreezing. According to the same authors the relationship of the old level of equilibrium to the new level and the rate at which the system moves toward the new level can be used as a measure of the success of those introducing the change.

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Figure 2. The stages of change

As to the nature of these force fields, they can be examined at two different levels: at the organizational level and at the psychological level.

At the organizational level, it can be said that traditional business organizations run on a vertical line, relying almost solely on superior-subordinate relationships whereas modern technology has developed in a horizontal plane (project management). Jasinski (157) claims that superimposing a strictly vertical organization structure on a technology which emphasizes horizontal and diagonal relationships can and does cause obvious difficulties. He recommends the use of project co-ordinators, frequent meetings among representatives of different departments, and encouragement to facilitate non-formal relations.

Cartwright (158) sees the situation from a different angle. He postulates that the behaviour, attitudes, beliefs and values of

individuals are all firmly grounded in the groups to which they belong. Whether they accept or resist change would be greatly influenced by the nature of these groups. So, the Group Dynamics Theorists (159) hold the view that to introduce and manage a change successfully, the people who will be affected by the change and those introducing it, must have a strong sense of belonging to the same group, and the need for change must be perceived and shared by all the members of the group. Spicer (160) is not far away from Group Dynamics Theorists when he states that cultural differences between the two parties can cause resistance. An empirical study of change carried out by Gruenfeld & Foltman (161) on 40 first-line manufacturing supervisors showed that supervisors who were relativley more integrated with the management group, more satisfied with management, and relatively high in job satisfaction, were more likely to accept a management-initiated technological change.

According to Bennis (162), a change must be regarded as influencing the entire organization. Thurley (163) basically agrees with him when he proposes three ways of introducing change without trouble:

- a) Equilibrium model: the mechanism of change depends on the release of tension through anxiety reduction.
- b) Organic model: the mechanism is power redistribution, conflict resolution.
- c) Development model: the mechanism of change in this case is the transformation of values.

The implications of these theories on the introduction of network analysis into an organization would seem to be: Firstly, it is the rule rather than the exception that the introduction of network analysis is accompanied by the establishment of a central planning department. This in turn invariably produces changes in the management structure and this can cause difficulties. Jasinski's recommendations (157) of regular meetings and informal relationships have therefore to be investigated. Secondly, it has never been investigated whether site managements ever felt the need for a more advanced planning technique and whether they regard those introducing the change, namely, in this case, top management or planning engineers, as belonging to the same group as theirs. And finally, whether network analysis was introduced via a planning department, an Operational Research unit, consultants, or top management would also be of considerable importance to the future success of network analysis.

At the psychological level, Zander (164) draws a parallel between the process of change and the treatment of a mental case. He finds that the pattern of behaviour used by the patient (which makes him a "sick" person) is a means to some satisfaction for him even though it also may make him ineffective and unhappy. According to Zander, resistance occurs in the patient when the process of change (therapy here) comes close to being successful. When faced with the unpleasant necessity of giving up the behaviour he does not like but somehow needs, the patient begins to be disappointed, discouraged. Therefore, when the therapist is attempting to change the behaviour of the patient, he expects resistance from him.

Mann & Neff (156) state that an individual's reaction to a change appears to be related directly to the clarity of his perception of the meaning of the change, and his evaluation of the effect that the change will have on him as an individual with certain aspirations

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and expectations. A questionnaire survey of 246 office employees conducted by Hardin (165) supported the hypothesis that a person's desire for specific changes in his job is governed by the discrepancy between the attractiveness to him of existing and potential job characteristics and by his assessment of the very process of change. Zander (164) agrees with this view and further adds that resistance to change will be encountered in cases where changes are made on personal grounds rather than impersonal requirements, ignoring the institutionalised patterns of work, and/or abruptly attempting to create a new state of affairs which demands that old established customs be abolished without further consideration.

Some conditions conducive to resistance are stated by Lawrence (166) to be: the change in human relationships that accompany technical change; the exaggerated preoccupation of those introducing the change with its technical aspects; the ignoring of the criticisms made by those affected by the change; the failing to explain the change to those affected by using simple understandable terms; the rushing of the change in a shorter period of time than anticipated by those involved. Crozier (167) on the other hand, believes that change in bureaucratic organizations can only come as a result of a crisis, whereas, at the other extreme, Chin & Benne (168) and some others (169) deal only with planned changes, i.e., with situations in which attempts to bring about change are "conscious, deliberate and intended".

Apart from the common theory of "inertia", there are mainly two schools of thought as to why changes are not often accepted and assimilated easily and how this can be prevented.

a) Resistance to change: This school holds the view that the overt

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or covert rejection of a change is not directed towards the change itself, but towards the way it is introduced. In general, theorists recommend "participation" as the means to avoid this occurance. If the staff involved in the particular activity are allowed to participate in the decision to introduce the change, or in discussions as to how the change should be introduced, it is claimed that they will gladly accept the change and they will even suggest additional changes.

"Participation" is defined by French et al (170) as a process in which two or more parties influence each other in making certain plans, policies, and decisions. It is, however, restricted to decisions which have future effects on those making the decision and on those represented by them. The same authors also differentiate between, what they call "psychological participation" which refers to a person's perception of the amount of influence he has on jointly made decisions and which is of paramount importance, and "objective participation" which refers to the objectively observed amount of influence as determined by a social scientist.

"Participation" was first investigated by Coch & French (171) in 1948. During an experiment carried out on female operatives working under individual piece-rate system in a pyjama factory, they formed three main experimental groups: a no-participation group where the change was introduced without any prior discussion with operatives; a total participation group where the change was discussed at meetings attended by all operatives; and a participation by representatives group where the change was discussed with a few representatives selected by the operatives. The results indicated that the no-participation group improved little beyond their early efficiency ratings and that resistance develped almost immediately after the change occured; the representation group showed a good relearning curve; and the total participation group recovered faster than the others.

These series of experiments by Coch & French (171) appear to demonstrate that a participative approach to the introduction of technical change results in (172):

- (i) higher levels of production output
- (ii) decreased variability in individual task performance, indicative of increased motivation to achieving higher work norms
- (iii) decreased retraining time (and costs), in that, standard output is achieved over a shorter time period
 - (iv) reduction of labour turnover and removal of acts of aggression against management as concommitants of the introduction of technical change
- b) Opposition to change: The second school of thought claims that overt or covert rejection of a change is due to anxieties about the perceived nature of the change expressed as technical aspects (such as measurable modifications in the physical routine of the job), and basic securities (such as amount of pay, status, employment, etc.). According to Stewart (173), in such cases, the interests of those introducing the change and of those affected by it will diverge, and participation will be of no use.

Two major criticisms of participation are also used by this school to reinforce their position: the first one is that in the long run, when workers take participation for granted, it will not really produce the expected results; and the second one is that participation depends on respect and that cases of artificial participation (i.e., to call the staff for a meeting, ask them carefully calculated questions, and try to give them the impression that they are participating, while, in fact, they are not) are all too frequent.

Stewart (173) speculates also that it is possible that in firms or industries where there has been a long history of technological change, any given change in the present or future will meet with less resistance than would be the case if such change were a rare or unknown phenomenon. He, furthermore, observes that many of the cases of resistance to technological change occur in the declining or stationary industries.

One of the aims in this study has been to find out how and by whom the decision to introduce network analysis was taken. Did site management for example, participate in this decision? Does this participation or non-participation situation make any difference in the success of future applications?

The second point directly related to the psychological aspects mentioned in this section is the determination of network analysis users' perceptions of the effect of network analysis on them: Do they believe there has been any reduction in their authority, in the pay package they take home, in the status they enjoy in the company, in the chances of promotions, or in any of their basic securities; and what are the consequences of these on their attitude towards network analysis?

The third point, which has been most thoroughly covered by the literature, is the one of education and training. There is no doubt

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that, as stated before, the more an individual knows about a change, the less he will resist it provided it does not endanger his interests. All the writers agree that the education and training of all the levels of management is more important to the future success of network analysis than further research in the technical aspects (See e.g., 33, 34,37,38,101), although the short-term effects may not be very spectacular (20). Pinschof (174) reported after investigating several contracting companies that the site staff members who were the most critical of network analysis were the ones with least basic education.

One theory supported by Archibald & Villoria (39), Walton (44), and Handy & Hussain (175) is that different levels of management should receive different sorts of education and training: practitioners should be trained and educated by long courses to be expert network analysists; senior management must be "sold" on the technique, must be educated to understand what it is but has no need to be proficient; users, i.e., people receiving outputs must be thoroughly indoctrinated and educated.

There are different views, as to the methods of training and their consequences. The Bureau of Building Marketing Research (56) reports for example that 66% of the contractors in their sample got familiarized with network analysis through articles in magazines; 49% attended seminars or courses; and 44% learnt through the use within the company. In another survey carried out by Sobczak (176), again in the USA, but a couple of years earlier than the preceding survey, it has been found that the large majority of PERT supervisors (23 out of 25) were self-taught specialists by means of articles and text-books; that 86% of the technicians were self-taught by means of
on-the-job training; that 50% of the technicians attented company or government sponsored schools and/or seminars consisting of one day indoctrination courses and one to four days of supervision courses. Baboulene (177) and Archibald & Villoria (39) believe that sending people to short courses has disastrous effects and that the best way of dealing with this is on-the-job training. Buesnel (178) adds that every company should have an expert whose job should be to train the others. A combination of seminars and TV series is reported by Schmidt (105) to have yielded good results. Woodgate (96) and Coker (140) leave open also the possibility for any member of staff to examine the literature and teach himself network analysis without attending a course. This last alternative has the advantage of being the cheapest method.

It is also important that if courses are run, they should stick to practical aspects as much as possible and should not consist of a one-shot briefing but should be continuous.

The forth point is directly related to a warning by Lawrence (166) that too much preoccupation with technical aspects on the part of those introducing the change may cause resistance among those at the receiving end. How does site management view the situation? Is there a need for better human relations between the planning staff and the site staff?

And finally, the fifth point which has been investigated is whether the very initial attitude to network analysis by top management, by planning staff and by site management had any effect at all on the success of future network analysis applications. The literature abounds with papers which explicitly state that top management support is absolutely essential in network analysis applications (See e.g., 25,

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37,38,42,96,130,179) and also that to fail to orient middle and site managements is conducive to failure (See e.g., 20,22,29).

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5. Organizational characteristics:

One definition of organization is "the division of work among. people whose efforts must be co-ordinated to achieve special objectives" (180).

There may be three basic approaches to the study of organizations: 1. The Classical Approach which is based on the "Machine Theory". This theory regards the organization as a closed system whose internal efficiency is of primary importance. This efficiency depends entirely on the adequate design of the organizational structure.

- 2. The Human Relations Approach which tends to believe that the behaviour of people and groups in organizations is the main object of study. The objectives of the organization are more likely to be achieved when people co-operate. Therefore, the division of work must be designed so as to evoke willingness to co-operate.
- 3. The Systems Approach which claims that organizations are open systems which have links with their environment. These links are essential to their existence and therefore, channels of communication must be taken special care in the design of organizations.

It is obvious that neither of these three approaches is sufficient when considered separately and in different situations. They must be accepted as complementary. Thus, a combination of these three approaches gives quite a complete picture of the main aspects of organizational problems. In one of their early articles about the study of 52 formal work organizations in the Midlands, Pugh et al (181) admit that such an approach taking all of these

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three facets into consideration would be the ideal way of tackling the problem of the comparative study of organizations (*).

The comparative analysis of organizations has been emphasized more and more by social scientists during these last few years and methods of measurement have been devised for this purpose (**). But, before devising methods of measurement, all these researchers had to conceptualize their research on a theory of organization which would allow them to get as universal and valid results as possible. A survey in this connection shows that the theories and hypotheses which were put down and/or empirically tested by a large number of social scientists have their basis in Max Weber's concepts of bureaucracy. According to Blau & Scott (70), since their publication in Wirtschaft und Gesellschaft about forty years ago, the principles of bureaucracy have had a profound influence on almost all subsequent thinking and research in the field.

Weber (185,186) analyses formal organizations as part of his theory of authority structures and defines three types of organization : a) Traditional organizations: In this type of organization past tradition legitimizes present actions. The ruler is extremely powerful and the social order is viewed as inviolable. Subjects are bound to their ruler by the traditional feeling of loyalty. An absolute monarchy is a good example of this type of organization.

b) Charismatic organizations: In this type of organization the leader is again very powerful but this time not for traditional hereditary

(*) For a comprehensive study of organizational theories see Scott (182).

(**) Perrow (183) is an example; but for a full discussion of these methods see Udy (184). reasons, but because his followers identify themselves with the cause he is advocating. This type of organization tends to be initiated as a reaction to a set order and has generally anarchistic features.

- c) Bureaucratic organizations: This type is based on legal authority and is legitimated by the supremacy of the law. According to Weber, this type of organization leads the way to a maximization of rational decision-making and administrative efficiency. He enumerates the distinctive characteristics of a bureaucratic organization as follows:
 - (i) There is a high degree of specialization
 - (ii) There is a clear-cut hierarchical structure which usually has a pyramidal form
 - (iii) A formally established system of rules and regulations governs official decisions and actions
 - (iv) Interpersonal relationships between hierarchical levels are informal
 - (v) Employment is based on the technical qualifications of the candidate rather than on his political, family or other connections.

Some examples of theoretical and/or empirical studies where Weber's dimensions of bureaucracy have been used, are reported in Appendix H. It must be noted that these studies are only a few from a large number of similar studies, and that the majority of social scientists accept "bureaucracy" as central to modern organizational theory. It is for this reason that the organizational implications of using network analysis in contracting companies has been investigated in the light of this concept. One of the most complete studies of organizations which uses Weber's dimensions of bureaucracy successfully is the one by the Administrative Research Unit, University of Aston in Birmingham. This study is of particular importance to this research project and has been selected to form the basis for measuring organizational characteristics for the following reasons:

1. It incorporates the Classical and Systems approaches to the study of organizations. Indeed, the published series of papers (181,187,188,189,190,191,192,193) deal mainly with "structural" and "contextual" aspects. In these studies, "contextual" is defined as "the setting within which structure is developed" rather than the environment in its broader sense. It is believed, however, that this limited definition of "context" is perfectly satisfactory for the purposes of this research project.

- 2. The variables proposed in these papers are not merely theoretical, but have been demonstrated to be empirically meaningful. Indeed, the research unit has used statistical methods to formulate into basic dimensions, the data collected from 52 formal work organizations in the Midlands.
- 3. The study was designed not to come up with a typology like the classical theorists' (for example Weber's classification of organizations into three distinct types: charismatic, traditional, and bureaucratic) but to give a multi-dimensional continuum (*).

^(*) A continuum may be defined as the range given by a scale on which a variable may have a score, (as opposed to a "typology" where a variable will have to be included in one of the types representing the two extremes for example). The continuum is called multi-dimensional when the characteristic to be measured is formed of more than one independent variable.

It is claimed by the authors that such an approach gives the best basis to which the behaviour of groups and individuals can be systematically related. Indeed, in his comparison of bureaucratic and craft administrations, Stinchcombe (194) agrees with them when he states that "..... the components of Weber's ideal type (bureaucracy) do not form an inherently connected set of variables. Some of the components of the ideal type are relatively uncorrelated with others, while some are highly correlated". Hall (195) backs up this suggestion by demonstrating in his study of intra-organizational structural variables of ten organizations that "..... the bureaucratic dimensions existed independently in the form of continua". The bureaucratic and democratic types of organization are criticized by Glueck & Dennis (196) who believe that each organization lies somewhere within these two extremes depending on environmental demands. Finally, this study had the advantage of offering an abbreviated version which was proved by Inkson et al (193) to be strongly correlated to the original study. Apart from not jeopardising the technical soundness of the original study, this version was also more convenient to use because it required less time to administer and a smaller number of interviewees.

4.

A brief description of the Administrative Research Unit's work is believed to be essential for a better understanding of the following sections related to organizational aspects, and is given below. Further information can be obtained from references 181,187, 188,189,190,191,192,193.

After a careful examination of the literature on organizational structure, the Administrative Research Unit decided that they ".....

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must first of all isolate the conceptually distinct elements that go into Weber's formulation of bureaucracy" (181). In this manner, Pugh et al (187) were able to conceptualize six elements to be considered as dimensions of organizational structure. They constructed scales to define these dimensions operationally; they collected data from 52 industrial organizations in the Midlands; they carried out item analysis on each particular variable to test whether the scales could represent a dimension; principal components analysis was then used in the identification of underlying factors which resulted in 64 scales. The six structural dimensions and the most important of the scales related to these dimensions are given below (181,187):

1. Specialization: This dimension was concerned with the "division of labour within the organization, the distribution of official duties among a number of positions". It was examined in two separate parts. In the first part 16 functions were derived. These functions were assumed to exist in all organizations. The possible functional specializations were then compared among organizations. The second part dealt with role specialization in each of the 16 functions.

Standardization of procedure: This was measured by the number of events which have "regularity of occurrence and are legitimized by the organization", and which are "covered by rules and definitions". This dimension was examined under three main variables: overall standardization, procedures defining task and image, and procedures controlling selection, advancement, etc.

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- 3. Formalization: This dimension denoted the "extent to which rules, procedures, instructions and communications are written". It was felt by the authors that it would be desirable to spilt this dimension into three variables concerned with formalization of role definition, formalization of information passing, and formalization of recording of role performance.
 - Centralization: This dimension was defined as "the locus of authority to make decisions affecting the organization". It was examined by means of two variables, namely, overall centralization (the place of authority in the hierarchy was determined by means of a pre-set vertical authority scheme), and autonomy (the number of decisions given by the organization and those given by head-quarters, or parent organization determined autonomy).
- 5. Configuration: This dimension represented "the shape of the role structure". Data about this dimension were obtained from a detailed organization chart. The variables used were: chief executive's span of control, subordinate ratio, vertical span, percentage of workflow superordinates, non-workflow personnel, and percentage of clerks.
- 6. Flexibility: This dimension was later renamed as "traditionalism". It represented "the potential population of customs in organizations". A custom was defined as "an implicitly legitimized verbally transmitted procedure". This dimension was measured by constructing a variable composed of relevant characteristics of "standardization" and of "formalization".

About 30 studies which investigated these bureaucratic dimensions have been reviewed and the results of each study have been classified

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according to the dimension (or dimensions) used in it. This classification (Appendix I) is useful to see inter-relationships among dimensions and their relationship to other aspects such as performance characteristics.

Intercorrelations among these variables suggested a factor analysis, which in turn resulted in four basic independent variables. It is claimed by the authors that such a simplification improves the interpretation of the results (*). The four new variables and the sub-variables encompassed by them are given below:

- Structuring of activities: formed of standardization, formalization, specialization, and vertical span,

 Concentration of authority: covering organizational autonomy, centralization, percentage of workflow superordinates, and standardization of procedures for selection and advancement,
 Line of control of workflow: including subordinate ratio, formalization of role performance recording, percentage of workflow superordinates, and standardization of procedures for selection and advancement,

- Relative size of supportive component: containing percentage of clerks, vertical span, non-workflow personnel.

It was Pugh et al's view (181,188) that the study of the structure of organizations should be conducted in relation to the social and economic context in which it is found. In order to examine these relationships, they defined eight salient elements of context; they developed operational variables (40 in total) for each of them; and then they reduced these to fourteen by means of factor analytical

(*) For the statistical details see Levy & Pugh (197).

methods. The eight contextual elements and the salient variables related to each of them are given below:

- Origin and history: Three variables were selected as representing this dimension: impersonality of origin, age of the organization, and historical changes, each being measured by means fo sub-variables.
- 2. Ownership and control: This dimension contained two variables, namely public accountability of the organization, and the relationship of ownership to management, each containing a number of subvariables.
- 3. Size: This dimension was measured by means of two variables: number of employees and net assets of the organization, and size of parent organization.
- Charter: This dimension was defined as "an organization's social function, goals, ideology and value systems". The two variables used for measuring it were: operating variability, and operating diversity, each containing a number of sub-variables.
 Technology: This dimension was defined as "the sequence of physical techniques used upon the workflow of the organization". Two main variables, namely workflow integration, and labour costs were used to measure this dimension; but the former of these variables contained five sub-variables each formed of a number of scales.
- Location: This was defined as "the geographical, cultural, and community setting" which influence the organization. It was determined by counting the number of operating sites.
- 7. Resources: This dimension was not pursued as it was thought by the authors that material and capital resources were better

examined under aspects of "size", and that the relative disposition of these resources was better regarded as an aspect of "technology".

Dependence: This dimension reflects "an organization's relationships with other organizations in its social environment", such as suppliers and customers. It was measured by two variables: dependence on parent organization, and recognition of trade unions. The former was formed of two levels of sub-variables.

By means of multivariate inter-correlation analyses between the structural and the contextual dimensions, Inkson et al (13) later determined the most salient structural and contextual variables as the following:

- Structuring of activities, containing functional specialization, and formalization of role definition,
- Concentration of authority, which is determined by the extent of autonomy the organization has,
- Workflow integration, which is a variable of "technology" and which is measured by three sub-variables called automaticity mode, automaticity range, and specificity of criteria of quality evaluation of outputs,
- Dependence, covering impersonality of origin, status of organization unit, public accountability, and size relative to owning group.

These four dimensions of organizational structure and context were selected — for reasons mentioned earlier in this section to quantify and measure organizational characteristics in contracting organizations. There were, however, doubts that these variables,

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originally designed to measure organizational characteristics in all kinds of formal work organizations would not be sufficiently discriminating when used to get similar information from one particular industry — in this case the construction industry. But this difficulty was later overcome by adapting certain variables to the particular conditions of the construction industry. The major modification was made on two of "Workflow Integration" sub-variables "automaticity mode and range" (193) which were replaced by similar scales measuring "mechanization mode and range" (See Appendix K, Part 4).

6. General characteristics:

When a management technique is introduced and used in a company its success depends not only on the way it is introduced and applied, but also on the environment in which it is used. Organizational characteristics deal with one of the environmental aspects, and this group of variables, General Characteristics, is designed to take care of the reamining aspects. "Environment" is a very vague word; it can be interpreted to mean anything around the object of study. However, for operational reasons, this definition had to be limited to aspects related to the jobs planned by network analysis and to the company.

A cliche that is frequently used by writers who describe the evolution of network analysis is: "increasing technical complexity in most modern projects necessitated the use of more advanced planning techniques such as network analysis". The immediate "environment" can therefore be identified as the job in which network analysis is used. According to Woodgate (96) highly complex one-off jobs which have a large element of uncertainty are those which are most suitable for network analysis planning. Mahoney (125) believes that best results can be obtained if jobs have a relatively stable and inflexible sequence of activities, and if speed is more important than economy. Again, speaking on the time-analysis aspect of network analysis, Hancock (102) suggests that, for a good "pertability rating", a job should have a high proportion of time-bound rather than resource-bound activities, that the task sequence should be as inflexible as possible, and that the extent of repetition should be very little. The study carried out for the Department of the Environment (25) about the use of network analysis techniques in the Department agrees with Hancock's suggestions. Barmby (124) finds

that network analysis has its principal utility in programmes where time is of essence, and Wiest & Levy (42) claim that large, nonrepetitive jobs are better suited to be planned by network analysis.

A number of empirical studies have also investigated the effects of project characteristics on the applicability of network analysis techniques. The survey carried out by the Bureau of Building Marketing Research (56) showed that according to the views of the majority of the contractors, network analysis worked best on complicated and large projects; some contractors felt that the method was not practical on buildings that take only six or seven months to complete, with perhaps one exception: additions to existing buildings which can be very complicated. A study of 16 medium sized building contractors carried out by the Building Management Research Unit in the London School of Economics and Political Science for the Ministry of Public Building and Works in 1964-65 (198) indicated, among other things, that highly complex projects planned by informal methods like bar-charts, suffered the most serious delays; and that the simpler jobs planned by formal methods like network analysis had least delay. It was also found that delays, though not as serious, were not absent from any of the complex projects even with the use of formal planning and control techniques. According to Wade's investigation (31) the main criterion in deciding whether to use network analysis or not is the complexity of the project. Some contracting companies used also the size of the project, £100,000 being the limit above which network analysis was used. MacDonald's study (32) strongly supports Wade's findings, since, in this case, 78% of the firms stated that it was the complexity of the contract that made them use network analysis; the remainder said it was both

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the complexity and the value of the job.

Besides complexity, extent of repetition, flexibility, uncertainty and contract value, some writers also argue that the kind of job (i.e., building as opposed to civil engineering), and the kind of contract (such as competitive, negotiated, etc.) are also important factors (See e.g., 174).

As to the characteristics related to the company, the most popular factor used, is the size of the company expressed either in terms of its annual turnover or in terms of the number of employees. Schoderbek (57), Davis & Hogle (27), Davis (29), and MacDonald (32) agree in their findings that the companies who use network analysis are generally the larger ones. Furthermore, Davis & Hogle (27) report that experience with network analysis is also related to company size, larger firms having used the technique longer. The only investigation which took into consideration success in network analysis applications — as measured by the subjective assessment of the situation by top management — (29) indicated that there is a larger number of "very successful" users among larger companies than among smaller companies.

Apart from the size aspect, it was noted in the preliminary survey that the expansion policy of the company, the policy for the number, the size and the nature of jobs to compete for, and the geographical location of the company were also factors with influence on network analysis applications (See e.g., 49).

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CHAPTER IV

METHODOLOGY

1. Conduct of the investigation:

- The research study contains seven main steps which are listed below in chronological order:
 - 1. The literature survey.
 - 2. The case study.
 - 3. The preliminary field survey.
 - 4. The main field survey.
 - 5. The statistical analysis.
 - 6. The feedback survey.
 - 7. Final interpretation and evaluation.
- The aim of the literature survey was to establish what various writers had said about network analysis, its advantages, its disadvantages, its effects on individuals, etc., etc.
- 3. At about the same time as the literature survey, the independent study of "Receipt of Information by Contractors" was carried out (See Appendix A). It involved visiting a number of contracting organizations and was to be a preparation for future contacts with the industry, as well as an opportunity to see how British contracting organizations work in practice.
- 4. The case study was carried out in a company who had an annual turnover of over £10 million. Eight persons were interviewed by using a check-list (See Appendix E). The persons interviewed were selected so as to include at least one member of staff from each hierarchical level, from managing director to site agent. The object was to determine the factors which are regarded by

respondents as important and relevant to success in network analysis applications. Further information about the case study can be found in Chapter II, Section 3.

The preliminary field survey was carried out by means of interviews conducted by the same check-list used in the case study, but this time, reinforced by a number of loosely structured "open" (or "unrestricted") questions (*) related to each item in the check-list. These questions were developed after, and as a result of, the case study. The exercise involved at least two persons - one planning engineer and one site manager - in a random sample of 10 contracting companies, mostly companies already contacted for the study on "Receipt of Information" (Appendix A). The object was to test the questions prepared after the case study - i.e., to make sure that they do not represent a special case -, and to gather enough information to be able to formulate "closed" (or "restricted") questions for the final questionnaires. Further information about the preliminary field survey is given in Chapter II, Section 3. Two sets of questionnaires were prepared for the main field

survey: one set to be completed by planning engineers, and the other by site managers. A copy of each can be seen in Appendix J. These questionnaires were developed after, and as a result of, the literature survey, the case study, and the preliminary field survey. They contain mostly "closed" (or "restricted") questions

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^(*) Questions are called "closed" or "restricted" when a number of alternative answers are specified below the question; the respondent has to select one or many according to the nature of the question. They are called "open" or "unrestricted" when the respondent can answer the question in his own words.

to facilitate the quantification of variables explained in Appendix K.

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A study of research procedures in this sort of circumstances indicated that there was considerable support for a thorough preliminary investigation before attempting to design final questionnaires (See e.g., 199,200,201). The study of research methodology showed also that interviews and mail questionnaires had their respective advantages and disadvantages (See e.g., 200, 201,203,204). In order to avoid most of the pitfalls, a compromise solution where questionnaires were administered during interviews, was found to be convenient. Apart from administering the questionnaire, interviews were also used to collect a certain amount of information deliberately excluded from questionnaires. The subjects discussed in interviews can be seen in Appendix J, Part 3.

8. After the interviews were completed and the questionnaires were received back, tranformation of this information into quantitative variables started (See Appendix K). As explained in Chapter III, these variables were categorized into four groups: methods of application, methods of introduction, organizational characteristics, and general characteristics. Success scores for each respondent were calculated on the basis of the procedure described in Appendix K, Part 1.

Statistical analysis of the data involved a multiple regression analysis between success scores (the dependent variable) on the one hand and the four groups of variables (independent variables) considered separately. Eight multiple regression equations were therefore established, four (one for each group) for planning

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engineers, and four for site managers. Two more multiple regression equations were calculated, one of them between the planning engineers' success scores on the one hand and all the independent variables (all four groups put together) on the other; the other equation consisted of the site managers' success scores and all the independent variables. Intercorrelations among all variables were also calculated for planning engineers and for site managers separately. An alphabetical list of all the variables is given at the end of the thesis.

10. Statistically significant results at 10% can be seen on the foldout pages at the end of Sections 2,3,4 and 5 in Chapter V. The independent variables in these pages are arranged in order of their relative importance. The figure in parantheses following the variable name, is the standard deviation multiplied by the regression coefficient. It represents the magnitude of the change that the dependent variable would undergo if there were a standard change in that particular independent variable. There seems to be no standard method to determine the relative importance of independent variables which have different measurement scales. The above mentioned method is accepted by statisticians to be a logical way of showing the independent variables in a comparable uniform way.

11. Bearing in mind the relatively small number of companies who took part in the survey (15 companies) and the exploratory nature of the study involving a large number of complex subjective assessments, it was decided that a significance level of 10% would be a satisfactory limit. The same reasons mentioned

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above accounted for the decision not to exclude one to two companies from the sample for future testing of the validity of the statistical relationships. Instead, a feedback survey of a limited number of respondents was organized.

- 12. Because of the large number of variables, a computer program had to be used to carry out these calculations. In this instance, the XDS3 Statistical Analysis Package written for the ICL 1900 Series machines was used (205).
- 13. The feedback survey consisted of a visit to 4 of the original 15 companies, involving a short discussion with the respondents who had taken part in the main survey. The object, this time, was to assess people's reactions to the findings, and furthermore, to establish whether there is any causality in some statistical relationships. A copy of the document attached to letters sent to respondents, and a summary of the subjects discussed in the interviews can be seen in Appendix L. Finally, it is important to stress that statistical relation-14. ships do not show causality. It is not therefore possible to explain the entire phenomenon of "success" in network analysis by simple causal chains. However, causal explanations were cautiously given for a number of findings by logically interpreting the results in the light of the first hand evidence collected by the author in the case study and the following three field surveys.

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2. The sample:

Four main criteria were used in selecting the companies to form the sample for the main survey.

Specialization: Companies were analysed by the trade they 1. specialize in. The categorization was limited to building contractors, building and civil engineering contractors, and civil engineering contractors. Appendix M gives statistical information related to various aspects of the construciton industry. Table 1 in this Appendix shows the number of companies, and the value of work done, analysed by trade of firm. It will be noted that there is a large proportion of general builders, but that building and civil engineering contractors carry out most of the work measured in terms of their value. The large number of general builders as compared with other trades can be attributable to the fact that a large majority of these are small firms employing less than 15 persons (See Appendix M, Table 2). It was therefore agreed that the bulk of the sample (i.e., 60-70% of it) should be formed of building and civil engineering contractors; building contractors should occupy the second place with about 15-20%; and civil engineering contractors should be represented by very few companies (i.e., about 10-15% of the sample)

2. Size measured by the number of employees: Appendix M, Table 2 shows the number of companies, and the value of work done analysed by size of company measured by the number of employees. It can be noted that 98.2% of the companies have less than 115 employees, but that more than half of the work (55.9%) is carried out by companies having more than 115 employees. It was assumed that most of the companies below the 115 employees line were small

builders and sub-contractors like joiners, carpenters, roofers, etc. It is possible however that there are some general contractors in that group who sub-contract most of their work and who consequently employ a small number of staff. But, this was not sufficient to disrupt the decision that the sample should contain only companies employing more than 115 persons; and that most of them should be above the 1200 employees limit.

 Region of registration: Appendix M, Table 3 shows the number of companies and the value of work done analysed by region of registration. It will be noted that the percentages given in the two columns more or less correspond for every region, except for London where the value of work done is considerably higher than the number of companies. This is due to the fact that many national and international companies are registered in London. It was therefore agreed that 60-70% of the companies in the sample should be registered in London, the Southern regions and in the Midlands, and the rest, 30-40%, should be registered in the remaining parts of the country, i.e., in the Northern regions, Scotland and Wales.

4. Size measured by annual turnover: This criterion had later to be dropped because of lack of information. Indeed, national figures related to annual turnovers in the construction industry do not seem to exist in any of the statistical sources the author referred to (206,207,208). The only information related to financial aspects was encountered in the BRS Collection of Construction Statistics (209) which gives some information about the ratio of net profits to turnover; but it dates back to 1961-62. Beardsall (210) also gives in her paper a number of financial figures, but all this information is arranged as a fucntion of size of company as measured

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by the average number of employees. Even if this sort of information at national level were available, it would still not be possible to use it as a criterion, because financial figures for individual companies are not available. Despite the 1967 Companies Act (211) which states that groups of companies should publish financial figures for the group and for their main subsidiaries and branches, there is generally no information about subsidiaries and branches in any financial report. This aspect had therefore to be included in the study as an ordinary variable.

Efforts were therefore made to select a number of companies which would represent roughly a cross-section of the industry. The criteria used in this selection have been discussed above, and it must be emphasized that the sample is representative of the construction industry in Great Britain only to the extent that these criteria are valid and controllable. The sample of 15 companies used in the main survey had the following characteristics:

- Ten of the companies were building and civil engineering contractors; 3 of them were building contractors and 2 of them civil engineering contractors.
- Out of the 9 companies for whom the number of employees was known, 6 had over 1200 employees, and the rest employed between 115 and 1200 persons.
- Four of the companies were registered in London, 3 in the Southern region, 4 in the Midlands, and 4 in the Northern regions. The 2 companies in Wales and Scotland were not using network analysis at all and decided later to drop out.

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Annual turnover figures varied between £2.5 million and £100 million with an average of £24.8 million.

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The following is a chronological account of how the companies were selected, contacted and visited:

Information about individual companies were collected from a number of sources including the Exchange Telegraph Statistical Services (212), Kompass - Register of British Industry and Commerce (213), Guide to British Enterprises (214), the Stock Exchange Official Yearbook 1969 (215), and an article in the Contract Journal (216). This information was used to select 31 companies who would satisfy the criteria mentioned earlier. These 31 companies were approached by letter to which was attached a one page circular signed by Professor E.G. Trimble (See Appendix G). These letters were addressed to the chairmen, vice-chairmen, or managing directors of the companies and stated explicitly that information received would be kept strictly confidential. Experience in previous studies had shown that agreement to co-operate by a senior executive, had resulted in easier access to and more genuine co-operation from members of staff who were involved in the investigation. This, once again, proved to be true.

3. Of these 31 companies 5 did not reply at all despite a second letter sent to them. Another 5 wrote back and indicated that they were not interested: one of these expressed interest in other subjects but not in network analysis; the remaining four indicated that they did not have the time and/or the staff available for surveys of this nature. A report prepared in 1968 for the Ministry of Public Building and Works (217) reports that the direct work involved in supplying data for statistics, has been estimated by a large national contractor at something between 500 and 600 man-days a year. According to the same report, this represents 0.012% of the firm's employment, or 0.045% of its monthly paid staff. Depending on the mood of the industry, this can be interpreted as a considerable waste of time. It is not therefore surprising that 10 companies refused to supply information for this study and that 4 of them specifically mentioned lack of available extra time.

4. A random 10 of these 21 companies were used in the preliminary survey; and once the final questionnaires were ready, these 21 companies were contacted again. All of them confirmed that they wished to co-operate.

- 5. Appointments were fixed with managing directors or directors who introduced the author to senior planning engineers or chief planning engineers who in turn made arrangements for a meeting with a site manager. In some cases, the original appointments were fixed directly with senior planners.
- Five of the 21 companies visited indicated that they had never used network analysis before and that the information they were likely to contribute was very limited. In the light of the fact that this research study aimed to investigate network analysis usage, agreement was reached that these 5 companies would be omitted from the final sample, reducing it to 16 companies.
 After a refusal by a company to fill in the questionnaire on the basis that most answers contained confidential information, the sample was reduced to its final size of 15 companies.

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CHAPTER V

THE MAIN FIELD SURVEY AND THE FEEDBACK SURVEY -FINDINGS AND DISCUSSION

The main survey was carried out in the early months of 1972. It covered 15 contracting companies whose characteristics are given in Chapter IV. It consisted of at least two visits to each company, one to a senior planning engineer and one to a site manager. The meetings were arranged in order to explain the aim of the study, to discuss a number of topics which might not be suitable for inclusion in the questionnaire (See Appendix J, Part 3), and finally, in some instances, to assist the respondent to complete the questionnaire. Interviews lasted on average 13 hours with planning engineers, and 14 hours with site managers.

The feedback survey was carried out about a year later, after statistical analyses had been completed. The purpose was twofold, firstly to assess the reaction of respondents to the findings, and secondly, to find out whether causality existed in some relationships. It involved visiting 4 of the 15 companies who had taken part in the main survey. These companies were selected to form a reasonable cross-section of the sample, in terms of "success scores". Interviews lasted one hour on average. A resume of the points discussed can be seen in Appendix L.

The data collected, the results of statistical analyses, and discussion and interpretation of these findings in the light of the information collected in the feedback survey, are given in the following four sections. Statistical relationships do not show causality and all attempts to explain these relationships are made in the light of the information the author gathered during the three surveys. Regression equations are all significant at 10%, or in some cases, less. Correlations are significant at 10% if their magnitude is larger than 0.44. However, smaller correlation coefficients have also been interpreted because it is believed that they can be valuable in explaining certain phenomena in this type of research study where subjective assessments do not allow high correlation to appear (*).

Since they appear frequently in this chapter, "planning engineer" is denoted by PE, and "site manager" by SM.

(*) For supportive information about the possibilities of interpreting relationships with larger or no significance levels, see papers in Henkel & Morrison (272).

1. Methods of Application:

1.1. Updating:

In a study on "Receipt of Information by Contractors" carried out by the author among 7 contracting companies (See Appendix A), it was determined that average overall delays in project durations amounted to 19% of the average programmed project durations. The most important factors conducive to delay were determined as: — Insufficient information for reliable estimates,

--- Unforeseen weather conditions,

---- Unpredictable delays in delivery of materials,

- Strikes or other labour troubles,

- Unexpected site conditions,

- Variation orders.

Any of the above mentioned factors or a combination, can sometimes cause considerable delay and therefore can necessitate a thorough review of the rest of the programme. For example, in the survey on "Receipt of Information", it was determined that, on average, 54% of the total number of drawings (including both original, about 45% of the total; and revised drawings, about 55% of the total) were received after activity start dates. Although, not necessarily representative of the contracting industry, these alarming figures give an idea of the impact that these factors may have on a programme based on the information available at the start of a project. Similarly, in one of the sites visited in the main survey (Company No. 13), strike action taken by electricians accompanied by go-slows by bricklayers in sympathy, had caused a one year delay in a project of two years estimated duration. At the time of the survey, the job was not complete, and nobody, including the SM knew how long the strike would last or how long the job would take.

In another site (Company No. 10) there were delays due to the late delivery of steel reinforcement bars caused by a national crisis in the British steel industry. Finally, on one site (Company No. 15) it was reported that a combination of bad weather, lack of information and additional works had resulted in six months delay.

It is clear, therefore, that, because of the inherent uncertainty in the construction industry, delays are inevitable. Consequently, programmes frequently become out of date and this necessitates updating.

As demonstrated in Chapter III, Section 2, updating is accepted by the literature as an intrinsic part of network analysis applications. Most authors insist that not updating a network may yield undesirable consequences in its application, by limiting the degree of exactness in evaluation the existing situation and by limiting control in the management of the activities to come.

However, one of the findings of this study is that there is considerable confusion among SMs as to what updating means and what it achieves. The SM's general opinion is that the less a programme is updated the more successful it is. In the opinion of the PEs interviewed, over 50% of the SMs were disillusionned when their programme had to be updated frequently. This is not due to a shortcoming of the technique, but to a misunderstanding on the part of SMs as to the purpose of updating. One SM (Company No. 14) commented that "networks are more definite than bar-charts", and that "they finalize everything and cannot really be modified according

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to the prevailing conditions". When they are modified, SMs' reactions are often negative. Furthermore, it was determined that although only 19% of the PEs and only 11% of the SMs expected a network to be inflexible, in real life situations, inflexibility in networks happened more frequently in the SMs' opinion, as shown in Figure 3.



Figure 3. Frequency of cases where networks were too inflexible (*)

The inflexibility of networks and its implications are discussed in greater detail in Section 1.1.3. in this Chapter. 1.1.1. Frequency of updating:

All the companies who took part in the main survey updated their programmes for most of their projects planned by network analysis. The situation was the same five years ago and the expectation for the future is that every programme will be updated.

(*) Answer to the first item in the last part of each questionnaire (See Appendix J, Parts 1 and 2). Figure 4 shows how frequently updating takes place. It is noted that in the last five years, there has been an increase in the companies who update their projects regularly. The same rate of increase can be seen in the group of companies who use a combination of regular updating and updating when necessary according to the particular conditions of projects.

It is also noted that expectations for the future tend to support regular updating.

The updating frequency variable (UPDAT1) does not appear in any of the regression equations. Despite the fact that they are not high, simple correlations are however interesting.



Updating when felt necessary Combination Regular updating

Figure 4. Frequency of updating

UPDAT1 has a correlation coefficient of -0.25 with PEs' success scores and of -0.28 with SMs' success scores, which means that success is likely to be greater when updating is not done on a regular basis, but whenever the necessity arises.

The trend observed in Figure 4 and these correlation coefficients seem at first sight to contradict each other; in reality, they don't. The trend observed in Figure 4 is the result of routinization that can be seen whenever a technique has been used for a period of time. The whole organization becomes geared to the routine of preparing the sequence, assigning duration estimates, carrying out calculations, and do this every three weeks or so, whether or not conditions demand it. However, the fact that PEs and SMs regard network analysis as being more successful when no regular updating is carried out, is the result of being more discriminating in different situations that arise in different projects. It is only natural that the PE would not like to review a project that in his opinion does not need reviewing. Likewise, it is understandable that the SM would not like to receive a revised programme, say, every three weeks, if he thinks this is not justified.

1.1.2. Frequency of regular updating:

Figure 5 shows the frequency of updating in those companies where programmes are updated regularly. The first point that is noticable is that monthly updating is and has been for the last five years the most common updating period. However, a drop can be observed in favour of shorter and longer frequency periods. The curve which shows the PE's expectation for the future is

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therefore flatter than the others.

UPDAT2 (the variable which measures the frequency of regular updating) does not appear in any regression equation and the simple correlations with PEs' and SMs' success scores are not very high (-0.24 and -0.27 respectively). The signs however point out to the fact that success scores are likely to be higher if regular updates are carried out at long intervals. The argument put forward in the last sub-section about PEs' and SMs' tendencies to move towards updating when necessary is to a certain extent justified by these results.



Figure 5. Frequency of regular updating

1.1.3. <u>Nature of updating</u>:

The nature of updating (UPDAT3) was determined by a question asking whether only durations were reviewed or whether both the durations and the logical sequence activities were considered at each update. The results for 1966 and 1972; and the expectations for 1976 are shown in Figure 6.

The main result is that the large majority (83%) of the companies review both durations and logic when updating their projects planned by network analysis.





Durations and logic updated in every project Combination depending on project Only durations update in every project

Figure 6. Nature of updating

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The only difference in the last five years, has been a very small shift (about 3% of the companies) towards more discrimination, i.e., towards a combination of updating only durations in certain projects which do not need a review of the logic, and updating both durations and logic where applicable.

When Methods of Application variables are considered, the variable used to measure the nature of updating (UPDAT3) appears in the regression equations for both PEs and SMs, at 5% significance level. However, one significant aspect is that the signs are different. Pes' success scores are likely to be higher if both durations and logic are reviewed at each update; whereas SMs' success scores are likely to be higher if only durations are updated and the logical sequence of activities is preserved.

Updating of durations and logic whenever necessary, is an essential part of network analysis applications for a better understanding of the situation existing at a given stage of a project, and a better control of the activities to be carried out. As far as the results are concerned, this is precisely how one can interpret PEs' attitudes to updating. In the main and the feedback surveys not much comment was made on this topic by any PE and the general atmosphere was that updating is an accepted and routine task that is carried out for all projects mostly taking into consideration both durations and the logical sequence of activities.

On the other hand, the SMs' general attitude was that a programme is a good programme if one can stick to it and if no major changes are made during the course of construction. Most SMs, with only very few exceptions, were in favour of minor time

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alterations, but none sympathized with the view that logic also should be reviewed at each update. Some typical comments were: "SMs are suspicious of changing programmes, because, when the programme is updated everything is back on time. False illusions!" (Company No. 5).

"Once sub-contractors and material deliveries are organized, it is extremely difficult to change everything at every update" (Company No.9).

It is important to stress here that different signs for PEs and SMs must not be regarded as a pure contradiction which casts doubt on the data and perhaps the methodology; it is, in fact, evidence that different people situated in different parts of the organization have different reactions depending on various factors. PEs have been taught at college or have read in the current literature that updating must involve some sort of logic review. On the other hand, delays are inevitable in the majority of jobs and increase the likelihood of a network becoming out of date after a period ot time. The combination of the likelihood of delays and the conditioning of the PE, can be accepted as factors promoting readiness for frequent logic reviews. However, it is also fair to add that according to the results of the feedback survey, most PEs were aware of the difficulties that frequent logic changes can cause on site, but could see no other way of planning.

The SMs' case is however slightly different. It is true that the same conditions which cause delays do exist in both cases. But the SM's special place in the organization and his professional background (the majority of SMs came from trades rather than universities in 53% of the companies) tend to have a larger influence on his attitudes to updating. The SM is a very busy man who has to give a large number of non-routine decisions in addition to the control of a considerable number of routine activities. He therefore sees a complete review of the programme as an addition to his duties which will take a considerable amount of his time to study and digest. It will be shown in a later subsection that SMs become quite pessimistic about network analysis when their work-load is increased as a direct result of using network analysis.

Another factor which is important is that, the SM must have a certain amount of trust and even faith in the programme which he will try to stick to. It is believed that major changes of logic during the course of construction cause a feeling of insecurity and demands more attention and thought than would otherwise be necessary. One SM (Company No. 15) reported that "there have been so many updatings that the programme we are using now looks nothing like the original programme and consequenlty we are not really using it". This was found to be a common view.

1.2. The use of computers:

It has been determined that in 1971, about 67% of the companies in the sample used computers to a greater or lesser degree for network calculations. The last five years have seen a small increase of about 7% in the use of computers for this purpose, and the PEs expect that this trend will continue in the five years to come with approximately the same rate of increase (Figure 7).

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Figure 7. Extent of computer use

However, this trend can be observed to be missing in Figure 8, which shows the percentage of projects in which network analysis calculations are carried out by means of computer programs. In the last five years, there has been a drop of 4% in the number of projects where computerized network analysis is used; a drop which is not consistent with the 7% increased use of computers as a whole. This is a strong indication that those who use network analysis nowadays are more aware of the shortcomings and limitations of computer programs and that they are being more selective when they decide whether to use a computer program or carry out the calculations manually.



Project planned manually Project planned by computers

Figure 8. Percentage of projects planned by computerized network analysis

An interesting result which is worth mentioning here, is that correlation coefficients for both SMs and PEs are nearly significant at 10% and have a negative sign (-0.43 and -0.36 respectively) which means that success scores are likely to be higher when a smaller number of projects are planned by computerized network analysis. This result also reflects the doubts that exist in the minds of both PEs and SMs regarding network analysis computer programs. For example, 44% of the PEs expected the input requirements for a computerized application to be too complicated. No detailed question has been asked in the questionnaire about different aspects of computerized applications. Nevertheless, this subject has been discussed in interviews, especially with SMs, the comments of some of whom are worth quoting:

"At every update, they send us piles of computer printouts which you can see in this drawer. I use the bar-chart on the wall for almost all my decisions and I am lucky I have got one" (Company No. 13).

"SMs regarded network analysis with suspicion initially. However, this was not because it was network analysis, but because it was computers" (Company No. 2).

"Because the input is generally full of rubbish, all we get in our printouts is complicated rubbish" (Company No. 6).

"I receive the printouts at every update but it is too much paper and is extremely hard and time consuming to understand. We had a meeting with the directors the other day and they felt exactly the same way I do about these printouts" (Company No. 4).

"I have trouble with computer printouts. I have no time to read all these figures, and I don't understand most of them anyway" (Company No. 15).

There is no doubt that a human problem connected to computer usage does exist in many companies. There are also difficulties in the collection of the right information, the classification of this information for input purposes, the form of the output, and the amount of information included in it. Various data forms are being used by PEs to get around the first two problems and a large number of companies are using bar-chart transformation of networks to make them more easily understood by and acceptable to SMs and the site staff in general. It was found that the bar-chart presentation of networks (no matter whether links and dependencies, float, latest, earliest times, etc., are shown or not) was favoured by the large majority of SMs. This subject will be discussed in fuller detail in a later section.

1.2.1. Kind of computer facility:

PEs working in those companies using computer programs for network analysis calculations were asked to specify whether they were using their own computer (if any) or whether thet were using the services of a computer bureau. The results (Figure 9) show that 45% of the companies use their own computer and 61% use a computer bureau (one company uses both facilities). It is also noted that there has been a well emphasized shift from the use of computer bureaux in favour of acquiring a computer and using it



Figure 9. Kind of computer facility

for planning purposes. Most of the larger companies contacted, expected to buy their own computer in the near future and use it for planning purposes, although in all cases, without exception, the main reason for acquiring a computer was for accountancy purposes. Figure 9 shows that PEs expect this trend of acquiring computers and using them for planning purposes to continue in the next five years.

It is interesting to note that COMPT1 which indicates what sort of computer facility was used, appears in the regression equation carried out for PEs, using Methods of Application variables. It appears that PEs' likelihood of scoring high in success is dependent upon the use of company owned computers rather than relying on service bureaux. One of the PEs (Company No. 14) reported that generally, by the time they receive the printouts the results are out of date and useless, and it happened at least once that they had to wait for six weeks before they could get the printouts. Another example of long waiting periods was the one reported by the SM in Company No.11, who stated that the normal turn-round time was "unfortunately" between two to three weeks. Campbell's findings (112), reported in Chapter III, Section 2, that turn-round times offered by computer bureaux were generally quite lengthy, seems therefore to be right and furthermore of importance in interpreting the results in this study. A number of PEs thought also that the use of computer bureaux was much more expensive than what it would have cost if they had their own computer and used it for planning.

Simple correlation coefficients for PEs support the trend

in Figure 9 (-0.42 for COMP1A, the use of computer bureaux, and +0.48 for COMP1C, the use of own computer; the first coefficient is nearly, and the second one fully significant at 10%).

For SMs, simple correlations are not as high as those for PEs (-0.22 for bureaux, and +0.15 for own computer), but the signs do support the general argument.

1.2.2. Kind of computer program used:

In the preliminary study, it was observed that a number of companies had expert computer staff whose job was to prepare the input documents, and in addition to this routine job, to improve and even sometimes completely redesign the existing program which was used. It was also noticed that the programs some companies were using had been designed by their own staff some years ago and were supposed to be tailor-made for the purposes of and conditions in the company.

Figure 10 shows that 78% of the companies who took part in the survey were using a standard package (and 5 out of the 7 companies who used standard packages, used ICL 1900 PERT). The trend however is very pronounced and can be seen to shift from standard packages towards company made programs.

When the variables included in Methods of Application were subjected to a regression analysis, it came out that one of the main factors which affected the equation (top of the table of importance) was COMPT2, the variable which indicated what sort of program was used. The regression coefficient has a positive sign which means that PEs' success scores are likely to be higher if programs used are specially designed to satisfy the needs of the company. Simple correlations for PEs are not high (+0.17 for



Program developed within company Standard package

Figure 10. Kind of computer program

COMP2A, programs developed within the company; and -0.14 for COMP2C, standard packages) but the signs are in accordance with the argument mentioned above.

One obvious interpretation is that when a PE uses a program for his network analysis calculations, he naturally wants his input forms not to be restricted by the limitations of a standard package, but to have a format which would integrate as completely as possible in the existing system of data collection and manipulation. The same argument can be put forward for output printout sheets in the case of SMs. It is fair to say here that most good standard packages have a multitude of options for both fhe input and output formats. One snag is, however, that manuals are much too often too complicated and need expert advice for better understanding (112).

The computer program used, affects SMs' success scores in the same way it does PEs'. Correlation coefficients are much higher in this case (+0.46 for COMP2A programs developed within the company, significant at 10%; and -0.30 for COMP2C, standard packages) and the signs suggest that the above mentioned argument about "the printouts being in accordance with the needs of those who use it", holds to a larger extent for the SM, who, in fact, is the person who actually has to live and base his decisions on the information contained in the output sheets.

1.2.3. The size of the network in manual and computerized

applications:

The number of activities in a network is a measure of size, and if it is taken as a ratio to the project cost, it may be used as a measure of detail. However, the purpose in asking a question about the smallest and largest number of activities in both manual and computerized network applications, was to find out what sort of numbers PEs dealt with, when carrying out manual calculations or when preparing the data for computer processing. The same purpose applies for SMs, i.e., to find out what sort of numbers SMs received either as the result of manual calculations, or as computer printouts. Whether these numbers have any effect on success scores is also considered in the statistical analyses.

Figure 11 shows the data collected. It can be seen that the smallest number of activities in a manual application ranges from 75- to 200 activities, while the range for the largest number is about 200 to 2000+. One underlying feature is that the majority



	•
M	
E	• •

Manual : Smallest No. of activities
Manual : Largest No. of activities
Computer : Smallest No. of activities
Computer : Largest No. of activities

Figure 11. Largest and smallest number of activities in manual and computerized applications

of the companies (86% of them) have less then 75 activities in their smallest networks.

In the case of computerized applications, the range for the smallest number of activities covers all the spectrum from 75- to 2000+, while the largest number of activities is between 750 and 2000+. It is interesting to note that the first two groups (i.e., 75- and 75-150) contain mainly companies who used computer programs as a matter of policy for all their project planning, whatever the size of the network.

The data also shows that in a number of companies, the range covered in manual applications overlapped with the range covered by computerized applications. That is, in some companies some projects were either planned by manual network analysis or by computerized methods, according to prevailing conditions. What these conditions were, and what they should be for higher success are described in the next sub-section.

Multiple regression analysis between SMs' success scores and Methods of Application variables' shows that COMPSM, i.e., the smallest number of activities in computerized applications, affects success scores. The negative sign of the regression coefficient suggests that the smaller COMPSM is, the larger become the success scores. This is also backed up by the results of the correlation analysis (correlation coefficient -0.39). COMPSM does not seem however to have any effect on PEs' success scores since it is not present in any of the PEs' regression equations and since the correlation coefficient is extremely small (+0.04).

One interpretation of the result described above is that SMs are eager to have some sort of standardized planning procedure. If computer programs are used in a number of projects, they prefer to receive computer printouts for as many jobs as possible (hence, including more and more smaller jobs with smaller number of activities) as a routine matter. Interviews have indicated that there is enough evidence to support this view.

The other variables do not appear in any regression equation. Correlation analysis shows however that the smaller is COMPLG (i.e., the largest number of activities in computerized applications), the higher are likely to become SMs' success scores (coefficient -0.50, significant at 10%). Correlation coefficients for the rest of the variables are not statistically significant at 10%.

The findings seem to indicate therefore that the number of activities in a network has very little influence on PEs' success scores. The signs of the correlation coefficients suggest that smaller numbers would contribute to greater success. As to SMs, the findings show that a smaller number of activities, especially in computerized applications, is likely to enhance success.

1.2.4. Criteria for computerization:

Every company who uses a computer program for network calculations has its own reasons for doing so. In general, it has more than one reason and it was determined in the preliminary study that the most common of these were the ones listed in the questionnaire, namely;

- A clause in a contract (SPECIF),
- A large number of activities, (NOACT),
- Familiarity of site staff with computer printouts (SSFAMI),
- --- Familiarity fo planning staff with input requirements (PDFAMI),
 - Acceptability of anticipated computer costs (COMPCO).

The results are shown in Figure 12. The sum of the percentages shown considerably exceeds 100, because of the multitude of reasons every company had. One result is that 50% of the PEs ticked "others" specifying reasons such as: for improved planning, whenever resource analysis is used, whenever the job is very complex, when a high frequency of updates is necessary, and whenever it is the policy of the company.

Figure 12 shows that the most frequent reason for using computer programs were clauses in contracts that specifically asked for computerized network analysis. Two companies (No. 5 and No. 6) used computer programs only when it was contractually required.



- A: Contract clauses
- B: Number of activities
- C: Familiarity of PE
- D: Acceptability of computer costs
- E: Familiarity of site staff
- F: Others

Figure 12. Criteria for using computer programs

The second mostly used criterion was the number of activities in the network. This is the variable which is most favoured by the literature. It is generally claimed that the larger the network, the more difficult, costly, and time consuming it becomes to handle it by manual methods. The average limit set by the seven PEs who specified it, was 262 activities, implying that larger networks were generally analysed by computer programs. This limit more or less corresponds to limits set by most authors (See Chapter III, Section 2).

The familiarity of planning staff with computer procedures was the third most used criterion with 45% of the companies considering it. It is surprising to see however that the acceptability of anticipated computer costs and the familiarity of site staff with computer printouts were the last two criteria, being least used by the companies in the sample. It is surprising because one would expect the management to evaluate the economic implications of using computers and at the same time to determine whether those who use the printouts, (i.e., the site staff) would be able to understand and exploit the new presentations and get sufficient benefit to justify the extra expense incurred.

Statistical analysis indicated that the present state of affairs concerning the use of computer programs is not satisfactory: Firstly, PEs' success scores are likely to be higher if the number of activities is not accepted as a criterion. This is the result of both regression analyses between PEs' success scores and Methods of Application variables, and between PEs' success scores and all variables. The SMs' correlation coefficient (-0.41) supports this finding.

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Secondly, regression analysis of SMs' success scores and Methods of Application variables indicated that success is enhanced in cases where there is no contractual obligation to use computers. The PEs' correlation coefficient (-0.28) supports this finding.

Thirdly, the regression equation between PEs' success scores and all variables indicates that success is enhanced if site staff's familiarity with computer printouts is taken into consideration before using computer programs.

Fourthly, a positive correlation coefficient (+0.25) between PEs' success scores and anticipated computer costs (COMPCO) indicated that this variable also should be taken into consideration for higher success.

It can therefore be stated that the companies in the sample used computer programs mostly when it was required in a contract and when the size of the network was large enough (larger than 263 activities on average). Statistical analyses, however, show that this way of handling this decision is not contributing favourably to both the PEs' and the SMs' success scores. More practical and down to earth criteria, namely the familiarity of site staff with computer printouts and low computer costs are indicated to contribute more favourably to success.

The correlation coefficient for planning staff familiarity with computer procedures (PDFAMI) carries a negative sign for SMs (-0.18) and suggests that this should not be a primary consideration, the idea behind it being perhaps that most PEs are expected to know something about computers and programs anyway.

1.3. Preparation of the network:

This sub-section consists of variables which deal with various aspects of the procedures undertaken when a network is being prepared at the start of a project.

One subject that was brought up in almost all interviews with PEs, and which is worth mentioning for this reason, is the procedure used when the logical sequence of activities is set up. It is common knowledge that the literature advises the PE to draw the sequence of activities in a purely logical manner, without taking any notice of resource and time limitations. It was found that the majority of the PEs found this way of constructing a network impossible in practice. "When I draw my network, I do my resource analysis at the same time", was one of the stronger comments; but it is clear that some sort of resource arrangement is carried out sometimes consciously and sometimes unconsciously by the large majority of PEs when the sequence of activities, and the complicated interrelationships are decided.

A number of characteristics such as the procedure for allocating float time, for presenting the results on site, for determining the degree of detail and so forth were investigated, and the results are reported in the following sub-sections.

1.3.1. Allocation of float:

The question asked, aimed at determining which of the following six methods were used when float was allocated at the end of a time analysis to determine the final work schedule: ---- Earliest starts are used (EARLYS),

- Latest starts are used (LATEST),

--- Float is evenly distributed among activities (EVENDI),

--- Certain activities which seemed to need some more time are allocated floats (CHOICE),

Float is distributed arbitrarily among activities (ARBITR),
This is dictated by the results of a resource analysis (DICTAT),
A look at trends in Figure 13 shows that in the last five
years the use of earliest start dates for working schedules has
remained quite static with 57% of the companies employing this
method. There are however increases in the number of companies
who use resource analysis results. It seems therefore that this
latter method of allocatiog float is being accepted by PEs and SMs'
although the fact remains that in 57% of the companies the





Figure 13. Allocation of float

Bearing in mind that some companies use a combination of these procedures (i.e., they use different procedures in different projects according to prevailing conditions), the regression equations gave the following results for Methods of Application variables, at 5% significance level: PEs' success scores are likely to be higher if float is evenly distributed rather than allocated to those activities thought likely to become critical. SMs' success scores are however likely to be higher if a resource analysis determines the allocation of floats. Correlation analysis for SMs (coefficient for EVENDI: +0.48, significant at 10%) supports the evidence found for PEs that even distribution of float among activities is one of the ways which lead to increases in success scores, although its use has been on the decline.

The finding that even distribution of float enhances success was difficult to interpret. Apart from the obvious explanation that it is much easier to allocate float values evenly, there seems to be no possible way of interpreting it. This issue was discussed in the feedback survey with both PEs and SMs. All respondents agreed that float could be allocated in an efficient way only after a close examination of resources. Nobody seemed able to give an interpretation for the finding that even distribution is likely to enhance success. Eventually, it has been accepted that this particular question was misunderstood by most respondents, because it is possible that "even distribution" was interpreted as "proportional distribution".

1.3.2. Presentation of results:

One of the outcomes of the preliminary study was the realization that the companies contacted, used a large variety

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of methods for presenting the results of network analysis for site use. It must be emphasized that every single presentation seen on site, differed from each other in at least one respect. It was however possible to form five main groups, each containing similar characteristics: These were:

- Only networks (precedence or arrow diagrams),

- Time-scaled networks,

- Networks and bar-chart translations used together,

- Logic linked bar-charts,

---- Only bar-chart transformations.

The general trend in presenting results, as seen in Figure 14, is away from network based methods towards bar-chart based presentation. In the last five years, the use of "bar-chart together with network" combination, as well as the use of logiclinked bar-charts and pure bar-charts have increased, whereas pure networks and time-scaled networks have been used less. It seems that the "network and bar-chart" combination is the main way of presentation with 67% of the companies using this method. Furthermore PEs in 77% of the companies expected that they would be using this method more frequently in the near future.

This trend is also apparent when the correlation coefficient between PEs' and SMs' success scores and PRERES (the variable which determines what sort of presentation is used) are considered. Although these coefficients are not very high (-0.29 and -0.27 respectively) their sign indicates that the more bar-chart based presentations are used, the higher the success scores are likely to be.

The results obtained for PRERES do not need a great deal of



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Only networks Networks and bar-charts Only bar-chart transformation Logic-linked bar-charts Time-scaled networks

Figure 14. Presentation of results

explanation. Network analysis users realize that people on site are used to work with bar-charts and that no matter what planning method is used the results must be presented in barchart form if the people using them on site are to understand and efficiently apply them. It seems therefore that as long as the results are presented in some sort of a bar-chart, PEs are satisfied because they can communicate more easily with SMs; and SMs are satisfied, because, besides improved communication with PEs, they can see more clearly what is said on the programme. It was reported in one company (No. 11) that whenever a SM saw a PE preparing a network for his job, he would immediately ask when he could get a bar-chart transformation of it. Furthermore, SMs thought that, most of the time, high effort was spent by the staff involved, to understand fully the results of a network analysis. Figure 15 illustrates this finding.



to be understood by staff involved.

Interviews with PEs however, led the way to a relatively unimportant but rather interesting discovery. It was found that' although PEs were satisfied with the above mentioned explanation, the majority of them longed for the time when they would not have to use bar-chart presentations. It was understood that this desire was brought about by two reasons, one economical and one emotional. Those who used computer programs thought that it was extremely expensive to use the bar-chart printing option of any standard package; and those who used manual methods claimed that the time, effort and money spent for the transformation (into a bar-chart) was extremely high and sometimes not justified. For example, half of the PEs interviewed, indicated that it would require high effort and cost to present the results of an analysis in a suitable way so that it is fully understood by the staff involved. In addition to this, most PEs thought that network analysis was not fully exploited when the results were presented in terms of the limitations of a bar-chart.

It is only fair to join the PEs in their worry when this subject is discussed, with the reservation that the existing situation could be accepted as a transition period which is necessary for the assimilation of certain new aspects by site staff. Figure 14 shows that a larger number of PEs expected using time-scaled networks in the future and it is believed that this sort of transition, with network analysis characteristics more and more incorporated in the bar-chart presentation, is certainly a much better way of introducing network analysis. The results of the correlation analysis support this point of view.

There is however one more point that only a few PEs and many SMs mentioned during discussions; a pure network with no timescale has practical in-built limitations (such as inconvenience to mark and show progress) that makes it unacceptable to most SMs. It was generally believed that a network with a time-scale would be the most likely final stage to be reached.

1.3.3. Breakdown of projects into activities:

The breakdown of a project into a number of activities that will form the network is the first step in the construction of a network. A question that asked what the average cost of each activity was in an average project has not been answered by nearly half of the PEs interviewed, and although the rest gave an average figure, they made it clear that it varied considerably depending on the project and on the activity. Therefore when a project is broken down into activities, the cost associated with each activity is not generally arranged to be the same. There were three main ways of defining activities:

- --- By trade: This facilitates resource allocation if carried out.
- If resouce analysis is not carried out, it gives an approximate idea of labour conditions (sub-contracted labour or not).
 By resource (other than labour): This method also facilitates resource allocation especially when the project needs the use of a lot of equipment and machinery which have to be co-ordinated.
 By location: This method has the advantage of recording and assessing progress more easily than in the other methods.

Figure 16 shows how network analysis users have defined their activities in the last five years and what they expected in the





Figure 16. Breakdown of project into activities

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near future. The figures point out that the majority of PEs used either one of the three methods depending on the situation and on the particular limitations of the project. It is worth noting that the proportion of companies who adopt this procedure has increased considerably in the last five years, whereas the use of location and trades as standard procedures has declined, while resources other than labour have never been used as a standard procedure in breaking down a project into activities. This shows that when PEs have to decide on a method of preparing a network, they are more discriminating and selective than they were a few years ago. They, not only, are not satisfied with rigid updating procedures, but they also differentiate among projects so as to use the most appropriate way of breaking them down into activities.

The regression analysis carried out between SMs' success scores and all the variables grouped together, shows at 2% significance level that SMs' success scores are likely to be enhanced if activities are not classified according to their location. Since SMs mostly receive the results of network analysis in some sort of a bar-chart (See Chapter V, Section 1.2.3) it is believed that the advantage of using location (i.e., recording progress more easily on a network) does not apply, hence resulting in such a finding. The highest correlation coefficient for SMs is the one for trades (+0.18) indicating that a breakdown by trades is the most favoured process. It is believed that a breakdown by trades gives SMs a better chance to control labour resources especially if a resource analysis is not carried out. Correlation coefficients for PEs are rather small except for LOCATN which, contrary to what has been found for SMs, is positively correlated to PEs' success scores (+0.38). PEs commented on this result by saying that the logical sequence of activities could be more easily obtained when one was able to visualize the steps necessary for the actual construction in terms of their physical start and end, rather than in terms of various resources used for each activity.

1.3.4. Staff involved in the estimation of durations:

According to Pinschof (174) who investigated, among other things, the use of network analysis in several contracting companies, the site staff members who were most critical of the technique, were those who were not contacted at the planning stage. Most writers believe that constant contact at planning stage between the PE on the one hand, and the SM, the contracts manager, the sub-contractors, the material firms, and other related departments (such as the work study department, the operational research department -if any-, or the estimating department), is essential for successful network analysis applications. Good communication and co-ordination in the preparation stage have always been accepted as crucial when the reliability of the network is considered.

The data collected and shown in Figure 17, suggest that most PEs are in constant touch with the SM, the contracts manager, and the sub-contractors, as recommended by the literature. In cases where PEs had not contacted some sub-contractors, it was discovered that these were nominated sub-contractors who were not yet nominated by the clients. This happens quite often,



M.C.: Material company

Figure 17. Staff involved in the estimation of durations

and one extreme case was observed in one of the sites visited (Company No. 15) where half of the job (£4.5 million out of £9 million) was carried out by nominated sub-contractors; at the time the author visited the site (over half-way the project period) there were a number of sub-contractors who were still not nominated. In the case of SMs, it was determined that the no-consultation situation arose generally when SMs were scarce either due to a shortage of staff, or due to a large number of projects going on. In such cases, the SMs would be completing contracts some distance away from the office containing the planning department. The PE would thus plan the job in the SM's absence, without the SM's involvement. Statistical analyses, on the other hand, give no evidence that this variable is in any way related to success in network analysis applications. INVPRE which is an indicator of the number of persons involved in the preparation of the network, does not appear in any regression equation and the correlation coefficients are small. It seems therefore that a continuation of the present state of affairs in relation to the people involved in the estimation of durations, is likely not to have any negative (or, positive) effects on success scores. 1.3.5. Degree of detail:

Discussions with PEs and SMs in the preliminary survey highlighted a point about which there was a lot of confusion: the problem of how to determine what sort of detail a network needs. Five main criteria have been determined at the end of the preliminary survey:

- Clients requirements (CLIENT),

- Time limit for planning (TIMELI),

--- Complexity of the project (COMPLE),

--- Ability of the SM to cope with complicated networks (SMABIL), --- Ability of the PE to construct complicated networks (PEABIL),

In addition to the results in Figure 19, it was determined by a question in the last part of both questionnaires (See Appendix J, Part 1 and 2), that 31% of the PEs and 33% of the SMs expected a network to be too detailed or not detailed enough. In real life situation SMs were more concerned about this aspect because in their opinion, an inconvenient degree of detail was used more frequently than what PEs claimed. This is shown in Figure 18.



Figure 18. Frequency of cases where the degree of detail is not convenient

In later paragraphs, when the results of regression analyses are discussed, it will be seen that the regression equation for SMs contains four "degree of detail" variables while the PEs'has got only one. The data given in Figure 19 may be accepted to be one of the reasons why SMs are so preoccupied by the detail of the network.

Figure 19 shows that the large majority of PEs (80%) considered the complexity of the project when they were deciding how detailed their network was going to be. Clients' requirements, and planning time limitations were also considered by about 45% of the PEs. An example of very tight limitations was given by the PE interviewed in Company No. 2; he stated that he had been allowed only six weeks by the client, to plan a fl3 million hospital job of three and a half years contract duration. Considerations about the ability of PEs and SMs to cope with complicated and detailed networks were not frequent.

When Methods of Application are considered, the SMs' regression equation can be observed to contain four of the five



A: Complexity of project B: Client requirements C: Time limit D: Ability of PE E: Ability of SM F: Others

Figure 19. Criteria to determine the degree of detail

variables mentioned at the beginning of this sub-section. Consequently, a change of policy on how to determine the detail of a programme is likely to affect considerably SMs' success scores. According to these results, SMs' success scores are likely to be higher if the complexity of the project, the requirements of the clients, and SMs' ability and knowledge to cope with complicated networks, are considered, rather than relying solely on PEs'ability to produce a highly detailed network. Discussions with SMs rendered easier the explanation of the last phrase in the last sentence, because the point was made that PEs must be competent enough to produce a simple or a highly detailed network, and that this should not be a criterion for determining the degree of detail. The effect of project complexity is understandable since the more complex the project, the more the SM will want to know about sequences and interrelationships of much smaller activities than usual.

The finding that SMs success scores are likely to be higher if client requirements are also used as a criterion, is interesting because an entirely oppostie result is produced by the PEs' regression equation (i.e., PEs' success scores are likely to be higher if client requirements are not considered as a criterion for determining the degree of detail). The SM who is in costant touch with the client either directly or through the contracts manager has to satisfy him as to the way everything, including the planning, is carried out. In some projects, it was observed that the programme was checked by the client's office for approval before final use on site. The PE, however, is not in direct touch with the client and it is only natural that he would not like it if an outsider sets up the rules for him when he determines the degree of detail of his own network. A trace of professional pride can be detected in this argument.

1.3.6. The cost associated with each activity:

This is a variable aimed at gathering complementary information to the previous sub-section about the determination of the degree of detail of a network. Interviews with PEs indicated that most PEs never took the size of an activity (in monetary terms) into consideration when they were drawing a network. Therefore, the value associated with each activity is not a criterion by which the degree of detail is decided upon. The data collected (Figure 20) confirm this finding by the high percentage (47%) of PEs who could not tell the value associated with an average activity. It was made clear by the rest that the group they were indicating had nothing to do with the determination of detail, but was an average figure which had a very high standard deviation. As a matter of fact there were respondents who ticked several groups. Indeed, the sum of the percentages exceeds 100 in Figure 20.

In addition to this, multiple regression equations do not contain COSTA2 (the cost associated with an average activity), and correlation coefficients are low (+0.14 for PEs, and -0.04 for SMs). It seems therefore that this variable has little effect



A: <f1000 B: 1000-5000 C: >f5000 D: No reply

Figure 20. Cost associated with each activity

on success in network analysis applications.

1.3.7. The use of sub-networks:

The majority of PEs (60%) used sub-networks in all the projects they planned by network analysis. As seen in Figure 21 there were another 13% who used sub-networks in some projects but not in others.

The use of sub-networks has not been thoroughly discussed with either the PEs or the SMs. The idea of taking a critical part of a programme (no matter whether it is a network or a barchart) and blow it up into a larger and more detailed programme is not a novelty, and to the best knowledge of the author, has





Figure 21. Use of sub-networks

been practised by almost every PE or SM. Therefore, there is a consensus of opinion that sub-networks are useful tools whenever a particularly critical and complex part of a project is to be built. This fact is reflected in the regression equation for Methods of Application variables for PEs. SUBNWK which indicates whether sub-networks are used or not, is an important variable in this equation and supports the fact that PEs are generally in favour of sub-networks. Correlation analysis for SMs does not show any correlation at all, implying that SMs are not interested in sub-networks as long as they get a workable programme.

1.3.8. <u>Resource analysis</u>:

As shown in Figure 22, resource analysis has been carried out in conjunction with time analysis by the majority of the companies (80% in 1966, and 93% in 1971) during the last five years. Most PEs with whom the subject was discussed made the point that time analysis is of much more use if it is accompanied by a resource analysis. As mentioned in an earlier section (Chapter V, Section 1.3) the usual practice when drawing a network, is to take resource limitations into consideration, no matter whether resource analysis will be carried out later on, or not. However, most PEs thought that network analysis is not complete without a resource analysis.

This way of thinking sharply contradicts SMs' attitude to resource analysis, as reflected in regression equations for both General Characteristics, and all variables. These equations show that the less resource analysis is used, the higher SMs' success scores are likely to be. Therefore, TIMRES which indicates whether resource analysis is used or not, is a governing





factor in the SM's case and its impact must be given some more thought.

Although Figure 22 shows that 93% of the companies in the sample resource analysed their projects in 1971, this high figure is slightly misleading, in that is does not show the extent to which each company used this facility. It was possible to collect information to elucidate this point and the data is given in Figure 23. This diagram shows that in 1971, only 36% of the projects (in monetary terms) were planned by time and resource analysis applied together. This is quite a low percentage when compared with the 93% cited earlier and it demostrates that resource analysis is not a very popular method,



Figure 23. Extent of resource analysis use, expressed as percentage of turnover

and that it is not used as a standard practice whenever time analysis is carried out. As a matter of fact, only slightly more than half of the projects which were time analysed were also resource analysed.

The SMs' attitude to resource analysis was rather curious. One would tend to think that, because resource analysis gives a lot of important information about labour and machinery limitations, this sort of approach should be invaluable to SMs. But, in practice SMs are extremely dissappointed with resource analysis. One comment was "Up to now, I have never seen a resource analysis which contained correct information to assist me in my decisions". This lack of trust coupled with the on and off use
of resource analysis are believed to be the main reasons for SMs' reactions and for the results obtained in this study. It was also thought that this reaction could have been caused by the way resource analysis is applied. In order to investigate this possibility, a question was asked, to find out whether resource analysis was carried out for only parts of the project at a time, or whether the entire project was resource analysed at the very start.

RESANA, the variable which indicates the way in which resource analysis is carried out, is an important governing factor in the case of SMs. Regression analysis between SMs' success scores and Methods of Application variables indicates that RESANA is the third important variable in the equation. The negative sign in front of the regression coefficient suggests that SMs' success scores are likely to be higher if parts of projects are resource analysed whenever it becomes necessary, rather than analysing the entire job at the start. One interpretation of this finding, as expressed by most SMs in the feedback survey is that the resource analysis carried out at the pre-contract stage is too often found to be inaccurate. As a matter of fact, as mentioned in the CIRIA report, (Appendix A) the amount of information available at the start of a project is generally so limited that in most SMs' opinion, resource analysis of the entire job results in nothing more than an educated guess. And since frequent updatings are disliked by the majority of SMs, the idea of having a loose resource programme at the start of a project and of modifying it according ot the situations that arise as the job progresses,

is apparently not acceptable to them.

RESANA is not a governing factor in the case of PEs, and the correlation coefficient is +0.23. Although this is not a high correlation coefficient the positive sign suggests that PEs are in favour of resource analysing the entire project at the start of the job, contrary to what SMs would prefer.

Figure 24 shows that there has been a steady increase in the number of companies who resource analyse the entire project at the start, and a consequent drop in companies who analyse parts of projects at a time. It is significant to observe that about 25% of the companies have used either method according





Whole project at the start Combination Parts of project at a time

Figure 24. Kind of resource analysis

to the particular conditions of the projects. Having stated this fact, it is also worth noticing that PEs' expectations for the future lie in analysing parts of projects as a routine, which is more in line with SMs' requirements.

There are three main points that emerge from the abovestated findings. Firstly, it seems that PEs have resource analysed a larger proportion of entire projects in 1971 than they did in 1966, despite the fact that SMs openly show preference (and this is reflected in the findings of statistical analyses) for resource analysis carried out for parts of projects. This fact implies that PEs generally ignored SMs' requirements in the past five years. Secondly, there is a good 25% of PEs who use either of the two systems according to prevailing conditions. This is an indication that PEs are discriminating among systems and is encouraging as far as the future of network analysis is concerned. Thirdly, PEs' expectations for the future show that they think there will be a small increase in the proportion of projects which are resource analysed part by part. This indicates that PEs are nowadays more concerned with SMs! attitudes and reactions, and that they are beginning to try to synchronize what they are doing and what SMs expect them to do.

1.4. Application of the technique:

This sub-section consists of variables which give information about various procedural aspects both on site and at the planning department.

1.4.1. Logical planning and control:

In the preliminary survey it was observed that a number of

companies used network analysis to assist them in the logical planning of the job and that they did not exploit at all the control capacity during the course of construction. These companies regarded network analysis as a tool to help them understand and more easily visualize the intricate relationships among activities, but not as a control technique to be used during construction. Although, theoretically speaking, one of the biggest advantages of network analysis is accepted to be its potential capacity for control, it was thought that the view expressed by the companies mentioned above could be valid in certain situations and that it should be taken into consideration.

The results are given in Figure 25. It is noted that in 1966, 14% of the companies applied the view expressed above. In 1971, however, the majority of companies (73% of them) used network analysis for planning <u>and</u> control purposes; 27% of them used either one of the two systems, depending on prevailing conditions; and finally, there were no companies who used network analysis for planning purposes only. The general trend considering the expectations for 1976 as well — is towards a more indiscriminate use of network analysis for planning <u>and</u> control purposes.

LOGPLA, the variable which determines whether jobs are controlled as well as planned by network analysis, has a very low correlation coefficient with PEs' success scores (+0.05). However, it has a coefficient of +0.30 for SMs, which increases the likelihood of SMs' success scores to be higher in cases where network analysis is used for planning <u>and</u> control purposes.

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Only logical planning in all projects Logical planning + control in some projects, and only logical planning in others Only logical planning + control in all projects

Figure 25. Logical planning and control

This result is in line with the trend observed in Figure 25 and there is consensus among respondents that, in the future, the large majority of jobs planned by network analysis will also be controlled by the same technique. Davis's findings (29) that the majority of "very successful" firms in his sample had used network analysis to plan <u>and</u> control their jobs, is supported by these results.

1.4.2. The status of the planning department:

One of the results that emerged from the case study (Chapter II, Section 3) was that the introduction of network analysis had increased the authority of the planning department and that consequently SMs' authority was reduced. PEs had assumed the role of a contracts manager and had started monitoring progress on site and reporting it to the director in charge of contracts. It was observed that this change of emphasis in authority which was attributed to the increased use of network analysis by both site staff and planning staff, had caused considerable uneasiness in both sides: SMs complained because they were not the boss on site any more, and because there was a PE who visited the site from time to time and put pressure on them to stick to the programme; PEs complained because contracts managers were interfering with their job. The situation had reached a crisis stage and although there was no open discontent on the part of the site staff (because, after all, the contracts manager's role was being integrated into the PE's), there was a continuous discussion among PEs who usually disapproved of the contracts manager's existence. There was an open campaign to get rid of contracts managers for good, and instead, to let PEs absorb the contracts managers' functions.

This situation which eventually turned out to be a special case, originated a question to find out what sort of authority the planning department had on the site staff. Lateral authority means that the planning-department is used as a staff department which offers its services to different project managers if and/or when they want it. It plays a consultative role and has no direct power to influence decisions. Its responsibility is restricted to the correctness of the network and the calculations, and does not cover delays and overruns on site. In this case the real direct authority lies with the SM. The results did not confirm what the case study had implied. It was found that all the planning departments in all the companies (100%) had lateral authority and merely provided services to project managers. It is obvious that no regression equation includes this variable and the correlation coefficients with success scores are nil. This variable, therefore, turned out to be a special case for the case study considered, and it can be said that it has no effect at all on success scores. 1.4.3. Correctness of time estimates:

The estimation of activity durations is a critical operation in the preparation of a network. As mentioned earlier (Chapter V, Section 1.3.4) the number of people (SMs, sub-contractors, etc) consulted by the PE during this process does not seem to be important, but it is believed that the usual correctness of these estimates influences the users' trust in network analysis to a large extent.

The data collected (Figure 26) show that there were a large percentage of companies (36%) where time estimates were always incorrect. The proportion of companies where time estimates were always correct was only 28%. It seems therefore that the process of determining how long an activity is going to take under given conditions, is a difficult job, and that in many cases it produces unreliable activity durations.

The data given in Figure 27 show whether incorrect time estimates were optimistic or pessimistic. It is not surprising to see that the majority (70%) of the companies where durations were not esimated correctly were on the optimistic side. The estimates of the rest (30%) of the companies were sometimes



- 1. Always correct
- 2. Sometimes correct, sometimes incorrect
- 3. Always incorrect

Figure 26. Correctness of time estimates



- A: Pessimistic
- B: Sometimes pessimistic, sometimes optimistic
- C: Optimistic

Figure 27. Nature of incorrect time estimates

pessimistic and sometimes optimistic. This can mean that the impressive delays reported in the study on "Receipt of Information by Contractors" (See Appendix A) are caused by these optimistic estimates. It can also mean that these estimates are generally optimistic because most activities are delayed due to uncontrollable reasons, such as unforeseen weather conditions, unpredictable delays in the delivery of materials, strikes or other labour troubles, unexpected site conditions, and a large number of variation orders. It seems therefore that it would be quite difficult to seek a causal relationship between the correctness of time estimates and the delays incurred during construction. The relationship seems to work both ways. ESTIMA which measures the correctness of time estimates, is not included in any regression equation, but it is negatively correlated to both PEs' and SMs' success scores (-0.24 and -0.43 respectively), which means that success scores are likely to be higher if time estimates are incorrect. Although not very large, these coefficients shatter all of what has been said in the first paragraph of this sub-section and deserve some more exploration. A possible way of explaining this finding is given in the following three paragraphs:

1. The fact that the large majority of incorrect estimates are optimistic suggests that incorrectness is possibly related to the frequent occurance of delays due to uncontrollable events, or to the PEs' natural tendency to optimize in the absence of contrary evidence.

 It was observed in the study on "Receipt of Information by Contractors" (Appendix A) that to open a claim file at the start of a project had become a routine job in most companies. The main survey showed that virtually all PEs and SMs (100% and 94.4% respectively) regarded network analysis as a better tool than conventional planning techniques when claims were negotiated. Furthermore, it has been determined that this quality was used quite frequently in real life situations, as shown in Figure 28 and in the following examples. Two of the sites visited were awarded a longer project duration, in the first case, because they were able to show better on a network the implications of a late delivery of reinforcing bars due to a national shortage (Company No. 10), and in the second case, because they were able to show by using network analysis, the effect that a combination of bad weather, lack of information, and additional work had had on the overall duration (Company No. 15).



Figure 28. Frequency of cases where claims for delays are determined and verified more easily by network analysis

3. It follows that the result of the correlation analysis can be explained by speculating that delays due to uncontrollable events and/or due to PEs' tendency to optimize in the absence of sufficient information, are unavoidable; that these cause time estimates to be optimistic; and that this in turn, causes contracting companies to negotiate claims from an advantageous position.

1.4.4. <u>Site knowledge of float values associated with each</u> <u>activity</u>:

Float is accepted to be one of the big advantages of network analysis over conventional techniques. It gives an implementation flexibility that so often lacks in bar-charts. However, it is an extremely delicate task to assign activity start dates by taking float values into consideration. There are a number of methods which assist the PE in determining how to use float and these are dealt with in an earlier sub-section (Chapter V, Section 1.3.1). All of these methods show as a final result how much float there is at the start or at the end of each activity. In cases where the entire set of results are sent to site, a number of people such as the SM, foremen, and gang leaders become aware of the existence of these slack times. As stated earlier in this paragraph, the allocation of float is a delicate matter; but its interpretation is also as delicate, because it needs good knowledge of the principles and is likely to cause enormous harm in case it is wrongly interpreted.

The case study, the preliminary survey and the main survey showed that PEs' chronic fear was that float would be misunderstood on site. This is a well founded fear, because, especially in networks having a large number of activities in series rather than in parallel, the consumption of float in the first few activities can cause all the remaining activities to become critical, and the probability of completing the job on time can be reduced considerably. This observation brought up the issue whether site staff should be allowed to see float values associated with each activity, or whether only the final schedule should be issued for site use.

The data collected show that (Figure 29) every SM in almost all the companies (93%) was aware of float values. Considering that SMs in 87% of the companies were involved in the preparation



- A: SM
- B: Foreman
- C: Ganger

Figure 29. Site knowledge of float associated with each activity

of the network (See Chapter V, Section 1.3.4), this result can be accepted to be normal since most of them are expected to follow up the results of the network calculations. The number of companies who disclosed this information to foremen was much lower (57%), and those who let the gang leaders know as well were practically nil (7%).

SITEFL which indicates the number of persons aware of float values, does not appear in any regression equation. Correlation coefficients, however, indicate that success scores for PEs and SMs are likely to be higher when less people on site are aware of float values (-0.31 and -0.41 respectively). It is interesting to note that the SMs' coefficient is also negative implying that they are as worried as PEs that misguided interpretation would result in relaxation and would consequently cause delays in activities to come.

Interviews with SMs in both the preliminary and the main surveys indicated that most (not all however) SMs had a clear idea of the implications of using float arbitrarily. Their worry that float would be misunderstood, extended not only to foremen and gang leaders, but especially to sub-contractors. In a few cases the author was told by the SMs that they had been accused of bad intentions because they had forced a sub-contractor to start an activity on one date while they could have let him start at a later date. One SM (Company No. 14) made it clear that, in the light of his past experience, he never shows float values to sub-contractors.

It seems therefore that there is more good than harm in letting the SM know how much float is associated with each

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activity, because, after all, he is the one who manages the site and makes the decisions which, more frequently than not, rely quite heavily on his knowledge of float. There is however evidence (both statistical evidence -negative correlation coefficients- and evidence gathered during interviews) to support the view that site staff members other than the SM, and subcontractors representatives should not be informed about float values, especially about those associated with their own activities. The likelihood of their misinterpreting it and relaxing was thought by respondents to be extremely high. This view is reinforced by the answers to one of the questions in the last part of both questionnaires asking whether float made people. relax, till, in the end, every activity became critical. The average answers shown in Figure 30 indicate that SMs were more worried about their foremen, trades foremen, gang leaders, subcontractors, material firms, etc., than PEs were about the site in general.



Figure 30, Frequency of cases where float makes people relax, till, in the end, every activity becomes critical

1.4.5. <u>Reliability of the first network:</u>

This question was included in the questionnaire in order to investigate allegations that the late receipt of information by the contractor renders the job of preparing a network very difficult and sometimes impossible. Indeed, many respondents indicated in the preliminary survey that the first network drawn at the start of a project was generally incomplete, full of wildly estimated information, and that it would not be a reliable network to work with.

It is true that the construction industry suffers of what has been labelled as "bad communications" between professions. The untimely issue of information by architects and/or consulting engineers is only part of this problem, but it is an important part which has serious repercussions on aspects like planning and estimating.

In the small sample of contracting companies investigated in the CIRIA study (See Appendix A), it was found that 30% of the original drawings on average, were received after activity start dates. Starting from the point that an activity cannot start without the receipt and examination of its original drawings by the site staff, it may be suggested, as it is in the CIRIA report, that drawings are received on time, but that activity start dates have not been updated. There is undoubtedly some truth in this hypothesis, but this does not rule out the fact that, in general, a large number of drawings are issued fairly close to the activity start dates.

The following three examples (Companies No. 5,6 and 9) illustrate how much design information can change during the

course of construction. In the first example, there were a total of 700 variation orders issued during the construction of a £7.7 million office block with a contract period of two years. The second example was an undergound construction, and the total project duration was extended from 190 weeks to 250 weeks by the clients because of additions and alterations decided during the course of construction. Finally, the third example was a residence block and the contract value of over £1 million was cut down to less than its original value due to alterations. These examples together with the additional three given in the CIRIA report, reinforce the argument that the problem of receiving the right kind of design information, with the right kind of detail, at the right time is quite a common and serious problem. The data collected during the main survey indicates further that this problem affects the reliability of the first network. Figure 31 shows that the large majority of the companies (97%) did have this problem in certain projects, depending on circumstances; 27% answered that their first network was never reliable in any project.

The seriousness of the situation can also be seen in the results of the multiple regression analysis carried out between PEs' success scores and Methods of Application variables. ISTNWK which indicates whether the first network is regarded as reliable or not, occupies the third important place in this regression equation. The regression coefficient is positive and therefore suggests that the PEs' success scores are likely to be higher if there is enough design information to construct a reliable network at the start of a project.



A:	Yes		ļ
B: 🕤	Somet	imes	5
C:	No	- 1 A	1

Figure 31. Unreliable first network due to insufficient information

This, in its own is not a variable that is directly related to network analysis, because the late receipt of information exists no matter what planning technique is used. However, network analysis being by its very nature, a more precise and usually more detailed technique than conventional ones, it is most affected by this shortcoming of the construction industry.

This finding has little to suggest for the improvement of network applications apart from the obvious recommendation that most drawing information must be received at the time of planning. This, in turn, points out that research into the causes of late issues of drawings would be very valuable and would have quite a bearing on network analysis applications as

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well. It must, however be mentioned that during the CIRIA investigations, the author tried to find out the causes for delayed drawings but found the exercise extremely difficult, if not impossible to carry out. As a matter of fact, as stated in the report, the whole idea was dropped because of time limitations.

1.4.6. <u>Hierarchical reporting</u>:

Especially in cases where computer programs are used for network calculations, there is the possibility of selecting the amount of detail in printouts, and therefore the possibility to present incumbents of different positions in the hierarchy, with reports containing the right amount of information. For example it is possible for the contracts director to have a report on the late and critical activities, whereas the SM will receive every sort of information related to every single activity. This is called "hierarchical reporting" and is accepted to be an advantage over conventional planning techniques.

The data collected and shown in Figure 32 indicate that 57% of the companies contacted, used reports containing selected information for different hierarchical levels in the organization. It seems that this facility which receives a lot of support in the current literature is not fully exploited.

The correlation coefficient for PEs (+0.28) suggests that hierarchical reporting increases the chances of having higher success scores. HIERAR which indicates whether hierarchical reporting is practised or not, also appears in two regression equations for SMs. In the first analysis between SMs' success scores and Methods of Application variables, it is situated at



Figure 32. Hierarchical reporting

the bottom of the table of importance and has a positive regression coefficient, meaning that SMs' success scores are likely to be higher if hierarchical reporting is carried out. The second multiple regression equation that contains HIERAR, is the result of the analysis carried out between SMs' success scores and all the variables taken together. Again, it is situated in the bottom half of the table of importance, but this time, the sign of the regression coefficient is negative, implying the opposite reasoning made for the first result.

According to statisticians, the reason for these conflicting results lie in the second analysis: it is likely that one of the variables added in the second analysis is highly correlated to HIERAR, causing a high level dependency, which in turn forces HIERAR to change its sign. That is why, on the recommendation of statisticians, the result obtained in the second analysis has been ignored. It seems therefore, that hierarchical reporting is likely to enhance success.

1.5. Economic factors:

This section contains two variables and is only a crude attempt to determine to what extent network analysis is economically viable and to what extent this affects success in network applications. It is a crude attempt, because the two questions used for this purpose do not form a strict measure of economic viability as such. The first question was designed to find out how much network analysis costs in terms of percentage of the total project cost. And the second question aimed at some sort of subjective assessment of network analysis's effect on the overall company profitability.

1.5.1. The cost of using network analysis:

Analysis of the literature (See Appendix C, Part 1) indicates that the cost of planning by network analysis varies between 0.1 and 5% of the total project cost. This range was divided into four groups and respondents were asked to tick the group in which they thought the average cost of their network analysis applications i lied.

According to the results shown in Figure 33, 83% of the PEs indicated that network analysis cost less than 0.5% of the total project cost, whereas the rest (17%) indicated that it cost slightly more, between 0.5 and 2%. There was no company where the cost of network analysis exceeded 2% of the total



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A: 0.0-0.5% B: 0.5-2.0% C: 2.0-5.0% D: 5.0%+



project cost.

Examination of the regression equation between PEs' success scores and Methods of Application variables, shows that COSTNA which gives an idea of the average cost of using network analysis, has a negative regression coefficient, indicating that PEs' success scores are likely to be higher if the cost of using network analysis is as low as possible. A cautious interpretation of this result is that PEs are very much aware of the cost implications of the technique they are using. The lower but again positive correlation coefficient for SMs' success scores (+0.13) indicates that this awareness had not developed to the same extent in SMs.

1.5.2. Economic justification for using network analysis:

This question was aimed at finding out what PEs thought of network analysis in terms of its contribution to the overall profitability of their company. Is network analysis worth it? Does it really increase profits? Or is it just another technique which has no more effect on profits than any other planning technique? In brief, is the use of network analysis economically justifiable?

Figure 34 shows that 57% of the planning engineers found the use of network analysis "often" and "always" economically justifiable. 21% found it "seldom" justified the cost incurred, and



- A: Always
- B: Often
- C: Seldom
- D: Never
- E: Don't know

Figure 34. Economic justification of the use of network analysis

22% answered "Don't know". Furthermore, it has been determined that while 75% of the PEs and 89% of the SMs expected to reduce their project costs by using network analysis, the average of achievement in real life situations was less than "sometimes" for both respondents (Figure 35).



Figure 35. Frequency of cases where project costs are reduced

Despite the fact that there is such a wide negative difference between expectations and ahievement on that matter, and although 22% of the PEs do not even know whether network analysis is economically justifiable or not, it is interesting to note that the use of network analysis has not been discontinued in any of the companies. In a survey carried out in USA, the Bureau of Bulding Marketing Research (56) asked respondents to specify how much saving they would expect from using network analysis. The average expected saving for CPM was 4.8% of the total project costs. Yet, only very few companies in Davis's survey (29) reported definite cost savings. Furthermore, a survey by Booz Allen Applied Research Inc. (39) indicates that economic considerations are not a major deterrent to network analysis use. It seems therefore that the findings reported in this sub-section are consistent with the findings in various surveys that economic justification is difficult to prove in terms of short-term immediate cost savings.

ECOJUS which measures economic justification does not appear in any regression equation and correlation coefficients are extremely small, implying that this variable does not affect success as measured by the questionnaire. It must be emphasized that success was measured by means of a list of 20 advantages and 14 disadvantages which were all weighted according to their importance as perceived by respondents. The system used therefore a large variety of tangible and intangible aspects which contribute to a greater or lesser degree towards overall efficiency and profitability; it was deliberately not based solely on economic data, since this would be impractical and perhaps impossible (See Chapter II, Section 2.2). The fact that there is no correlation between success scores and ECOJUS, does not hinder the use of the system developed in this study for two reasons: a) Economic justification is extremely difficult to prove. Furthermore, respondents who answered this question, made it absolutely clear (as was the case with respondents in other surveys mentioned in this sub-section) that their answer was entirely intuitive and not based on any concrete evidence.

b) The measurement system used in this study considers a large

number of criteria which are all conducive to higher efficiency and profitability.

The following multiple regression equations show the relationship between success scores and <u>Methods of Application</u> variables at 5% significance level. The figure on the left is the regression coefficient; the figure in parantheses, following the variable name, is a measure of importance. (Regression coefficient multiplied by the standard deviation). It denotes the change undergone by the dependent variable, for a standard change in that particular independent variable. The variables are given below in order of importance:

Planning engineers' success scores are likely to be higher when: -19.55 COMPT2 (25.29): computer programs are specially developed to suit the particular requirements of the company; -41.73 CHOICE (19.10): float is not allocated to activities thought to be likely to be late, without formal analysis; +32.80 ISTNWK (16.24): there is sufficient information at the start of a project, in order to construct a reliable network; +17.69 SUBNWK (15.92): sub-networks are used whenever necessary; -23.62 NOACT (12.20): the number of activities is not the criterion used in deciding whether or not to use computers; -30.56 COSTNA (10.54): the cost of using network analysis is small; + 7.15 COMPT1 (8.29): the company's own computer, rather than a service bureau, is used; +22.11 EVENDI (6.20): float is distributed evenly among activities; + 6.02 UPDAT3 (3.39): both durations and logic are reviewed at each update; - 4.78 CLIENT (2.37): clients' requirements do not influence decision on the detail of networks. Site managers' success scores are likely to be higher when: -78.21 SPECIF (39.00): contractual obligation is not the only criterion in deciding whether or not to use computers; +72.38 SMABIL (26.28): SMs' ability to cope with complicated networks is considered in deciding the detail of networks; -22.22 RESANA (18.40): resource analysis is carried out on parts of projects at a time, rather than on the entire job at the start; -29.57 PEABIL (10.74): PEs' ability to construct complicated networks is not considered when deciding the detail of networks; -18.08 UPDAT3 (10.49): only durations are reviewed at each update and the logic is preserved; +14.57 DICTAT (5.29): float is allocated according to the results of resource analysis; + 7.00 COMPLE (2.98): complexity of job is considered when deciding the detail of networks; - 0.01 COMPSM (1.83): the number of activities in computerized applications is small; + 2.28 CLIENT (1.14): clients' requirements are considered when deciding the detail of networks; + 0.39 HIERAR (0.19): reports with different degrees of detail are sent to different levels in the hierarchy. Planning engineers' correlation coefficients at 10% significance level; success is likely to be greater when: SPECIF (-0.52): contractual obligation is not the only criterion in deciding whether or not to use computers (*). Site managers' correlation coefficients at 10% significance level; success is likely to be greater when:

COMPLG (-0.50): the number of activities in computerized applications is small; EVENDI (+0.48): float is evenly distributed among activities.

(*) Significant at 5%.

2. Methods of Introduction:

2.1. Reasons for introducing network analysis:

Network analysis was developed in the first place, to plan and control extremely complex military projects; then it was found that it had potential capacity for planning construction work. Nowadays, the construction industries of the United States and of Great Britain are the major users of network analysis. However, after the case study, and the preliminary survey, the author's impression was that some companies started using network analysis not because they desperately felt the urge for a new, more advanced, more adequate technique, but because of a combination of reasons that were later formulated into a question in the final questionnaire. These reasons were:

- Traditional planning techniques were inadequate (INADEQ);
 Someone in senior management pushed it through (SENMGT);
 There were compulsion clauses in contracts (CLAUSE);
- --- It was fashionable (FASHIO);
- The computer of the company had some idle time (IDLETI).

The data summerized in Figure 36 show that the majority of the companies (70%) started using network analysis because they thought the existing conventional planning techniques were not adequate for increasingly complex jobs with stricter time limitations. Positive correlation coefficients for INADEQ which indicates whether or not network analysis was introduced as a response to inadequate conventional methods (+0.22 for PEs; and +0.48 for SMs), show that a need should exist -especially on the part of SMs where the correlation coefficient is significant at 10%- before attempts are made to introduce network analysis. It is also noted that the inadequacy of



A: Inadequate conventional techniques
B: Push by senior management
C: Clauses in contracts
D: Fashion
E: Use of computer idle time
F: Others

Figure 36. Reasons for introducing network analysis

conventional techniques was never the only reason for introducing network analysis. A combination of reasons were used in every case, as indicated by the sum of percentages which exceeds 100.

The second most popular reason (63% of the companies) for introducing network analysis was the influence of one personality in senior management. It is quite common for a director or a managing director to read about network analysis, or to hear about network analysis from his colleages in other companies, or to come across network analysis in a professional meeting, and then try to introduce it to his company. SENMGT indicates whether network analysis was introduced by a senior executive. Correlation coefficients for this variable are negative (-0.24 for PEs, and -0.37 for SMs), implying that success scores are likely to be higher if network analysis is not pushed through by a senior executive. There are two different ways of interpreting this finding:

- The timing of the action taken by the senior executive does not correspond to a felt need for a better technique throughout the organization. This was the case in about 1/3 of the companies in the sample.
- 2. The person in higher management who advocates the use of network analysis and takes action for its introduction, is not fully aware of the implications of introducing a new technique. Neither is he well informed about the capabilities of network analysis, and of its implications on the planning staff, the site staff, the internal procedures of the company, in brief on all the organization. Company No. 16 who later decided to drop out of the sample was a good example for this case.

The third most popular reason for introducing network analysis is seen in Figure 36 to be clauses in contracts that specifically ask for the use of network analysis. The first experience of 40% of the companies with network analysis was partially caused by a clause in a contract. CLAUSE which indicates whether network analysis was introduced as a response to contractual obligations, appears in the regression equation between PEs' success scores and Methods of Introduction variables, at 10% significance level. The negative sign of the regression coefficient indicates that PEs' succes scores are likely to be higher if the introduction of network analysis is not related to contractual obligations. Although quite low, the correlation coefficient for SMs (-0.21) supports the above statement. It is thought that whenever the contract specifies the use of network analysis, there is general resentment against the technique if the organization is not ready to adopt it. It was observed that in such cases, network analysis was used only in appearance, for the only reason of satisfying the client.

The fourth popular reason for introducing network analysis was "fashion". 20% of the companies thought that network analysis had become fahionable, that their competitors were using network analysis more and more, and that it would be a good advertisement gimmick. It is significant to note that this point of view was always present when there was senior management involvement in the introduction. It is not surprising to see that correlation coefficients for FASHIO have negative signs (-0.32 for PEs, and -0.33 for SMs).

The last option, idle time of computers (IDLETI) was not ticked by any PE. This variable seems therefore not to be related to success.

It can therefore be concluded that high success is likely to be achieved if network analysis is introduced not because one member of senior management wants it, or because the clients specifically ask for it in their contract, or because it is fashionable, but if there is a well defined need for better techniques than the existing ones.

2.2. <u>Calculation of the first network used in the company:</u>

It was agreed in an earlier section (Chapter V, Section 1.2) that there is definitely a human problem in the use and especially in the introduction of computers. Most writers who advocate the use of network analysis, take special care to recommend that computer programs should not be used in the first few applications. It is generally believed that the introduction of a new technique (network analysis) causes enough problems on its own, and that it would be wise to start using computer programs later, when network analysis has once settled.

Figure 37 shows that 83% of the companies in the sample had used manual methods to analyse the first network ever constructed in their company. Only a minority of 17% had used computer programs. MANUCO which indicates how the first network is calculated, is not a governing factor, but is strongly correlated to success scores (-0.54 for PEs, and -0.51 for SMs, both significant at 10%). The negative signs indicate that success scores are likely to be higher if the first ever network is calculated by manual methods. It seems



Figure 37. Calculation of the first network

therefore that the use of computers in the very first application is likely to cause undesired additional problems to those already caused by the introduction of network analysis. In this context, it is worth re-quoting the comment made by the SM in Company No. 2: "SMs regarded network analysis with suspicion initially. However, this was not because it was network analysis, but because it was computers".

2.3. Staff situation when network analysis was introduced:

When the decision to use network analysis is taken, there are three possibilities concerning the staff situation in a company. Either the planning staff and the site staff are already aware of the basic principles of network analysis; or they are trained by some means to master the new technique; or a number of new staff are recruited.

The data collected (Figure 38) show that in the majority of companies (87%) the staff was trained to cope with network applications; in 13% of the companies they had enough knowledge to implement it; and in 13% of the cases new staff was recruited. Analysis of the data indicates that the recruitment of staff was always accompanied by training schemes. This suggests that one of the new recruits' jobs was possibly to train the existing staff.

STAFF which gives an idea of the staff situation, is not a governing factor because it does not appear in any regression equation. However, correlation coefficients (+0.33 for PEs and +0.30 for SMs) indicate that success scores are likely to be higher if people with previous network experience are engaged. Considering the observation made in the preceding paragraph, it is fair to deduce that the recruit of experienced personnel (especially of



A: Staff trainedB: Staff knew alreadyC: New staff recruited

Figure 38. Staff situation when network analysis is introduced

network analysts) would serve a double purpose, one of planning, and one of training the existing staff. The second purpose is indeed important because "on-the-job" training is particularly favoured by SMs (See Chapter V, Section 2.1.2).

2.4. <u>Training courses:</u>

It was determined in the case study (See Appendix E) that an intensive course was organized with the help of the university and the CITB on "Planning and Production Control" for planning staff and senior site staff including contracts managers, SMs, and some senior foremen. In addition to this, it was observed in the preliminary study that most companies sent their personnel involved in planning, to courses run by external organizations such as the CITB, the NFBTE, the BAS, the BRS, etc. The basic purpose was to teach the staff the elementary principles of network analysis, or sometimes to broaden their horizon by letting them attend more advanced courses.

As mentioned in Chapter III, the literature gives very strong support to training schemes and it is generally believed that the root of the problem lies in the ignorance of prospective users of network analysis. It is argued that success in network applications relies heavily on some sort of training and that only training could ensure better understanding of the implications of the technique.

The data collected show (Figure 39) that not many companies (only 20% of them) ran regular courses related to planning.



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In addition to this, 50% of the companies organized no planning courses at all. It must be admitted however that to organize a management course within an organization (possibly with the help of outside expert organizations) can be very costly. That is probably why 30% of the companies ran only occasional courses whenever they considered them to be necessary.

INTCOR (for internal courses) and EXTCOR (for external courses) do not appear in any regression equation. Correlation coefficients for INTCOR (-0.08 for PEs, and -0.47 for SMs) show that while there is practically no correlation for PEs, there is a relatively high negative correlation (significant at 10%) for SMs. According to the information collected in the feedback survey, SMs generally dislike and sometimes resent internal courses. If the right kind of atmosphere is not generated by the course organizers (and these are generally the PEs) it is understandable why SMs with many years of practical site experience dislike the idea of being taught how to manage their job. The same argument can be put forward for the correlation coefficient between EXTCOR and SMs' success scores (-0.20), although the coefficient in this case is smaller.

The correlation coefficient between EXTCOR and PEs' success scores is also negative (-0.33) and relatively high to deserve some explanation. According to the feedback survey, a common opinion shared by most PEs who attended external courses (and by most SMs as well) was that courses are generally very theoretical and tend to concentrate on mathematical intricacies while little attention is given to practical aspects. The time table and the brief summaries of the lectures delivered at one such course have been examined. It seems that there is sufficient evidence to support

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this argument.

Another way of interpreting these consistently negative correlation coefficients is by assuming that an introductory course inevitably increases the expectations of the participants. Indeed, it was reported in the feedback survey that some PEs and some SMs had become over-enthusiastic after attending courses. Higher unrealistic expectations are however likely to cause dissatisfaction with the technique.

2.5. <u>Regular meetings between PEs and SMs at different stages of</u> <u>the project</u>:

Most textbooks and papers advocate an atmosphere of full cooperation as a prerequisite for success in network applications. This atmosphere of full co-operation is generally accepted to exist whenever there is enough contact between the man who prepares the network and carries out the calculations, and the man who actually uses it on site, provided that there are no difficulties of communication such as the SM working on a contract some distance away from the office where the PE is preparing the programme.

The results shown in Figure 40 indicate that the majority of companies have followed the recommendation. Indeed, there were regular meetings between PEs and SMs, at the planning stage, in all the companies; and there were regular meetings at pre-contract stage and during construction in 87% of the companies.

No regression equation contains REGMET which is an indicator of meetings organized at different stages. Correlation coefficients for REGME1 (meetings at pre-contract stage) and REGME2 (meetings at planning stage) are negligibly small. REGME3 (meetings during construction) however shows a weak but interesting relationship with


- C
- A: Pre-contract stage
- Planning stage B:
- C: 1 During construction

Figure 40. Regular meetings between the PE and the SM

PEs' success scores (correlation coefficient -0.28). This indicates that PEs' success scores are likely to be higher if meetings between PEs and SMs to discuss programme, progress and control are not organized on a regular basis. It was reported in Section 1.1 that PEs favoured updating the programme whenever they thought it was necessary. Since most meetings between PEs and SMs during the course of construction are to discuss updating, the finding reported above is consistent with the one reported in Section 1.1.

2.6. Kind of interpersonal relationship between PEs and SMs:

It is believed that the atmosphere of co-operation mentioned in the preceding section (2.5) can be achieved not only by means of frequent meetings, but also by a convenient interpersonal relationship

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between PEs and SMs. That is why a question inquiring about the formality of this relationship was included in both PEs' and SMs' questionnaires. None of the respondents reported that PEs had a superior role. In Section 1.4.2 of this Chapter, it was shown that planning departments in all the companies contacted, had the status of a staff department which offered its services to SMs. It was therefore natural that SMs were regarded as the superior by PEs and SMs alike.

According to the rest of the information collected (Figures 41 and 42), most PEs (71% of them) regarded themselves as having a non-formal relationship with SMs, whereas most SMs (64% of them)



- A: PE superior formal
- B: SM superior formal
- C: Non-formal

Figure 41. Relationship between PEs and SMs, as reported by PEs



A: PE superior formalB: SM superior formalC: Non-formal

Figure 42. Relationship between PEs and SMs, as reported by SMs

thought it was a straight forward, formal superior-subordinate relationship. A difference of opinion therefore existed between PEs and SMs.

Respondents in the feedback survey provided three categories of possible reasons for this result:

- a) The SM is normally the formal superior, but he lets the PE believe that the relationship is informal, in order to secure his support.
- b) The PE is regarded as a spy by some SMs, and

c) Some SMs are worried that PEs have too much say in decisions.

The correlation coefficient for PEs (-0.22) indicates that PEs' success scores are likely to be higher if their relationship with

SMs is as informal as possible. PEs are members of a staff department and they are supposed to be experts on planning. Specialists who work in staff departments do not generally regard themselves to be simple subordinates; they rather accept their status as advisory. It was apparent in most cases that PEs' self-image was somewhat above the simple subordinate concept. In addition to this, interviews indicated that PEs generally preferred to have a friendly atmosphere between them and SMs, because in this way, they believed they were able to understand much better what SMs' problems were. One other reason was that such a relationship made the "selling" (as some PEs called it) of the technique much easier.

On the other hand, the correlation coefficient for SMs (+0.32) suggests that SMs' success scores are likely to be higher if their relationship with PEs is a clear-cut superior-subordinate relationship. SMs are generally well aware that PEs are trying to "sell" them this new technique (in cases where they are not already "sold" for it). The result of the correlation analysis is possibly caused by a reaction to this, and possibly because SMs generally regard themselves as the boss of every single member of staff contributing to the project. In the preliminary survey, the author had the impression that SMs were eager to demonstrate their superiority because they feared that PEs would impinge on their authority. Although all SMs in the sample indicated that PEs did not interfere with their authority (See Chapter V, Section 1.1.4b), the impression the author had in the preliminary survey, remained unchanged.

2.7. Preoccupations of PEs:

This section is closely related to the atmosphere of co-operation

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between PEs and SMs, mentioned in the preceding two sections. A question which was included in both questionnaires, inquired about PEs' predominant preoccupations in their relationship with SMs. It was believed at the time the questionnnaires were being prepared, that PEs were very much preoccupied with technical details and adminstrative procedural aspects rather than trying to create a convenient ambiance for a healthy relationship with SMs.

Figures 43 and 44 show the average answers given by PEs and SMs, arranged on a continuum of "priority". Both PEs and SMs believed that the primary preoccupation of PEs was the technical aspects such as the logical sequence, the time estimates, the calculation of the critical path parameters, etc. The only difference between the two groups of respondents, is that SMs placed this aspect much nearer the "high priority" end than PEs did, implying that PEs paid more attention to these aspects than they cared to admit.

According to PEs, their second most important preoccupation was human relations, and the third, administrative aspects. In the SMs' opinion however, human relations aspects occupied the third place with lowest priority; they believed that PEs neglected the human aspects of the relationship between them and that instead, they concentrated on administrative aspects such as filling in forms, taking care that the right information is sent to the right person through the proper channel.

The hypothesis set up in earlier chapters that certain aspects can be perceived in different ways by PEs and SMs, proves therefore to be right in this instance. Furthermore, the effects of this sort of difference of perception can be observed in the results of the statistical analysis. Multiple regression equations for PEs do not

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		-175-			
Techni	cal Hum	an Rel. 1	Admini	strative	
ligh Priority		2 2		3	
	Figure 43. F	reoccupation	ns of PEs,	ow Priority	
	ð	s reported t	y PEs		
Techr	nical Adminis	trative	Human Re	1.	
1 High Priority		2	Lo	 3 w Priority	
	Figure 44. Pi a:	reoccupation s reported b	s of PEs, y SMs		

contain any of these three variables and furthermore correlation coefficients are relatively low (+0.21 for technical aspects, -0.09 for administrative aspects, and -0.15 for human relations). These findings weakly suggest that less technical emphasis and more concentration on interpersonal relationships are desirable.

The results for SMs' statistical analyses are however very different. Multiple regression analysis for Methods of Introduction variables indicates at 10% significance level that technical aspects and human relations are the first two most important factors in the equation. The signs indicate that SMs' success scores are likely to be higher if PEs stop emphasizing the technical aspects of network analysis and instead, if they concentrate on creating a convenient atmosphere for a better relationship. Very high correlation coefficients for SMs (+0.51 for technical aspects, and -0.59 for human relations) both significant at 5%, support the findings of the multiple regression analysis.

Therefore, the answer to this question does not rest with any particular class of executive in the organizational hierarchy. Every individual occupying a different post visualizes the situation in the light of his position, his interests, and his relationships with other individuals; and this sort of difference in perception may lead to serious repercussions such as, in this case, the coming to light of a very important factor that PEs were not practically aware of.

Respondents indicated in the feedback survey that they fully agreed with the results of the statistical analysis. Two of the SMs went even further and stated that this was the most important finding of the study.

2.8. Frequency of constructive consultation between PEs and SMs:

This question aimed at determining how frequently PEs consulted SMs, while preparing the contract programme. It was included in both questionnaires, mainly as a double-check.

According to Figures 45 and 46, the majority of PEs (83% of them) and the majority of SMs (79% ff them) indicated that constructive consultation took place "often". The author's suspicion that there could be a difference of opinion over this matter has therefore been proved to be ill-founded.

SMIDEA indicates the frequency of consultation between PEs and SMs. Correlation coefficients for SMIDEA are quite low (-0.15 for PEs, and +0.17 for SMs); but their signs suggest that PEs' success scores are likely to be higher if they prepare the programme without any interference from SMs, whereas SMs' success scores are likely to be higher if they have a say in the preparation of the network. Both results seem to be understandable because:

- a) PEs generally work alone at the pre-tender stage, because it is not possible to appoint a SM to every job the company tenders for. Since the contract programme is later prepared on the basis of the pre-tender programme, PEs prefer to get on with it rather than making modifications suggested by SMs.
- b) SMs want a programme which is in complete accordance with what they think of the job. In order to have such a programme their views must be incorporated in it; and this can be done if PEs modify the programme according to the suggestions made by SMs.

Although this variable has been examined in a long paragraph, it must be emphasized that the coefficients are quite low to suggest a strong relationship. However, contradictory signs indicate that



Figure 45. Frequency of constructive consultation between PEs and SMs, as reported by PEs



Figure 46. Frequency of constructive consultation between PEs and SMs, as reported by SMs

a difference of opinion does exist between PEs and SMs. 2.9a. <u>PEs' opinion of SMs' knowledge of network analysis:</u>

This question was asked to PEs only and its main purpose was to determine the situation that existed at the time of the survey, rather than to find out its effect on success scores. It is obvious that the more a PE thinks the SMs he is working with, are competent in network analysis, the more his success score is likely to be higher. As a matter of fact, this is shown to be so when the results of the correlation analysis are examined. The correlation coefficient for ATTIPE which gives an idea of PEs' opinions on SMs' knowledge of network analysis (+0.28), indicates that PEs' success scores are likely to be higher if the SMs they are working with are quick to learn all the intricacies of network analysis.

The important part about this facet is however shown in Figure 47, which indicates that in 41% of the PEs' opinion, most SMs have an adequate knowledge of network analysis that is sufficient for implementation. This is not a very high figure; indeed, when the rest of the list is considered it may even sound alarming, because nearly half of the PEs indicated that SMs were slow to learn the capabilities, limitations, and various interpretations of network analysis; and that they never had a complete knowledge of it. However, 15% of the PEs believed that SMs learned quickly and made rapid progress.

The situation is not, in fact, as bad as it sounds, because discussions with SMs and PEs indicated that the SMs who were very slow to learn and who had trouble in catching up with new techniques, were the older members of site management. The general belief was that all SMs would have an adequate knowledge of network analysis

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- A: Enough to implement
- B: Slow to learn
- C: Never know everything
- D: Learn quickly

Figure 47. PE's opinion of the SM's knowledge of network analysis

once the older members were gradually replaced by the younger generation. Furthermore, in some interviews it was mentioned that SMs' professional backgrounds were also related to the amount of knowledge they had about modern techniques. It was determined that in over half of the companies most SMs were ex-tradesmen. It was claimed that these SMs were slower and more reluctant to learn the details of network analysis, when compared with SMs with university education. There is however no statistical evidence to accept or refute this view.

2.9b. SMs' opinion of PEs' site experience:

After the preliminary field survey, it was believed that SMs' opinions of PEs' site experience were of great importance for two reasons:

- a) If the PE is not familiar with site conditions, activities, and sequences, the network he will prepare will be far from being a realistic representation. Furthermore, time estimates are likely to be wrong.
- b) If the PE has not much site experience, he will fail to see the SM's difficulties; and consequently a barrier of communication will be formed between them.

According to the data shown in Figure 48, the majority of SMs (63% of them) believed that most PEs had adequate knowledge of what was going on on site. 23% thought that they had just sufficient knowledge, while only 14% believed this knowledge was advanced. No SM ticked "poor knowledge". Although this point was specifically



Poor Just Adequate Advanced sufficient

Figure 48. SMs' opinion of PEs' site experience

included among the questions asked in the preliminary survey, an issue was made of it by almost all SMs interviewed. The finding cited above are therefore in sharp contrast with what had been observed earlier.

PESITE measures SMs' opinion of PEs' site experience. The correlation coefficient for PESITE is low (+0.12) but indicates that success is enhanced if PEs' site experience is as good as possible.

2.10. Attitudes to change in general:

Network analysis is an innovation, and every year in every company there are a number of things that are replaced by new things. These "things" may be the furniture in the building, or the installation of a computer to replace clerks in the accounting department. As mentioned in Chapter II, Section 1, it is generally believed that the construction industry is more conservative than most other industries and is slow to accept and absorb innovations.

This question was asked to both PEs and SMs. The aim was to determine to what extent changes in general received support from people occupying different positions in the organization. The results shown in Figures 49 and 50 indicate that there is reasonable consensus between PEs and SMs. For example PEs are reported to be "accepting" "supporting" and "enthusiastic" by both sets of respondents. Similarly, the reaction of senior management is reported by both groups never to be "resisting" or "opposing" changes. The only difference between responses is that PEs regarded SMs as rather more conservative than what SMs thought of themselves.

The data collected indicate furthermore, that PEs were the most supportive element in cases where a change occurs. Senior management



Figure 49. Attitudes to change in general as reported by PEs



Figure 50. Attitudes to change in general as reported by SMs

seemed to be more cautious about changes, but never "opposing" or even "resisting" them. This fact seems to be slighlty tautological because, after all, the introduction of an innovation has to have the approval of senior management. SMs however belong to a group which has a minority (about 7 to 8%) of "resistants". Although SMs regarded themselves as generally "supporting" changes, PEs believed that they rather "accepted" them and frequently "tolerated" them. This finding makes of SMs the less progressive and the most resisting group among the three considered in this section.

Correlation coefficients for SMs are very low (-0.07 for PEREAC, PEs' reaction to changes; -0.12 for SMREAC, SMs' reaction; and -0.06 for SRMTRE, senior management's reactions). PEs' correlation coefficients however, are high enough to require elaboration. They show that PEs' success scores are likely to be higher if PEs themselves and the senior management are progressive enough and supportive of changes in general (+0.38 for PEREAC, and +0.55 for SRMTRE significant at 5%). The coefficient for SMREAC is small (+0.06). 2.11a. PEs' reaction to network analysis when it was first

introduced and at the time of the main survey:

This question was included in both questionnaires. Respondents were asked to indicate on a six point attitude scale (enthusiastic, supporting, accepting, tolerating, resisting, opposing) what they thought PEs' reactions were when network analysis was introduced and at the time of the survey. Figures 51 and 52 show the results. PEs' answers point to the fact that PEs were very enthusiastic about network analysis when it was first introduced, and that the enthusiasm has worn off as time went by. However, apart from a minority of 20% who "accept" network analysis passively, the majority



Figure 51. PE's reaction to network analysis, as reported by PEs



Ш	PE	when
•	DE	

introduced

PE now :1

Figure 52. PE's reaction to network analysis, as reported by SMs

still support it although not as enthusiastically as they used to. SMs' answers (Figure 52) show the same trend but this time the wearing off of PEs' enthusiasm is more accentuated. According to SMs, there are PEs who even "tolerate" network analysis, let alone "accept" it.

Correlation coefficients for PEs (+0.27 for PETHEN, PEs' reaction to network analysis when it was introduced; and +0.62 for PENOW, PEs' reaction to network analysis at the time of the survey) indicate that success scores are likely to be higher as long as the majority of the PEs support network analysis. The particularly high correlation coefficient for PENOW is significant at 2% and suggests that the method developed for success measurement in network analysis (See Appendix K, Part 1) is sound. Indeed, the philosophy behind this method (See Chapter III, Section 1) pre-supposes that such a relationship exists. The fact that it was possible to establish it in statistically significant terms, is of considerable bearing to the validity of the method.

The correlation coefficient between the third variable in this set (PEDIFF which is an indicator of PEs' changing reactions to network analysis over time) and PEs success scores is also high (-0.51) and significant at 5%. This indicates that PEs' success scores are likely to be enhanced when their support increases with time. It is very difficult to try to find some sort of causal relationship between these two factors. Even PEs themselves indicated in the feedback survey that there was no means to find out whether it was successful applications that caused increased support on the part of PEs, or whether it was increasing support that caused successful applications. The relatively high correlation coefficient shows nevertheless that they are closely related to each other.

Correlation coefficients for SMs are not high (+0.04 for PETHEN, +0.26 for PENOW, and -0.23 for PEDIFF), but except for the first one which is practically nil, they support the findings for PEs. 2.11b. SMs' reaction to network analysis when it was first

introduced and at the time of the main survey:

Both sets of respondents were asked to indicate on a six point attitude scale what they thought SMs' reactions were when network analysis was introduced and at the time of the survey. Figure 53 shows that according to PEs, the majority of SMs were "accepting" network analysis when it was introduced, whereas at the time of the survey, a larger majority were "supporting" it. The change of SMs' attitude over the years towards a more supportive stand, can clearly be seen in Figure 53.

Figure 54 shows SMs' opinion of their own attitude to network analysis. It is noted that, the majority of SMs "tolerated" network analysis when it was introduced, but nowadays it seems that most SMs "support" it. The trend in Figure 54 suggests that the divided opinion which ranged from "opposing" to "enthusiastic" at the time of introduction seems to have come closer to a consensus. Although percentages differ in Figures 53 and 54, a similar trend towards higher support can be observed in both cases.

SMTHEN, SMs' reaction to network analysis when it was introduced, appears in the regression equation between SMs' success scores and Methods of Introduction variables. The sign of the regression coefficient indicates that the more enthusiastic SMs are when network analysis is introduced, the higher their success scores are likely to be. This is an important finding, because it brings about the problem



Figure 53. SM's reaction to network analysis, as reported by PEs



Figure 54. SM's reaction to network analysis, as reported by SMs

of how to win SMs' support before network analysis is even introduced. In order to have high scoring SMs, it is necessary to have their full support (and even enthusiasm) when network analysis is introduced. The management has to think about this before deciding to replace existing planning techniques. Indoctrination and training courses, positive propaganda and support by higher management, incentives and similar motivating means have been suggested as possible solutions by the current literature.

Correlation coefficients for SMTHEN (+0.18 for PEs, and +0.09 for SMs) are low but their signs do support the above argument.

SMNOW, which indicated SMs' reaction to network analysis at the time of the survey, does not appear in any regression equation but has high correlation coefficients (+0.61 for PEs, significant at 2%; and +0.47 for SMs, significant at 10%), indicating that support from SMs is essential for higher success scores. This is a slightly tautological result, but nevertheless, is evidence for the validity of the success measurement used in this study.

SMDIFF is a measure of SMs' changing reactions to network analysis, over time. Correlation coefficients for SMDIFF (-0.30 for PEs, and -0.13 for SMs) are quite low, but their signs indicate that increasing SM support is likely to enhance success. This finding is in line with Davis's finding (29) that the reason why "unsuccessful" network analysis users failed, was reported by senior management to be lack of support from people "down below".

2.11c. Senior management's reaction to network analysis when it was

first introduced and at the time of the main survey:

Both groups of respondents were asked to assess on a six point attitude scale, senior management's reactions to network analysis

when it was introduced and at the time of the survey. PEs' views of senior management's reactions are shown in Figure 55. It can be seen that extreme behavioural characteristics have decreased in favour of a more "middle of the road" attitude. Therefore, according to PEs, the change in senior management's attitude had been towards more "support" and passive "acceptance", rather than "enthusiasm" or "opposition".

Figure 56 shows SMs' opinions of the situation. Although the actual percentages are different, the same trend seen in Figure 55 can again be observed in this figure. But in this case, "enthusiasm" has fallen off quite considerably, while "acceptance" has increased equally considerably.

Multiple regression analysis between SMs' success scores and Methods of Introduction variables indicates at 10% significance level that senior management support at the time when network analysis is being introduced (SRMTTH) is essential for greater success.

The second variable in this set SRMTNO, which determines senior management's attitude at the present time, does not appear in any regression equation but it has quite high correlation coefficients (+0.61 for PEs, significant at 2%; and +0.37 for SMs). The positive signs indicate that higher success scores are dependent on high senior management support. These two findings coincide with the view put forward by a multitude of writers that senior management support at all stages is essential for greater success. The only difference however, is that these writers depended heavily on limited experience and common sense, whereas this study produces concrete evidence that senior management involvement, support and even enthusiasm are necessary at all stages for a more successful network



Figure 55. Senior management's reaction to network analysis, as reported by PEs



Figure 56. Senior management's reaction to network analysis, as reported by SMs

analysis application.

The third variable, SRMTDI measures the difference between senior management's attitude to network analysis when it was first introduced and at the present time. This variable appears in two different regression equations. The first equation is for PEs and is the result of the analysis incorporating all possible variables. The second equation is again for PEs, but this time the analysis considers only Methods of Introduction variables. SRMTDI is the most important variable in both equations, and has a negative regression coefficient in both cases. These findings, backed up by the results of the correlation analysis (coefficient -0.69 for PEs) indicate that the chances of higher success scores for PEs depend heavily on whether senior management gives enough support to network analysis all through the time since its introduction. As was the case for PEDIFF and SMDIFF, it is very difficult to prove any causality in this relationship. Whether it was increasing top management support which increased success in network analysis, or vice versa, was not possible to be determined from the information collected in the main survey. However, according to the findings mentioned above, the minimum condition necessary for greater success seems to be an awareness by senior management that a technique called network analysis has been introduced, is being used, and needs top management support for better application. It is this awareness that can be observed to lack in most less successful companies.

PEs and SMs agreed in the feedback survey that senior management support at the introduction stage and in later applications were fundamental for higher success. But, none of them was able to explain the relationship in causal terms. The general feeling was that it

worked both ways.

As a conclusion to this section, it can be said that, the attitude of top management to network analysis was found to be extremely important in both PEs' and SMs' views. The role of senior management must therefore be a conscious attempt to motivate and encourage PEs and SMs. The importance of top management support has also been determined by Davis (29) in a survey of network analysis use, carried out among top management members and lower ranking executives. "Good top management support" was the most frequently cited reason by both groups in "very successful" companies in network analysis, when they were asked to indicate why they were successful.

2.12. SMs' first job planned by network analysis:

When a SM is appointed to a job, where for the first time in his life he has to use network analysis as the standard planning method, there are five possibilities as to how management can initiate him into the technique:

- a) He may already be familiar with the technique,
- b) He can be sent to a course (internal or external),
- c) The technique can be explained to him briefly before he starts,
- d) He can be sent for a while to a site where network analysis is being used,
- e) He can participate in the decision to use (or not to use) network analysis in that particular project.

The data shown in Figure 57 indicate that most companies used a combination of these items. They also show that the most popular way of initiating a SM in network analysis was by a brief explanation about the main features of network analysis, possibly given by a PE.



A: Technique explained
B: Sent to course
C: Participation in decision
D: Already familiar
E: Sent to site using network analysis

Figure 57. The SM's first job planned by network analysis

The next most popular action was to send the SM to a course where he could get sufficient training for adequate implementation. A less popular way was to consult the SM before the final decision to use network analysis was given; in these cases, the SM was left free to accept or reject the use of the technique. It is only in the minority of the cases that the SM had enough knowledge of network analysis at the time he was appointed to his first job planned by network analysis. It is also interesting to note that no SM was sent to another site using network analysis.

Correlation coefficients for most of these variables are negligibly small except for two of them SENTCO (sent to a course) and PARTIC (participation in the final decision). Correlation coefficients for SENTCO are quite high and significant at 2% (-0.63 for PEs, and -0.66 for SMs). This indicates that success scores are likely to be higher if SMs are not sent to courses as an initiation exercise. This finding is consistent with the results reported in Section 2.4, that SMs dislike and sometimes resent both internal and external courses, either because the contents are generally too theoretical and beyond the reach of most SMs' practical minds, or because the right kind of atmosphere is not generated.

Correlation coefficients for PARTIC (-0.33 for SMs, and -0.16 for PEs) suggest that SM participation in the decision to use network analysis for the first time, does not enchance success. The theory that participation in decisions reduces the chances of high resistance, is therefore defeated in this case. It is believed that major decisions of this sort are expected to come from the top in most contracting organizations.

2.13. Effects of network analysis on site staff's basic securities:

This question was asked to both PEs and SMs. It contained four parts: Amount of pay (PAY), intensity of work (INTWRK), promotional advantage (PROMOT), and status of prestige (STATUS). Each of them were rated by respondents on a three point scale: enhanced, not changed, threatened.

Figures 58 and 59 point out that except for intensity of work (INTWRK), network analysis has no major effect on any of the remaining three aspects. Network analysis had therefore no adverse effect on the pay package the SM or the foreman takes home, or on their chances of getting promoted, or on their prestige among the other members of staff. In some few cases, both SMs and PEs thought that these were even enhanced. The explanation given for these few cases was that



- Threatened A:
- Not changed B:
- **C:** Enhanced

Figure 58. Effects of network analysis on site staff's basic securities, as reported by PEs



- A:
- **B:** Not: changed
- **C:** Enhanced



jobs completed on time, were better seen and better appreciated on a network; this led to higher prestige, to a better chance of getting more important jobs, and eventually to better money. It is, of course, possible for this argument to work the other way around; i.e., jobs not completed on time can be better assessed by a network and consequently prestige may fall. This has been reported to be happening by only one PE and the results indicate that it has no adverse effect on promotional advantage and the pay package. Intensity of work is however seen to be affected more than the other aspects. 40% of the PEs thought that the site staff's intensity of work was enhanced because most of the planning was carried out by PEs, leaving additional time for SMs to spend on other activities. About the same percentage of SMs thought also in the same way; but about 14% of SMs believed that network analysis meant more work for them. They claimed that the time necessary to study the printouts and the network took much longer than studying a simple bar-chart. Regression analysis for SMs indicated that this worry is well founded. The equation for Methods of Introduction variables shows that INTWRK has a positive regression coefficient. Although it appears near the bottom of the table of importance, the positive sign suggests that SMs' success scores are likely to be higher if using network analysis does not mean spending a lot of time trying to decipher printouts.

Correlation coefficients for all but one of these variables are practically nil. Only STATUS is relatively strongly correlated to PEs' success scores (coefficient +0.54, significant at 5%) indicating that PEs' success scores are likely to be higher if SMs acquire more prestige as a result of using network analysis. This

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is, in a way, self-explanatory, because according to PEs, higher
prestige is exactly the right kind of motivation for SMs.
2.14a. PEs' opinion of SMs:

This question was directed only to PEs. Its main purpose was to determine the existing situation by inquiring about PEs' opinions on different aspects related to SMs. It was believed that information of this kind would facilitate the interpretation of some of the findings. The aspects investigated are listed below: — They have adequate knowledge of network analysis (ADEQUA) — They come from trades rather than university (COMTRA) — They come from trades rather than university (COMTRA) — They exploit every aspect of network analysis (EXPLOI) — They have great practical site experience (SITEXP) — They feel a need for network analysis (NEEDNA) — They cannot do without the help of a PE (NEEDPE) — They are inclined not provide information for updating (NOUPDA)

— They tend to use their intuition rather than what the network shows (INTUIT)

— They become quickly disillusioned when the network has to be updated frequently (FREUPD)

Figure 60 shows that in the majority of the PEs' opinion (93% of them), SMs had rather advanced site experience. Not surprisingly, SITEXP appears in the multiple regression equation for PEs when Methods of Introduction variables are considered. The positive sign of the regression coefficient indicates that PEs' success scores are likely to be higher if SMs have adequate site experience. This variable is the second important variable in the regression equation, and is a rather obvious result, because the more SMs are competent



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1. SMs have great practical site experience 2. SMs have adequate knowledge of network analysis 3. SMs come from trade not from industry 4. SMs use intuition rather than network 5. SMs are disillusioned when the network is updated frequently 6. SMs are inclined not to provide update information 7. SMs cannot do withour PE 8. SMs feel a need for network analysis 9. SMs exploit every aspect of network analysis

Figure 60. PE's opinions on SMs

in their job, the more easily they will understand what network analysis is likely to achieve. Furthermore, communication with PEs will be more effective, and discussions will lead to more constructive ideas which in turn will produce a more reliable network.

This result seems also to effect SMs' attitude towards planning in general. Indeed, it was determined that over half of the SMs were inclined to use their intuition (INTUIT), which is, no doubt, based on their previous site experience, rather than making full use of network analysis.

In about 60% of the PEs' opinion, SMs had an adequate knowledge of network analysis. This finding constitutes a check on the answers reported in Section 2.9 in this Chapter, that about 56% of the SMs knew enough about network analysis to implement it adequately. The correlation coefficient (+0.30) indicates that PEs' success scores are likely to be higher if SMs' knowledge of network analysis is as comprehensive as possible. A similar result was also obtained in Section 2.9.

According to Figure 60, over half of the SMs were ex-tradesmen (generally ex-carpenters), rather than university graduates. This fact has been used by PEs, in many occasions, to explain the reason why network analysis was not welcomed with open arms by most SMs.

Another interesting result, which has already been mentioned in an earlier section related to updating (Chapter V, Section 1.1), is that over half of the SMs were disillusioned when a network had to be updated frequently. Nearly half of them were inclined not to provide information for such reviews. As discussed in Section 1.1, the reason for this, is believed to be the confusion that exists in SMs' minds as to what updating a network means and what it achieves.

Finally, only 27% of the PEs thought that SMs needed either a PE or network analysis. This is a rather curious finding which is worth elaborating on. It means that PEs are offering their services to SMs, and they are offering them an advanced technique which they believe has many advantages over conventional techniques; but they also think that SMs (in the majority of cases) need neither their services, nor network analysis. The first part about the need of a PE may be an understatement on the part of the PE trying not to be pretentious; or it may be an acceptance of SMs' planning abilities, which, in the author's opinion is rather unlikely. PEs interviewed in the feedback survey suggested that SMs did not often take PEs' opinion into consideration, and that this may well be a reason for this finding. Another possibility was mentioned to be the belief that if it is not the PE who does the planning, someone else in the site staff will do it. In any case, all the respondents in the feedback survey agreed that SMs definitely needed the assistance of a planner.

The second part about the need for network analysis is more understandable. A number of SMs interviewed insisted that their jobs had been planned by ordinary bar-charts for a long time, and that everything had gone smoothly. They did not feel any need for a more advanced technique and moreover, they were convinced that network analysis did more harm than good. It is not therefore surprising that PEs sense this way of thought and express it in a way which gives the results in this section.

2.14b. <u>SMs' attitudes towards PEs:</u>

This question appaered in SMs' questionnaires only. The motive behind it was fo find out what PEs represent in the SMs' opinion. The aspects investigated are given below:

- He regards the PE as someone belonging to the same group as his (SAMEGR)
- He trusts the PE (TRUST)
- The PE has high prestige in the eyes of the SM (PEPRES)
- He feels that he needs the PE (NEEDPE)
- He tolerates the PE (TOLER)
- --- He sees the PE as an impingment on his authority (IMPAUT)

The results are shown in Figure 61. The majority of the SMs (84% of them) reported that they needed a PE to assist them in planning and perhaps even controlling the job. This is in direct contrast with PEs' opinion that was reported in the preceding section (2.14a).



SM needs PE
 SM trusts PE
 SM sees Pe as belonging to the same group
 PE has high prestige in SM's eyes
 SM tolerates PE
 SM views PE as ab impingment on his authority

Figure 61. SMs' attitude towards PEs

It is interesting to note that SMs' attitudes to PEs were on the whole quite favourable. The average SM needed a PE, used his services, trusted him and his programme, and did not regard his activities as an impingment on his authority. Furthermore, he regarded the PE as someone belonging to the same group as his and not to a special breed of specialists; consequently, the PE's prestige in the eyes of the SM was not higher than any other member of the construction staff.

There seems to be three important points that emerge from these results. The first one is the contradiction that exists between PEs' and SMs' opinions of whether PEs are needed or not. This may be due to an understatement by PEs (trying to avoid to be pretentious), or it may be due to the fact that there is a genuine misunderstanding of the situation. PEs and SMs with whom this was discussed in the feedback survey made clear that they would not deny the importance of the PE in the construction team. But, they were able to explain why such a result was obtained. According to PEs, SMs do not take too much notice of PEs' suggestions thus making them feel not needed. According to SMs, PEs do not realize that they have not got enough time to plan their own job, and that therefore they need the assistance of a PE.

The second point is the fact that SMs regarded PEs as any other member of staff and not as an expert with high prestige and power occupying a privileged position. In the preliminary survey, the argument was put forward by some SMs that the PE was a "young man, with a newly obtained university degree, and a lot of knowledge on mathematics and operational research, assigned to put right inefficiencies on sites". This particular result indicates that the majority (64%) of the SMs did not support this way of thinking.

Finally, it is also significant that all SMs did not regard the activities of PEs as an impingment on their authority. The case study (See Chapter II, Section 3, and Appendix E) had indicated that there was considerable uneasiness on the part of the SMs because the PEs were reporting directly to directors rather than to the SMs themselves. The data collected in the main survey show however that this was an exceptional case which did not apply in any of the companies in the sample.

2.15. <u>Changes in the planning department due to the introduction</u>

of network analysis:

It was observed in the case study, and the preliminary survey

that a number of changes had happened in organizations who had introduced network analysis. Some of them had established a planning department and staffed it with newly recruited or newly trained network analysts, whereas before the introduction of network analysis every SM used to do his own planning; some of them had enlarged the planning department to cope with the increased demand of assistance by SMs; some of them had completely centralized the entire planning operation, while some of them had decentralized it by assigning a PE or even a small planning department to each site; in some companies the planning department had acquired a lot of prestige because of the success obtained with network analysis, while on others the planning department had lost prestige because of failures and friction with SMs; some planning departments had acquired more authority than just consultative powers while some others had lost authority completely and become a pure service department with little say in decisions.

All these aspects were investigated by including exactly similar questions to both questionnaires. The reason why the questions about the formation/enlargement (PDFOR1), and centralization/ decentralization of the planning department (PDCENT) were asked to both sets of respondents, was double-checking the answers. In the case of the remaining questions, prestige (PDPRES) and authority (PDAUTH), differences of opinion were the main point of interest.

It is apparent from earlier research on innovation that when a novelty (a new procedure, a new technique, new machinery, new technology, etc.) is introduced into an organization, its effect is most apparent in the department most concerned. But, effects do not confine themselves to the boundaries of the department concerned,

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and repercussions of these can be observed primarily in the departments closely related to (sometimes dependent on) the department where the change takes place. The effects of change can be described like a wave caused by the dropping of a stone (the change) into calm water, that is strongest in the center (the department concerned) and becomes weaker as the radius increases (other departments in decreasing order of connection with the department where the change takes place). The aim of this study is, among others, to determine the effects of the introduction of network analysis. Its effect on the planning department, on site management, on contracts managers, on SMs, on senior management, and on the entire organization is assessed by different questions. This particular section deals with the changes in the planning department.

Figures 62 and 63 show the data collected for this question. There seems to be consensus between 21% of PEs and SMs that a planning department was established as a direct result of introducing network analysis (PDFOR1). However, it was believed by a larger number of SMs (38% against 18% of the PEs) that the planning department which already existed had been enlarged. It is true that in the majority of the companies contacted, the planning staff had increased in number in the last few years; but whether this increase was due to network analysis is entirely a question of opinion, In this case, however, the author thinks that the PE's assessment of the situation is much nearer to the reality. Multiple regression analysis between PEs' success scores and all possible variables shows that PDFOR1 is present in the equation at 2% significance level. This indicates that PEs' success scores are likely to be lower if a planning department is established as a direct result of introducing


Figure 62. Changes in the planning department due to the introduction of network analysis, as reported by PEs



Figure 63. Changes in the planning department due to the introduction of network analysis, as reported by SMs

network analysis. There is no correlation between this variable and SMs' success scores.

The question about the centralization/decentralization of the planning department (PDCENT) received also differing answers form PEs and SMs. Although the large majority in both cases believed there had been no change, 18% of the PEs claimed that network analysis had led to decentralizing planning operations whereas no SM agreed with it. The correlation coefficient between this variable (PDCENT) and SMs' success scores is negligible (-0.05); but it is higher for PEs (-0.24). This indicates that the more decentralized a planning department becomes as a result of network analysis, the higher will be PEs' success scores.

These two results for PDFOR1 and PDCENT are rather important because they do not comply with what the literature advocates. Indeed, the large majority of writers foretell in their writings that network analysis would necessarily lead to the formation of a centralized planning department which would be similar in structure to an estimating department. This, it is alleged, will increase efficiency in planning, by concentrating the planning effort into one office (especially in cases where computer applications are common) and by pushing specialization in network analysis as far as possible. Statistical analyses however, show that the formation of a centralized planning department does not enhance PEs' success. The main reasons for this are believed to be twofold:

a) A centralized planning department means a department staffed with

specialists and experts, who, as time goes by, become more and more disinterested in site activities. They start concentrating on the technical aspects of network analysis and become less aware of

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the reality going on on site. They become alienated of sites.
b) With larger and more complicated jobs using more complicated technology, SMs are bound to ask for full-time resident PEs.
Some of the sites visited had either a full-time resident PE (Company No. 16) or a small planning department composed of two or more PEs (Company No. 2). In one of the sites, the PE was appointed as a deputy SM and he had responsibility for preparing and reviewing the network, and enough power and authority to implement it (Company No. 11).

PEs with whom the subject was discussed in the feedback survey indicated that the formation of a planning department to carry out one single planning technique -network analysis- was bound to cause failures. In their opinion, success could be obtained only with a planning department who applies the right planning technique in the right project.

PDPRES determines whether the planning department acquired more prestige as a result of the introduction of network analysis. About half of the PEs (42%) indicated that there had been no change while 58% claimed that they had acquired more prestige. The majority of the SMs (77% of them) thought however that PEs had gained prestige. The correlation coefficient between PDPRES and PEs' success scores is low but positive (+0.13). On the other hand, the correlation coefficient for SMs is negative (-0.28) and indicates that acquisition of larger prestige by PEs is not welcomed, possibly because they feel that it is acquired at their own expense.

PDAUTH determines whether the planning department's authority has changed in any way due to the introduction of network analysis. The majority of the PEs (81%) believed that it had not, but the

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rest (19%) thought that it had increased. In the case of the SMs, the percentage of those who thought the planning department had acquired more authority is nearly double of the PEs' percentage (37%), but the majority (54%) thought that it had not changed. Two examples of increased authority have been observed by the author: In the case study, PEs had assumed the role of contracts managers, and had become, in a way, SMs' superiors. In a site (Company No. 11) in the main survey, a PE had been appointed as the deputy SM hence incorporating a fair amount of authority with his responsibilities as a planner. When Methods of Introduction variables are considered, multiple regression analysis for SMs shows that PDAUTH is present in the equation, at 10% significance level. The positive sign of the regression coefficient indicates that SMs' success scores are likely to be higher if PEs acquire more authority as a direct result of introducing network analysis. This is a controversial result which has to be examined in the light of earlier findings. Apart form the site in company No. 11 mentioned earlier, the author did not come across any other site in the main survey where the PE had any authority whatsoever. Furthermore, no SM was reported to indicate that PEs' activities were impinging on his authority (See Chapter V, Section 2.14b). After having discussed the matter with SMs in the feedback survey, it is believed that SMs interpreted "more authority" rather as "more involvement". In Section 1.4.2 of this Chapter, it is clearly stated that the planning departments in every single company in the sample had no direct authority whatsoever, and that they all acted in a consultative capacity. It is therefore not possible for a PE to acquire "more authority" as such, as a result of using network analysis; but it is possible for him to be involved much more than before in the day to day running of the site.

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2.16. <u>Changes in the status of contracts managers and in the site's</u> autonomy, due to the introduction of network analysis:

The preceding section (2.15) dealt with the consequences of introducing network analysis only in the planning department, the department most concerned. This section covers the effect it had on the site (SIAUT) and on the contracts manager (CMFORM), these two being sections closely related to the planning department in any contracting organization. It is fair to add also that this question was originated after the case study where PEs tried openly to get rid of contracts managers in order to fulfill this function themselves; and where SMs were complaining of loosing their autonomy because of PEs' increasing pressure and control over the site.

As mentioned in a number of occasions in earlier sections, the situation which was observed in the case study was not seen to happen in any of the organizations which took part in the main survey. Indeed, Figures 64 and 65 show that according to every single PE and SM the post of contracts manager had not changed at all as a direct result of introducing network analysis. Consequently, correlation coefficients are nil.

In the case of the site's autonomy (SITAUT), there seems to be reasonable agreement among the majority of PEs and SMs that the change from conventional planning techniques to network analysis had mostly no effect at all. There were a few SMs and PEs who thought that the use of network analysis had paved the way for increased site autonomy; but there were also a few PEs who believed that network analysis caused a reduction in sites' autonomy.

The PEs' correlation coefficient for SITAUT (+0.32) shows that high site autonomy enhances success. This is in line with what has



- 2. Not changed
- 3. Abolished
- 2. Not changes
- Less autonomy
- Figure 64. Changes in the office of contracts manager and on the site's autonomy due to the introduction of network analysis, as reported by PEs



Figure 65. Changes in the office of contracts manager and on the site's autonomy due to the introduction of network analysis, as reported by SMs

been said in the preceding section (2.15) about decentralized planning departments. Indeed, a decentralized planning department means that PEs work as members of a site team, and report only to SMs and nobody esle. It is clear that this sort of setting increases the site's autonomy to a large extent. The SMs' correlation coefficient for SITAUT is comparatively low (+0.12). 2.17. The SM's involvement in his job:

This question was asked to SMs only. It was situated at the end of the first part of their questionnaire (See Appendix J). The idea was to determine whether the extent to which SMs are involved in their job has any direct bearing on their success scores.

The job involvement scale which was used, was originally developed by Lodahl & Kejner (80) as an exercise in psychology. Most SMs showed surprise when they first read the question, but the large majority (except two of them who misunderstood the question) did answer it.

Correlation analysis shows that job involvement (JOBINV) is negatively correlated with SMs' success scores (-0.25). It means that high job involvement is likely to enhance SMs' success scores. The main reason for this finding was thought to be related to the fact that networks are generally found by SMs to be much more detailed than bar-charts (Figure 66). As a matter of fact, networks generally contain a larger number of activities, they show interrelationships among activities, they indicate critical activities and float values, and they show the possible consequences when delays occur. Network analysis produces a larger bunch of information for a larger number of activities, and it can therefore be said that it requires higher involvement from SMs. Indeed, SMs must constantly

-Seldom -Seldom -Sometimes -Often -Always

Figure 66. Frequency of cases when networks give a very detailed programme

SM

check progress on the network and try to assess the implications of delays by simulating them before they happen. SMs with low job involvement characteristics however, are quite satisfied by following a bar-chart and not being bothered about the rest.

It is fair to add here that the argument put forward in the preceding paragraph was not strictly true in a number of cases. Indeed, older SMs who had worked with bar-charts all their lives tended to be much more involved in their job than the younger generation of SMs.

The following multiple regression equations show the relationship between success scores and Methods of Introduction variables at 10% significance level. The figure on the left is the regression coefficient; the figure in parantheses, following the variable name, is a measure of importance. (Regression coefficient multiplied by the standard deviation). It denotes the change undergone by the dependent variable, for a standard change in that particular independent variable. The variables are given below in order of importance: Planning engineers' success scores are likely to be higher when: 28.58 SRMTDI (24.28): there is continuous and increasing senior management support (*); + 56.63 SITEXP (14.62): SMs have considerable site experience; - 21.94 CLAUSE (11.13): network analysis is not introduced as a direct response to contractual obligations. <u>Site managers' success scores are likely to be higher when:</u> - 53.19 HUMAN (37.05): PEs concentrate more on human aspects (*); +105.54 TECHN (28.21): PEs concentrate less on technical aspects; + 43.59 PDAUTH (26.64): the planning department becomes more involved in the day to day running of jobs; + 12.35 SMTHEN (18.15): SMs support the use of network analysis when it is introduced; + 15.60 INTWRK (11.26): SMs' workload does not increase as a direct result of introducing network analysis; + 7.03 SRMTTH (9.69): senior management supports the use of network analysis when it is introduced; Planning engineers' correlation coefficients at 10% significance level; success is likely to be greater when: (-0.63): SMs are not sent to courses as an initiation exercise (*); SENTCO (+0.62): PEs support the use of network analysis (*); PENOW SMNOW (+0.61): SMs support the use of network analysis (*); SRMTNO (+0.61): senior management supports the use of network analysis (*); SRMTRE (+0.55): senior management is progressive enough to support changes in general (*); MANUCO (-0.54): the first application of network analysis in the company is calculated manually and not by a computer program (*); STATUS (+0.54): SMs' status is enhanced as a direct result of introducing network analysis (*); PEDIFF (-0.51): there is continuous and increasing support for network analysis by PEs (*); PDFOR1 (+0.48): the planning department is not established as a direct result of introducing network analysis; FREUPD (-0.44): SMs are not disillusioned by frequent updatings. Site managers' correlation coefficients at 10% significance level; success is likely to be greater when: SENICO (-0.66): SMs are not sent to courses as an initiation exercise (*); MANUCO (-0.51): the first application of network analysis in the company is calculated manually and not by a computer program; INADEQ (+0.48): network analysis is introduced as a direct response to a need felt for more advanced techniques; INTCOR (-0.47): there are no internal courses on network analysis; SMNOW (+0.47): SMs support the use of network analysis. (*) Significant at 5%.

3. Organizational Characteristics:

3.1. Workflow integration:

This variable is formed by the addition of three sub-variables which were defined in Chapter III, Section 5:

- Mechanization mode (AUTMOD).

- Mechanization rate (AUTRAN), and

- Specificity of quality evaluation (QUAEVA).

High scores indicate a high degree of mechanization coupled with a strict routine quality control of the construction at regular intervals.

When Organizational Characteristics are considered, multiple regression analyses for both PEs and SMs indicate at 5% significance level that WRKINT (Workflow integration) is the only variable that is included in the equations. The sign of the regression coefficient in both equations is negative and therefore indicates that success is likely to be enhanced in organizations who score low in workflow integration. This result is supported by high correlation coefficients (-0.56 for PEs, and -0.30 for SMs).

Examination of the individual sub-variables indicate however, that the first two sub-variables dealing with the degree of mechanization are the most important ones in this relationship. As a matter of fact, AUTMOD and AUTRAN have correlation coefficients of -0.29 and -0.59 respectively for PEs, and -0.55 and -0.31 respectively for SMs, whereas the smallest coefficients are those for QUAEVA (-0.23 for PEs, and -0.17 for SMs). This consideration leads to the conclusion that lower degrees of mechnization, (i.e., avoiding the use of non-standard, made to order equipment and using mostly light equipment) are likely to yield higher success scores in general. This result is very much supported by MECHAN (degree of mechanization) which is a simple addition of AUTMOD and AUTRAN. Correlation coefficients for MECHAN are -0.61 for PEs and -0.64 for SMs, both significant at 2%.

3.2. Dependence:

This variable (DEPEND) reflects the relationship between an organization and other organizations in its social environment, such as suppliers, clients, competitors, sub-contractors, etc. The abbreviated form of this variable covers all these relationships and is formed of four main components:

--- Impersonality of origin (IMPORI),

--- Status of organization unit (STATUN),

- Public accountability (PUBACC), and

- Size relative to owning group (SIZERE).

A high score in DEPEND characterizes organizations with a high degree of dependence which tend to be impersonally founded, publicly accountable, small in size relative to their parent organization and low in status.

DEPEND does not appear in any regression equation, but is strongly positively related to PEs' success scores (correlation coefficient +0.47, significant at 10%) implying that success is likely to be higher in companies who have the characteristics mentioned in the preceding paragraph. The particularly large correlation coefficient for SIZERE (+0.45, also significant at 10%) makes the finding consistent with a result reported in a later section (4.9) that network analysis is likely to be more successful in smaller organizations. The SMS' correlation coefficient for DEPEND is not as large (+0.13) but supports the above finding for PEs. It is not possible to interpret this finding to a greater depth, because the limited information about organizational features does not allow such an explanation.

3.3. <u>Structuring of activities:</u>

This variable (STRACT) involves functional specialization (FUNSPE) and formalization of role definition (FORMAL). It indicates the extent to which the intended behaviour of employees is overtly defined. An organization scoring high in STRACT would have gone a long way in the regulation of the work of its employees.

None of these variables appear in regression equations and correlation coefficients for SMs are particularly low (-0.16 for FUNSPE, +0.08 for FORMAL, and -0.02 for STRACT). Correlation coefficients for PEs (-0.23 for FUNSPE, -0.09 for FORMAL, -0.03 for STRACT) indicate that the main variable STRACT is negatively correlated to success scores (-0.30) and that the large portion of the cause lies in functional specialization (FUNSPE: -0.23). These results suggest that PEs' success scores are likely to be higher if there is not a high degree of specialization in the organization. This finding is in line with the result reported in an earlier section (Chapter V, Section 2.15) that the formation of a specialist planning department does not seem to enhance success in network analysis applications. It is difficult to interpret this finding in more detail, in the context of the entire organization, because of the lack of necessary information about specialized departments in each of the companies in the sample. However, the findings point out that future research should investigate this area thoroughly.

3.4. Concentration of authority:

This variable (CONAUT) describes the levels at which formal

authority rests. In other words, it reflects the locus of decisionmaking across levels in the organization. Typically, an organization scoring high in CONAUT would have most decisions taken at a level of authority within the organization's own structure and not at a higher level of authority such as a parent organization.

CONAUT appears in the PE's regression equation when all the variables are considered. The equation shows at 2% significance level that the more autonomous in decision-making the organization is, the higher success scores are likely to occur for PEs. It is believed that highly autonomous companies have better chances of determining their own needs and of giving the appropriate decisions. It has been shown in an earlier section (Chapter V, Section 2.11) that for successful network analysis applications, support from all levels of management is essential. Furthermore, it has also been determined that successful network analysis applications follow an introduction as a result of a felt need throughout all levels involved, and not as a result of imposition from higher levels of authority (Chapter V, Section 2.1). The finding reported in this section seems to be consistent with the two results mentioned above. A high concentration of authority within an organization seems to be therefore, an important factor which promotes success. The SMs correlation coefficient (+0.23), although not very high, seems to support the above finding.

The following multiple regression equations show the relationship between success scores and <u>Organizational Characteristics</u> at 5% significance level. The figures on the left are the regression coefficients.

<u>Planning engineers' success scores are likely to be higher when:</u> -19.61 WRKINT: the company scores low in "workflow integration", implying a technology using a low degree of mechanization.

<u>Site managers' success scores are likely to be higher when:</u> -24.78 WRKINT: the company scores low in "workflow integration", implying a technology using a low degree of mechanization.

Planning engineers' correlation coefficients at 10% significance level; success is likely to be greater when: DEPEND (+0.47): the organization scores high in "dependence", which implies a company which is impersonally founded, publicly accountable, small in size relative to its owning group, and low in status.

Site managers' correlation coefficients at 10% significance level; success is likely to be greater when: None.

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4. General Characteristics:

4.1. Length of time for which network analysis has been used:

The data collected indicate that the companies who took part in the final survey, used network analysis for an average of 8.6 years. The earliest user (Company No. 4) had started in 1960, while the latest user (Company No. 3) had introduced network analysis in 1969. The fact that all companies in the sample used network analysis, is not significant on its own, because, as explained in Chapter IV, the sample was deliberately formed of network analysis users.

SINCEW which indicates the length of time for which network analysis has been used, appears in the regression equation for PEs when all the variables are considered. The positive sign of the regression coefficient indicates that PEs' success scores are likely to be higher in companies who have been using network analysis for a longer time. This is a rather obvious finding which has an obvious interpretation. Indeed, those who have used network analysis for a long time have normally accumulated enough experience to be able to understand and appreciate its advantages over conventional techniques, and at the same time, to be more aware of its shortcomings and limitations. They become therefore more selective in their choice of projects to be planned by network analysis, they become more discriminating as to what sort of procedure to use, and they become more aware of the human problems involved. The result is a combination of habit and self-confidence which can only be acquired by means of experience all through the years they have been using it. This variable (SINCEW) has a negligibly small correlation coefficient (-0.05) for SMs.

4.2. Multi-project scheduling and various computer facilities:

Figure 67 indicates that only very few companies carried out multi-project scheduling; that only very few of them had visual display units such as a cathode ray tubes; and that a comparatively larger number of companies (about 40%) used the special facility offered by most computer programs to print out a graphical output.

The first variable MULPRO (multi-project scheduling) appears in the PEs' regression equation at 10% significance level when General Characteristics are considered. It is situated at the bottom of the list of importance and indicates that PEs' success scores are likely to be higher if multi-project scheduling is not used.



Multi-project scheduling
 Visual display units
 Graphical outputs

Figure 67. Multi-project scheduling and various computer facilities

Multi-project scheduling is a complicated process of combining the existing programmes for individual projects. The purpose is to have a single programme for all or the most important few projects so as to be able to see more clearly resource and cost implications. Furthermore, multi-project scheduling is basically a tool to help decision-making at senior management level. The reason why multiproject scheduling was not used extensively has been explained by a number of PEs. Some indicated that they had enough problems in planning single projects; some claimed that because of the variety of jobs a multi-project schedule covers, the degree of accuracy becomes so low at the end that is is not worth it; and finally, according to some PEs, it was not worth preparing such a schedule because senior management did not generally appreciate it. SMs' regression equations do not contain MULPRO but the correlation coefficient (-0.28) does support the above finding.

Visual display units (VISDIS), also called CRT terminals, linked directly to a computer, have been in the process of development for quite a long time. Some writers such as Barnetson (273) and McMullan (110) have described the advantages of using such devices, but their use is generally accepted not to be beneficial in the construction industry. Only a couple of companies in the sample used this sort of facility, mainly in a move to explore the possibilities of having a permanent unit. It was made clear in all cases, that these units were experimental. However, the PEs' regression equation for General Characteristics contains VISDIS at 10% significance level. The negative regression coefficient means that PEs do not appreciate CRT displays and that their success scores are likely to be higher if they are not used at all, the main argument behind it being possibly that they are not suited to construction jobs. The SMs' correlation coefficient (+0.07) is small to deserve interpretation.

Graphical outputs (GRAPH) were used by less than half of the companies in the sample. Although basically similar, graphical representations produced in each company, differed in detail. In one of the companies it was called "Cascade Charts", because it was a sort of logic-linked bar-chart which showed the earlier activities on the top left hand side of the diagram, and the later activities on the bottom right hand side, so as to give a "cascade" impression (*). In some companies, the graphical output was a simple bar-chart; in some, it was a logic-linked bar-chart; and in some, a time-scaled network rather similar to the one described by Feneck & Croissant (272). GRAPH does not appear in any regression equation, and correlation coefficients (-0.06 for PEs, and -0.09 for SMs) are not high enough for interpretation.

4.3. Characteristics of projects planned by network analysis:

Respondents were asked to rate their projects planned by network analysis in regards to seven characteristics, by comparing them with their projects planned by conventional techniques. These characteristics were complexity (COMPLX), extent of repetition (REPET), flexibility (FLEXI), uncertainty (UNCERT), time limitations (TIMLIM), resource limitations (RESLIM), and cost limitations (FINLIM). The results are seen in Figure 68. Each variable will be examined separately in the following paragraphs.

One of the main advantages of network analysis over conventional

 ^(*) The principles of "Cascade Charts" are given in a paper by Miller & Cordiner (138), and the experience of a company is described in a paper by Rist (100).



Complexity Flexibility Time limit Cost limit Repetitivity Uncertainty Resource limit



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Figure 68. Characteristics of projects planned by network analysis

planning techniques is claimed by experts to be its ability to cope with extremely complex situations. The historical development of network analysis points out (Polaris, Apollo, etc.) that there is an element of truth in this claim. That is probably why no PE in this sample of companies attempted to plan a simple project by network analysis.

A complex project implies a large number of activities interrelated to each other in a complex way. The advantage of using a network in such a case is fairly obvious since no bar-chart can show so many inter-relationships which sometimes can be crucial in decisionmaking. PEs' and SMs' correlation coefficients for COMPLX (-0.22 for PEs, and -0.41 for SMs) indicate that network analysis is thought to be more successful whenever the job is not highly complex. Respondents in the feedback survey explained the reasons for this finding in a number of ways: Firstly, it was reported that it was extremely difficult for a PE to construct a highly complex network. Indeed, the chances of making logical mistakes in this sort of situation are extremely high, and furthermore, the chances of identifying this sort of mistake at planning stage are extremely low. Secondly, a number of SMs reported that it was extremely diffcult for them to understand what a highly complex network is trying to show. Finally, as mentioned in an earlier section (Chapter V, Section 2.14) SMs became disillusioned as this sort of complex network tended to be updated fairly frequently.

The extent of repetition in a job (REPET) is a subject that has not been thoroughly investigated by writings on network analysis. However, the general belief is that highly repetitive jobs are not very well suited to be planned by network analysis (See Chapter III, Section 6). Line of balance seems to be preferred by many authors in this sort of situation. The results in Figure 68 indicate that the large majority of projects planned by network analysis (77% of them), were rated as non-repetitive jobs while the rest were labelled "average". No PE in this sample had ever tried using network analysis in a highly repetitive, say social housing project. Correlation coefficients (-0.26 for PEs, and -0.18 for SMs) indicate that success is likely to be greater in low repetitive situations. FLEXI (for flexibility) and UNCERT (for uncertainty) show up in a number of regression equations. FLEXI is present in the PEs' regression equation containing only General Characteristics variables. It also appears in the SMs' regression equation when

all variables are considered. Regression coefficients in both cases are positive and indicate that success scores are likely to be higher when network analysis is applied to highly flexible projects.

UNCERT appears in both the PEs' and the SMs' regression equations when General Characteristics are considered. Positive signs in both cases indicate that higher success with network analysis is obtained in jobs which are charaterized by high uncertainty.

According to the large majority of PEs and SMs, the construction process is very indeterminate, i.e., relationships among activities are variable, sequences in which the activities are carried out are often a matter of choice, and there are a number of uncontrollable factors which add a great deal of uncertainty to the durations. PEs believed that network analysis was of much more assistance when drawing the logical sequence of activities of highly flexible projects. Being an analytical technique, network analysis was helpful in determining various alternative ways of carrying out the job, and in selecting the best solution among them. The same argument was put forward by a number of PEs, when uncertainty was discussed. It was possible to make allowances on certain activities which presented special problems of uncertainty, and moreover, it was always possible to see their consequences on the rest of the activities. This ease for better prediction was also the reasoning put forward by some SMs. Finally, quick and precise updating possibilities (especially in computerized applications) was accepted to be a useful advantage when dealing with unforeseen events.

The remaining three variables deal with the limitations of projects. Data shown in Figure 68 indicate that over half of the

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projects planned by network analysis were tightly time limited and that the remaining were categorized as "average". The percentage of projects that were highly resource limited was lower (31%), but again all projects planned by network analysis had either "tight" or "average" resource limitations. The same data for cost limitations indicate that most projects planned by network analysis were in the "average" category.

TIMLIM (for time limitations) appears in the PEs' regression equation when all the variables are considered. It is the third most important variable in the equation. This is an expected result, consistent with the views expressed by most authors (See Chapter III, Section 6) that network analysis is most useful when there are tight time limitations, because it pinpoints the critical activities which are most likely to cause delays.

RESLIM (for resource limitations) appears in the PEs' regression equation when General Characteristics are considered. The positive regression coefficient indicates that PEs' success score are likely to be higher if network analysis is used in tightly resource limited projects. As mentioned in an earlier section (Chapter V, Section 1.3.8), time analysis without a resource analysis was accepted by most PEs to be incomplete. Indeed, all PEs interviewed in the main survey indicated that they expected network analysis to give them a better chance of using resources efficiently. The finding that greater success can be achieved in tightly resource limited projects, is believed to be the expression of PEs' hopes for a fuller exploitment of the entire technique.

FINLIM (for cost limitations) does not appear in any regression equation but correlation coefficients (-0.16 for PEs, and -0.34 for

SMs) tend to indicate that success in network analysis is more likely to be achieved when cost limitations are not tight. This is not a surprising result because cost analysis is very seldom carried out in conjunction with networks, and it is generally believed that tight cost limitations cannot be controlled by network analysis in the form it is presently practised.

4.4. Extent of network analysis use:

Of the 21 companies who were contacted for the main survey, only five had never used network analysis. Later on, it was agreed with these five companies that they should be excluded from the sample, as the information they were going to provide, would have been of little use to this study. After a sixth company's decision to drop out, the sample was reduced to 15. The data therefore show that all the 15 companies who took part in the main survey used network analysis to a greater or lesser degree. Figure 69 shows to what extent these companies used network analysis, expressed as a percentage of the total cost of the projects they were undertaking. To form a better picture of the situation network analysis has been divided into three main groupings; namely time analysis (TIMANA), time and resource analyses (TIMRES), and finally time, resource and cost analyses by networks (TIRECO).

Figure 69 indicates that there has been an increase in all three of the groups in the last five years. Furthermore, PEs indicated that they expected this increasing trend to continue.

A second point which is worth mentioning is that only an average of 50% of all the projects (money wise) undertaken by these companies were, in fact, being planned by network analysis. The initial impression that one gets (all 15 companies use network

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Time Analysis Time+Res.Ana. Time+Res.+Cost Ana.

Figure 69. Extent to which network analysis is used, expressed as a percentage of project cost

analysis) that network analysis is an extremely popular planning technique is therefore slightly misleading.

TIMANA, the variable that measures the extent to which time analysis is used, is not present in any regression equation. Correlation coefficients (+0.32 for PEs, and +0.15 for SMs) tend to indicate however that success scores are likely to be higher if the percentage of projects that are time analysed is as large as possible. It seems therefore that SMs, and especially PEs, are in favour of time-analysis as a standard planning technique, to be used in as many projects as possible.

TIMRES, the variable for time and resource analyses, appears in SMs' two regression equations for General Characteristics and for all

the variables. In both equations, it occupies an important place (2nd and 3rd respectively). The negative regression coefficients indicate that SMs' success scores are likely to be higher if resource analysis is <u>not</u> carried out in conjunction with time analysis. The correlation coefficient (-0.13) is weak but supports the above finding.

In cases where resource analysis is carried out in conjunction with networks, rather than on bar-chart presentations, a computer program has to be used. Furthermore, in such cases, it is customary to analyse the entire project rather than parts of it at a time. The finding stated in the above paragraph is therefore consistent with those in Sections 1.2 and 1.3.8 of this Chapter, where the extensive use of computers and resource analysis of the entire project are shown to be likely to cause harm to SMs' success scores. According to the SMs interviewed in the feedvack survey, resource analysis is necessary but unrealistic if carried too far. This variable (TIMRES) is very weakly correlated to PEs' success scores (-0.07).

Finally, cost analysis in conjunction with time and resource analysis does not appear to be very widely used. The very few companies who used cost analysis by networks and/or who envisaged using it in the future, have all indicated that this was (or would be) strictly experimental. However, the PEs' regression equation for General Characteristics shows at 10% significance level that PEs' success scores are likely to be enhanced if cost analysis is not carried out by networks. PEs in one company (No. 8) who did use this technique, indicated for example, that senior management did not seem to be aware of the importance of the information supplied to them. They consequently thought that cost control by networks was not yet appreciated by those who should make full use of it. Furthermore, the existing form of the Bills of Qunatities does not seem to suit the requirements of cost control by networks. Operational Bills of Quantities have been developed, but are not in common use. It is also believed that systems like PERT/COST are most effective in jobs where design has been carried out by the contractor. SMs' success scores are very weakly correlated (+0.03) to this variable.

PEs interviewed in the feedback survey agreed with the finding. They stated that cost control by networks was too complicated and that it would involve a merger with the costing department which would be frustrating for both departments.

4.5. Kind of diagram used:

Figure 70 shows that the majority of the companies in the sample, used arrow diagrams rather than precedence diagrams. It can also be observed that there has been a shift towards using more precedence diagrams in the last five years. PEs believed that this trend would continue.

The SMs' regression equation for General Characteristics contains this variable (ARROW) at 10% significance level. The positive regression coefficient supported by a positive correlation (+0.25), indicates that SMs' success scores are likely to be higher if arrow diagrams, rather than precedence diagrams, are used.

PEs' success scores are however negatively correlated (-0.12) to ARROW. Although this is not a strong correlation, it suggests that PEs favour the shift to precedence diagrams.

A literature survey of the advatages and disadvantage of precedence diagrams is given in Appendix B. PEs in companies using



Figure 70. Kind of diagrams used

precedence diagrams indicated that they were doing so because of a combination of the items enumerated in the list of advantages (See Appendix B, Part 1). An advantage no PE forgot to mention was that it is easier to represent overlapping activities on precedence diagrams.

Two of the SMs with whom this subject was discussed in the feedback survey were not clear as to what their objections to precedence diagrams were. The other two believed that it was a question of training and of habit.

A few years ago, precedence diagramming was not the popular way of drawing a network, mainly because there were very few computer programs to process it. The large majority of organizations who use

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precedence diagrams today, have, in fact, started with arrow diagrams. It is thought that it is the shift from arrow diagrams to precedence diagrams that causes resistance on the part of the SM. A SM who was faced with a new technique a few years ago is naturally not in favour of changing the procedure today after he just became used to arrow diagrams.

4.6. Extent of computerized applications:

COMPUT the variable which measures the extent of computerized applications, has been grouped with General Characteristics. But, for reasons of convenience, the results and their interpretations are presented in Section 1.2, of this Chapter, where other data related to computerized applications are also investigated.

4.7. Kind ot time estimate used:

It is generally observed that introductory literature to network analysis tends to give a considerable amount of information about probabilistic networks. All textbooks on the subject contain at least one chapter explaining the three time estimates (pessimistic, most likely, and optimistic), the β distribution, and the calculation of the probability of completing a project on time by means of a normal distribution. It was thought at the start of this study that this sort of difference in procedure would be relevant to success, and that it should be included in the questionnaire. Figure 71 shows however, that none of the companies in the sample used three time estimates. Only one of them experimented with it a few years ago, and is willing to try it again in the near future.

It is believed, quite apart from the results shown in Figure 71, that there are very few companies in the entire construction industry who use probabilistic networks. As a matter of fact, according to



Figure 71. Kind of time estimates used

the majority of PEs, three time estimates are useful only in research and development projects which are characterized by a very high degree of uncertainty that is never reached in construction jobs. 4.8. <u>Kind of resource analysis used</u>:

The majority of the companies who resource analysed their projects planned by network analysis, are shown in Figure 72, to use resource levelling rather than aggregation. It is common practice to aggregate resources when there are no practical resource limitations. The purpose is to plan ahead so that each item is acquired at the right time. The contracting industry works however under great time and resource limitations. Labour is scarce and machinery are expensive. The optimum use of resources is essential to achieve



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Figure 72. Kind of resource analysis used

reasonable profit margins. This is possibly why network analysis
users opt generally for resource levelling rather than aggregation.
 RESAGG which indicates what sort of resource analysis is used,
has very small correlation coefficients (+0.06 for both PEs and SMs),
and therefore, has little effect on the PEs' and the SMs' success
scores.

4.9. Size of organization:

Three criteria have been used to determine the size of the organizations who took part in the main survey. These are, the annual turnover of the company (TURNOV), the annual profit before taxation (PROFIT), and the total number of employess (NOEMPL).

It was observed that a number of PEs contacted, did not provide information related to one or more of these variables. Some believed that they could not divulge strictly confidential company secrets, but some seemed to have no idea of the answers. For example, two PEs did not answer how large their company was, in terms of annual turnover. The reason why these figures were not obtained from published statistics is explained in Chapter IV.

All three of these variables are negatively correlated to PEs' and SMs' success scores (TURNOV: -0.27 for PEs, and -0.46 for SMs; PROFIT: -0.32 for PEs, and -0.23 for SMs; NOEMPL: -0.62 for PEs, and -0.69 for SMs). It is interesting to note that all coefficients are negative, implying that success scores are likely to be higher if the size of the company as described by any of the above mentioned variables, is smaller.

NOEMPL seems to be the governing variable among the three, because it appears in three different regression equations, and occupies quite important positions in each of them. It is the second important variable in the regression equation for PEs when General Characteristics are considered. It also appears in first place in the SMs' regression equation when General Characteristics are taken into consideration. Finally, it can be seen in the SMs' regression equation when all the variables are considered. In this case, it occupies again the most important place in the equation. A common feature in all these three cases is that regression coefficients are always negative, implying that the interpretation given in the preceding paragraph is supported and strengthened.

Contrary to this finding, in a survey of network analysis use in the United States, Davis (29) found that a group of large companies contained a larger proportion of "successful" (in network analysis) companies than did a group of small companies. He attributes this to the "larger firm's generally greater experience with use of CPM". This point was discussed in the feedback survey. Except for one site manager (who incidentally, did not give any reason for his answer) all PEs and SMs agreed that smaller companies had a better chance of succeeding in network analysis applications. Two main reasons were given to support this argument: Firstly, in small companies everybody would be involved in a novelty like network analysis, whereas in larger companies differences of opinion would cause the fromation of opposing and supporting groups. Secondly, in smaller companies senior management would be much closer to the people who actually use network analysis, and their support would more easily be appreciated.

4.10. Number of projects currently undertaken:

The number of projects undertaken by each company at the time when the main survey was carried out (NOPROJ) ranged from only 2 projects to about 200 with an average of approximately 84 projects. This variable (NOPROJ) follows the three size criteria described in the preceding section (4.9) because it can also be accepted as an indicator of size.

The SMs' regression equation for General Characteristics shows at 10% significance level that NOPROJ is present with a negative regression coefficient which indicates that SMs' success scores are likely to be higher if a small number of projects is undertaken at any time. The SMs' correlation coefficient (-0.41), and although quite low, the PEs' correlation coefficient (-0.10) support this finding which is consistent with the findings related to the previous three size criteria.

4.11. Kind of job undertaken:

Ten out of the 15 companies who took part in the survey were Building and Civil Engineering contractors, and the rest were either Builging (3 of them) or Civil Engineering (2 of them) contractors.

KINDJO which indicates the kind of job the company specializes in, appears in the SMs' regression equation when all the variables are considered. The positive sign of the regression coefficient indicates that SMs' success scores are likely to be higher if they are working on a civil éngineering job rather than a building job. The PEs' correlation coefficient (-0.12) does not support this finding but is relatively small.

This finding was discussed with SMs in the feedback survey. All SMs accepted the finding as being very realistic. They explained it by stating that civil engineering jobs were less complex than building jobs, and that civil engineering programmes contained a smaller number of activities which in turn were more compact and better defined.

4.12. Kind of contractual arrangement:

Figure 73 shows that all the companies who took part in the main survey competed for open tenders (OPENT); they also undertook other sorts of contractual arrangements. About 64% of them negotiated contracts with their clients (NEGOT), while a smaller number of companies (36%) operated in the speculative building construction market (SPECUL).

OPENT (open tenders) appears to have no effect at all since all companies in the sample competed for open tenders. But SPECUL (speculative building) does have an effect on PEs' success scores, as it appears in the latter's regression equation when General





Figure 73. Kind of contractual arrangement

Characteristics are considered. The negative regression coefficient indicates that PEs' success scores are likely to be higher if speculative building construction is <u>not</u> undertaken by their company. This finding is consistent with earlier findings that less repetitive jobs (Chapter V, Section 4.3) of civil engineering nature (Chapter V, Section 4.11) are better suited to network analysis. The correlation coefficient is negative (-0.05), but it is too small to support this finding.

NEGOT (negotiated contracts) does not appear in any regression equation but is positively correlated to both PEs' and SMs' success scores (+0.25 and + 0.37 respectively).

4.13. Geographical location of jobs:

As seen in Figure 74, all the companies carried out jobs at local and national levels but only a few (20% of them) carried out jobs abroad.

JOBLOC which shows the radius of operation for each company, appears in the SMs' regression equation when General Characteristics are considered. The regression coefficient is positive, which implies that SMs' success scores are likely to be higher if the company's radius of operation is as large as possible. The PEs' correlation coefficient with JOBLOC is positive but very low (+0.05).



1. Local

2. National

3. International

Figure 74. Geographical location of jobs

This finding appears not to be consistent with earlier findings that success scores are enhanced in smaller organizations (Chapter V, Section 4.9). An interpretation which was reported by SMs in the feedback survey was that material delivery schedules and resource programmes were extremely important in overseas jobs, because most of these were imported.

4.14. Expansion policy:

Except for one company (No. 6) who considered this information to be strictly confidential, all companies in the sample answered this question. Figure 75 shows that the majority of the companies intended to expand in the line of jobs they were undertaking at the time of the main survey. Some of these were also eager to expand into new fields.



- 1. Present field
- 2. New field
- 3. No expansion

Figure 75. Expansion policy
Before reporting the results of the statistical analyses, it would be useful to emphasize the fact that the data collected for this variable are not related to the actual expansion of the companies during the last few years. They are rather related to general company policy for the near future.

EXPANP which quantifies expansion policy, appears in the PEs! regression equation when General Characteristics are considered. It is the third important variable in the equation and has a positive regression coefficient, which indicates that an ambitious expansion policy is likely to increase PEs' success scores. The SMs' correlation coefficient is too low (+0.03) to support this finding. However, this result can be tied in with the findings described in Section 2.1 of this Chapter, that for a change to occur, there must first be a situation of need for it. The results for that particular section (2.1) indicated that success scores are likely to be higher if the planning staff and site management have developed enough need for a more advanced technique than the one they are using. It is believed that an ambitious expansion policy helps a great deal in the creation of this need. Three of the four planning engineers interviewed in the feedback survey agreed with this explanation and indicated that an ambitious expansion policy is a prerequisite for the successful use of any advanced management technique. The fourth planning engineer could not see such a causal relationship and claimed that the relationship worked both ways.

4.15. Low bids:

Whether companies accept low bids for prestige reasons (LOWBID) was observed to be of some importance in a few network analysis applications in the preliminary survey. For example a major highway contractor had at that time won a tender by bidding considerably lower than the normal limit, in order to preserve his reputation of "major highway contractor" and to use his machines and equipment which would otherwise have remained idle.

Underpriced jobs are generally failures, because they often end up with considerable loss if the advantage of using idle staff and machinery are not taken into account. It was believed that network analysis would be the perfect planning tool under such circumstances, in order to minimize the already high probability of delay and financial loss. LOWBID however is weakly but negatively correlated to PEs' success scores (-0.29), and it is not correlated at all to SMs' success scores (+0.03). It seems that PEs do not like to be pressurized in this manner. The finding is consistent with an earlier finding (Chapter V, Section 4.3) that PEs' success scores are likely to be <u>lower</u> if they are networking jobs which have tight cost limitations. PEs who commented on this aspect, indicated that it was extremely difficult to plan a job which everybody knew would be a failure.

The data collected indicate that only 20% of the companies in the sample practised this sort of prestige bidding.

4.16. Foundation year of the company:

The youngest company in the sample was founded in 1968 while the oldest company had been in service for 150 years.

FOUND which indicates the age of the company, is negatively correlated to both PEs' and SMs' success scores (-0.25 and -0.24 respectively), which implies that higher success rates are obtained in younger companies. It is difficult to interpret this finding because of the multitude of possible intervening factors. However, a likely explanation is that old established organizations tend to be rather more conservative than younger organizations who generally absorb changes more readily.

4.17. Range of contract values:

Figure 76 shows that the smallest job undertaken by the majority of the companies (71% of them) at the time of the main survey, was below £10,000. The same figure also shows that the largest job undertaken by the majority, was over £1 million. Examination of the data indicates that most of the companies undertook jobs covering a wide range of contract values.





Largest jobs:

A. <£10,000 B. £10,000-100,000 C. £100,000-1 million D. >£1 million

Figure 76. Smallest and largest jobs undertaken at the time of the survey

Correlation coefficients for OPERAN, which shows the range of contract values, are quite high (-0.60 for PEs, significant at 2%; and -0.32 for SMs) and their sign indicates that success is likely to be higher if the company undertakes jobs that do not vary a great deal in value. It is possible to see in this finding a tendency on the part of contractors to become more specialized by undertaking jobs of limited value and possibly of the same nature. Network analysis is accepted to be <u>the</u> planning technique for complicated, one-off jobs which bear no resemblence to any other job; however, there is no doubt that network analysis is much more easily applied possibly in a more successful way, in simpler jobs where the staff is already familiar with the job. The following multiple regression equations show the relationship between success scores and <u>General Characteristics</u> at 10% significance level. The figure on the left is the regression coefficient; the figure in parantheses, following the variable name, is a measure of importance. (Regression coefficient multiplied by the standard deviation). It denotes the change undergone by the dependent variable, for a standard change in that particular independent variable. The variables are given below in order of importance:

Planning engineers' success scores are likely to be higher when: 1.56 TIRECO (40.19): resource and cost analyses are not carried out in conjunction with networks (*); 0.02 NOEMPL (36.02): the number of employees is relatively small (*); +102.61 EXPANP (30.22): the company has an ambitious expansion policy; + 30.43 UNCERT (19.44): the jobs planned by network analysis are characterized by high uncertainty; - 25.56 SPECUL (12.25): the company does not operate in the speculative building construction market; - 34.80 VISDIS (9.71): cathode ray tube devices are not used; + 20.88 RESLIM (9.43): the jobs planned by network analysis are characterized by tight resource limitations; + 6.33 FLEXI (4.40): the jobs planned by network analysis are characterized by high flexibility; - 10.32 MULPRO (2.66): multi-project scheduling is not carried out. Site managers' success scores are likely to be higher when: - 0.02 NOEMPL (34.35): the number of employees is relatively small (*); 0.91 TIMRES (24.44): resource analysis is not carried out in conjunction with networks (*); 0.36 NOPROJ (19.58): the number of projects undertaken by the company is relatively small (*); + 26.32 JOBLOC (11.21): the company operates at national level, and possibly undertakes overseas jobs as well (*); + 0.18 ARROW (8.78): arrow diagrams rather than precedence diagrams are used; + 9.30 UNCERT (6.15): the jobs planned by network analysis are characterized by high uncertainty (*). Planning engineers' correlation coefficients at 10% significance level; success is likely to be greater when: OPERAN (-0.60): the company undertakes jobs which do not vary a great deal in contract values (*).

Site managers' correlation coefficients at 10% significance level; success is likely to be greater when: TURNOV (-0.46): the annual turnover of the company is relatively small. (*) Significant at 5%. The following multiple regression equations show the relationship between success scores and <u>all the variables</u> considered together, at 2% significance level. The figure on the left is the regression coefficient; the figure in parantheses, following the variable name, is a measure of importance. (Regression coefficient multiplied by the standard deviation). It denotes the change undergone by the dependent variable, for a standard change in that particular independent variable. The variables are given below in order of importance:

Planning engineers' suc	ccess scores are likely to be higher when:
-47.18 SRMTD1 (40.05):	there is continuous and increasing senior management
	support for network analysis;
-46.90 NOACT (24.22):	the number of variables is not the criterion used in
	deciding whether or not to use computers;
+42.18 TIMLIM (21.09):	time analysis only is carried out by networks:
+ 3.25 CONAUT (13.13):	most decisions are given at a level of authority within
	the organization:
-26.99 PDFOR1 (11.07):	the planning department is not established as a direct
	result of introducing network analysis:
+ 8.78 SSFAMI (3.60):	site staff familiarity with computer outputs is
	considered before using computer programs:
+ 1.08 SINCEW (2.74):	the company has been using network analysis for a
· · · · · · · · · · · · · · · · · · ·	long time.
Site managers' success	scores are likely to be higher when:
- 0.03 NOEMPL (51.52):	the number of employees is relatively small:
-56.42 LOCATN (24.11):	the job is not broken down on the basis of the physical
	location of activities:
- 0.74 TIMRES (22.32):	resource analysis is not carried out in conjunction
	with networks:
-29.20 HIFRAR (14.24):	hierarchical reporting is not carried out:

+13.98 KINDJO (8.61): jobs of civil engineering nature are undertaken; + 7.60 FLEXI (5.48): the jobs planned by network analysis are characterized by high flexibility.

CHAPTER VI

CONCLUSIONS

Five multiple regression equations were calculated for PEs, one for each of the four groups of variables (Methods of Application, Methods of Introduction, Organizational Characteristics, and General Characteristics), and one containing all the variables put together. Similarly, five equations were calculated for SMs. The findings based on these ten regression equations, and also including statistically significant correlations at 10%, are given below:

PEs' success scores have been found, at 10% significance level, to be likely to be enhanced if:

Methods of Application

- 1. The cost using network analysis is kept to a minimum;
- Sufficient information is available at the start of a project to construct a reliable network;
- The company's own computer (and not a computer bureau) is used -if computers are employed;
- 4. Computer programs developed for the particular requirements of the company (and not standard packages) are used -if computers are employed;
- 5. Site staff familiarity with computer printouts (and not contractual obligations, and/or the number of activities in the network) is taken into consideration before deciding whether or not to use a computer program;
- Both durations and the logical sequence of activities are reviewed at each update;

- 7. Float is distributed evenly among activities (and not allocated to activities expected to be late);
- Clients' requirements are not the only way by which the degree of detail is determined;
- 9. Sub-networks are used as much as possible;

Methods of Introduction

- Network analysis is not introduced as a direct response to contractual obligations;
- The very first network analysis is carried out manually and not by a computer program;
- 12. A planning department is not established as a direct result of introducing network analysis;
- 13. The status of the planning department is enhanced by the use of network analysis;
- 14. Site managers are not sent to courses to initiate them to network analysis;
- 15. Senior management is progressive enough to support changes in general;
- 16. PEs, SMs, and senior management all support network analysis;
- 17. PEs' and senior management's support is continuing and increasing since the days of introduction;
- 18. SMs have considerable site experience and are not disillusioned by frequent updatings;

Organizational Characteristics

- The technology used by the organization is characterized by a low degree of mechanization;
- 20. The organization is relatively small and dependent on the parent organization, but sufficiently autonomous to give most internal decisions;

General Characteristics

- 21. The organization has used network analysis for a long time;
- 22. The organization is relatively small, undertakes jobs whose contract values do not vary much, and has an ambitious expansion policy;
- 23. Multi-project scheduling and visual display units such as cathode ray tubes are not used;
- 24. The jobs planned by network analysis have high flexibility, and high uncertainty characteristics and are time and resource limited;
- 25. Cost control is not carried out in conjunction with network;
- 26. The jobs undertaken are not in the speculative housing category.

SMs' success scores have been found, at 10% significance level, to be likely to be enhanced if:

Methods of Application

- Only durations are reviewed at each update and the logical sequence of activities is preserved;
- Contractual obligations are not the main criterion in deciding whether to use a computer program;
- The number of activities in computerized applications is kept as small as possible;
- 4. Float is allocated evenly among activities and/or as dictated by the resource analysis;
- 5. Projects are not broken down into activities on the basis of the physical location of each activity;

- 6. The complexity of the job, clients' requirements, and the ability of site managers to cope with complicated networks (and not the PEs' ability to construct complicated networks) are considered when determining the degree of detail;
- 7. Resource analysis is carried out for parts of projects at a time, and not for the entire job at the beginning;

Methods of Introduction

- Network analysis is introduced because the existing planning techniques are considered to be inadequate;
- 9. The very first network analysis is carried out manually and not by a computer;
- PEs concentrate more on human relations with SMs, rather than emphasizing the technical aspects;
- 11. SMs always support the use of network analysis (i.e., when it is in used and when it was introduced);
- 12. Senior management supports the use of network analysis when it is introduced;
- 13. Internal courses are not run, and SMs are not sent to courses (internal or external) to initiate them in the technique;
- 14. Network analysis does not increase the already considerable workload on SMs;
- 15. The planning department becomes more involved in the day to day running of projects;

Organizational Characteristics

 The technology used by the organization is characterized by a low degree of mechanization;

General Characteristics

17. The jobs planned by network analysis have high flexibility and

high uncertainty characteristics;

- 18. Arrow diagrams rather than precedence diagrams are used;
- 19. Resource analysis is not carried out in conjunction with networks;
- 20. The organization is relatively small, undertakes a small number of civil engineering jobs at a national, and possibly at an international level.

The immediate apparent feature of these findings is that there are areas of consensus and areas of complete disagreement between the findings for PEs and for SMs. For example there is agreement that the first network should be calculated manually; that SMs should not be sent to courses as an initiation exercise; that the contribution to success of computer programs used because of contractual obligations would be limited; and finally, that network analysis seems to be more suitable in cases where jobs are characterized by high flexibility, high uncertainty and low mechanization. On the other hand, PEs and SMs disagree completely as to what should be reviewed at each update, and whether clients' requirements should have any influence on the process of determining the degree of detail of a network. There are also a multitude of findings between agreement and disagreement. Sometimes these findings are complementary. For example, PEs' findings indicate that network analysis should not be introduced as a direct response to contractual obligations; and SMs' findings indicate that network analysis should be introduced as a result of a need felt for a more advanced technique. Excluding the few areas of consensus, it seems that the answer to the problem does not rest with any particular class of executive in the

organization. The findings are therefore consistent with the view that incumbents of different positions have different objectives, expectations, values, aspirations and opinions which govern their attitude and behaviour towards network analysis.

Keeping this differentiation in mind, it is worth exploring the findings in the framework of the analytical model set up in Chapter III, Section 1, that success in network analysis applications is related to the way it is applied, to the way it is introduced, and to the particular environment (the project, the organization, and the surrounding conditions) in which it is used.

When Methods of Application variables are considered, it is noted that the general literature's preoccupations with updating procedures, the use of computers, the degree of detail, and the allocation of float are reflected to a large extent in the findings for both PEs and SMs. The remaining factors which this analysis shows to be of importance are the cost of using the technique, and the availability of information for building up a reliable network, in the case of PEs; and the nature of resource analysis (entire project or parts of it at a time) in the case of SMs.

As far as updating is concerned, it is interesting to note that the frequency of each review does not seem to have any significant influence on success, whereas the modifications involved at each review seem to be of importance. The construction process is fairly indeterminate, and uncontrollable factors affect programmes to a great extent. The importance attached to the nature of updating can be interpreted partly as a reflection of this intrinsic characteristic of the construction industry, and partly as the outcome of a clash of interests between PEs and SMs. Indeed, whereas PEs try to safeguard their programme by modifying whatever they think necessary, SMs prefer to assess progress and discuss it with sub-contractors, clients, directors, architects and/or consultants, on the basis of a fixed programme. The general literature which is rather more concerned about the frequency with which programmes should be updated, seems to have neglected to identify SMs' problems, by taking for granted that modifications are carried out whenever PEs think fit. A closer look should therefore be taken into SMs' problems of spending considerable time and effort to absorb and digest extensive alterations at each review; and of communicating with a large number of parties on the basis of an ever-changing programme. A possible solution which was observed in some of the companies, is the use of target dates.

It was not possible to establish statistically whether computerized applications are desirable for greater success. However, it was possible to determine that the use of standard packages run in service bureaux tended to reduce PEs' success scores, and that computerized networks containing a very large number of activities tended to reduce SMs' success scores. It is also noted that PEs are concerned as to the criteria by which computerization is decided. Statistical analysis indicated that PEs' success scores are likely to be higher when site staff familiarity with computer printouts, rather than the well established criteria of contractual obligations, and of the number of activities in the network, are considered. It is possible to detect in these findings a concern on the part of PEs for the effects that computerized applications may have on SMs.

Yet another difference of view between PEs and SMs, can be seen

when the degree of detail of networks is considered. The results are very much in line with what has been said before: SMs are in a position to familiarize themselves with a programme, and to negotiate with other parties on that basis. The detail of the programme plays an important part in both these activities. The results for SMs indicate that the complexity of the job, clients' requirements, and the ability of site staff to cope with complicated networks (and not PEs' ability to construct a complicated network) should be the criteria by which PEs decide how detailed the programme is going to be. The appearance of such a large number of these variables in the multiple regression equations show the preoccupation of SMs with this particular aspect. As a direct contrast, however, PEs' regression equations contain only one of these variables; furthermore, according to this finding, clients' requirements should not be considered by PEs when deciding the detail of a programme. These results and the general attitude of most writers, indicate that PEs are not aware of the problems they are causing SMs by not using the specified detail in their programme. There seems to be a definite need for PEs to be more aware of the problems with which SMs are faced. An awareness of this sort, coupled perhaps with some concessions on the part of PEs, seems to be conducive to greater success.

When Methods of Introduction variables are considered, it is noted that there is a well-marked difference between PEs' and SMs' results. Both of them seem to give particular weight to the reasons why network analysis was introduced in the first place, the way of calculating the first experimental network, and whether support is necessary by various participants in the process; but the essential difference can be seen in that SMs are much more aware of the effects of interpersonal relationships on the success of applications than PEs, who are more worried about the effects that network analysis would have on the status of their own department. It is indeed interesting to observe how little PEs are aware of the existence of a human problem, whereas SMs findings indicate by two variables which cover a large portion of the variability in the regression equation, that PEs should also concentrate on human relations. Apart from this aspect, it is possible to observe a number of phenomena which are also closely related to the problems: at psychological level that one can face when introducing changes. Whereas neither SMs nor the PEs seek a way by which they can participate in the decision which introduces network analysis into their company, it is interesting to note that both of them are concerned as to how and why it is introduced. Indeed, PEs do not regard contractual obligations as sufficient for making this decision, and SMs' view is that there must be a reaction in the organization to existing inadequate planning techniques, and a need for more advanced ones. Furthermore, they both agree that support (and even enthusiasm) on the part of all members concerned, including PEs, SMs, and senior management, is essential for successful applications.

As to whether success is related to the effect that network analysis has on the basic securities of site staff members; the amount of pay and/or prestige gained -or lost- do not seem to be of primary importance. However, according to SMs' results, success is greater when network analysis reduces their workload; according to PEs', success is greater if SMs' status is enhanced as a direct result of introducing network analysis. It is possible to observe, here, an uneasiness on the part of PEs that network analysis would somehow restrict SMs' freedom of movement and consequently constitue a threat to their status. Although there is no concrete evidence to support this view, the author believes that there is an element of truth in it, and that the PEs' awareness of the situation results in the finding mentioned above.

An unexpected result in this group of variables is the finding that success (for both PEs and SMs) is higher when SMs are not sent to courses as an initiation exercise. If one accepts the assumption that individuals' reactions to change are related to the clarity of their perception of the change, then it seems that the only way of explaining the change and its consequences is by means of on-the-job training, as recommended by Archibald & Villoria (39), Baboulene (177), and Buesnel (178).

It seems therefore that most of the problems that can occur when introducing changes, do exist when network analysis replaces existing planning techniques. Furthermore, statistical relationships indicate that the human element in these problems is of major importance.

When Organizational Characteristics are considered, it is observed that three of the four main variables are significantly related to PEs' success scores, and one of them to SMs! success scores. It is interesting that so many of these variables are related to success; however, due to the very generalized information these variables give, it is difficult to interpret the results in a meaningful way. What these findings do indicate, is that organizational characteristics definitely influence success, as was hypothesized in Chapter III, Section 5. However, further

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research is necessary to follow this lead and to determine which of the bureaucratic dimensions (i.e., specialization, formalization, centralization, standardization, configuration, and flexibility) play the most important parts in this relationship. It is indeed possible to conduct such an investigation by using the measurement methods developed by Pugh et al (181,187,188), and not those in Inkson et al's abbreviated version (193) which resulted only in limited but basic information that such a relationship exists.

When General Characteristics are considered, the findings seem to be mostly complementary, except for two areas of strong consensus. There is agreement that success is likely to be greater in smaller companies who undertake jobs which have high flexibility and high uncertainty characteristics. The fact that so many variables in this group are found to be related to success, demonstrates the importance of the organizational context within which network analysis is used. This cannot be either ignored as unimportant, or assumed to be benign to the introduction and implementation of the technique, as many of the writers imply.

A variable which is not present in any regression equation and whose correlation coefficients are extremely low is "economic justification". This implies that success as measured in this study is not related to economic justification. However, this finding carries very little weight since all the respondents made it clear that their assessment was based on intuition rather than on concrete data. The measure of success used in this study can be accepted as a reasonable indicator of economic justification, as all the 34 factors used in this measurement contribute to a greater or lesser degree to the efficiency and profitability of companies.

Finally, a few words about the methodology used in this study: A good deal of criticism has been directed by social scientists (See e.g., 88) to the use of statistical techniques in the explanation of phenomena, especially at exploratory level. It is indeed possible to come out with a finding that success in high school courses is significantly related to the colour of students' eyes. Such a relationship is difficult to interpret, (indeed, it might be spurious) if it is not explored within a carefully worked out explanatory framework from which the questions are derived. The variables in this research study have been observed in a comprehensive literature survey, a case study, and a preliminary field survey to be carefully related to success in network analysis applications. The statistical relationships presented in this piece of work are not therefore figures without meaning, but figures which explain hypotheses set down within a carefully prepared analytical framework developed at the end of considerable preliminary investigation. As to the causality in these relationships; in theory, it is not possible to prove causal relationships within a statistical approach; but there seems to be no reason why survey data may not be used to provide evidence towards a causal explanation. A feedback survey was organized to test the validity of some of the causal explanations attempted during the interpretation of the findings, and to investigate whether causality existed in some of the less obvious relationships. The large majority of the respondents in this survey, expressed their views in causal terms, and these have been reported in their original context, throughout this thesis.

The analytical model which was proposed in Chapter III, Section 1 has therefore proved to be of value when examining the problem of success in network analysis applications. It can be seen that success does not depend only on how the technique is applied, but also on how it is introduced and in what sort of environment it is used. Indeed, the results obtained point out that the behavioural and contextual aspects mentioned in the preceding paragraphs explain statistically a large portion of success (or failure) in the use of network analysis, in the case of both the PE and the SM, the two key positions in the application process.

An abbreviated version of the findings, including only the three most important variables in regression equations significant at 5%, are given below. It is believed that such a presentation combining the results of PEs and SMs, will enable the reader to form a clearer picture of the governing factors in network analysis applications. Greater success is likely to be obtained when:

- Programs developed for the particular requirements of the company (and not standard packages) are used in computerized applications;
- The criteria by which computerization is decided, do not contain the size of the network, and contractual obligations;
 There is sufficient information at the start of a project to

construct a reliable network;

- Float is not allocated to certain activities without a formal analysis;
- 5. SMs' ability to cope with complicated networks is taken into consideration when determining the detail of a network;

- 7. PEs concentrate more on the human aspects of the relationship with SMs;
- There is continuous and increasing senior management support for network analysis;
- The technology used by the organization is characterized by a low degree of mechanization;
- Only time analysis (no resource analysis and/or cost analysis) is carried out;
- 11. The company is relatively small.

1.

The conclusions of this study can be summarized as follows: Methods of Application are important in network analysis implementation. This group of variables provided the largest number of variables significantly related to success at 5%. Some of the findings suggest that success should be obtained if the system is not very costly to run, is reliable (i.e., based on adequate information, and not necessitating many reviews), produces networks with a degree of detail consistent with site management's requirements, uses computer programs specially developed for the requirements of the company, etc., etc.

2. It must be recognized that all the problems that occur when introducing a technological change into an organization, exist when a company decides to replace its conventional planning techniques by network analysis. The human element is of paramount importance in this operation.

- 3. The structural characteristics of an organization are linked to success in network analysis applications. In order to assess the exact magnitude of this effect, further research covering all bureaucratic dimensions separately, is necessary.
- 4. The immediate environment in which network analysis is used (i.e., the projects undertaken, and the company itself) seems to be related to success. For example, it has been found that greater success was achieved in smaller companies who had an ambitious expansion policy and who undertook jobs of civil engineering nature characterized by high flexibility and high uncertainty.
- 5. Success in network analysis applications and the factors which affect it, are differently perceived by the incumbents of the two key positions in the implementation process. Further research covering senior management attitudes, and therefore giving more weight to profitability aspects would be of value in obtaining a more complete picture of the situation.

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REPORT OF THE STUDY ON RECEIPT OF INFORMATION BY CONTRACTORS

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Part 1:

General Information:

 This project has been carried out as part of a larger research project dealing with contractors' cost control and funded by the Construction Industry Research and Information Association.
 "As the design of an effective cost control system must depend on the extent to which design information is available, in advance of construction" it was decided to collect statistical data on this point.

2. Letters asking for co-operation have been sent to 17 companies. 6 of these were already contacted by Mr. P.F. Miller in the earlier stages of the project. The rest (11 companies) were chosen from the Stock Exchange Official Yearbook 1968, and standard circulars explaining the purpose of the project were sent by Professor E.G. Trimble.

3. The result of the correspondance is as follows: Wish to co-operate : 11 Do not wish to co-operate : 5 Did not reply : 1

4. Visits have been done to 10 of the 11 companies who wished to co-operate. The remaining one did not suggest a definite appointment date, but agreed to supply the basic information required. No information has been received from them up to this date. The result of the visits is as follows:
Agreed to supply information : 7
Gave no information : 3

5. The degree of detail of the information obtained is given below:

The full set of information obtained :	N	None			
Some basic information obtained :	3	(No. 3,8,12)			
Very little information obtained :	2	(No. 9,10)			
Waiting for information	2	(No. 7,13)			
No information :	3	(No. 4,6,16)			

6. In each company, a minimum of one and a maximum of four projects have been examined, making a total of 13 projects for the 7 companies who agreed to supply information. Special care has been taken in choosing the projects, so that they were the most typical ones available at that time in the companies.

Part 2:

Difficulties encountered during the investigation:

 Although all persons contacted seemed to be very willing to co-operate for this project which would show at the end "a very important defficiency in the construction industry", in fact, the general way of thought (except in companies No. 3 and 8) was that: "the drawings are always late, the architect and/or the client are responsible for it, and it is a better idea to try to eliminate this defficiency by working on the forms of contract rather than to prove it statistically".

2. Although the fact that all information would be kept

strictly confidential was mentioned, the majority of the companies visited (4 out of the 7 companies who agreed to supply the necessary information, No. 7,8,9,13) were very reluctant to supply the names of the architects and/or the places of construction.

3. Taking into consideration that contracting companies are

extremely busy at this time of the year, help has been offered for compiling the necessary information from the existing records. Only 3 out of these 7 companies accepted this offer (No. 3,8,10). The rest of them were very keen to keep their records secret:

4. Two of these 7 companies (No. 7,13) insisted on compiling the required information themselves and promised to send them as soon as they would be ready. In spite of several phone calls exchanged with both of the companies, no information has been received up to now.

5. The records of the basic information required (ie, latest drawing requirement dates, actual drawing receipt dates, and start dates of activities) did exist in all the companies. The reasons why these records are kept have been explained as follows: --- They will be used in case a claim is necessary.

— They will be used for checking that the latest revisions are being used on site.

(There are 2 exceptions to this paragraph. These are 2 projects each carried out by a different company, (No. 8 and 9). All drawings were supplied before construction started and hence there was theoretically no necessity for determining a drawing requirement schedule. In fact, in both projects, there were so many revisions during the construction of the project that they were both delayed).

6. The main difficulty I experienced was in obtaining informa-

tion about the reasons why the amendments were done and their cost implications.

7. Revised drawings include mostly in their top right hand corners, information about all the amendments made to the original drawings. The only way of determining the reasons for each amendment would require a considerable amount of time of a senior member of the company, who had been extremely familiar with the project. He would look through all the drawings and try to remember the reasons for the revisions.

8. On the other hand, the contractor thinks that his job is to construct according to the drawings supplied by the architect. If there are alterations or amendments, he does not bother to keep the records of the reasons of these changes. Since all kinds of extra work are paid for by the client afterwards, he only bothers whether the building can properly be constructed by means of the existing drawings. Therefore, there is no purpose in looking for

- this information in the contractor's company.
- 9. Generally cost records are kept on a time basis rather than separately for each activity. This fact makes it impossible to determine the effects of alterations or late receipt of drawings on the cost of a particular activity.
- 10. The reason for this has been explained in most of the visited companies as follows:
- When work is stopped in an activity due to some reason, the same labour force is used in another part of the site, i.e., in another activity. This fact makes the job very complicated in case records are kept on the activity basis. Besides, the disruptive side effects cannot be measured.
- Materials come to the site in bulk form. It is not practical (or at least it needs a considerable amount of additional labour) to check what amount is used in a certain activity, whether there are any surplus, whether this surplus is transferred to another activity, etc.

Part 3:

Results and conclusions:

. Before starting to give the numerical results, it will be

advantageous to comment on the general situation of the companies which have been visited. It has been noticed that in each of the companies:

- a different planning technique,

— a different method for determining and requiring information, — a different form of recording the receipt of drawings . were used. While one company did not plan at all, some used bar-charts of different degrees of detail, and some others used the most sophisticated network analysis techniques for jobs of almost the same importance. In some companies it was not the usual procedure to prepare an information requirement schedule while in some others most detailed schedules were prepared. Coming to drawing receipt records, I had the chance of examining records which contained practically no information and records where every single detail was written down.

2. This situation made the job of collecting standard data for the purpose of this project extremely difficult; in fact, in the evaluation of the results which will be given in the following paragraphs, only a maximum of 6 projects have been considered.

3. This situation also shows the lack of an efficient standard system in the administration and management of projects in the construction industry and gives an indication of the chaos in which the industry is. A standard system would not only make easier the task of the researcher in this field, but, it certainly would solve, to a certain extent, the problem of bad communications in the construction industry.

4. It has been determined that an average of 46% of the total number of drawings are received before activity start dates, while 54% are received after activity start dates. In this context, the total number of drawings is meant to be the sum of all original drawings and all revisions; activities may be defined as parts of the job, used in bar-charts or networks, and whose size is determined by the contractor.

5. Starting from the assumption that no activity can be started unless all information about the activity is available, this very high percentage of drawings received after activity start dates may be explained by the following suggestions:

— The programmes are not updated as frequently as they should be; i.e., because of some delay in the preceding parts, the real activity start dates are actually later than those shown on the programme which has been used in the evaluation of these figures.

 There is a tremendous amount of revised drawings giving additional information while carrying out the job.

6. The examination of the contracts in question showed very

clearly that the first suggestion given in the preceding paragraph holds in most of the cases. But, it has not been possible to measure quantitatively to what extent this suggestion is true. However, it has been determined that 30% of the <u>original</u> drawings are received after activity start dates, which is an indication that programmes are not updated very frequently.

 On the other hand, the second suggestion made in paragraph 5 is justified by the fact that an average of 45% of the drawings are original drawings while 55% are revised drawings.

8. Therefore, considering the results given in paragraphs 6

and 7, the reason for this very high percentage of drawings received after activity start dates can be explained by a combination of the two suggestions given in paragraph 5.

9. There are three major reasons for amending drawings:

- The change of mind of the client.

- The change of mind of the architect.

--- Suggestions from the contractor.

The first reason results in major or minor alterations depending on the nature of the project. The last two reasons are due to insufficient, incorrect or inadequate information in the drawings, as well as decision changes among different alternatives in the case of the second item. As stated in paragraph 7 in the second part (Difficulties Encountered During the Investigation) it is very difficult to determine the relative weights of these reasons. However, according to the approximative estimates made by persons contacted, it seems that the predominant factor is the first reason. This fact suggests that the quality of drawings in general is not as bad as some claim.

10. It has been noticed that in all of the projects examined, there were delays of different magnitudes. As an average, these delays amounted to 19% of the average programmed project periods. In two of the projects where information was available, the percentage of delays has been plotted against the percentage of drawings received after activity start dates, for each activity, expecting a curve with positive slopes. But, this trial was not successful because the points plotted were far from giving a definite trend. This fact proves that although the late receipt of drawings is of some importance in the occurance of delays, it has also some non-measurable side effects, which, when combined with other important factors (such as bad planning or bad management), are sufficient to change the expected curve.

11. When a contract is obtained, it has become for most contractors, a routine task to open a claim file. Although statistical data about claims has not been collected, according to the persons contacted, it seems that they can generally obtain only 50 to 60% of the amount claimed, the main reason for their claim being the late receipt of drawings. One of the reasons for this situation is that, in cases where contracting companies realise that they will not be able to complete the job on schedule, they willingly do not chase drawings, so that at the end they have a reason for their claim.

- 12. It has been found out that the drawing requirement dates are determined in different ways, in different companies:
 1 company (No. 3) fixed a definite amount of time before the activity start dates.
- 2 companies (No. 7 and 10) claimed that it was not possible to determine a schedule for drawings, because one did not know much at the beginning about what will be needed, So, drawings were required in periodical meetings as time went on.
 4 companies (No. 8, 9, 12 and 13) determined their drawing
- requirement schedules taking the market situation of materials into consideration and using their past experiences.
- 13. Some of the projects which have been examined were based on the understanding that all drawings would be supplied at the start of the job, in which case no information requirement schedules

were prepared. In two of the projects where information was available it has been determined that only an average of 49% of the drawings were received before requirement dates.

14. Finally, in order to show the situation of design information at the stage when construction has not yet started, let us take three different examples:

In a project in company No. 9, 2000 drawings were handed over in the final pre-contract meeting. Although the architect claimed that every single information was contained in these drawings, there were 1000 more drawings issued during construction.
In one of the projects (traditional contract) carried out by company No. 8, only 421 drawings were issued before the starting date of the construction while there were 2822 more drawings issued afterwards.

In another project carried out by the same company and in which the architects "stressed that the works were already fully designed, that working drawings were available and that no significant variations were contemplated", the construction started with 1376 drawings and 3157 additional drawings were issued later, during the construction.

15. Taking into consideration all the results given in the preceding paragraphs, it is obvious that the premeasurement of quantities is bound to be a process of low accuracy.

16. It is realised that the figures given in this report cannot be generalised for the entire construction industry of Great Britain, but they certainly give an idea of the situation.

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APPENDIX B

New Station

ADVANTAGES AND DISADVANTAGES OF USING PRECEDENCE DIAGRAMS

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Advantages and disadvantages of using precedence diagrams:

The advantages and disadvantages of using precedence diagrams (listed in the following two Parts of this Appendix) have been compiled after a review of the following literature: Burgess et al (1), Priluck (28), O'Brien (33), Antill & Woodhead (35), Battersby (38), Archibald & Villoria (39), Moder & Phillips (51), Nuttall & Jeanes (53), Armstrong-Wright (94), Woodgate (96), Rist (100), Barnetson (107), Larkin (118), Fondahl (123), Carruthers (218), Jeanes & Britten (219), Reynaud (220), Anonymous article in Engineering News Record (221), Faherty (222), Holden & McIlroy (223), a "Learning Text" published by the Construction Industry Training Board (224). The items are listed in order of frequency of appearance in the above-mentioned literature.

Part 1:

Advantages of precedence diagrams:

- No dummies are necessary. (According to Burgess et al (1), about 40% of the activities in an arrow diagram are dummies).
 It is easier to draw for a newcomer.
- It is easier to represent overlapping activities. It gives greater flexibility in adding new restrictions. It is possible to show lead or lag times, and thus, to eliminate the need for breaking up activities merely for network construction purposes.
 Alteration of project logic is simple, requiring only addition or subtraction of links in the diagram.
- 5. It is easier to be understood. In an arrow diagram, people think that the length of the arrow denotes time. There is no confusion of this sort in precedence diagrams.
- An activity can be represented by only one reference number.
 This does not change when the logic is amended.

7. Usually, the number of activities is smaller.

- 8. It is better when communicating the logic of a problem to others in outline (that is, not in great detail), and particularly when explaining the problem to several people at a time.
- 9. Activity times are more easily calculated.
- 10. The number of dependency lines is often fewer.
- 11. The time taken in initial analysis can be reduced by someone experienced in the technique.

 There are standard computer packages which accept data from arrow or precedence diagrams.

Part 2:

Disadvantages of precedence diagrams:

- There are few computer programs written for precedence diagrams.
 Precedence diagrams are not suited to presentation on a time scale.
- 3. Certain situations, frequently encountered, where some important event has several activities entering it directly and several leaving it directly, are much clumsier to represent.

4. It lacks the visual appeal of an arrow diagram.

- 5. It is more difficult to draw.
- 6. Computer programs take longer processing time.
- 7. It eliminates events which, in fact, may be necessary in certain cases.
- 8. Path tracing is difficult since the linkage between event numbers is not present.
- 9. It seems more logical to represent an activity which represents the passage of time and progress from start to finish, by an arrow, than by a circle or box, which give a static impression.
- 10. The numbering of activities, not being sequential, makes computer processing cumbersome.
- Large precedence diagrams are inclined to become cluttered in view of the size of the circles that have to be drawn to enclose the description.
- 12. The reason why precedence diagrams are not used more frequently is because the Government agencies require arrow diagrams.

APPENDIX C

1

COST AND TIME REDUCTIONS DUE TO NETWORK ANALYSIS, AS REPORTED BY VARIOUS WRITERS

Part 1: Cost of using network analysis 301 Part 2: Cost savings obtained by using network analysis 306 Part 3: Time reductions obtained by using network analysis 309

Part 1:

Cost of using network analysis:

In their annual report 1969-1970, the Division of Building Research of CSIRO (37) reports finding that the time analysis of reasonably detailed networks updated once per fortnight should not exceed 0.25% of the related construction cost.

Mahony (125) indicates that according to statistics, in some manufacturing industries 10% of the basic cost of each unit produced on a production line is spent on planning, whereas in construction it is less than 2%.

O'Brien (33) calculates that for projects in the general value range of \$2 to \$10 million, the cost of a complete CPM application (including consultation and computer costs for the preliminary plan, the working plan and updating) is 0.5% of the project cost. He expects a slight reduction in projects over \$10 million, and a sharp increase to 1.0% in projects of about \$500,000. He estimates that resource and cost analyses would add approximately 0.45% to these figures.

In a lecture entitled "The Economics of Using Network Analysis" delivered to the Project Network Analysis Study Group of the Operational Research Society 1970, Rogers (41) reported the results of statistical analyses on data collected from a number of contracting organizations. He found that: y = 685 + 0.00059x where y is the total working cost of network analysis, and x is the capital cost of the job.

Battersby (38) reports that one of the pioneering firms of consultants in the field has estimated the cost of network analysis to be 0.5% of the total project cost for a large research and development application, and 1% for other types. He also quotes in an earlier edition (38) a survey by Frambes (46) that covered 50 American companies. Half of them gave estimates of the cost of operating the system, ranging from 0.2 to 5.0%, with a mean of 1.8% and a modal value of 1.0%.

According to Lock (34), as a rough general guide, total expenditure on computer based network scheduling need not add more than 0.50% to factory cost, and might typically add 0.25%.

Wiest & Levy (42) report that the US Air Force have estimated that PERT costs have averaged 0.1 and 0.5% of total project costs, with the higher figure more typical of research and development programmes.

In a French experiment of network analysis application to a building construction, it has been reported by Pacaud (43) that the cost of using the tedhnique was about 2% of the total project cost.

Antill & Woodhead (35) estimate in the latest edition of their book that the total cost of providing complete CPM coverage to major projects, including detailed pre-planning and resource levelling, with regular monthly updating for project control, should not exceed 0.50%, and with project cost control 0.75% of the contract price.

According to Shaffer, Ritter & Meyer (36), the cost of using CPM varies among organizations, with a commonly quoted figure of 0.1% of the bid price.

The DOE report on the use of network analysis in the Ministry (25) indicates that CPA probably costs more to implement than other planning techniques, and quotes figures from Walton (44) that in the British Oxygen Co. Ltd. the cost of CPM for turnkey capital projects is about 0.25% of the total project cost; and that overhaul and other resource allocation projects seem to work out at about

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1.5 to 2.0% of the total cost of resources controlled.

In an experimental use of network analysis in a \$1.1 million high school project in Australia, Kennedy et al (45) report a cost of 0.96% of the contract value, but later estimate that using faster computer programs and a fully experienced analyst this figure could come down to 0.47%.

Archibald & Villoria (32) quote a research study carried out by Booz Allen Applied Research Inc., which states that: "The variety of conditions present in companies makes it difficult to come to any precise conclusions on what it may cost to apply PERT. Some 47% (of the respondents) regarded the cost of applying PERT as minimal, some 45% as moderate, and 8% as high". The typical answers ranged from "too insignificant to measure" to "about 1.0% of the project cost"; and "the general consensus of companies using PERT is that cost is not a major deterrent to its use".

Archibald & Villoria (32) further state that, in the construction industry, the cost of using PERT seems to be between 0.1% and 0.5% of construction costs. They estimate it to be 0.25% for residential construction and report that for a heavy civil engineering job it had cost 0.5% of engineering billings. The same authors quote also a statement by the US Navy that the original PERT effort for the Polaris Fleet Ballistic Missile Program had cost approximately 0.1% of the total contract price.

Miller (47) finds it appropriate to view the implementation of PERT as costing initially something in the order of twice that of a conventional planning system. In his book published the next year (22), the same author indicates that, according to "the results of several studies", the cost of implementing PERT/TIME ranged from 0.2 to 1.0%

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of total costs.

The following chart prepared by CEIR Inc., and published by Szuprowicz (40) shows network analysis implementation costs plotted against project sizes in terms of \$ million.



Project cost (\$ Million)

Figure 77. Network analysis implementation costs Martin (225) estimates that the cost of using network analysis in building jobs of £500,000 to £3 million should be around 0.20% of the estimated project cost; 0.06% of this is the cost of setting up the network and establishing the schedule, and the rest, 0.14% is monitoring and updating the network. The author believes that network analysis would cost more for projects below the £500,000 limit. He also quotes US Government agencies that the cost of using additional techniques to time analysis was estimated to be 1 to 5% of the project cost, but adds that these figures contain the cost of learning to apply these methods satisfactorily. A more realistic figure is given as 0.5%.

Breakdown of network analysis implementation costs:

According to Szuprowicz (40), about half of the cost of implementing network analysis is generally represented by management planning, estimating and review time. The rest is equally divided between network engineering and data processing.

O'Brien (33) estimates that for a typical project of \$2 to \$10 million, computer costs amount to 30% of the total network analysis implementation cost. He calls the rest (70%) consultation costs. These become 47% and 53% respectively when extensions of the technique, such as resource planning and cost control, are used.

The CSIRO annual report for 1969-1970 (37) indicates that, in their experience 1/3 of the total network analysis implementation cost is computer costs and the rest (2/3) is staff time.

The DOE study (25) states that computer costs for network analysis planning amount to 0.25% of the contract cost.

According to Archibald & Villoria (39) the ratio of labour to computer costs is at least 10 to 1 in a 1000 event network; whereas Martin (225) believes that this ratio is about 3 to 1 for projects between £500,000 and £3 million.

Part 2:

Cost savings obtained by using network analysis:

O'Brien (33) calculates that by using the basic CPM, there should be a joint net saving of 2.95% for the contractor and the client. He further estimates that by using resource planning and cost control by networks, this saving could be increased to 5.55% of the total project cost.

Pocock (21) gives some examples of monetary savings obtained through CPM planning:

- a) Du Pont, shutdown maintenance of Louisville plant; gained more than 1 million pounds of production.
- b) International Minerals & Chemical, maintenance of mine hoist requiring shutdown of mine: \$100,000 saved.
- c) Catalytic Construction Company, 47 contruction projects: expediting
 costs reduced by an average of 15%.
- d) Sun Maid Raisin Growers, construction of plant properly timed to growing season: estimated savings of \$1 million.

Archibald & Villoria (39) indicate that construction companies in the US have reported cost reductions of from 5 to 30% of the total project cost.

Sytnik and Rybalski (226) report that network analysis applications in the USSR have resulted in considerable success by increasing the speed of contruction and reducing its cost.

A survey of large American contractors by Davis (29) showed that only 13% of the companies stated that definite cost savings were made. A number of them said that they did <u>probably</u> make cost savings but had no supportive data. The author has also found that success in network analysis as viewed by top management was strongly correlated with cost savings.

Miller (22) agrees with Woodgate (96) that network analysis causes such improvements in management that profit returns of companies increase without any doubt. Gleason & Ranieri (20) go further and claim that the direct economic benefits of the correct application of CPM is a matter of substantial record and that they are almost taken for granted.

Reynaud (220), Hancock (102), Battersby (38), Lock (34), Brown (130), Martin (225), Nuttall & Amos (133), and McLaren & Buesnel (227) agree that it is extremely difficult to demonstrate exactly how much money can be saved by using network analysis, because the benefits are usually hidden in overhead figures. They also agree that the rewards in money, prestige, good-will for time saved, reduction of overtime, savings in equipment rentals, delivery performance, smoother work sequence, confidence generated in both the customer and the contractor, etc., etc., etc., can justify the money invested in network analysis. According to these authors, and to very many others, network analysis means good planning, and good planning invariably reduces project costs: one must consider the potential cost of not using network analysis.

Pacaud (43) reports that in an experimental application of network analysis in a building construction in France, it was impossible to determine any savings in the final cost. Pascoe (24) explains that whereas the cost of network analysis was easy to assess, the benefits were not so apparent in his company; the marked improvement in performance which he had anticipated did not in fact occur.

In a survey carried out in USA in 1965 by the Bureau of

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Building Marketing Research (56) respondents were asked what sort of saving they would expect from using network analysis. The average expected saving for CPM (as opposed to PERT) was 4.8% of the total project cost.

Part 3:

Time reductions obtained by using network analysis:

Bromilow (228) quotes a CSIRO annual report that 24 contracts considered to be satisfactorily controlled by CPA had execution times averaging more than 30% better than the industry average for contracts of the same values; the overrun of time beyond that specified in the contract for these 24 contracts was only 1% compared with the equivalent industry average of 47%.

O'Brien (33) estimates that through planning of the preconstruction phase, the owner can usually cut 20% from a noncontrolled preconstruction period; according to his experience, this value should actually be closer to 50%. He refers again to his past experience with network analysis when he estimates that shorter contract durations of about 10% can be obtained.

Pocock (21) quotes a few individual examples of time reduction: a) Deere & Company, product development in Ottumwa works: estimated time reduction 28%.

- b) Du Pont, shutdown maintenance of Louisville plant: reduced shutdown time by 37%.
- c) International Minerals & Chemical, maintenance of mine hoist requiring shutdown of mine: 27% time reduction.
- d) Catalytic Construction Company, 47 construction projects:
 Average time reduction 22%.
- e) Sun Maid Raisin Growers, construction of plant properly timed to growing season: time reduction 25%.

According to Antill & Woodhead (35) the use of network analysis in the US construction industry has led to decreases of up to 20% in project times over similar projects not employing CPM as a management tool.

Ρ

Berman (23) reports that Perrini Pacific Ltd. succeeded to cut 100 working days of the Port Mann Bridge Project by using network analysis.

Archibald & Villoria (39) quote a survery of 44 PERT user companies, carried out by Booz Allen Applied Research Inc. The following table shows the results:

ercent of	project	time	saved	Number	of	<u>compani</u>	ies
1%	through	5%			1. 1. 1. 1. 1. 1. 1.	7	
6%	through	10%			1	2	
11%	through	15%				9	
16%	through	20%				9	
21%	through	25%				2	
26%	through	30%				3	
31%	and over	r		•		2	

Over two-thirds of the companies in the survey estimated therefore time savings of 6% to 20%.

A survey in the UK, carried out by Wade (31) asked respondents whether they had project time reductions as a direct result of using network analysis. Of the 20% who answered this particular question, 66% felt that there had been a saving in time whilst 34% felt there had not.

According to a survey by the Bureau of Building Marketing Research (56) contractors reported time savings ranging from 5 to 40% with an average of 30%. APPENDIX D

ADVANTAGES AND DISADVANTAGES OF USING NETWORK ANALYSIS,

AS REPORTED BY VARIOUS AUTHORS

Part 1: Advantages of using network analysis313Part 2: Disadvantages of using network analysis315

Advantages and disadvantages of using network analysis:

Network analysis has received considerable attention since the days of the Polaris project. A large number of books and articles have been written about it, and the advantages and disadvantages of using it have been reported by many writers. A survey of this literature resulted in a compilation of these characteristics as reported by the following writers: Gleason & Ranieri (20), Miller (22,47), a report for the DOE (25), O'Brien (33), Antill & Woodhead (35), Shaffer, Ritter & Meyer (36), Battersby (38), Archibald and Villoria (39), Wiest & Levy (42), Moder & Phillips (51), Nuttall and Jeanes (53), Burgess (92), Oxley & Poskitt (95), Woodgate (96), Broome (101), Hale (102), Hancock (102), Lomax (117), Stires and Murphy (120), Fondahl (123), Mahoney (125), Bauer (126), Brown (130), Kabos (131), Nuttall & Amos (133), Baboulene (177), Horowitz (179), McLaren & Buesnel (227), Baker (229), Kaufman & Desbazeille (230), Schoderbek (231), Boverie (232), Simms & Britten (233).

Part 1:

Advantages of using network analysis:

- 1. Project time is reduced.
- 2. Project costs are reduced.
- Management by exception is applied by concentrating on critical activities.
- 4. There is better communication and co-ordination between the company and outside organizations. For example:
 - a) The ability to give early information to sub-contractors as to when work would be available for them and the possible consequences if they are late.
 - b) Precise knowledge of delivery requirements which simplifies ordering and avoids congestion on site.
 - c) The ability to show the effect of late drawings and specifications on the completion time, which eases the relationship between the contractor and the architect and/or the consultant.
- 5. There is better communication and co-ordination between departments within the company.
- The consequences of delays, changes, alterations, modifications are worked out in sufficient time to take corrective action.
- 7. Senior management supervises the projects less frequently since progress can be predicted with more confidence.
- 8. Claims for delays are determined and verified more easily.
- 9. It requires less intuitive skill and experience.
- 10. It is easily explainable, and easily calculated.
- 11. It is a disciplined, systematic and logical approach to projects.
- 12. It gives a very detailed programme.
- Staff members become more involved in the project and know everything that goes on.
- 14. It is easier to take a partially completed job and to become familiar with the project and progress.
- 15. It gives a better chance for the efficient use of resources.
- 16. It speeds the process of decision-making at all levels.
- 17. Cost optimization (time-cost trade-off) techniques can be used in association with it.
- 18. Cost control can be carried out in association with it.
- 19. It is used in all stages of project management: pre-tender planning, contract planning, progress control.
- 20. It provides the ability to test alternative solutions.
- 21. Planning the sequence of work and scheduling the times are separated.
- 22. It shows inter-relationships among activities.
- 23. It is possible to use computers.
- 24. It is fashionable.
- 25. Criticalness and float are shown.
- 26. It provides better overall project control.
- 27. It can be applied to a wide variety of projects.
- 28. It pinpoints responsibilities.
- 29. It enables the systematic review of the programme as situations arise.

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Part 2:

Disadvantages of using network analysis:

- 1. It is not flexible enough.
- 2. It is either too detailed or not detailed enough.
- 3. It produces programmes which are uneconomic and sometimes unworkable.
- 4. Float makes people relax, till, in the end, every activity becomes critical.
- 5. It requires high effort and cost for the presentation to be understood by staff involved.
- Being a relatively new development, it meets with inertia on the part of users.
- 7. There is not enough literature to help network analysis users in real life: most of the literature in this field is elementary, repetitive and theoretical.
- 8. A technical terminology of code-words frequently causes confusion.
- 9. Input requirements are very complex.
- 10. It is used as a means of ascribing blame to individuals for failing to meet targets.
- The preparation of the network and the analysis take too long.
 High effort is needed to update and absorb changes.
- There are serious problems in determining contingencies for activity durations and resource figures.
- 14. Specialist support staff is needed.
- 15. There are serious difficulties in drawing complicated networks.
- 16. It is impossible to say how much money can be saved by using network analysis.
- 17. The cost of using network analysis is higher than the cost of

using bar-charts.

- 18. It may require information which sometimes is secret.
- Operating levels do not like the idea of giving top management a very detailed programme.
- 20. It is not a particularly good technique for uncertain situations, such as research and development projects.
- 21. The planner may make big errors if he is not competent enough.
- 22. The planner needs a very good knowledge of the job he is planning.
- 23. The durations for each activity have to be calculated and not simply guessed.
- 24. Site staff must be absolutely convinced that the technique will help them.
- 25. It cannot be applied to all projects indiscriminately.
- 26. It needs regular and if necessary, extensive reviews.

APPENDIX E

THE CASE STUDY THE CHECK LIST AND FINDINGS

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Part 1:

The check-list:

- 1. Kinds of network analysis techniques.
- 2. Bar-charts.
- 3. Resource Analysis.
- 4. Cost control and optimization techniques.
- 5. Extent up to which these techniques are used.
- 6. Economic justification.
- 7. Conditions under which these techniques were first introduced.
- 8. The use of computers.
- 9. Changes in the administrative structure.
- 10. Training schemes.
- 11. Qualifications of the personnel.
- 12. Authority.
- 13. Co-ordination between planning department and team on site.
- 14. Integration with other management techniques.
- 15. Controlling the job.
- 16. Input requirements.
- ~ 17. Suitability of output.

18. Logical sequence.

- 19. Data for activities.
- 20. Degree of detail.
- 21. Complexity of the job.
- 22. Updating.
- 23. Use of float.
- 24. Resistance to change.

Part 2:

The case study:

A. General information:

 The company who accepted to co-operate in this research study was a public company with an annual turnover of over £10 million, and subsidiaries in three large cities.

2. The initial contact was made by Professor E.G. Trimble by approaching the managing director of the company. Once the agreement was reached in principle, the managing director and the director in charge of construction and planning were visited and the full extent and aim of the study were explained.

3. A total of eight members of staff took part in the study. These include: the managing director, the director in charge of construction and planning, the chief planning engineer, the training officer, a contracts manager, a planning engineer, and two site agents.

4. Interviews were carried out by means of a check list given in Appendix F, and a few very loosely defined questions related to each item in this check-list. The aim was to discuss aspects which were found to be of importance and relevance by the interviewee.

5. Interviews ranged from a forty-five minute talk with the managing director to a two and a half hour meeting with the chief planning engineer. The average interview lasted one hour and twenty minutes.

B. History of network analysis applications in the company:

 Network analysis was first introduced in 1963 by the director in charge of construction and planning who was then the general manager. He had used the technique himself and had found it useful. After 1963, it became official company policy to use network analysis.

 It was about this time, 1963, that a major reorganization was taking place in the company. Because of higher annual turnover, and greater expansion there was a forced change in the organization of the company.

3. Before 1963, the company was managed by a small builder

system; i.e., there was a director and a manager, and they would divide the jobs between them. They were their own contracts managers. After 1963 contracts managers were introduced, a planning department was established, and one of the directors took charge of financial aspects while the other (the ex-manager) took charge of construction and planning.

4. It is not clear whether it was the establishment of a planning department which showed the way to the introduction of network analysis, or whether it was the felt necessity for network analysis which led the way to the establishment of a planning department. It seems likely that both arguments are valid and that the true reason for the introduction of network analysis and for the establishment of the planning department is the reorganization of the company.

5. The first planning department consisted of a chief planner, who was a technician with prior experience in planning, and of his assistant who had a B.Sc. degree in civil engineering.

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In 1966-67 the planning department grew to a total of six members. When the survey took place, there were still six persons working in the planning department: one B.Sc., two H.N.C., two technical certificates in building, and one graduate trainee.

6. The first network analysis applications failed completely.

The planning department produced networks and sent them to sites. Site agents had no idea of what network analysis meant and consequently took no notice of networks and continued to manage their job as always by hastily drawn small bar-charts. This situation grew to a point where it became a violent clash between planning and site staffs.

7. It is only after eighteen to twenty months, late in 1964 that top management became aware of this clash. They decided that training courses on network analysis were necessary for site staff. They also sacked the chief planner. The older members who were interviewed claimed that these two measures ended the clash between planning and site staffs.

8. The first training course for site staff took place late in

1964. It was arranged by the university and the Construction Industry Training Board (CITB). This was an introductory course to give some idea of network analysis and was given for six weeks, five hours every saturday morning. There was agreement among interviewees that this scheme was successful in the sense that after the course people on site were able to read and understand networks.

9. The second training course was run in September 1969. This was

a one week condensed course for agents, general foremen, site supervisors and technicians. Again the CITB helped the programme to be designed and lectures were given by professional lecturers from the City of Leicester Polytechnic. This course was designed to enable staff on site to read complicated networks, do their own short-term planning, draw their own bar-charts from the information on networks, and do their own resource scheduling on these bar-charts.

- 10. Another training course was being planned to take place a short time after the completion of the interviews. It was going to be similar to the second course but a bit more advanced.
- According to an old member of the planning department, until three years ago 90% of the projects were planned by bar-charts.
 But, at the time of this study the policy of the company was clear: to use network analysis in as many projects as possible. The reason for this change of policy was explained by three factors.
- a) The type of contract became more complex.
- b) They started to use a great variety of sub-contractors, and
- c) The time factor became more important.

C. The findings:

The findings are presented in categories and in the order of the items listed in the check-list given in Appendix F.

- 1. Kinds of network analysis techniques:
 - Networks were generally only time analysed. Resource analysis was carried out very seldom, in about 10-15% of the projects planned by network analysis. Cost analysis was never used in conjunction with network analysis.
 All programmes were resource levelled, but in 90% of the cases this was done by using the final bar-chart transformation.

Mainly arrow diagrams had been used up to the time of the study. A few precedence diagrams had been drawn only for internal use in the planning department. These were not issued to avoid confusion in site staff who had attended courses where only arrow diagrams were covered. The chief planning engineer stated that precedence diagrams used less space than arrow diagrams at drawing stage, and that sectionalization was better done; but he also added that he would always prefer an arrow diagram. The planning engineer, however, was for precedence diagrams on the ground that it was much more easier to translate a precedence diagram into a bar-chart.

2. Bar-charts:

About 3-10% of the projects were planned by bar-charts.
These were generally small alterations or very small jobs.
50-60% of the projects planned by network analysis were transformed into a bar-chart. About 90% of these were some sort of time-scaled network and the rest, 10%, were pure bar-charts. Normally, these bar-charts were issued every two months.

The reason why networks were transformed into bar-charts was that site staff preferred it that way, because it was more difficult for them to understand a network. The director in charge of planning and the chief planning engineer believed that agents should be using networks and no bar-charts, whereas the planning engineer, the contracts manager and the site agents thought that there would always be a need for bar-charts on site, one reason for this being that it was easier to mark progress on a barchart. A case also was mentioned by the training officer where they had to transform the network into bar-chart form for the sake of the architects who did not have any idea of what network analysis was.

In the majority of cases, the network and the computer printouts (if any) were sent to site together with the barchart transformation. The idea was that if the agent is in difficulty, he can always refer back to the network. However, the two agents interviewed had never used this facility. They both agreed that networks were more detailed than bar-charts and gave more information. But, one of them added that the technique was for inexperienced young agents and not for old and experienced agents like him who knew their job like tha back of their hand.
Everybody agreed that time-scaled networks were the best solution as they had the advantages of both the network and the bar-chart.

3. Resource analysis:

Resource analysis in conjunction with the network was carried out very seldom, in about 10% of the projects planned by network analysis because computers were used very little. The rest were resource levelled manually using the final bar-chart presentations issued every two months.

- Jobs were always time-limited and never resource-limited. So, according to the chief planning engineer there was really not much need for a formal resource analysis at the start of a project. He believed that drawing the logic of a network was a sort of resource analysis and furthermore indicated that he had never seen any formal resource analysis to be successful.

4. Cost control and optimization techniques:

 Cost control was carried out by means of job cards, entirely separately from network analysis. They did not intend to use cost control by networks in the near future, the main reason being that computers were used very little.
 Cost optimization (time-cost trade-off) was never attempted in any project.

- PERT/COST was not used at all. It was once used, but without success, and was abandoned.
- 5. Extent up to which these techniques are used:

— 90-98% of the jobs were time analysed by networks. The rest, 2-10%, were planned by bar-charts.

--- About 10% of projects planned by network analysis were

resource analysed. The rest, 90%, were resource analysed

manually using the final bar-chart presentation.

- Cost analysis was not carried out by networks.

6. Economic justification:

- The two site agents interviewed stated that network analysis increased profits and reduced costs because it introduced a struggle for time and gave better detail. The planning engineer stated that it was not a coincidence that the profit margin increased after the introduction of network analysis and that this was primarily due to network analysis. And finally, the chief planning engineer attributed their high profit/turnover figures to the use of network analysis;
he claimed that their subsidiaries were making less profit/ turnover because they were using only bar-charts.
The only person who did not see any economic justification for using network analysis was the contracts manager. He had never believed that network analysis could reduce costs.
According to the chief planning engineer network analysis cost about 1% of the total project cost; he also agreed with his planning engineer that this can be fully recovered and a profit made on top of it.

It was company policy to keep claims to a minimum. However, everybody, except the contracts manager, agreed that network analysis formed a better basis for negotiating claims.
Conditions under which these techniques were first introduced:
These conditions are described in paragraphs 3,4,5 and 6 under "History of network analysis in the company".
The use of computers:

 The company did not own a computer but was going to acquire one soon for accountancy purposes.

- It was company policy to use computer programs as little as possible, only when they were bound by a contract, or when they wanted to use the resource analysis option. The main reasons for this were that there were not enough competent planners to use computer programs (only two in the planning department) and that the majority of site personnel were not familiar with computer printouts. Another reason was that the size of the jobs they got was not large enough to warrant the use of a computer. So, the very large majority of networked programmes were computed manually, including those having more than 4000 activities. According to the planning engineer, one cannot use a computer if the number of activities is too high because computer costs become too high.

The first computer application had been carried out in 1964 in a housing project because the clients had required it. There was complete agreement among interviewees that this was a complete failure because, according to site management the planners did not have enough site experience, and according to planning staff, the planners did not have enough computer experience.

- Site managers generally complained of receiving too many documents after each computer run and of being lost among them. They found that computer printouts were helpful only in determining material delivery dates.
- 9. Changes in the administrative structure:
 - These changes are described in paragraphs 3,4,5 and 6 under "History of network analysis in the company".

The conflict between the planning department and contracts managers, which is mentioned in one of the paragraphs mentioned above deserves more explanation: The contracts manager interviewed was not satisfied with the place of the planning department reporting to the director responsible for contracts and would prefer it to report to the managing director. The planning department's view was, however, that contracts managers know less on network analysis than planners, and less on construction than agents; that they are convinced that network analysis has no value; that they avoid attending training programmes, do not like making decisions at early stages, have a fear of ridicule in case they make a mistake and are found to be wrong, and finally fear a reduction in their authority and power. As a consequence, they were not helpful at planning stage and the networks produced were not very accurate for this reason. The planning department supported the view that the contracts manager and the planning engineer should be merged in some way, implying that contracts managers should altogether be taken off as was done in two other subsidiaries with successful results.

— A copy of the organizational chart is attached. Training schemes:

10.

The evolution of training courses in the company is discribed in paragraphs 7,8,9 and 10 under "History of network analysis in the company".

As a total, 65 persons mainly from site management attended the courses mentioned in the above-mentioned paragraphs.
Of these thirty three were general foremen, five were undergraduate trainees, eight basic supervisors, ten gangers, and nine technicians.

The courses were generally accepted as useful and successful, but there were some reservations about them. The chief planning engineer believed that similar courses should be run every six months to refresh the memories. One of the agents interviewed indicated that the usefulness of these courses



ORGANIZATION CHART

depended mainly on the individuals attending them. He stated that two out of the seven persons who attended with him one of these courses had not benefited at all and had slipped back to bar-charts immediately. The other agent complained that whereas all his staff should have attended at least one of these courses, in reality only one of his trades foremen had.

— There was no library in the company but they were receiving a number of periodicals.

--- Some agents and foremen were also sent to external courses mainly run by the CITB. They generally found these courses too theoritical and not very beneficial.

11. Qualifications of the personnel:

At the time of the study, the planning department contained:
 One B.Sc. in civil engineering, experienced on site, chief planning engineer; one Higher National Certificate in Building, associate member of the Institute of Builders; one Higher National Certificate in building; two Full Technical Certificates in building, and one graduate trainee.
 The criteria used in recruiting personnel for the planning

department were as follows:

- a) Minimum two years on site compulsory.
- b) A Higher National Certificate in building desirable.
- c) An Ordinary National Certificate in building, or a construction technical certificate acceptable.

— Most of the site agents were ex-tradesmen. One of them who was interviewed had started in the company in 1949 as a joiner; then had become a trades foreman, then general foreman and finally site agent. This was accepted by most people as a typical situation.

-- There were only two planning engineers who could carry out computerized network analysis; and only a very limited num-

ber of site agents were familiar with computer printouts. However, no specialist, or expert, or consultant help had ever been used.

- According to the contracts manager and to the planning engineers, much better results in network analysis applications could be obtained if the site staff were better educated. At the same time, the two senior planners agreed with site managers' view that the majority of planners lacked sufficient site experience.

12. Authority:

— Most decisions related to logical sequences and time estimates were made by planning engineers within the limits set by the contracts manager and the agent. The responsibility to produce a workable network remained therefore with the planning engineer.

Before being used on site, the final approval for the network came from the contracts manager. He had the authority to make changes related to head office business such as financial problems clashes with the architect, etc.; he delegated to the site manager the authority to make changes related to site business. But, he had the final responsibility to see to it that the network was properly applied on site.

Planning engineers had the authority to make minor changes

in the network, but these had always to be approved by the contracts manager. So, they reported to both their department head and to the contracts manager. The chief planning engineer and the contracts manager were both at the same hierarchical level and reported to the director in charge of contracts.

The introduction of network analysis accompanied with the establishment of a planning department had changed the decision-making process in the organization. Whereas, before the introduction of network analysis all decisions were given jointly by site managers and contracts managers, after network analysis there had been an addition to the group: the planning engineer. According to planners, contracts managers believed that this had reduced their authority and power by bringing in a third party who was reporting to the same director as them; they further saw the change as a move by the head office to tighten control on sites and on the activities of contracts managers.

- The two site agents and the contracts manager interviewed did not agree with the planners' view expressed in the preceding paragraph. They indicated that they had still the same authority and that they were pleased to receive a service from the planning department.
- 13. Co-ordination between the planning department and the team on site:

— According to the usual procedure, the plan of action was discussed before the job starts by the contracts manager, the site agent and the planning engineer. The network was

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drawn by the planning engineer in the light of this discussion.

— There was generally no resident planning engineer on site. Updatings were done by frequent visits. Everybody interviewed seemed to be pleased with this arrangement.

14. Integration with other management techniques:

- The introduction of network analysis did not interfere with any other management technique in use in the company. The planning department had very little to do with other departments; they would sometimes receive some feedback information from the buying and estimating departments.

- 15. Controlling the job:
 - The planning engineers' view was that network analysis is the best method to control the progress of a job, but that site managers and contracts managers never use it for that purpose.
 - The contracts manager and the two site managers regarded network analysis as a good control device, in the sense that they could see clearly who is doing what and when, and what is going on on site. But, they did not believe it is a good tool for controlling progress.

16. Input requirements:

— It was generally believed that there is not sufficient information before starting a project, in order to plan correctly, unless it is a repetitive housing construction.

- In the few computer applications, the situation where they fed the computer with wrong data and obtained stupid printouts frequently occured. 17. Suitability of output:

— This aspect is described in sub-section 2, Bar-charts, and in sub-section 8, the Use of Computers.

18. The logical sequence:

— It was the general feeling that there were too many variables in the construction process that could not be foreseen at the planning stage, and that the construction process itself was of a very flexible nature offering a large number of alternatives.

- Consequently, the contracts manager believed that the logic of a network was not always impeccable. But, planning staff claimed that once the job was broken down into finer detail and once alternatives were discussed, there was no reason why the logic should not offer the best solution.

Before drawing the logical sequence of activities, the planning engineer got informed as to what sort and what amount of labour and/or machinery would be used in each activity. He regarded the drawing of a network as a sort of resource levelling, contrary to text-book recommendations that the logic of a network should be drawn independently of any resource limitation.

--- Loops and the overlapping of activities were not major problems in drawing networks, especially if the planning engineer was experienced enough. The major difficulty was indicated by planners to be the communication with parties involved in the job.

19. Data for activities:

Most time estimates were given by the planning engineer

within the broad limits set down by the contracts manager and the site agent. Once the network was completed, the time estimates were approved (or new ones proposed) by the contracts manager or the sub-contractor responsible for a particular activity.

According to planners, people responsible for particular activities tended to give pessimistic time estimates. This happened frequently with sub-contractors. According to the contracts manager, time estimates differed by 40-50% from actual durations. The precision of time estimates was accepted by planners to be directly related to the size of activities, because the larger the activity, the larger the actual time, and the larger become the variations.

20. Degree of detail:

- A technique called "sectionalization" was used. A summary network was prepared and then divided into sections for each of which a more detailed network was prepared. After the calculations were carried out separately for each sub-network, they were assembled. The number of sectionalization stages depended on the complexity of the job. With this system they were able to compute manually networks containing as many as 4000 activities.

Activities were split by trades. Site managers were particularly pleased with this set-up because they were able to control the performance of each trade separately and they were able to give directives to each trade separately. Networks were accepted by site managers to be more detailed than ordinary bar-charts. But, according to planning engineers, the degree of detail of a network was a function of the complexity of the job.

21. Complexity of the job:

The generally accepted criterion was that smaller jobs were better planned by bar-charts, and that larger and hence more complex jobs were better suited to network analysis planning.
The chief planner regarded the precedence diagramming system as particularly useful for extremely complex jobs.

22. Updating:

Networks were not updated regularly. They were updated only when it was felt necessary. This happened when there were big alterations, or when they thought they were sufficiently away from the logic rather than being behind in time. The minimum time between two updates was one month.

Only the summary network which had been broken down into "sections" was updated. The more detailed "section" was not updated at all, presumably because they consumed too much time and effort.

- Feedback was obtained by frequent visits from the planning engineer to the site. They had a "reporting system" according to which the planning engineer recorded progress against planned values and reported it to the chief planning engineer, who in turn discussed it with the director in charge of contracts.

23. The use of float:

— There were two ways of allocating float in the final schedule. In some projects earliest start dates were used as scheduled dates. In some projects, how much float will be allocated to what activity was decided as time goes on, according to the likelihood of being short of time in certain activities. - Generally, everybody on site was aware of float values associated to each activity. Sometimes, this had a negative effect on them because the knowledge that they could complete certain activities in a longer period of time, made them relax. However, according to the planners, this happened very seldom as most of the site agents refer only to the bar-chart presentations and since most of them did not really know what float means.

24. Resistance to change:

As described in "History of network analysis in the company", there had been resistance to the use of network analysis since its introduction, and there still was some. The views of different management levels are reported below:
The top management thought that resistance to network analysis on the part of contracts managers was due to a fear of the new system and to a fear of the new generation.
According to the training officer, the major reason for resistance was ignorance. He believed that after the few training courses resistance to network analysis had decreased.

The contracts manager indicated that he never regarded network analysis as a panacea to all problems as so many of those introducing it did. He claimed that those who introduced network analysis agreed with him now that it solves only a limited number of questions.

--- For site agents nothing much had changed with the advent of

network analysis, because, they had continued to receive their bar-charts as always. They believed that network analysis had had no impact on site management.

- According to planners, network analysis had not been improved on site management, but had smoothly evolved. They admitted however, that there was also some imposition, as otherwise nobody would have taken any notice of it. They believed that the fiercest resistance was expressed by contracts managers because they did not like making decisions at early stages, had a fear of ridicule in case they are found to be wrong, feared a reduction in their authority and power, and finally they particularly disliked a younger planner to tell them what to do.

Planners believed that resistance to network analysis in an overt or covert form has always been expressed and would always exist unless drastic changes were made in the staff and in the organization (such as firing resisting members and hiring personnel with network analysis experience, and abolishing the office of contracts managers). They also believed that resistance had decreased over the years, but at a very slow rate.

APPENDIX F

THE PRELIMINARY FIELD SURVEY

Questions related to each item in the check list, and findings

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Questions related to each item in the check-list, and the findings

- I. Kinds of network analysis techniques:
- 1. Has any network analysis technique ever been used in your company?
 - Yes: 10 companies
 - --- No : None

2. Are you still using it?

- Yes: 8 companies
- --- No : 2 companies

The two companies who were not using network analysis any more had had a bad experience with it and saw no economic justification for using it. These were the 2 companies at the bottom of the annual turnover list. They both specialized in repetitive housing construction and one of them was the only private firm in the sample.

- 3. What are network analysis techniques used for?
 - Time analysis only : 1 company
 - Time + resource analysis : 6 companies

- Time + resource + cost analysis: 1 company

The general view was that at least half on the value of network analysis lies in time analysis and the other half in resource analysis.

What sort of network diagram do you use?

- Arrow diagrams : 8 companies
- Precedence diagrams: None
- 5. Are network analysis techniques used for multi-project scheduling? — Yes: None

--- No : 8 companies

One company used the multi-project scheduling option of a computer program to relate various parts of a single large project

to each other.

- II. Bar-charts:
- 1. In planning your project do you use only bar-charts?

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- -Yes: None
- --- No : 10 companies
- 2. Do you use bar-charts in some projects and network analysis in some others?
 - Yes: 8 companies
 - --- No : 2 companies
- 3. In your opinion, if a bar-chart is thoughtfully and carefully prepared by a competent planner, is it as good as a network analysis technique?

Only 3 of the companies answered this question (2 "No", 1 "Yes") and the rest insisted that this question cannot be answered because so much depends on the job, on the company, on the site manager, on the planner, etc.

- 4. What do you think of a compromise between network analysis and bar-charts, in the sense that bar-charts used only for display purposes?
 - --- Positive: 8 companies
 - --- Negative: None

All the user companies translated their networks into bar-charts and believed that this is the only way of using network analysis successfully.

- 5. What other planning techniques are used in your company?
 - Bar-charts only
 - --- Bar-charts and network analysis: 5 companies

: None

Bar-charts and Line of Balance
 Bar-charts, network analysis and Line of Balance: 3 companies
 Line of balance users made clear that they were using this
 technique only in repetitive housing construction.

III. Resource analysis:

- Is it the usual procedure to use a resource analysis method?
 Yes: 7 companies
 - --- No : 1 company
- Is it done in conjunction with a network or separately?
 In conjunction with network analysis: 2 companies
 - Separately, on the final bar-chart : 4 companies
 - Separately, on the innar bar-chart : 4 companies
 - --- Both ways : 2 companies
- 3. For how long a period is the analysis of resources done?
 - --- Entire period of project: 7 companies
 - Parts of project : 1 company
- 4. Do you think that, especially in long projects, the preparation of a resource analysis for the entire project period is not practical from the point of view of the accuracy of the estimates?
 - ---Yes: 2 companies
 - .
 - No : 6 companies
- 5. Which method do you use for the analysis of resource?
 - Levelling : 6 companies
 - Aggregation: None

Two companies did not answer this question. One of them used resource analysis to a negligible extent.

- IV. Cost control and optimization techniques:
 - Is it the usual procedure to use a cost control method in conjunction with the network?
 - Yes: 1 company

1.

- --- No : 7 companies
- 2. Is the cost control made under a:
 - --- Cost code : None
 - --- Responsibility code: None
 - --- Resource type : 1 company
- Is it the usual procedure to use cost optimization techniques?
 Yes: None
 - No : 8 companies
- Are any cost optimization techniques used in special circumstances?
 Yes: None
 - -- ies. None
 - No : 8 companies
- 5. Do you think that cost optimization should be a standard procedure
 - at pre-tender stage?
 - Yes : None
 - -- No ; 2 companies
 - --- Don't know: 6 companies
- 6. Why, do you think cost optimization techniques are not used very extensively?

Again 6 companies did not answer this question because they had never used cost optimization techniques and had no idea of their capabilities and limitations. Two companies however, indicated that these techniques would be extremely difficult to apply in the construction industry. What is the percentage of the projects (in terms of turnover) in which network analysis techniques are used?

In the user companies, this figure ranged from 2% to 99% with an average of 47%.

2. What is the percentage of the projects for which the following analyses are carried out?

Time analysis : ranged from 2 to 99% with an average of 47%.
 Resource analysis: in the 7 companies where resource analysis was carried out, an average of 73% of projects planned by network analysis were resource analysed.

— Cost analysis : in the only company who used cost analysis by networks, all projects planned by network analysis were cost analysed.

3. What is the trend in the use of network analysis techniques in your company?

- Increasing: None

--- Decreasing: None

--- Settled : 8 companies

4. Why do you think this is so?

- Satisfied with present level: 2 companies

--- No justification to use more: 2 companies

--- Don't know : 4 companies

It was interesting to note that the two companies who indicated satisfaction were using network analysis in the very large majority of their jobs; and the two companies who saw no justification in increasing the use of network analysis were using it in a very little number of jobs.

VI. Economic justification:

 Is there any justification that network analysis techniques increase profits in your company, when compared with other methods?

--- Yes: 5 companies

--- No : 3 companies

A typical answer for this question was: "If it were not increasing our profits, we would not have used it".2. How much have your profits increased as a result of using network analysis?

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- Don't know : 2 companies

- Does not increase profits: 3 companies

Those companies who claimed that profits are increased by network analysis but that this cannot be quantified, generally put forward the argument that network analysis increases efficiency and control, and that profit is a function of efficiency and control, and that therefore it is bound to go up.

3. Is this figure an approximate estimate or is it calculated from actual similar projects in which network analysis techniques and others have been used?

Not applicable since no company could give a figure for increased profits due to network analysis.

4. What is the effect of the use of network analysis techniques on the total cost of a project?

Five companies indicated that they do not have any idea of the

cost of network analysis as a percentage of total project costs. One company said it was 2.5%, another 0.25%, and another indicated that it was much more than the cost of using bar-charts. The interesting point was, however, that the company who said 2.5% was quite satisfied with it whereas the company who said 0.25% found that this was far too much. All the answers to this question give a gook idea of the uncertainty and ignorance of users as to what network analysis costs and what it should cost.

5. Does the use of network analysis techniques form a better basis when negotiating claims?

- Yes : 6 companies
- No : None
- Don't know: 2 companies

Those companies who answered "Don't know" indicated that they submit claims very seldom and that therefore they would not know whether network analysis is better in those circumstances.

- 6. What are the advantages of network analysis techniques from the economic point of view?
 - Increase in profit: 5 companies
 - --- Cannot say : 1 company
 - ---- None : 1 company
 - Don't know : 1 company
- VII. Conditions under which these techniques were first introduced:
 1. When were network analysis techniques introduced into your company for the first time?

The earliest year was 1960 and the latest 1966; the average year was 1963. There was no pattern showing that larger companies

used network analysis first and smaller companies followed.

- 2. During the introduction of network analysis was there a belief that profits would increase because of these techniques? — Yes: 6 companies
 - --- No : None

One company indicated that it started using network analysis just as an experiment, and another company said it started using it to keep up with development.

- 3. Was there a factor of contractual compulsion in starting the use of network analysis techniques in your company? (i.e., a clause in a contract specifically asking for the use of network analysis).
 - ---- Yes: 2 companies
 - --- No : 6 companies
- 4. Who was the person who introduced network analysis to the company?

The answers were: a director and two engineers; the chief planning engineer; the top management; the deputy chairman; one man in head office; the regional manager; one director; in one company nobody knew who had introduced network analysis.

- 5. Did the company own a computer when network analysis techniques were first introduced?
 - Yes: 1 company
 - No : 7 companies
- 6. Was the first network analysis operated manually or by means of a computer program?
 - --- Manual : 6 companies
 - --- Computer program: 1 company
 - --- Don't know : 1 company

VIII. The use of computers:

1. Does the company own a computer?

- Yes: 3 companies

--- No : 5 companies

2. Does the company use a computer-bureau?

--- Yes: 6 companies

— No : 2 companies

Of these 6 companies, 5 did not own a computer, but one had a newly installed computer which was not used for planning purposes. 3. What are the jobs run in the computer?

The two companies who answered this question indicated that their computers were used for payrolls, accountancy and staff records.

4. What is the smallest number of activities in a network run in a computer?

This varied between 100 and 1000 activities, with an average of 320 activities. Only 6 companies answered.

5. What is the maximum number of activities encountered up to now? Only 5 companies answered. It ranged from 150 to 3000 activities, with an average of 1030 activities.

6. What is the criterion used to distinguish between projects to be planned manually, and those to be planned by a computer program?

Of the 6 companies who answered, one used no criteria at all and used a computer program for all projects; one used as little computer as possible. The remaining 4 companies used either the size of the network, or clients' requirements, or a combination of these.

IX. Changes in the administrative structure:

1. What is the size of the planning department?

Among the 7 companies who answered, there were planning departments as small as two persons and as large as nine persons. The average was five to four persons in each planning department.

2. What was the size of the planning department before the introduction of network analysis?

-- No planning department at all: 4 companies

--- Same as today : 4 companies

3. Have there been any changes in the administrative structure after network analysis was introduced?

--- No change : 4 companies

--- New planning departments: 4 companies

4. What are your critical views about these changes?

Only 2 companies answered this question. They had both a new planning department as a result of introducing network analysis. They both complained that the centralization of planning services was not desirable and caused complications.

X. Training schemes:

- 1. Have there been any internal courses on network analysis?
 - ---- Yes: 5 companies
 - No : 3 companies

2. To whom were they given?

--- Department heads, contracts managers,

senior site staff, and planning engineers: 3 companies

: 1 company

- Senior site staff only

- Senior site staff and planning engineers : 1 company
- 3. Is this a regular procedure?
 - --- Yes: 1 company
 - --- No : 4 companies
- 4. What is the frequency of those courses?

The only company who indicated that regular internal courses were run said that they were five day courses run three times a year.

- 5. Has any member of the company been sent to an external network analysis course?
 - --- Yes: 6 companies
 - No : 2 companies
- Is this a typical situation or does it happen once in a while? 6. — Typical : None
 - --- Once in a while
 - : 5 companies
 - Only when it was introduced: 1 company
- How many members have been sent to such courses in what length 7. of time?
 - Not answered
- 8. Is there an adequate library in your company?
 - --- Not answered
- How many books are there in it and what is the percentage of 9. construction management books?
 - Not answered
- 10. Are these books in the immediate access of any member of staff? --- Not answered
- 11. When network analysis techniques were first introduced, was the entire personnel trained to cope with it or was a recruitment of qualified expert personnel necessary?

- -- Training : 4 companies
- Training + recruitment: 2 companies
 - Don't remember : 2 companies
- 12. In your opinion, do you think that these courses (internal and/or external) are successful?
 - Yes : 3 companies
 - --- Moderately: 4 companies
 - No : 1 company

XI. Qualifications of the personnel:

- 1. What are the qualifications of the staff in the planning department?
 - This question was later dropped
- 2. What is the present policy of the company regarding the recruitment of staff for the planning department?
- Only 3 companies answered this question, as the remaining 5 had no definite policy. One of them stated that all planners were recruited from among the site staff; one of them looked for quick mindedness, intelligence and site experience; and the last one required extensive planning and site experience.
- 3. Do you receive any expert help in the planning stage?
 - Yes: None
 - No : 8 companies
- 4. What are the qualifications of the staff on site?
 - Mostly ex-tradesmen : 4 companies — Mostly engineers : 1 company
 - Mostly engineers : 1 company
 - Half tradesmen, half engineers: 1 company
 - Don't know exactly : 2 companies

- 5. What is the present policy of the company regarding the
 - recruitment of staff for site jobs?
 - Don't know exactly: 8 companies
- 6. Do you think that with a better qualified team in the planning department you would obtain better results?
 - --- Yes: 1 company
 - No : 7 companies

It must be noted that these results were reported by planning engineers; and that site managers' views differed slightly with two more answers in the "Yes" category. Site managers generally complained that planning engineers did not have sufficient site experience to draw a realistic network.

- 7. Do you think that with a better qualified team on site you would obtain better results?
 - Yes: 7 companies
 - --- No : 1 company

Most site managers agreed with this finding.

XII. Authority:

- What kind of authority does the planning department have on final decisions?
 - Direct : None
 - --- Lateral, or consultative: 8 companies

 What are exactly the responsibilities of the planning department? The answer in all cases was to produce and update a reliable network.

- 3. To whom is the planning department responsible?
 - --- Site manager: 1 company

--- Contracts manager

: 1 company

- Director or managing director: 6 companies
- 4. Who is responsible for the implementation of the network?
 - --- Site manager : 6 companies
 - ---- Contracts manager: 2 companies
- 5. Does the planning department have any authority for making decisions and changes in the network?

All 8 companies indicated that planning engineers had enough authority to make minor alterations without seeking prior acceptance from site managers.

6. In your opinion, does the introduction of network analysis techniques reduce the authority of certain persons, such as the contracts managers?

---- Yes: 4 companies

--- No : 4 companies

Answers given by site managers showed a 5 to 3 situation in favour of "Yes", which shows that site managers are more worried than planning engineers when network analysis is introduced.

XIII. Co-ordination between planning department and team on site:

Is there any co-ordination between the planning department and the team that has been appointed to site, at the start of the project (not at pre-tender stage, but after the award of the contract)?

- Yes: 8 companies

--- No : None

2. Is there any co-ordination between the planning department and the team on site, during the construction of the job?

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- Yes: 8 companies

- No : None

3. Is there normally a member of the planning staff resident on site?

- Yes: 1 company

--- No : 7 companies

Three companies indicated that they have resident planning engineers only in larger jobs.

XIV. Integration with other management techniques:

 Are network analysis techniques properly integrated with other management techniques?

This question was not applicable in companies not using cost analysis in conjunction with networks, because time and resource analysis are almost totally independent of any other management technique. The only company who used cost analysis answered this question positively.

2. Are the results obtained from network analysis used in any other management technique?

- Yes: None

--- No : 8 companies

3. Do you think that network analysis should further be provided with characteristics to better fit in the present system? — Don't know: 8 companies

4. Do you think that your present system should be modified for getting better results out of network analysis?
— Don't know: 8 companies

XV. Controlling the job:

 Do you think that network analysis techniques are a useful tool for control purposes?

- Yes: 7 companies

- No : 1 company

The company who answered "No" used only time analysis and employed it rather as forecasting technique rather than a control technique.

2. Is feedback done as a routine job or is it done only from time to time?

--- Routine : 5 companies

- From time to time: 3 companies

3. Are network analysis techniques primarily used for controlling the progress of the job?

- Yes: 1 company

- No : 7 companies

All the companies who answered "No" stressed that controlling the job was one of the aspects of network analysis.

XVI. Input requirements:

1. Are there sufficient selection possibilities as to the form of the input?

— Yes: 4 companies

--- No : 2 companies

One of the remaining companies did not use computer programs at all; and the other indicated that the answer depends on the program they happen to be using, as they had used several up to now. 2. Are the input requirements very complicated, in the sense that mistakes cannot be avoided unless checked several times?

- Yes: 8 companies
- -- No : None
- 3. Do network analysis techniques require more information as input, when compared with other methods?
 - Yes: 8 companies
 - No : None
- 4. Are the input requirements difficult to obtain?
 - Yes: 8 companies
 - --- No : None
- 5. When checked at the end of the project, does the input data show to be correct?
 - Reasonably correct: 4 companies
 - Pessimistic : 2 companies
 - --- Optimistic : 1 company
 - --- Don't know : 1 company
- 6. How much labour is involved in providing the input requirements, given as a percentage of the labour force involved in the application of network analysis? --- Don't know: 8 companies

XVII. Suitability of output:

 What is the final kind of the information issued at the end of the network planning period?

All companies indicated that they produce earliest and latest times and float values as basic information.

2. Are there sufficient selection possibilities as to the forms of output which best suits your requirements?

- Yes: 5 companies
- No : 2 companies

The remaining company did not use computer programs at all.

3. Do you think that the existing output form gives:

--- A lot of unnecessary information: 2 companies

- The right information : 5 companies
- Insufficient information : 2 companies

One company did not answer this question because they did not use computer programs at all. Two companies stated that their answer is a combination of "unnecessary" and "insufficient" information.

- 4. Are the final results of the network analysis transformed into a bar-chart form?
 - Yes: 8 companies
 - No : None
- 5. Are time-scaled networks used at all?
 - --- Yes: 1 company (sometimes)
 - --- No : 7 companies
- 6. Are bar-charts showing the logical links, the critical path,
 - floats, etc., used at all (logic-linked bar-charts)?
 - Yes: 5 companies
 - --- No : 3 companies
- 7. Do you think that the team on site is not sufficiently acknowledged to cope with a network presentation?
 - Yes: 7 companies
 - --- No : 1 company

The company who answered "No" had at least one engineer (as opposed to ex-tradesman) on each of their sites. It is also

interesting to note that site managers agreed with this finding generally.

- 8. Do you think that in the future, the time will come when there will be no necessity to transform networks into bar-charts?
 - --- Yes : 3 companies
 - No : None
 - Don't know: 5 companies

XVIII. Logical sequence:

- 1. Do you think that networks produced in the construction industry are indeterminate; i.e., where relationships among activities are very variable, where sequences in which the activities are carried out are very much a matter of choice?
 - Yes: 8 companies
 - --- No : None
- 2. Do you think that to devise a network in a purely logical sequence, without any regard to time limitations (which will be sorted out later in the time analysis), and to resource limi-tations (which will be sorted out later in the resource analysis) is possible?

One of the 2 companies who answered this question stated that this was not difficult, whereas the other indicated that it was practically impossible.

- 3. Are loops a major difficulty in drawing the logical sequence of a network?
 - Yes: None
 - --- No : 8 companies
- 4. Is the overlapping of activities (i.e., one starts before the

- Yes: 2 companies

-- No : 6 companies

5. What other difficulties are encountered in devising the logical sequence of a network?

Apart from 2 companies who stated that it was difficult to decide the degree of detail, there was no comment on this question.

XIX. Data for activities:

1. By whom is the data for the network prepared?

---- A single person: 4 companies

- A team : 4 companies

The single person was in all cases identified as the planning engineer.

- 2. Do you think that the time necessary for the collection of data is too long?
 - Yes : 7 companies
 - --- No : None
 - Don't know: 1 company
- 3. Do you think that the labour necessary for the collection of data is too much?
 - --- Yes : 7 companies
 - -- No : None
 - Don't know: 1 company

4. Is it a serious handicap that some of the data (in some projects) depend on outside organizations, such as sub-contractors, material firms, etc.? - Yes : 3 companies - No : 1 company

--- Not applicable: 4 companies

The companies in the "Not applicable" group indicated that they were not able to answer this question as very little of their works were sub-contracted.

- 5. If the data is prepared by a team, how many persons are there
 - in the team, and what are their status?
 - --- Planning engineer + site manager : 3 companies
 - Planning engineer + site manager +

contracts manager + estimator : 1 company

- 6. Is there the general tendency to give pessimistic time estimates, thus ensuring that they will not be proved to be wrong even if the worst happens?
 - Yes : 4 companies
 - No : 3 companies
 - Don't know: 1 company
- 7. Do the time estimates given by the following prove to be right?
 - a) Outside organization:
 - Yes : 2 companies
 - --- No : 4 companies
 - --- Don't know: 2 companies
 - b) The team or the planning engineer:
 - Yes : 5 companies — No : 2 companies
 - --- Don't know: 1 company

XX. Degree of detail:

- Is it the usual procedure to prepare more than one network each of a different degree of detail, for a single project?
 — Yes: 6 companies
 - No : 2 companies
- 2. Is every activity so specified that only one person, or department, or unit will be responsible for carrying it out?
 - -Yes : 2 companies
 - No : 3 companies
 - --- Varies: 3 companies

The 2 companies who answered "Yes" broke down their jobs into activities, each to be carried out by one trade. The 3 companies who answered "No" used time and/or piece of work, disregarding responsibilities.

- 3. Are the activities on the critical path or near the critical path broken down into more detailed networks?
 - --- Yes : 3 companies
 - --- No : 4 companies
 - Sometimes: 1 company
- 4. In breaking down a job into activities, what are the general criteria applied?
 - Trades : 2 companies
 - --- Pieces of work: 1 company
 - --- Time : 2 companies
 - Don't know : 3 companies

XXI. Complexity of the job:

- Do you think that network analysis techniques are better suited for complex jobs (complex job meaning complex in the relationship between activities, rather than the high number of activities)?
 - Yes : 6 companies
 - No : None
 - Don't know: 2 companies

2. Is it better to use precedence diagrams for complex jobs?

- Yes: None
- --- No : 8 companies

It must be noted that none of the 8 companies used precedence diagrams.

- 3. In complex jobs, are bar-charts always used for presenting the network more simply on site?
 - --- Yes: 8 companies
 - No : None

It must be noted that all 8 companies showed the final results in bar-chart form, even in simple jobs.

XXII. Updating:

- 1. When are the networks updated usually?
 - By regular intervals: 4 companies
 - When felt necessary : 3 companies
 - --- Not updated at all : 1 company
- 2. Do you think updating consumes too much time?
 - --- Yes : 7 companies
 - No : None
 - Don't know: 1 company

- -363-
- 3. What is the percentage of labour used for updating when compared with the entire labour force used in the application of network analysis?
 - --- Don't know: 8 companies
- 4. What is updating primarily used for?
 - Determining the present situation of progress: None
 - --- Having an idea of the future situations that
 - may happen ---Both : 8 companies

XXIII. The use of float:

 Is the use of float completely dependent on the allocation of resources?

- --- Yes : 5 companies
- No : 2 companies
- --- Varies: 1 company

2. In case it is not, how are the start dates decided?

- Earliest starts
 : 1 company
 ...
 Latest starts
 : None
 - Even distribution of float : None
 - Float is allocated to activities whose time
 - estimates are not considered to be very accurate: 1 company
- --- Float is allocated as time goes by, without
 - any predetermined decision : 2 companies
- --- Float is allocated according to the

allocation of resources

: 2 companies

The 3 companies who answered that float is not completely dependent on resource allocation, indicated two procedures each.

3. Are floats made known to the team on site responsible for carrying out the construction?

- Site manager only
 All site management
 Varies according to the site manager: 3 companies
- 4. If yes, does this make any negative effect on the productivity?
 Yes : 2 companies
 - --- No : 2 companies
 - No : 2 companies
 - --- Varies: 1 company

XXIV. Resistance to change:

- To your knowledge, was there any participation on the part of the site staff in the decision to replace bar-charts by network analysis?
 - Yes: 1 company
 - --- No : 7 companies
- Did the management take the views of the site staff as to how to implement network analysis?
 - -Yes: None
 - --- No : 8 companies
- 3. Did the management really used the recommendations of the site staff or was this participation in the final decision a simple routine meeting?
 - Not applicable since there is no participation
- 4. Were the site staff's problems thoroughly considered before applying this change?
 - --- Yes : 6 companies
 - --- No : None
 - Don't know: 2 companies

- 5. How long did it take for the settlement of this change?
 Don't know: 8 companies
- 6. Were the reasons of these changes completely explained to the site staff?
 - Yes: None
 - No : 8 companies
- 7. Were there any difficulties in explaining these reasons, i.e., were special measures taken to explain these reasons by means of a suitable language that can be understood by site staff rather than by means of complicated formulae and ambiguous analytical methods?

--- Not applicable

B. Did the management expect any resistance to this change?
— Yes: 8 companies

— No : None

9. Have there been any major changes in other management techniques used in your company?

--- Don't know: 8 companies

- 10. Has there been any change in the social status (i.e., amount of pay, status in the company, job-content, anxiety about employment, etc.) of any member in the company, because of the introduction of network analysis?
 - --- No : 1 company
 - Don't know: 7 companies

APPENDIX G

LETTERS AND CIRCULARS SENT FO COMPANIES

University of Technology

LOUGHBOROUGH LEICESTERSHIRE LEII 3TU Tel: 050-93-63171 Telex: 34319 Grams: Technology Loughborough

DEPARTMENT OF CIVIL ENGINEERING

Dear Sir,

I am a graduate civil engineer visiting this country for the purpose of completing a university PhD. research study sponsored by the British Council, of planning and control activities in a widely diversified group of British construction companies. I am especially interested in studying the methods and philosophies of using Network Analysis techniques and alternative methods when network analysis is not used.

A successful research study depends upon my being able to interview an executive responsible for the above-mentioned type of activities in each of a large number of companies. I am hoping that it may be convenient to arrange such an interview with a member of your staff concerned with the activities under study.

A series of interviews has already been completed in a local company as a case study. This was arranged by the directors of the company and Professor E.G. Trimble, the project supervisor. His views on the project are expressed in the attached circular.

May I add that, although all information I receive during interviews will be treated as strictly confidential, I am, in fact, not seeking information concerning actual "figures", but methods and opinions.

If you feel able to grant me the favour of arranging an interview, then perhaps you would like to suggest an afternoon interview on, or else on some subsequent date more to your convenience.

Yours faithfully,

D. Arditi.

University of Technology

LOUGHBOROUGH LEICESTERSHIRE LEII 3TU Tel: 050-93-63171 Telex: 34319 Grams: Technology Loughborough

DEPARTMENT OF CIVIL ENGINEERING

JUST HOW EFFECTIVE ARE NETWORK ANALYSIS TECHNIQUES?

When Critical Path Techniques were first introduced into the construction industry, many people thought they would have a dramatic effect on productivity and efficiency in general. However, their impact has been fairly limited in extent.

In principle Network Analysis is undoubtedly superior to programming achieved through the medium of bar charts alone. It has to be admitted that the recording of progress is less obvious with network and that fewer people understand the principles. However, in my view, the solutions to these technical deficiencies are so readily overcome that I remain surprised that the inroads achieved by Network Analysis have not been considerably greater.

There appear to be several possible explanations as to why Network Analysis has not been more successful. For example:-

- 1. Certain technical features may be unsatisfactory.
- 2. The technique may have been mis-applied e.g., updating may not have been done, bar-chart schedules may not have been produced, the communication between planners and executives may have been inadequate.
- 3. There may be some sociological reason, e.g., a new method might be seen by older executives as undermining the value of their hard won experience.
- 4. It may be just inertia, or
- 5. It may be that the economics are wrong; the cost of proper application exceeds the value of improved efficiency.

All these aspects of the problem are being examined in detail by Mr. Arditi and the outcome of his investigation is, I believe, of considerable importance since the answers to this problem could be of value to the industry as a whole and could release some of the potential that was originally envisaged for these indisputably powerful techniques. I hope therefore that contractors who are approached by Mr. Arditi will co-operate with him in his enquiries.

It goes without saying that companies who provide information will receive a summary of the general results of the enquiry.

E. Geoffrey Trimble Professor of Construction Management

APPENDIX H

A REVIEW OF SOME STUDIES USING WEBERIAN DIMENSIONS

A review of some studies using Weberian dimensions:

"Bureaucracy" as defined by Max Weber (185,186) is central to modern organizational theory. Indeed, a large number of research studies and theoretical writings have been based on Weberian dimensions of bureaucracy. Some of these studies are given below: 1. In his study of 43 industrial organizations, Harvey (234) used six variables (size, history, ownership and control, location, relationship with environment, and charter) to control his sample, and four others (specialization, levels of authority, supervisor/ total personnel ratio, and program specification) to test his hypotheses about the technology of organizations, which, as Hickson (235) shows has been a major field of research for almost all organizational theorists for the period 1900 onwards. He grouped his organizations along a continuum from "technical diffuseness" (a number of technical processes yield a wide range of products which are likely to vary from year to year as a result of changes in technological production processes) to "technical diffuseness" (less product variation and change). The result indicated that as technical specificity increased:

- a) the number of specialized sub-units increased,
- b) the ratio of managers and supervisors to total personnel increased,
- c) the number of levels of authority increased,
- d) the amount of program specification increased.

 Hall (236) analysed the variations in the internal segments of organizations by applying a model derived from Weber's organizational theory. The six bureaucratic attributes used in this model were: a well defined hierarchy of authority, a division of labour based upon functional specialization, a system of rules covering the

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rights and duties of positional incumbents, a system of procedures for dealing with work situations, impersonality of inter-personal relationships, and selection for employment and promotion based upon technical competence.

Hall first tested the hypothesis that organizational divisions or departments (horizontal cross-section) whose tasks are less uniform and routinizable are significantly less bureaucratic in all dimensions than the departments in which tasks are uniform and easily routinized. The hypothesis held for only three of the dimensions: authority, division of labour, and presence of external procedural specifications.

He then tested the same hypothesis for hierarchical levels (vertical cross-section) by grouping the participants into two groups: executives and non-executives. The results showed that executive levels operated in a less bureaucratic fahion in terms of the emphasis on hierarchy, division of labour, procedures, and impersonality. 3. Woodward (237) explored systematically the relationships between

technology and variations in organizational structure. She grouped 100 manufacturing firms in South East Essex along a scale of "technical complexity" ranging from unit or small batch production (leas technically complex), through large batch or mass production, to continuous flow or process production (most technically complex). She then examined the structural characteristics. Some of her findings that are of particular interest are:

- There was no significant relationship between technological mode and organizational size.
- b) The number of levels of authority in an organization increased with increasing technical complexity.
- c) The ratio of managers and supervisors to total personnel increased

with increasing technical complexity.

d) Firms at both ends of the scale of technical complexity were more likely to be characterized by "organismic systems" (*) than firms in the middle range of the scale.

4. In a theoretical approach to organizational systems, Likert (239) concludes that an organization should be outstanding in its performance if it has the "overlapping group" form of structure (loyal, effective groups with high performance goals, linked to each other by means of people who hold overlapping membership), effective communication and influence, decentralized and co-ordinated decision-making, and high performance goals coupled with high motivation. Although the source of the information is not clear, Likert claims that data "which were already available" have been used to test this theory. Results indicated that organizations with characteristics cited above gave high performance.

5. Carzo & Yanouzas (240) tested tall and flat organization

structures for their effects on group performance. Comparisons of performance on the time taken to complete decisions showed no significant difference between tall and flat organization structures. It took longer to process decisions through the several levels of a tall structure; but groups with flat organization took more time to resolve conflicts and to co-ordinate efforts. Tall organization structures were superior on two other measures of performance: profits and rate of return on revenues. Apparently the greater number of

(*) Burns & Stalker (238) define two ideal types of organization: The "organismic system" is characterized by such features as less formal definition of jobs, greater emphasis on adaptability, and communications along the hierarchy tending more to take the form of consultations rather than commands. The "mechanistic system" is the opposite.

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levels in the tall structure provided for more frequent evaluation of decisions and better performance on these two variables.

6. Eisenstadt (241) maintains that various internal structural aspects

of organizations, as well as their deviations from the ideal type of bureaucracy are systematically related to their goal orientations. He classifies organizations into three groups in relation to their goals: economic, socio-political, and cultural (*). He follows by claiming that the extent of specialization and of division of labour are greatest in economically oriented organizations, less in the culturally, and least in the politically oriented organizations. He believes that the internal structure of economically oriented orgazations has usually a relatively sharp demarcation between the policy-making, managerial-administrative, and technical roles, and that different types of specialization and skill are required on each level, and overlapping is very little.

7. Blaukenship & Miles (243) studied the relationship between three structural variables, namely, hierarchical position, organization size, and span of control, and five dimensions of managerial decision behaviour, namely, perceived influence on superiors, autonomy from superiors, reliance on subordinates, personal initiation, and final choice. They explored the subject for 190 managers in eight different companies engaged in light manufacturing. They found that the

(*) Eisenstadt's classification of organizations in relation to their goal orientations is rather similar to the typology proposed by Etzioni (242). Etzioni admits that organizations sometimes serve more than one function, but agrees with Eisenstadt that one function usually dominates, and that therefore it is possible to classify organizations according to their primary function. hierarchical position of a manager was the most important determinant of his decision behaviour. Span of control was found to be related to decision behaviour only to the extent to which a manager relied on subordinates in his decision-making. Organizational size had a differential effect depending mainly on the manager's position in the hierarchy.

 Carzo (244) examined the effects of standardization on groups required to make decisions on relativley complex problems by comparing their performance. He carried out tests on laboratory groups which he defined as tight, loose-written, and loose-oral.
 The evidence, at the end, indicated that the different structures had initially different effects on groups exposed to the same problem.
 Eventually, however, all groups, regardless of structure reached a level of performance that was approximately the same.

9. Pondy (245) tested his mathematical model which gives the

relationship between "administrative intensity" (number of managers, professionals, and clerical workers divided by the number of craftsmen, operatives, and labourers) and a number of organizational characteristics (size, functional complexity, ownership and control) by analysing data collected from 45 manufacturing companies. He assumed that "administrative intensity" was set so as to maximize profits, or more generally, to maximize the dominant managers' utility function. He found that "administrative intensity" decreased as organization size increased; and that it increased with increasing functional complexity and separation of ownership and management.

 Bridges, Doyle & Mahan (246) hypothesized that hierarchically differentiated groups would exhibit less risk taking behaviour,
 be less efficient, and be less productive than hierarchically less

-374-

differentiated groups. They tested these hypotheses on the staff of 10 schools and found that results confirmed all three hypotheses.

11. Chandler (247) makes a historical analysis of basic management

structures of large American corporations and concludes that there is a close connection between the nature of a company's business and its administrative structure. He shows that those firms whose activities cross established industry lines have tended toward product decentralization; that companies producing a relatively restricted line have decentralized on a functional or geographic basis; and that market-oriented firms tended to decentralize on a goegraphic basis.

12. After a critical examination of various aspects related to

specialization Fisch (248) concludes that the line-staff set-up is obsolete and that the "functional teamwork" concept would result in much better management.

13. Stinchcombe (194) makes a comparative analysis of bureaucratic and craft administrations by considering various statistics. He concludes that bureaucracy is a sub-type of rational administration. This implies that an organization involved in, say, mass production, may certainly be bureaucratic, but not all of its characteristics are distinctive of bureaucracy.

14. Peabody (249) examines writings by Weber, Urwick, Simon, Bennis, and Presthus who have contributed to the theory of organization by writing about bases of authority. He finds that there is considerable consensus despite the different terminologies used and then develops his own form analytical types of authority relations:

- a) authority of legitimacy,
- b) authority of position,

- c) authority of competence, and
- d) authority of person.

Peabody tested this typology on 76 members of 3 public service agencies and found it quite useful for ordering perceptions of authority. He also found that interactions between superiors and subordinates contained elements of all four types of authority, although the relative importance of each seemed to vary from person to person, as well as from organization to organization.

15. Cowan (250) carried out a survey of 28 public schools by means of questionnaires and interviews to find out patterns of organizational conflict. The findings indicated that size, specialization, hierarchy, complexity, staff additions, and heterogeneity were related to conflict, that participation in the authority system and cohesiveness of peer group relations seemed to be conducive variables facilitating conflict; and that experience and close supervision seemed to be integrative variables.

16. Hage (251) defines four "organizational means" (complexity or

specialization, centralization or hierarchy of authority, formalization or standardization, and stratification or status system) and four "organizational ends" (adaptiveness or flexibility, production or effectiveness, efficiency or cost, and job satisfaction or morale). He then interrelates these variables in seven basic propositions as suggested by the theoretical writings of Weber (the first three propositions), Barnard (the second three), and Thompson (the last one): a) The higher the centralization, the higher the production b) The higher the formalization, the higher the efficiency c) The higher the centralization, the higher the formalization d) The higher the stratification, the higher the production

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e) The higher the stratification, the lower the job satisfactionf) The higher the stratification, the lower the adaptiveness

g) The higher the complexity, the lower the centralization

Hage used these seven propositions to derive 21 corollaries and to define two ideal types of organizational systems. He tested this axiomatic theory consisting of 29 hypotheses against a number of research studies and found that it received considerable support.

17. In the investigation of a single factory seen in the light of Max Weber's theory of bureaucracy, Gouldner (252) suggests a typology of bureaucratic patterns principally based on the degree of tension and conflict associated with the different patterns. The three types are : Punishment centered bureaucracy, representative bureaucracy, and mock bureaucracy.

APPENDIX I

CLASSIFICATION OF 30 ORGANIZATIONAL STUDIES UNDER BUREAUCRATIC DIMENSIONS

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Part 4:	Centralization	385
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Part 6:	Flexibility or adaptiveness	389

<u>Classification of 30 organizational studies under bureaucratic</u> <u>dimensions</u>:

The organizational characteristics (See Chapter III, Section 5; Chapter V, Section 4; and Appendix K, Part 4) used in this study were adapted from a research study carried out by the Administrative Research Unit in the University of Aston in Birmingham. As reported in the series of articles by Pugh et al (181,187,188,189), Hickson et al (190), and Inkson et al (191,192,193), the Administrative Research Unit used six bureaucratic dimensions to define their own variables: specialization, standardization, formalization, centralization, configuration, and adaptiveness. Thirty organizational studies have been classified according to the bureaucratic dimension(s) they have used in their analyses. This gives an indication of how these dimensions are related to each other and to various other characteristics.

<u>Part 1</u>:

Specialization:

- 1. P.F. Drucker (253)
 - Two tank manufacturing plants, USA.

The plant with low specialization exceeded regularly its production quota, had a lower labour turnover, had lower absentecism, had lower accident rate, had more satisfactory labour relations.

- 2. H. Buley (254)
 - 47 Schools, USA.

Adaptiveness correlated positively with specialization, but negatively with efficiency.

3. C.R. Walker (86)

An IBM factory (shop-floor), USA.

Measures taken for keeping down specialization resulted in a better satisfied working force, lower costs of production, higher quality of products.

4. M. Dalton (255)

Theoretical.

Specialization undermines hierarchical authority.

5. J.D. Elliott (256)

Detroit Edison Company (office), USA.

Over-specialization was associated with increased costs, created duplication, caused monotony of jobs, did not utilize completely the intellectual abilities of each employee.

6. P. Lazarsfeld & W. Thielens Jr. (257)

70 colleges, USA.

Low centralization was related to high specialization and low efficiency.

7. S. Udy Jr. (258)

Non-industrial organizations, USA.

More centralized organizations were more likely to have low specialization and high stratification.

8. M. Janowitz (259)

Military forces, USA.

Increasing adoption of new programmes and techniques led to increased specialization and resulted in a decentralization of decision making.

9. J. Hage (260)

Community Hospitals, case study, USA.

Introducing changes was easiest in those departments that had the highest degree of specialization and a history of adaptiveness.

10. R.H. Hall (195)

Literature survey, USA.

Centralization had a high correlation with formalization and a lower correlation with specialization which in turn had almost no correlation with formalization.

11. L.R. Pondy (245)

45 Manufacturing companies, USA.

"Administrative Intensity" (the number of managers, professionals and clerical workers divided by the number of craftsmen, operatives and labourers. It is set so as to maximize profits) decreases as organization size increases. It increases with increasing functional specialization and separation of ownership and management.

Part 2:

Standardization:

1. P. Harrison (261)

Baptist Church, USA.

Absence of standardization caused low effectiveness.

2. R. Carzo Jr. (244)

Laboratory experiment on small groups.

All groups, regardless the degree of standardization reached a level of performance that was approximately the same.

Part 3:

Formalization:

1. S. Lipset (262)

An agricultural organization, case study, USA.

Adaptiveness was reduced in centralized and formalized organization.

2. J. Tsouderos (263)

Voluntary organizations, USA.

Increases in formalization resulted in raising larger amounts of funds (high production) and lower costs, but membership dropped.

3. P. Harrison (261)

Baptist Church, USA.

Low centralization and low formalization were associated with low effectiveness.

4. A. Bavelas (264)

Laboratory experiments on small groups, USA.

Centralization increased production, efficiency, and formalization, while lowering job satisfaction among the lower ranking members.

5. P. Blau & W.R. Scott (70)

Literature survey, USA.

High formalization was associated with high centralization, higher production, higher productivity, but lower job satisfaction and higher levels of turnover.

6. M. Zald (265)

Five correctional institutions, USA.

The structure was more decentralized when formalization was high; and the more decentralized organizations had lower efficiency.

- 7. R. Carzo Jr. (244)
 - Small groups, laboratory experiment.

All groups reached a level of performance which was the same, regardless the level of formalization.

8. R.H. Hall (195)

Literature survey, USA.

Centralization had a high correlation with formalization and a lower correlation with specialization which in turn had almost no correlation with formalization.

Part 4:

2.

Centralization:

- 1. S. Lipset (262)
 - An agricultural organization, case study, USA.

Adaptiveness was reduced in centralized and formalized organizations. N. Morse & E. Reimer (266)

Two departments in an organization.

Centralization resulted in a higher rate of production, but a lower rate of job satisfaction.

3. S.Lipset, M. Trow & J. Coleman (267)

International typographical union, case study, USA.

Low stratification caused a low level of centralization.

4. H. Leavitt (268)

Small groups in, USA.

Same results as Bavelas,

5. P. Lazarsfeld & W. Thielens (257)

70 colleges, USA.

Low centralization was related to high specialization and low efficiency.

6. P. Harrison (261)

Baptist Church, USA.

Low centralization and low formalization were associated with low effectiveness.

7. M. Janowitz (259)

Military Forces, USA.

Increasing adaptiveness was leading to increasing specialization and resulting in a decentralization of decision making.
8. S. Udy Jr. (258)

Non-industrial organizations, USA.

More centralized organizations were more likely to have low specialization and high stratification.

9. A. Bavelas (264)

Laboratory experiments on small groups, USA.

Centralization increased production, efficiency, and formalization while lowering job satisfaction among the lower ranking members.

10. A.M. Cohen (269)

Small groups, laboratory experiments. Reinforces results by Bavelas and Leavitt.

11. M. Zald (265)

Five Correctional Institutions, USA.

The structure was more decentralized when formalization was high; and the more decentralized organizations had lower efficiency.

12. P. Blau & W.R. Scott (70)

Literature survey, USA.

High formalization was associated with high centralization,

higher production, higher productivity, but lower job satisfaction

and higher levels of turnover.

13. J. Hage (260)

Community Hospitals, case study, USA.

Introduction of a new department led to the decentralization of decision making and increased costs.

14. R.H. Hall (195)

Literature survey, USA.

Centralization had a high correlation with formalization and a lower correlation with specialization which in turn had almost no correlation with formalization.

Part 5:

Configuration:

- 1. H. Ronken & P. Lawrence (270)
 - Case study, USA.

Status differences severely restricted communications and lowered job satisfaction.

- S. Lipset, M. Trow & J. Coleman (267)
 International typographical union, case study, USA.
 Low stratification caused a low level of centralization.
- 3. S. Udy Jr. (258)

Non-industrial organizations, USA.

More centralized organizations were more likely to have low specialization and high stratification.

4. P. Blau & W.R. Scott (70)

Literature survey, USA.

Status differences tended to reduce criticism of the ideas of those superior in power and prestige.

5. R. Likert (239)

Data not clear.

Companies which had "overlapping group" form of structure (linked to each other by people who have overlapping membership), effective communication, decentralized and co-ordinated decision making and high performance goals coupled with high motivation, were all above-average performance companies.

 E.M. Bridges, W.J. Doyle & D.J. Mahan (246) Ten schools, USA.

Hierarchically differentiated groups exhibited less risk taking behaviour, were less efficient and less productive than hierarchically less differentiated groups. 7. L.V. Blaukenship & R.E. Miles (243)

190 managers in 8 light manufacturing companies, USA. The hierarchical position of a manager was the most important determinant of his decision behaviour. Span of control was found to be related to the extent to which a manager relies on subordinates in his decision making.

8. R. Carzo & J.N. Yanouzas (240)

Small groups.

Tall organization structures had higher profits and return on revenues than flat organizations. Companies of performance on the time taken to complete decisions showed no significant difference between tall and flat organization structures.

Part 6:

Flexibility or adaptiveness:

- 1. H. Buley (254)
 - 47 schools, USA.

Adaptiveness correlated positively with specialization, but negatively with efficiency.

2. L. Coch & J. French Jr. (171)

Pyjama factory, experimental case study, USA.

Low job satisfaction led to resistance to change, implying low adaptiveness.

3. S. Lipset (262)

An agricultural organization, case study, USA.

Adaptiveness was reduced in centralized and formalized organizations.

4. B. Georgopoulos & A. Tannenbaum (271)

32 organizational units of a business organization, USA. Adaptiveness highly correlated with the lack of strain between supervisor and employees; but correlation with volume of production was lower.

5. M. Janowitz (259)

Military Forces, USA.

Increasing adaptiveness was leading to increasing specialization, and resulted in a decentralization of decision making.

6. J. Hage (260)

Community Hospitals, case study, USA.

Introduction of new department led to the decentralization of decision making and increased costs. Introducing changes was easiest in those departments of the hospital that had the highest degree of specialization and a history of adaptiveness.

APPENDIX J

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THE MAIN FIELD SURVEY FINAL QUESTIONNAIRES AND CONTENT OF INTERVIEWS

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RESEARCH PROJECT ON NETWORK APPLICATIONS QUESTIONNAIRE

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Part 1:

FOR PLANNING ENGINEERS

> D. Arditi University of Technology, Department of Civil Engineering, Loughborough, Leics.

January 1972.

PART I

- 1. Is your company:
 - a) A private company
 - b) A public company
- 2. What is the number of projects undertaken at the moment?
- What is the kind of job generally undertaken? (Tick both if appropriate)
 - a) Building
 - b) Civil Engineering
- 4. What is the kind of contract generally undertaken?
 - a) Open tenders
 - b) Negotiated contracts
 - c) Speculative building
 - d) Others
- 5. What is the geographical location of the jobs carried out
 - by your company?
 - a) Local
 - b) National
 - c) International
- 6. What is the policy of the company in regards to expansion?
 - a) To expand in the present field
 - b) To expand in new fields
 - c) Not to expand
- 7. Does the company offer low bids for prestige reasons?
 - a) Yes
 - b) No

- 8. When was the company founded?
- 9. Please indicate the approximate contract values of the <u>largest</u> and smallest jobs being undertaken at present by your company.
 - a) Less than £10,000
 - b) $\pounds10,000 \pounds100,000$
 - c) 100,000 1,000,000
 - d) Larger than £1,000,000
- 10. Equipment and machinery that can be used on a construction site are grouped below in five categories. Please indicate the approximate <u>percentage</u> of each group which is in use in your company.

	Percentage used
Hand tools	
Manual machines (Jackhammers, vibrators, tampers, welding equipment, and the like)	
Light equipment (Hoists, small concrete mixers, small lorries, and the like)	
Heavy equipment (Bulldozers, scrapers, cranes, large concrete plants, and the like)	
Special (Non-standard) equipment	
	Total = 100

- 11. Please indicate what sort of quality evaluation is generally carried out?
 - a) Full quality control by a resident site engineer(s), over
 - all aspects of the construction, at regular intervals.
 - b) Partial quality control over certain aspects only, and/or from time to time.
 - c) Quality evaluation at the end of the project.
- 12. How was the company founded originally?
 - a) By an existing organization
 - b) Personally, not by an existing organization

- 13.
 - . What is the status of the company?
 - a) Principal unit: Is independent of any larger group, but, may itself have subsidiaries or branches
 - b) Subsidiary unit: Is part of a larger group, but, has its
 own legal identity (e.g., own Board of Directors)
 - c) Head Branch unit: Is the major operating component of the parent organization, but has no separate legal identity
 - d) Branch unit: Is an operating part of the parent organiza
 - tion which does not satisfy the preceding criteria.
- 14. What is the number of employees in the company, expressed as a percentage proportion of the total number of employees in the owning group?
 - a) Under 5% of owning group
 - b) 5% 29% of owning group
 - c) 30% 89% of owning group
 - d) Over 91% of owning group
- 15. A function is defined as "specialized" when at least one person performs that function and no other function. Please indicate, in the following list of activities, those which are "specialized" in your company.
 - a) Develop, legitimize, and symbolize the organization's charter (Public relations, advertising, etc.)
 - b) Dispose of, distribute and service the output (Sales, service, customer complaints, etc.)
 - c) Carry output and resources from place to place (Transport)
 - d) Acquire and allocate human resources (Employment, etc.)
 - e) Develop and transform human resources (Education and training)
 - f) Maintain human resources and promote their identification

- with the organization (Welfare, medical, safety, magazine, sports, social, etc.)
- g) Obtain and control materials and equipment (Buying, material control, stores, stock control, etc.)
- h) Maintain and erect (for own use) buildings and equipment (Maintenance, etc.)
- i) Control the workflow (Planning, progressing, etc.)
- j) Record and control financial resources (Accounts, wages, costs, etc.)
- k) Control the quality of materials, equipment and outputs(Inspection, testing, quantity surveying, etc.)
- Asses and devise ways of producing the output (Work study, operational research, rate-fixing, method study, etc.)
- m) Devise new outputs, equipment and processes (Research and Development)
- n) Develop and operate administrative procedures (Registry,
 filing, statistics, organization and methods, etc.)
- o) Deal with the legal and insurance requirements (Legal, registrar, insurance, licensing, etc.)
- p) Acquire information on the operational field (Market research)
- 16. How many role-defining documents, such as an organization chart, are printed for use within the company?
 - a) None 👘
 - b) One
 - c) Two
 - d) Three
 - e) Four or more

17: To whom are these documents distributed?

- a) None
- b) Few employees
- c) Many employees
- d) All employees
- 18. Who are given a copy of the organization chart?
 - a) None
 - b) The Chief Executive only
 - c) The Chief Executive plus one other executive
 - d) The Chief Executive plus all or most Department Heads
- 19. Are any operating instructions such as task descriptions, labour, plant and material requirements, expected task durations, given to stie staff?
 - a) Yes
 - b) No
- 20. Are written terms of reference or job descriptions given to:
 - a) Direct workers
 - b) Gangers
 - c) Site Managers and/or office staff
 - d) Chief Executive
- 21. Is there any "Manual of Procedures" in use within the company?
 - a) Yes
 - b) No
- 22. Are the main policies of the company written down and circulated?
 - a) Yes
 - b) No

- 23. Are production schedules or programmes used?
 - a) Yes
 - b) No
- 24. Are any Research and Development programs and/or reports prepared and circulated within the company?
 - a) Yes
 - b) No
- 25. Please indicate which of the following activities are decided at a level of authority within the organization's own structure, and not at a higher level of authority (such as a parent organization).
 - a) Qualifications and number of site personnel
 - b) Appointment of site staff from outside the company
 - c) Promotion of site staff
 - d) Salaries of site staff
 - e) To spend unbudgeted or unallocated money on capital items
 - f) To spend unbudgeted or unallocated money on revenue items
 - g) What type or what brand of new equipment to be used
 - h) To undertake a new type of job
 - i) To determine marketing territories covered
 - j) The extent and type of the market to be aimed for
 - k) The costing system
 - 1) What sort of control and inspection to be used
 - m) Whether to use work study
 - n) Dismiss a site staff member
 - o) Training methods to be used
 - p) Buying procedures
 - q) Which suppliers or materials to be used

- r) What and how many welfare facilities to be provided
- s) The price of the output
- t) To alter responsibilities/areas of work of specialist department
- u) To alter responsibilities/areas of work of line departments
- v) To create a new department
- w) To tender for a new job

PART II

2.

- 1. Since when is Network Analysis being used by your company?
 - Please tick those of the following items that are in common use in network applications in your company. Please indicate by a tick in the appropriate column if they were used five years ago, and, if you think they will be used in five year's time.

	1966	1971	1976
Logical planning only Planning <u>and</u> control during construction			
Breakdown of activities by: — Trades — Resource types — Location of work			
Updating: — No updating — When felt necessary — Regularly: — Weekly — Fortnightly — Monthly — Longer periods			
— Only durations are updated — Durations <u>and</u> logic are updated			
Allocation of float: — Earliest starts used — Latest starts used — Even distribution among activities — Choice of certain activities — Arbitrary distribution as time goes by — Dictated by Resource Analyses			

1966 1971 1976 Presentation of results for site use: - Only network - Only bar-chart transformations of networks Networks and bar-chart transformations ---- Time-scaled networks Logic-linked bar-charts Computerized applications: - Use of own computer Use of computer bureaux ---- Program developed within company - Standard package: — ICL 1900 PERT - IBM 360 PMS - IBM 1130 PCS - IBM 1620 CPM - IBM 1620 PERT - Others **Resource Analysis:** --- Carried out for whole project --- Carried out for parts of project 3. What is the cost of using Network Analysis, expressed as a percentage of the total project cost? a) 0.0 - 0.5%b) 0.6 - 2.0% c) 2.1 - 5.0%d) 5.1 + % Are there any concrete economic savings which justify the 4. use of Network Analysis? a) Always b) Often c) Seldom. d) Never e) Don't know

What are the <u>smallest and largest number</u> of activities in manual and computerized applications?

	Manual	Computerized
Smaller than 75 activities 75 - 150 activities 151 - 300 " 301 - 500 " 501 - 1000 " 1001 - 2000 " Larger than 2001 activities		

What are the criteria for computerizing a network application? a) Specification in contract clauses

b) Number of activities involved (Please specify)

c) Familiarity of site staff with computer printouts

d) Familiarity of planning staff with computers

e) Acceptability of anticipated computer costs

f) Others (Please specify)

5.

6.

7.

Why was Network Analysis introduced in the first place?

Please tick as many as appropriate.

a) Traditional planning techniques were inadequate

b) Someone in senior management supported it and pushed it through

c) There were compulsion clauses in contracts

d) It was fashionable

e) The computer of the company had some idle time

f) Others (Please specify)

Was the first Network Analysis carried out:

a) Manually

b) By a computer program

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- 9. When Network Analysis was first introduced:
 - a) All staff concerned were trained
 - b) New staff was recruited
 - c) The staff concerned knew already about Networks
- 10. Are there any courses for the staff concerned with planning, and, application on site?

and and an and a second se Second second second Second second	Internal Externa Courses Courses	
No courses		
Some courses		
Regular courses		

- 11. What is the status of the Planning Department?
 - a) Has direct authority
 - b) Has lateral (consultative) authority
- 12. Is a different report issued for different levels in the management?
 - a) Yes
 - b) No
- 13. Do you find the time estimated to be generally:
 - a) Correct
 - b) Pessimistic
 - c) Optimistic
- 14. Please tick those of the following who are generally involved
 - in the determination of time estimates.
 - a) The Planning Engineer
 - b) The Site Manager (Agent)
 - c) The Contracts Manager
 - d) Subcontractors
 - e) Material firms
 - f) Others (Please specify)

- 15. What are the factors which determine the degree of detail of a network?
 - a) Client requirements
 - b) Time limit for planning
 - c) Complexity of the project
 - d) Ability of the Site Manager
 - e) Ability of the Planning Engineer
 - f) Others (Please specify)
- 16. Is the overall network broken down to smaller more detailed networks?
 - a) Yes
 - b) No
- 17. Can you give an average figure for the "cost per activity", i.e., the total project cost divided by the number of real activities?
 - a) Less than £1,000
 - b) Between £1,000 and £5,000
 - c) More than £5,000
- 18. Does the site staff know how much float is associated with each activity?

	Yes	No
Site Manager (Agent) Foremen		
Gangers		

- 19. Is it your experience that the first network of a project is considered to be unreliable due to insufficient information from architects and/or consultants?
 - a) Yes
 - b) Sometimes

- c) No
- d) Don't know

20. Is any multi-project scheduling used?

- a) Yes
- b) No

21. Are any of the following used?

	Yes	No
Visual display units Graphical outputs		

22. How would you rate your project planned by Network Analysis

in general, in regards to the following job characteristics?

	High	Average	Low	
Complexity				[·
Extent of repetition				
Flexibility				• •
Uncertainty				

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	Big	Average	Small	
Time limitations Resource limitations Financial limitations				

PART III

1. Are regular meetings held between the Site Manager and the Planning Engineer?

	Yes	No
At pre-contract stage		
At planning stage		
During actual construction		

2. How would you rate the relationship between the Site Manager and the Planning Engineer?

a) Superior-subordinate formal relationship (the Planning

Engineer being the superior)

 b) Superior-subordinate formal relationship (the Site Manager being the superior)

c) Non-formal friendly relationship

3. What are the two most important preoccupations of the Plan-

ning Engineer during the planning and implementation phases

of a project, when his relationship with the Site Manager

is considered? Please indicate first and second choices.

a) Technical, professional

b) Administrative

c) Human relations

- 4. How often does the Planning Engineer take account of the Site Manager's ideas (e.g., ideas on the logic, on the presentation of the results, etc.)?
 - a) Never
 - b) Seldom
 - c) Often
 - d) Always

What is the Planning Engineer's attitude towards the time taken by the Site Manager to digest every aspect of Network Analysis?

a) They never know everything about Network Analysis

b) They are slow to learn all, about it

c) They are quick enough to implement it adequatly after

a short time

5.

6.

d) They learn very quickly

How would you rate the attitude of the Planning Engineer, the Site Manager, and the Senior Management in regards to "changes" in general (technical, administrative, etc.)?

	Planning Eng.	Site Manager	Senior Mgt.
Enthusiastic Supporting Accepting Tolerating Resisting Opposing			

7. How would you rate the reaction of the Planning Engineer, the Site Manager, and the Senior Management in regards to Network Analysis when it was first introduced, and now?

	Planning Eng.		Planning Eng. Site Manager		Site Manager		Senior Mgt.	
	Then	Now	Then	Now	Then	Now		
Enthusiastic Supporting Accepting Tolerating Resisting Opposing								

8. When a Site Manager is assigned to his first job planned by Network Analysis: (Tick as many as appropriate)

a) He is chosen among those who are familiar with the

technique.

- b) He is sent to a course. (Internal or external)
- c) The technique is explained to him briefly before he starts work.
- d) He is sent for a while to a site where Network Analysis is being used.
- e) He participated in the decision to use (or not to use)Network Analysis in that particular project.
- 9. Are the basic securities (listed below) of the site staff threatened or enhanced in any way by the use of Network Analysis instead of a conventional technique?

	Threatened	Enhanced	Not Changed
Amount of pay Intensity of work Promotional advantage Status of prestige			

- 10. How would the Planning Engineer judge the Site Staff involved
 - in Network Analysis? (Tick as many as appropriate)
 - a) They have adequate knowledge of the technique.
 - b) They come from trade rather than university.
 - c) They exploit every aspect of Network Analysis.
 - d) They have great practical site experience.
 - e) They feel a need for Network Analysis.
 - f) They cannot do without the help of the Planning Engineer.
 - g) They are inclined not to provide information for updating.
 - h) They tend to use their intuition rather than what the network shows.
 - i) They become quickly disillusioned when the network has to be updated frequently.

a) The Planning Department:

11.

- (i) was established
- (ii) was enlargened
- (iii) was not changed
- (i) became more centralized
- (ii) became more decentralized
- (iii) was not changed
- (i) gained prestige
- (ii) lost prestige
- (iii) was not changed
- (i) acquired more authority
- (ii) lost some authority
- (iii) was not changed
- b) The office of Contracts Manager:
 - (i) was established
 - (ii) was abolished
 - (iii) was not changed
- c) The site's autonomy:
 - (i) was reduced
 - (ii) was increased
 - (iii) was not changed

PART IV

Below are listed a number of qualities attributed to Network Aanlysis by the current literature on the subject. Please tick in the first column marked "Expectations", the <u>items which you</u> <u>would expect to happen in any application</u> of Network Analysis. Also, please indicate by a tick in the appropriate column the <u>extent to which they</u> (whether expected to happen or not) <u>apply</u> <u>in the actual implementation</u> of Network Analysis by your company.

	NS	Extent in Application							
	EXPECTATIO	Never	Seldom	Sometimes	Often	Always			
Project time is reduced. Project costs are reduced. Project control is better. It is too inflexible. It is either too detailed or not detailed enough. Management by exception is applied by concentrating on critical activities. There is better communication and co-ordination between the company and outside organization. There is better communication and co-ordination between departments within the company. It produces programs which are uneconomic and sometimes unworkable. Float makes people relax till, in the end, every activity becomes critical. It requires high effort and cost for the presentation to be understood by staff involved. The consequences of delays, changes, alterations modifications are worked									
out in sufficient time to take corrective action.	. *	· · ·				5 			

	NS		Exte Appli	ent icat	in ion	
	EXPECTATIO	Never	Seldom	Sometimes	Often	
Being a new development, it meets with						T
Senior management supervises the projects less frequently since progress can be						
predicted with more confidence.						
Network Analysis users in noal life.						I
Most of the literature in this field is						
elementary, repetitive and theoretical.						
A technical terminology of code-words (e.g., total float, free float, etc.)						
frequently causes considerable confusion.						
Claims for delays are determined and						
Verified more easily.	1.00	•	8 . R			
experience.						
Input requirements are very complex.						l
It is used as a means of ascribing blame to individuals for failing to					а ^с	
meet targets.		1				
It is easily explainable and easily						
Calculated. It is a disciplined systematic and		$\lambda = 1^{N}$			- 14	
logical approach to projects.						l
It gives a very detailed programme.			1		· .	I
STATT MEMDERS DECOME MORE INVOLVED					•	
that goes on.						ļ
The preparation of the network and						
the analysis take too long. High effort is needed to undate and						
absorb changes.				а. 1911 г. – С		
It is easier to take a partially com-		х Х.У.				
pleted JOD and to become familiar with the project and progress						
It gives a better chance for the effi-					1. A. A.	
cient use of resources.				ta a		
Inere are serious problems in deter-	·					
durations and resource figures.	la se		• • ••			
It speeds the process of decision	1 .				1	
making at all levels.	1	1	• •			ļ

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	NS N		Ext App1	ent icat	in ion	
	EXPECTATION	Never	Seldom	Sometimes	Often	Always
Cost optimization techniques (time-cost trade-off) may be used in association with it.						
Cost control may be carried out in association with it. It is used in all stages of project management: pre-tender planning, con-						
tract planning, progress control. Specialist support staff is needed. There are serious difficulties in drawing complex networks.						

How would you rate the overall use of Network Analysis by your company?

- a) Very successful
- b) Successful
- c) Successful enough
- d) Little successful
- e) Not successful
- f) Don't know

Part 2:

RESEARCH PROJECT ON NETWORK APPLICATIONS QUESTIONNAIRE FOR

SITE MANAGERS

D. Arditi University of Technology, Department of Civil Engineering, Loughborough, Leics.

January 1972.

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						- 6			
		- 14							

PART I

- How would you rate the relationship between the Site Manager and the Planning Engineer?
 - a) Superior-subordinate formal relationship (the Planning Engineer being the superior)
 - b) Superior-subordinate formal relationship (the Site Manager being the superior)
 - c) Non-formal friendly relationship
- 2. What are the two most important preoccupations of the Planning Engineer during the implementation and planning phases of a project, when his relationship with the Site Manager is considered? (Please indicate first and second choices)
 - a) Technical, professional
 - b) Administrative

c) Human relations

- How often does the Planning Engineer take account of the Site Manager's ideas? (e.g., ideas on logic, on the presentation of the results, etc.)
 - a) Never
 - b) Seldom
 - c) Often
 - d) Always
 - . What is the Site Manager's attitude towards the practical site experience of the Planning Engineer?
 - a) Poor
 - b) Just sufficient
 - c) Adequate
 - d) Very advanced

5. How would you rate the attitude of the Site Manager, the Planning Engineer, and the Senior Management in regards to "changes" in general? (technical changes, administrative changes, etc.)

	Site Manager	Planning Eng.	Senior Mgt.
Enthusiastic Supporting Accepting Tolerating Resisting Opposing			

How would you rate the reaction of the Site Manager, the Planning Engineer, and the Senior Management in regards to Network Analysis when it was first introduced, and now?

6.

		anager	Planning	g Eng.	Senior Mqt.			
	Then	Now	Then	Now	Then	Now		
Enthusiastic Supporting Accepting Tolerating Resisting Opposing								

7. Are the basic securities of the Site Staff threatened or enhanced in any way by the use of Network Analysis instead of a conventional technique?

	Threatened	Enhanced	Not Changed
Amount of pay Intensity of work			
Status or prestige			

 What is the Site Manager's attitude towards the Planning Engineer? (Tick as many as appropriate)

 a) He regards the Planning Engineer as someone belonging to the same group as his.

b) He trusts the Planning Engineer.

- c) The Planning Engineer has high prestige in the eyes of the Site Manager.
- d) He feels that he needs the Planning Engineer.
- e) He tolerates the Planning Engineer.
- f) He sees the Planning Engineer as an impingment on his authority.
- 9. Have there been any changes in the institutionalized patterns of work, due to the introduction of Network Analysis?
 - a) The Planning Department:
 - (i) was established
 - (ii) was enlargened
 - (iii) was not changed
 - (i) became more centralized
 - (ii) became more decentralized
 - (iii) was not changed
 - (i) gained prestige
 - (ii) lost prestige
 - (iii) was not changed
 - (i) acquired more authority
 - (ii) lost some authority
 - (iii) was not changed
 - b) The office of Contracts Manager:
 - (i) was established
 - (ii) was abolished
 - (iii) was not changed
 - c) The site's autonomy:
 - (i) was reduced

- (ii) was increased
- (iii) was not changed
- 10. Please indicate by a tick in the appropriate column how you feel about your job.

	Strongly Agree	Agree	Disagree	Strongly Disagree
The major satisfactions in my life come from my job.				
The most important things that happen to me involve my work.		et an sain a tha 18 - Nasain sainte 18 - Nasain sainte 18 - Nasain Sainte		
I am really a perfectionist about my work.				
I live, eat and breathe my job.				
I am very much involved personally in my work.				
Most things in life are more important than work.	alas en tre alas entre			

PART II

Below are listed a number of qualities attributed to Network Aanlysis by the current literature on the subject. Please tick in the first column marked "Expectations", the <u>items which you</u> <u>would expect to happen in any application</u> of Network Analysis. Also, please indicate by a tick in the appropriate column the <u>extent to which they</u> (whether expected to happen or not) <u>apply</u> <u>in the actual implementation</u> of Network Analysis by your company.

	NS	Extent in Application						
	EXPECTATIO	Never	Seldom	Sometimes	Often	Always		
Project time is reduced. Project costs are reduced. Project control is better. It is too inflexible. It is either too detailed or not detailed enough. Management by exception is applied by concentrating on critical activities. There is better communication and co-ordination between the company and outside organization. There is better communication and co-ordination between departments within the company. It produces programs which are uneconomic and sometimes unworkable. Float makes people relax till, in the end, every activity becomes critical. It requires high effort and cost for the presentation to be understood by staff involved. The consequences of delays, changes, alterations, modifications are worked out in sufficient time to take corrective action.								

-418-						
	VS	- 	Exte \pp1	ent icati	in ion	
	EXPECTATION	Never	Seldom	Sometimes	Often	Ałways
Being a new development, it meets with inertia on the part of users. Senior management supervises the projects less frequently since progress can be predicted with more confidence. There is not enough literature to help Network Analysis users in real life: Most of the literature in this field is elementary, repetitive and theoretical. A technical terminology of code-words (e.g., total float, free float, etc.) frequently causes considerable confusion. Claims for delays are determined and verified more easily. It requires less intuitive skill and experience. Input requirements are very complex. It is used as a means of ascribing blame to individuals for failing to meet targets. It is easily explainable and easily calculated. It is a disciplined, systematic and logical approach to projects. It gives a very detailed programme. Staff members become more involved in the project and know everything that goes on. The preparation of the network and the analysis take too long. High effort is needed to undate and absorb changes. It is easier to take a partially com- pleted job and to become familiar with the project and progress						
It gives a better chance for the effi- cient use of resources. There are serious problems in deter- mining contingencies for activity durations and resource figures. It speeds the process of decision making at all levels.					•	

	VS		Ext Appl	ent icat	in ion	
	EXPECTATION	Never	Seldom	Sometimes	Often	Always
Cost optimization techniques (time-cost trade-off) may be used in association with it. Cost control may be carried out in association with it. It is used in all stages of project						
management: pre-tender planning, con- tract planning, progress control. Specialist support staff is needed. There are serious difficulties in drawing complex networks.						

How would you rate the overall use of Network Analysis by your company?

a) Very successful

b) Successful

c) Successful enough

d) Little successful

e) Not successful

f) Don't know

Part 3:

Subjects discussed in interviews:

- The aim of the project was briefly described; the questionnaire was briefly explained and the following points were made:
 - a) Many of the alternatives can be ticked if found appropriate
 - b) Comments are welcome on the back of the pages
 - c) The questionnaire can be completed in the presence of the interviewer
- 2. The following information for the company and not for the holding or the group of companies were asked for 1971:
 - a) Anual turnover
 - b) Net profits before taxation
 - c) Average number of employees
- 3. The extent of network analysis use was inquired with the following question: What is the approximate percentage of turnover that is planned by the following network techniques? What was it five years ago, and what do you estimate it will be in five years' time?

	1966	1971	1976
Time analysis			
Time analysis <u>and</u> resource analysis done in conjunction with the network			
Time analysis, resource analysis and cost analysis, all done conjunction with the network			

4. Various aspects of network analysis were investigated by the following question: What is the approximate percentage of network planned turnover (network planned = at least logic diagram drawn), in which the following are used? What was it five years ago, and what do you estimate it will be in five years' time?

	1966	1971	1976
Arrow diagrams Precedence diagrams			
Single time estimates Three time estimates			
Computerized Manual			
Resource aggregation Resource levelling		a na artes Bristo Alastation Participa	

- 5. General questions were asked about how well the company had been doing in the last five years, and about the general attitude of company staff to network analysis.
- 6. Respondents' professional backgrounds were investigated.
- General questions about the particular site were asked when site managers were inteviewed.
APPENDIX K

QUANTIFICATION OF VARIABLES

Part	1:	Success measurement in network analysis applications	424
Part	2:	Methods of Application variables	426
Part	3:	Methods of Introduction variables	432
Part	4:	Organizational Characteristics	438
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Quantification of variables:

The variables which were considered in statistical analyses and the procedure by which they were quantified are explained in detail in this Appendix. The six-letter names of variables used in the calculations with the XDS3 Statistical Package are also given.

Part 1:

Success measurement in network analysis applications:

Part IV of the questionnaire for planning engineers (Appendix J, Part 1), and Part II of the questionnaire for site managers (Appendix J, Part 2) contain the questions used in the evaluation of respective success scores. They are identical in content and format.

A total of 20 advantages and 14 disadvantages of using network analysis were extracted from the literature (Appendix D). These were the most frequently mentioned characteristics in the literature and in the preliminary investigation. Then, a combination of Thurstone and Likert scaling techniques (*) were used for the final calculation of success scores.

Respondents were asked two questions. The first one aimed at determining the relative importance of each of these 34 items among themselves. A weighting system, rather similar to, but not exactly the same as the Thurstone scaling technique was used for this purpose. Respondents were asked whether they expected these items to happen when they first started using network analysis. They answered "Yes" or "No" for each of the 34 items. The percentage of "Yes" answers to an item constituted the weight for that item. For example, if 10 of the 15 planning engineers expected, say the first item, "project time is reduced", to occur, then the weight for that item was calculated as 66.6.

(*) For a detailed description of these thecniques, see Oppenheim (204) and a publications by the Market Research Society (201). The second part of success measurement in network analysis, consisted of finding out to what extent these items actually happened in real practice. Respondents were asked to indicate on the given five position scale — never, seldom, sometimes, often, always — how frequently these characteristics were happening in actual applications. Two different scoring systems were defined for advantages and disadvantages. Scoring for advantages ranged from 0 for "never" to 4 for "always"; and scoring for disadvantages ranged from 0 for "never" to -4 for "always".

The score for each item was then multiplied by its weight. The resulting weighted scores for each item were added to (or in the case of disadvantages subtracted from) each other. The final figure obtained was divided by the number of items, which gave the "success score".

These steps are given below in a brief form:

Calculate weights (W): percentage expectation for each item.
 Determine scores (S) :

	Never	Seldom	Sometimes	Often	Always
Advantages	0	1	2	3	4
Disadvantages	0	-1	-2	-3	-4

3. Calculate weighted score (WS)

4. Calculate final success scores: ΣWS

Where n is the number of items.

Using this procedure 30 success scores were calculated — 2 for each company. Success scores for planning engineers (SCORPE) and site managers (SCORSM) differed from each other.

Part 2:

Methods of application variables:

1. Updating:

- 1.1. Updating frequency (UPDAT1):
 - --- No updating
 - Updating when felt necessary
 - --- Updating when felt necessary in some jobs,

: 0

: 1

: 2

:.3

:0

: 1

: 2

: 3

: 4

: 5

::6-

: 7

3

- and regular updating in others
- --- Regular updating
- 1.2. Frequency of regular updating (UPDAT2):
 - No regular updating
 - Longer than monthly
 - Monthly updating in some projects,
 - longer periods in others
 - Monthly updating
 - Fortnightly updating in some projects
 - monthly in others
 - Fortnightly updating
 - Weekly updating in some projects,
 - fortnightly in others
 - --- Weekly updating
- 1.3. Nature of updating (UPDAT3):
 - Only durations updated
 - Only durations updated in some projects,
 - and durations and logic updated in others: 2
 - Durations and logic updated

2. The use of computers:

- 2.1. Kind of computer facility (COMPT1):
 - Computer bureaux only
 - --- Computer bureaux in some projects
 - own computer in others
 - Own computer only
- 2.2. Kind of computer program (COMPT2):
 - --- Only program developed within the company: 1
 - Program developed within the company used
 - in some projects, standard packages used in others
 - Only standard packages
 - 2.3. Size of network in manual and computerized applications:
 - --- Size of smallest manual network
 (MANUSM)
 : No. of activities
 - --- Size of largest manual network
 - (MANULG) : No. of activities
 - Size of smallest computerized network
 (COMPSM)
 : No. of activities
 - Size of largest computerized network (COMPLG) : No. of activities
 - 2.4. Criteria for computerization:
 - Dichotomies; i.e., 0 for "No", and 1 for "Yes".
 - Clause in contract (SPECIF)
 - --- A large number of activities (NOACT)
 - Familiarity of site staff with computer printouts (SSFAMI)

: 1

: 2

: 3

: 2

- Familiarity of planning staff with computer procedures (PDFAMI)
- Acceptability of anticipated computer costs (COMPCO)

3. Preparation of the network:

3.1. Allocation of float:

Dichotomies; O for "No", 1 for "Yes".

- Earliest starts (EARLYS)
- Latest starts (LATEST)
- Even distribution among activities (EVENDI)
- --- Selection of certain activities likely to be late (CHOICE)

: 2

4

5

- Arbitrary distribution (ARBITR)
- Dictated by resource analyses (DICTAT)
- 3.2. Presentation of results (PRERES):
 - Only bar-chart transformations : 1
 - Logic-linked bar-charts
 - Networks and bar-chart transformations: 3
 - Time-scaled networks
 - Only networks
- 3.3. Breakdown of projects into activities:
 - Dichotomies; 0 for "No", 1 for "Yes".
 - By location only (LOCATN)
 - By trades only (TRADES)
 - By resource type only (RESTYP)
 - ---- By one of the above depending on job (COMBIN)
- 3.4. Staff involved in the estimation of durations (INVPRE): Dichotomies; 0 for "No", 1 for "Yes" for each item below.

and the second sec

Addition of all scores gives INVPRE.

- The planning engineer
- The site manager
- The contracts manager
- Sub-contractors
- Material firms
- --- Others
- 3.5. Degree of detail:
 - Dichotomies; O for "No", 1 for "Yes".
 - --- Client requirements (CLIENT)
 - Time limit for planning (TIMELI)
 - -- Complexity of the project (COMPLE)
 - --- Ability of the site manager (SMABIL)
 - Ability of the planning engineer (PEABIL)
- 3.6. The cost associated with each activity (COSTAC):
 - Smaller than £1000 : 1
 - --- Between £1000 and £5000: 2.5
 - ---- Larger than £5000 : 5
- 3.7. The use of sub-networks (SUBNWK):
 - -- Never : O
 - Sometimes: 1
 - Always : 2

3.8. Nature of resource analysis (RESANA):

Carried out for parts of the project at a time : 1 Carried out for the entire project in some jobs, and for parts of the projects in some others : 2 Carried out for the entire project : 3 4.1. Logical planning and control (LOGPLA):

- Only logical planning

- Only logical planning in some projects,

logical planning and control in others : 2

--- Only logical planning and control : 3

4.2. The status of the planning department (STATPD):

- Direct authority : 0

- Lateral authority: 1

4.3. Correctness of time estimates (ESTIMA):

--- Generally incorrect

- Sometimes correct, sometimes incorrect: 1

--- Generally correct

4.4. Site knowledge of float values associated with each activity (SITEFL):

Dichotomies; O for "No", 1 for "Yes". Addition of all scores gives SITEFL.

: 0

:: 2

- 3

— The site manager

---- Foremen

- Gang leaders

4.5. Reliability of the first network (ISTNWK):

- --- Generally reliable
- Sometimes reliable, sometimes not: 2

--- Generally unreliable

- 4.6. Hierarchical reporting (HIERAR):
 - No : 0

--- Yes: 1

- 5. Economic factors:
 - 5.1. Cost of using network analysis (COSTNA):
 - Larger than 5% of the total project cost
 - Between 2 and 5% of the total project cost : 2

- Between 0.5 and 2% of the total project cost: 3
- --- Smaller than 0.5% of the total project cost : 4
- 5.2. Economic justification for using network analysis (ECOJUS):
 - Never : 1
 - Seldom: 2
 - --- Often : 3
 - Always: 4

Part 3:

Methods of introduction variables:

- 1. Reasons for introduction:
 - Dichotomies; 0 for "No", 1 for "Yes".
 - --- Inadequate conventional techniques (INADEQ)
 - Pushed by senior management (SENMGT)
 - --- Clause in contract (CLAUSE)
 - ---- Fashionable (FASHIO)
 - Use of idle computer time (IDLETI)
- 2. Calculation of the first network analysis application (MANUCO):
 - Manual : O
 - By computer: 1
- 3. Staff situation when network analysis was introduced (STAFF):

: 2

3

- Staff already knew about network analysis: 1
- --- Staff was trained
- --- New staff was recruited
- 4. Training courses:
 - 4.1. Internal courses (INTCOR):
 - --- No internal courses
 - --- Some internal courses : 1
 - --- Regular internal courses: 2
 - 4.2. External courses (EXTCOR):
 - -- No external courses : 0
 - Some external courses
 - --- Regular external courses: 2
- 5. Regular meetings between the planning engineer and the site manager at different stages of the project (REGMET): Dichotomies; O for "No", 1 for "Yes". Addition of all scores gives REGMET.

- --- At pre-contract stage
- At planning stage
- At construction stage
- 6. Kind of interpersonal relationship between the planning engineer and the site manager (RESMPE):
 - Informal
 - --- Sometimes formal, sometimes informal: 1
 - --- Formal
- 7. Preoccupations of the planning engineer:
 - Ranking scale: 1 if it is the first preoccupation, 2 if it is the second, and 3 if it is the third.

- Technical aspects (TECHN)
- Administrative aspects (ADMIN)
- --- Human aspects (HUMAN)
- 8. Frequency of constructive consultation between the planning engineer and the site manager (SMIDEA):
 - Never : 1
 - --- Seldom: 2
 - --- Often : 3
 - Always: 4
- 9a. The planning engineer's opinion of the site manager's knowledge of network analysis (ATTIPE):
 - --- Never learn : 1
 - Slow to learn : 2
 - --- Adequate : 3
 - Quick to learn: 4
- 9b. The site manager's opinion of the planning engineer's site experience (PESITE):

- Poor : 1
- Just sufficient: 2
- Adequate : 3
- Advanced
- 10. Attitudes to change in general:

: 4

:1

: 2

The planning engineer's (PEREAC), the site manager's (SMREAC), and senior management's (SRMTRE) reaction to changes in general were measured by the following six point scale:

- Opposing
- Resisting
- Tolerating : 3
- Accepting : 4
- --- Supporting : 5
- --- Enthusiastic: 6

11. Attitudes to network analysis when it was introduced and at the present time:

The past and present reactions of planning engineers (PETHEN and PENOW), of site managers (SMTHEN and SMNOW), and of senior management (SRMTTH and SRMTNO) were measured by the following six point scale:

- Opposing : 1
- Resisting : 2
- Tolerating : 3
- Accepting : 4
- Supporting : 5
- Enthusiastic: 6

The difference in attitude between then and now was computed by subtracting the "now" score from the "then" score. PEDIFF = PETHEN - PENOW SMDIFF = SMTHEN - SMNOW SRMTDI = SRMTTH - SRMTNO

- 12. The site manager's first job planned by network analysis: Dichotomies; 0 for "No", 1 for "Yes".
 - He is already familiar with the technique (FAMILI)
 - --- He is sent to a course (SENTCO)
 - The technique is explained to him briefly (EXPLAI)
 - He is sent for training on a site using network analysis (SENTSI)

— He participates to the decision to use network analysis (PARTIC)

13. Effects of network analysis on site staff's basic securities: Effects on the amount of pay (PAY), the intensity of work (INTWRK), promotional opportunities (PROMOT), and status (STATUS) were measured by the following three point scale: — Threatened : -1

--- Not changed: 0

: 1

---- Enhanced

- 14a. The planning engineer's opinion of the site manager: Dichotomies; O for "No", 1 for "Yes".
 - They have adequate knowledge of network analysis (ADEQUA)
 - --- They come from trades rather than university (COMTRA)
 - They exploit every aspect of network analysis (EXPLOI)
 - They have great practical site experience (SITEXP)
 - They feel a need for network analysis (NEEDNA)
 - They cannot do without a planning engineer (NEEDPE)
 - --- They are inclined to provide information for updating
 - (NOUPDA)

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- They use their intuition rather than the network (INTUIT)
 They become disillusioned when the network is updated
 frequently (FREUPD)
- 14b. The site manager's attitude towards the planning engineer: Dichotomies; 0 for "No", 1 for "Yes".
 - He considers the planning engineer as someone beloging to the same group as his (SAMEGR)
 - He trusts the planning engineer (TRUST)
 - The planning engineer has high prestige in the eyes of the site manager (PEPRES)
 - --- He needs the planning engineer (NEEDPE)
 - He tolerates the planning engineer (TOLER)
 - He sees the planning engineer as an impingment on his authority (IMPAUT)
 - 15. Changes in the planning department due to the introduction of network analysis:
 - 15.1. Establishment of the planning department (PDFOR1):
 - --- Was established: 1
 - Already existed: 0
 - 15.2. Centralization of the planning department (PDCENT):
 - --- Became decentralized : -1
 - Did not change : 0
 - Became more centralized: 1
 - 15.3. Prestige of the planning department (PDPRES):
 - --- Lost some prestige : -1
 - Did not change : 0
 - --- Acquired more prestige: 1

15.4. Authority of the planning department (PDAUTH):

- --- Lost some authority : -1
- Did not change : 0
- Acquired more authority: 1

15.5. The office of contracts managers (CMFORM):

- --- Was abolished : -1
- Did not change : 0
- --- Was established: 1

15.6. The site's autonomy (SITAUT):

- --- Was reduced : -1
- Did not change: 0
- --- Was increased : 1

16. The site manager's involvement in his job (JOBINV):

The following scale was developed by Lodahl & Kejner

	Strongly Agree	Agree	Disagree	Strongly Disagree
The major satisfactions in my life come from my work.	1	2	3	4
The most important things that • happen to me involve my work.	1	2	3	4
I am really a perfectionist about my work.	7	2	3	4
I live, eat and breathe my job.	1	2	3	4
I am very much involved personally in my work.	1	2	3	4
Most things in life are more important than work.	4	3 .	2	1

Part 4:

Organizational characteristics:

1. Workflow integration (WRKINT):

This variable is calculated by adding the following three sub-variables.

1.1. Mechanization mode (AUTMOD):

This sub-variable is determined by assessing the bulk of the equipment used by the company.

		<u> </u>	1006	Kange
	Hand tools	:	0	0
	- Manual machines (Jackhammers, vibrators,			
	tampers, welding equipment, and the like):	1	1
	- Light equipment (Hoists, small concrete	•		
	mixers, small lorries, and the like)	11 4 1 1	2	2
	— Heavy equipment (Bulldozers, scrapers,	•.		an an ann an t- Thairte
	cranes, large concrete plants, and the	•		
•	like)	:	3	3
	Special (non-standard) èquipment	:	4	4
1.2.	Mechanization range (AUTRAN):	· · ·		
	This sub-variable is defined by the highest	so	coring	g piece o
	equipment in the above list, the company is	kr	nown	to use.
1.3.	Specificity of quality evalution (QUAEVA):	· .	· · · · ·	
e Sector	- Quality evaluation at the end of the pro	jeo	:t: 0	
	Partial quality control over certain asp	ect	s	
	only, and/or from time to time		: 1	
	Full quality control by a resident site	•		
	engineer, over all aspects of the constru	uc-	•	
	tion, at regular intervals	•	: 2	

2. Dependence (DEPEND):

This variable is calculated by adding the following four subvariables.

- 2.1. Impersonality of origin (IMPORI):
 - The company was founded personally : 0
 - The company was founded by an existing
 - organization
- 2.2. Status of organization unit (STATUN)
 - --- Branch unit : O
 - Head branch unit: 1
 - Subsidiary unit : 2
 - Principal unit : 3
 - Definitions of these different unit types are given in the questionnaire for planning engineers (Appendix J, Part 1).

: 1

- 2.3. Public accountability of organization (PUBACC):
 - Private company: 0
 - ---- Public company : 1
- 2.4. Size relative to owning group (SIZERE):
 - The company's score is its number of employees, expressed
 - as a percentage proportion of the total number of employees
 - in its ultimate owning group.
 - Over 90% of owning group : 0
 - --- 30% to 89% of owning group: 1
 - 5% to 29% of owning group : 2
 - Under 5% of owning group : 3
- 3. Structuring of activities (STRUCT):

This variable is calculated by adding the following two subvariables.

3.1. Functional specialization (FUNSPE):

- A function is specialized when at least one person performs that function and no other function. For each of the following activities for which there is a specialist, the organization scores 1. The total gives FUNSPE.
 - a) Develop, legitimize, and symbolize the organization's charter (Public relations, advertising, etc.)
 - b) Dispose of, distribute and service the output (Sales, service, customer complaints, etc.)
 - c) Carry output and resources from place to place (Transport)
 - d) Acquire and allocate human resources (Employment, etc.)
 - e) Develop and transform human resources (Education and training)
 - f) Maintain human resources and promote their identification with the organization (Welfare, medical, safety, magazine, sports, social, etc.)
 - g) Obtain and control materials and equipment (Buying, material control, stores, stock control, etc.)
 - h) Maintain and erect (for own use) buildings and equipment (Maintenance, etc.)
 - i) Control the workflow (Planning, progressing, etc.)
 - j) Record and control financial resources (Accounts, wages, costs, etc.)
 - k) Control the quality of materials, equipment and outputs (Inspection, testing, quantity surveying, etc.)
 - Asses and devise ways of producing the output (Work study, operational research, rate-fixing, method study etc.)

m) Devise new outputs, equipment and processes (Research and Development)

- n) Develop and operate administrative procedures (Registry, filing, statistics, organization and methods, etc.)
- o) Deal with the legal and insurance requirements (Legal, registrar, insurance, licensing, etc.)
- p) Acquire information on the operational field (Market research)

3.2. Formalization of role definition (FORMAL):

This sub-variable consists of the following:

3.2.1. Number of role defining documents (NOINF):

: 0

:1

— None

---- One

--- Two : 2

- Three ; 3

--- Four or more: 4

3.2.2. People to whom these documents are distributed (INFORB):

-- None : 0

- Few employees : 1

- Many employees: 2

- All employees : 3

3.2.3.

 People who are given a copy of the organization chart (ORCHAR):

--- None

- Chief executive only

- Chief executive plus one other executive: 2

: 0

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- Chief executive plus all or most
 - Department Heads : 3
- 3.2.4. Whether any operating instructions, such as task descriptions, labour plant and material requirements, expected task durations, etc., are given to site staff (WROPIN):
 - --- No : O
 - Yes: 1
- 3.2.5. Whether written terms or reference of job descriptions are given to:
 - Direct workers
 - --- Gangers
 - Site managers and/or office staff
 - Chief executive
 - Dichotomies; O for "No", 1 for "Yes". The addition gives JOBDES.
 - 3.2.6. Whether there is any manual of procedures (MANPRO):
 - No : O
 - Yes: 1
 - 3.2.7. Whether main policies are written down and circu
 - lated (WRIPOL):
 - --- No : 0
 - Yes: 1
- 3.2.8. Whether production schedules or programmes are
 - used (WFLPRO):
 - No : 0
 - Yes: 1

- 3.2.9. Whether any research and development programs and/or reports are prepared and circulated within the company (RESPRO):
 - --- No : 0
 - Yes: 1
- 4. Concentration of authority (CONAUT):

Twenty three types of decisions are given below. The company scores 1 for each decision given within the company. The addition of all scores gives CONAUT.

a) Qualifications and number of site personnel

b) Appointment of site staff from outside the company

- c) Promotion of site staff
- d) Salaries of site staff
- e) To spend unbudgeted or unallocated money on capital items
- f) To spend unbudgeted or unallocated money on revenue items
- g) What type or what brand of new equipment to be used
- h) To undertake a new type of job
- i) To determine marketing territories covered
- j) The extent and type of the market to be aimed for
- k) The costing system
- 1) What sort of control and inspection to be used
- m) Whether to use work study
- n) Dismiss a site staff member
- o) Training methods to be used
- p) Buying procedures
- q) Which suppliers or materials to be used
- r) What and how many welfare facilities to be provided
- s) The price of the output

- t) To alter responsibilities/areas of work of specialist departments
- u) To alter responsibilities/areas of work of line departments
- v) To operate a new department
- w) To tender for a new job

Part 5:

3.:

General variables:

- 1. Length of time for which network analysis has been used (SINCEW):
- 2. Multi-project scheduling and various computer facilities:
 - Dichotomies; 0 for "No", 1 for "Yes".
 - Multi-project scheduling (MULPRO)
 - ---- Vusual display units (VISDIS)
 - --- Graphical putput (GRAPH)
 - Characteristics of projects planned by network analysis:
 - Complexity (COMPLEX), degree of repetition (REPET), flexibility
 - (FLEXI), uncertainty (UNCERT), time-limitations (TIMLIM),
 - resource-limitations (RESLIM), and financial limitations (FINLIM) were marked on the following three point scale:

- Low (or relaxed in the case of the last three variables): 1
- --- Average
- High (or tight in the case of the last three variables) : 3
 4. Extent of network analysis use:
 - Percentage of projects (value-wise) for which time analysis
 is carried out (TIMANA)
 - --- Percentage of projects (value-wise) for which time and
 - . resource analyses are carried out (TIMRES)
 - Percentage of projects (value-wise) for which time, resource and cost analyses are carried out (TIRECO)
- 5. Kind of diagram used (ARROW):
 - --- Arrow diagrams : 1
 - --- Precedence diagrams: 0

- 6. Extent of computerized applications (COMPUT):
 - --- Computerized: 1
 - ---- Manual
- 7. Kind of time estimate used (SINGLE):

: 0

- Single time estimates: 1
- Three time estimates : O
- 8. Kind of resource analysis used (RESAGG):
 - --- Percentage of projects where resources are aggregated: 1
 - Percentage of projects where resources are levelled : 0

- 9. Size of organization:
 - Annual turnover (TURNOV)
 - Annual profits before taxation (PROFIT)
 - --- Number of employees (NOEMPL)
- 10. Number of projects currently undertaken (NOPROJ).
- 11. Kind of job undertaken (KINDJO):
 - Building jobs
 - Building and civil engineering jobs: 2
 - --- Civil engineering jobs
- 12. Kind of contract undertaken:
 - Dichotomies; O for "No", 1 for "Yes".
 - Open competitive tenders (OPENT)
 - --- Negotiated contracts (NEGOT)
 - Speculative building (SPECUL)
- 13. Geographical location of jobs (JOBLOC):
 - --- Local projects : 1
 - --- National projects : 2
 - --- International projects: 3

- 14. Expansion policy (EXPANP):
 - No expansion
 - --- Expansion in present field: 1
 - --- Expansion in new fields : 2
- 15. Whether the company accept low bids for prestige reasons (LOWBID): -- No : O

: 0

- Yes: 1
- 16. Age of company, in years (FOUND).
- 17. Range of operation (OPERAN):

This variable is determined by subtracting the contract value of the smallest job undertaken by the company from the value of the largest job.

APPENDIX L

THE FEEDBACK SURVEY

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The feedback survey:

On completing the analyses of the data a summary of the findings (Part 1 of this Appendix) was sent to all respondents. Interviews were then conducted wirh four planning engineers and four site managers on the basis of the questions itemized in Part 2. A synposis of the replies follows each question in Part 2.

Part 1:

FACTORS WHICH AFFECT SUCCESS IN NETWORK ANALYSIS

APPLICATIONS

by D. Arditi, research student, Department of Civil Engineering, University of Technology, Loughborough.

The degree to which NA is successful had been quantified in this study by assessing the extent to which it has come up to the expectations of key individuals occupying positions in the organisation which require direct involvement in its application. Employee satisfaction and welfare, apart from being an organisational aim in itself in many cases, is also assumed to be related to short term or long term company objectives.

It has been hypothesised that "success" as defined above is dependent on the way it is applied, on the way it is introduce, and on the environment in which it is used. These have been quantified and categorised into four main groups of variables: <u>Methods of</u> <u>Application</u> which deal with the procedural aspects of NA such as updating procedures and frequency, determination of the degree of detail, the use of computer programs, etc.; <u>Methods of Introduction</u> which contain attitudinal and behavioural variables such as perceived changes in status, authority, basic securities etc. due to the introduction of NA, extent of support for NA given by different echelons of management, attitudes to training courses, etc.; <u>General Company Characteristics</u> which deal with the context (size of company, types of jobs undertaken, expansion policy, etc.) in which NA is used; and finally, <u>Organisational Characteristics</u> which provide information about the organisation structure. Evidence was assembled from interviews with a Planning Engineer and a Site Manager in each of 15 companies that formed the sample. The reason why two persons were contacted in each company was the belief that incumbents of different positions in an organisation have different opinions, expectations and views (and sometimes they even perceive the same situation in rather different ways) depending on their interests, aspirations, status, background etc.

The data were analysed using multiple regression and correlation techniques. The principal findings of the research are:-

Success as viewed by Planning Engineers is likely to be higher if: (a) There is continuous and increasing senior management support.
 (b) They are working with SM's who have advanced site experience.

- (c) NA has not been introduced in the first place because of contractual obligations.
- (d) The cost of using NA is as small as possible.
- (e) They have sufficient information at the start of a project to construct a reliable network.
- (f) Computer programs (if used) are specially designed (preferably by company staff) to fit their particular requirements.
- (g) Sub-networks are used as much as possible.
- (h) The company they are working for is relatively small but has an ambitious expansion policy.
- (i) Cost analysis is not carried out in conjunction with networks.
- (j) The projects they undertake have high uncertainty, high flexibility characteristics, and they are time and resource limited.

(k) The company they are working for is as independent as possible,i.e., most decisions are given independently of parentorganisations.

- 2. Success as viewed by Site Managers is likely to be higher if:-(a) PE's stop emphasising the technical aspects of NA in their relationship with SM's and rather concentrate on human relations to make it work.
 - (b) There is sufficient support from senior management and the majority of SM's when NA is first introduced.
 - (c) SM's ability to cope with complicated networks, the complexity of the job and clients' requirements are used as criteria by PE's when determining the degree of detail of a network.
 - (d) Networks are updated as little as possible and when they are updated only the durations are reviewed and the logical sequence is kept fixed.
 - (e) The company they are working for is relatively small but gets overseas contracts also.
 - (f) The company they are working for undertakes mainly civil engineering jobs which have high uncertainty and high flexibility characteristics.
 - (g) Resource analysis is carried out separately and not in conjunction with the network; but, in case it is carried out in conjunction with the network, is carried out for parts of the project at a time rather than for the entire project at the start.
 - (h) Arrow diagrams rather than precedence diagrams are used.
 - (i) Contractual obligations are not the reason for introducing and using computer programs rather than manual methods.
- 3. Finally correlation coefficients indicate that success scores are likely to be higher if:-
 - (a) There is a felt need (especially on the site manager's part)

- for a new more advanced technique when NA is being introduced.
- (b) The first application is carried out by manual methods rather than a computer program.
- (c) Planning engineers and site managers are not sent to management courses to learn about NA.
- (d) Computer programs are used as little as possible.
- (e) Float values associated with each activity are not known to most people on site.

Part 2:

2.

Questions discussed in the feedback survey with planning engineers:

- Network analysis seems to be more successfully applied in smaller companies. Do you agree with this? Why?
 - Agree : 4
 - Disagree: None

Most planning engineers indicated that in smaller companies, everybody, including senior management, was more involved in the technique; one of them said that training was easier, and another indicated that the issue tended to become a common objective in smaller companies, whereas in larger firms two distinct groups were formed (one who likes network analysis and uses it, and one who dislikes it and avoids using it) producing a "lack of union". Network analysis seems to be more successfully applied in jobs which have high uncertainty, high flexibility, low degree of repetition, and low complexity characteristics. Would you agree that less complex jobs are better suited to network analysis? Why?

— Agree : 4

--- Disagree: None

All respondents agreed that it was easier to plan a job by network analysis if the job was not complex. They made it clear however that being more successful in less complex jobs did not mean that highly complex jobs were not suited to network analysis, but only more difficult to plan.

3. Network analysis is likely to be more successful in companies who have an ambitious expansion policy. Do you think there is any causal relationship between success and expansion policy? Two of the repondents indicated that an ambitious expansion policy was prerequisite for higher success in network analysis applications. One of them thought that it was the introduction of network analysis that helped formulating ambitious expansion policies. The fourth respondent's view was that this relationship worked both ways.

Planning engineers' success scores are likely to be higher if cost control is not carried out in conjunction with the network. Would you agree with this? Why?

- Agree :

4

5.

- Disagree : None

3

--- Don't know: 1

The reason given by those who agreed was that cost control by networks was too complicated.

Continuous and increasing senior management support is likely to enhance success as expected by planning engineers. Do you think there is any causal relationship between these? Why?

One of the respondents thought that success in network analysis applications was dependent on senior management support. The remaining three indicated that they had not observed a cause and effect relationship.

- 6. Planning engineers' expectations of success are likely to be higher if a planning department is not established as a direct result of introducing network analysis. Do you agree with this? Why?
 - Agree : 4

- Disagree: None

All respondents indicated that a planning department

established for the purpose of using one single planning technique was bound to fail. A planning department should use the appropriate technique for the appropriate job.

The majority of planning engineers regard their relationship with site managers as informal, whereas the majority of site managers regard their relationship with planning engineers as formal. Why do you think this is so?

7.

There were four different answers to this question. One of the repondents said that he did not know. The second one indicated that normally, the relationship was a formal one, but that the site manager being a diplomat let the planning engineer generally believe that it was an informal relationship. According to the third repondent, site managers regarded this relationship as formal because they regarded planning engineers as "spies". Finally, the fourth respondent agrees with the third respondent and added that personality played also an important part.

8. Planning engineers' success scores are likely to be higher if their relationship with site managers is as informal as possible, whereas it is completely the opposite for site managers. Do you agree with this finding? Could you explain why?

All respondents agreed that an informal relationship was the best kind of relationship for higher success.

9. The majority of planning engineers feel that site managers do not need the assistance of a planning engineer, whereas the majority of site managers think that they need a planning engineer to help them plan their job. Why do you think there is such a difference of reponse?

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All respondents agreed that site managers needed the assistance of a planner. As to the reasons for planning engineers' response: one respondent explained it by saying that the planning engineers in the sample worked probably with above average, very competent site managers; two respondents indicated that certain site managers did not take their planners' ideas into consideration very often, which perhaps lead planning engineers to think that they were not needed. Finally, the last respondent said that if the planning engineer did not help the site manager with the programming of the job, a member of site management probably would.

10. Success in general is likely to be higher if site managers are not sent to courses. Do you agree with this? Why?

— Agree 💠 : 🧎

- Disagree: 3

The respondent who agreed with this finding said that courses were too theoretical and that the best way of training people was to have them in the planning department for a while. The remaining three respondents agreed that courses were necessary and generally successful. They suggested however that a vital week at the start of a job spent in a course, and overenthusiasm after attending the course could possibly explain the finding.

11. Success as expected by planning engineers is likely to be higher if both durations and logical sequence are reviewed at each update, whereas success as expected by site managers is likely to be higher if only durations are reviewed at each update and the logical sequence is preserved. Why do you think
there is such a difference?

Two respondents agreed with site managers that the logical sequence should be kept fixed, because a change in logic would necessitate a change in site managers' way of thinking, causing considerable inconvenience. The remaining two respondents indicated that a review of the logic at each update was essential for higher success. They also indicated however that they could understand site managers' views that considerable time and effort were needed to absorb and digest extensive modifications at each update.

- 12. Planning engineers' success scores are likely to be higher if float is distributed evenly among activities. Do you agree with this? Why?
 - Agree : None
 - Disagree: 4
 - None of the respondents were able to interpret this finding.

Part 3:

Questions discussed in the feedback survey with site managers:

 Network analysis is likely to be more successful in smaller companies. Do you agree with this? Why?

- Agree : 2
- Disagree: 2

The two respondents who agreed with the finding offered the following explanations: network analysis is introduced and absorbed quicker in smaller companies; the individual who introduces network analysis knows everybody involved better than had he been in a larger company, and has the opportunity of selling it to each of them separately; the positive results of network analysis can be seen better, quicker, and by everybody in smaller companies; smaller companies undertake smaller jobs, and it is easier to plan smaller jobs; and finally, in smaller jobs there is more architect/consultant involvement which is necessary for better planning. The two respondents who disagreed with the finding did not see any reason why smaller companies should be more successful in network analysis applications. Both of them indicated that they would have expected larger companies to be more successful.

2. Network analysis is likely to be more successful if applied to jobs which have high uncertainty, high flexibility, low degree of repetition, and low complexity characteristics. Would you agree that less complex jobs are better suited to network analysis? Why?

- Agree : 4

— Disagree: None

The explanations provided were: less complex jobs need less detailed planning and therefore are likely to be more successful; and, highly complex programmes have to be updated frequently.

Network analysis is likely to be more successful in companies who undertake overseas jobs. Do you agree with this? Why?

— Agree :

3.

4.

--- Disagree : None

- Don't know: 1

Those respondents who agreed indicated that material deliveries were very important in overseas jobs and that one had to rely on the programme. One of them added that it was easier to plan in cases where labour is not scarce.

Site managers' expectations of success are dependent on the kind of diagram planning engineers use. Higher success is likely to occur when arrow diagrams rather than precedence diagrams are used. Do you agree with this? Why do you think this is so?

- Agree : 2

- Disagree : None

— Don't know: 2

Those who agreed indicated that this finding could possibly be the result of habit and initial training in arrow diagrams. Those who answered "Don't know" made clear that the only thing they were interested in was the final bar-chart transformation. 5. Network analysis is likely to be more successful in companies who undertake mainly jobs of civil engineering nature. Do you agree with this finding? Could you explain why?

- Agree : 4

- Disagree: None

All respondents agreed that jobs of civil engineering nature had a smaller number of less complex, better defined activities which were easier to programme. One of them added that there were not so many different materials and sub-contractors as in building jobs.

Success as expected by site managers is dependent on the extent to which site managers and senior management support network analysis when it is introduced. How important do you think this support is?

All respondents agreed that senior management support was very important when network analysis was being introduced. One of them said it was "fundamental". Another respondent indicated that it was senior management support that caused site managers to support network analysis as well.

Site managers' expectations of success are likely to be enhanced if planning engineers stop concentrating on technical aspects, and rather emphasize human relations to make the technique work. What do you think of this finding? Do you agree with it? Why? -- Agree : 4

6.

7.

— Disagree: None

Two of the respondents held the view that a good relationship between a planning engineer and a site manager should be one of the major objectives. According to one of these two respondents, this finding was the most important result of this research study,

8. The majority of planning engineers regard their relationship with site managers as informal, whereas the majority of site managers regard their relationship with planning engineers as formal.

Why do you think this is so?

Two of the rspondents said they did not know. One respondent indicated that site managers resented being told what to do by a planning engineer with little site experience, and consequently, kept the relationship as a formal superiorsubordinate relationship. According to the fourth respondent, planning engineers were kept at a distance by site managers because they were regarded as "spies".

9. Planning engineers' success scores are likely to be enhanced if their relationship with site managers is as informal as possible, whereas it is completely the opposite for site managers. Do you agree with this finding? Why?

Three respondents agreed that the best relationship was informal because it created a better working atmosphere. One respondent said he did not know.

10. The majority of planning engineers feel that site managers do not need the assistance of a planning engineer, whereas the majority of site managers think that they need a planning engineer to help them plan their job. Why do you think there is such a difference of response?

All respondents agreed that site managers needed the help of planning engineers. According to one of the respondents, planning engineers were not aware of the fact that they were an integral part of the site management team. Two respondents indicated that planning engineers did not feel needed because site managers did not always use their suggestions. According to the last respondent, planning engineers expected site managers to stick to the programme; when site managers regarded the programme only as a guide and made improvisations, they felt that their services were not really used.

Success as expected by planning engineers is likely to be higher if both durations and the logical sequence of activities are reviewed at each update, whereas success as expected by site managers is likely to be higher if only durations are reviewed and the logical sequence is preserved. Do you agree with this? Why do you think there is such a difference?

According to three of the respondents the logic of a network should never be modified. The major reason for this was stated as follows: after every major modification to the programme, site managers would have to spend considerable time and effort to study and understand the new programme, and to modify material schedules and sub-contracting arrangements accordingly. They could however understand why there was a different finding for planning engineers. They indicated that planning engineers were not generally practical minded and that they would modify the logic frequently for the simple purpose of safeguarding themselves and their programme.

12. Site managers' success scores are likely to be higher if resource analysis is not carried out in conjunction with the network. Do you agree with this? Could you explain why such a result has been obtained?

According to two of the respondents resource analysis was an unrealistic method. The other two indicated that resource analysis was essential, but not in conjunction with a network. In cases where resource analysis is carried out, site managers' expectations of success have been found to be higher when only

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13.

parts of projects are resource analysed at a time, rather than the entire project at the start. Do you agree with this? Why do you think this is so?

All respondents agreed that resource analysis of entire projects was bound to be unrealistic because there was not sufficient information at the start of a job.

- 14. Although resource analysis is not favoured by most site managers, results indicate that success as expected by site managers is likely to be higher if float is distributed evenly among activities, or according to the results of a resource analysis. Do you agree with this? Why?
 - Agree : 2
 - --- Disagree : None
 - Don't know: 2

The two respondents who agreed indicated that it was easier to distribute float evenly and that is saved the trouble of resource analysing the project.

- 15. Success in general is likely to be higher if site managers are not sent to courses. Do you agree with this? Why?
 - Agree : 4

- Disagree: None

All respondents agreed that courses were too theoretical and concentrated. Two of them said that site managers became over-enthusiastic after attending courses and that they tried to be "too clever".

16. Site managers' expectations of success are likely to be enhanced if the direct authority of the planning department increases as a direct result of introducing network analysis. Do you agree

with this finding? Why?

- Agree : 3

--- Disagree: 1

The three respondents who agreed indicated that when a network was prepared, responsibility for it was shared between the planning engineer and the site manager, hence transferring some of the site manager's workload to the planning engineer.

APPENDIX M

CONSTRUCTION STATISTICS

Part 1:	Number of firms and value of work done analysed	• •
	by trade of firm	467
Part 2:	Number of firms and value of work done analysed	e
	by size of firm	468
Part 3:	Number of firms and value of work done analysed.	
e a systemic Second	by region of registration	400

Table 1

NUMBER OF FIRMS AND VALUE OF WORK DONE ANALYSED BY TRADE OF FIRM

Trade of Firm	Number of Firms (%)	Value of Work Done (%)
General Builders	42.8	24.6
Building and Civil Engineering		
Contractors	3.8	34.7
Civil Engineers	1.9	9.4
Plumbers	10.4	3.3
Joiners and Carpenters	6.9	2.0
Painters	16.9	3.0
Roofers	1.9	1.8
Plasterers	3.9	1.4
Glaziers	0.4	0.4
Demolition Contractors	0.4	0.2
Scaffolding Specialists	0.1	0.6
Reinforced Concrete Specialists	0.3	1.3
Heating and Ventillating Engineers	1.7	4.7
Electrical Contractors	5.4	4.7
Asphalt and Tar Sprayers	0.3	1.9
Plant Hirers	1.5	2.5
Flooring Contractors	0.9	0.8
Constructional Engineers	0.5	2.7
Total	100.0	100.0

Source: These percentages were calculated by using the figures given in the Annual Bulletin of Construction Statistics 1968, MPBW, Construction Economics Division, No. 10, 1969.

Tabl	e	2
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NUMBER OF FIRMS AND VALUE OF WORK DONE ANALYSED BY SIZE OF FIRMS

Size of Firm	Number of Firms (%)	Value of Work Done (%)
NIL/1	25.2	1.0
2-7	45.6	7.8
8-13	11.3	5.5
14-24	8.1	7.4
25-34	3.0	4.9
35-59	3.0	7.6
60-79	1.1	4,4
80-114	0.9	5.4
115-299	1.2	13.4
300-599	0.3	9.8
600-1199	0.2	9.5
1200+	0.1	23.2
Total	100.0	100.0

Source:

These percentages were calculated by using the figures given in the Annual Bulletin of Construction Statistics 1968, MPBW, Construction Economics Division, No. 10, 1969.

Table 3

NUMBER OF FIRMS AND VALUE OF WORK DONE ANALYSED

BY REGION OF REGISTRATION

Region of Registration	Number of Firms (%)	Value of Work Done (%)
Northern	4.4	4.2
Yorkshire and Humberside	9.0	6.8
East Midlands	6.0	5.4
South West	9.1	5.3
Wales	5.1	3.2
West Midlands	9.4	10.0
North West	11.4	9.0
Scotland	7.3	8.4
East Anglia	3.2	2.9
South East London	13.8	28.0
Southern Counties	7.1 and 180	5.9
South Eastern Counties	8.3	6.1
Eastern Counties	5.3	4.8
Total	100.0	100.0

Source: These percentages were calculated by using the figures given in the Annual Bulletin of Construction Statistics 1968, MPBW, Construction Economics Division, No. 10, 1969.

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A COMPLEXE

A list of variables is given below in alphabetical order. The numbers in the first set of parantheses refer to sections in Chapter V, where findings are reported. The information in the second set of parantheses refer to sections in Appendix K, where measurement methods are described.

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