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CASE STUDIES ON INDUSTRIAL PROJECT IMPLEMENTATION

INDUSTRIAL PROJECT IMPLEMENTATION IN THE SUDAN.* (1969)

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INDUSTRIAL PROJECT IMPLEMENTATION IN THE SUDAN

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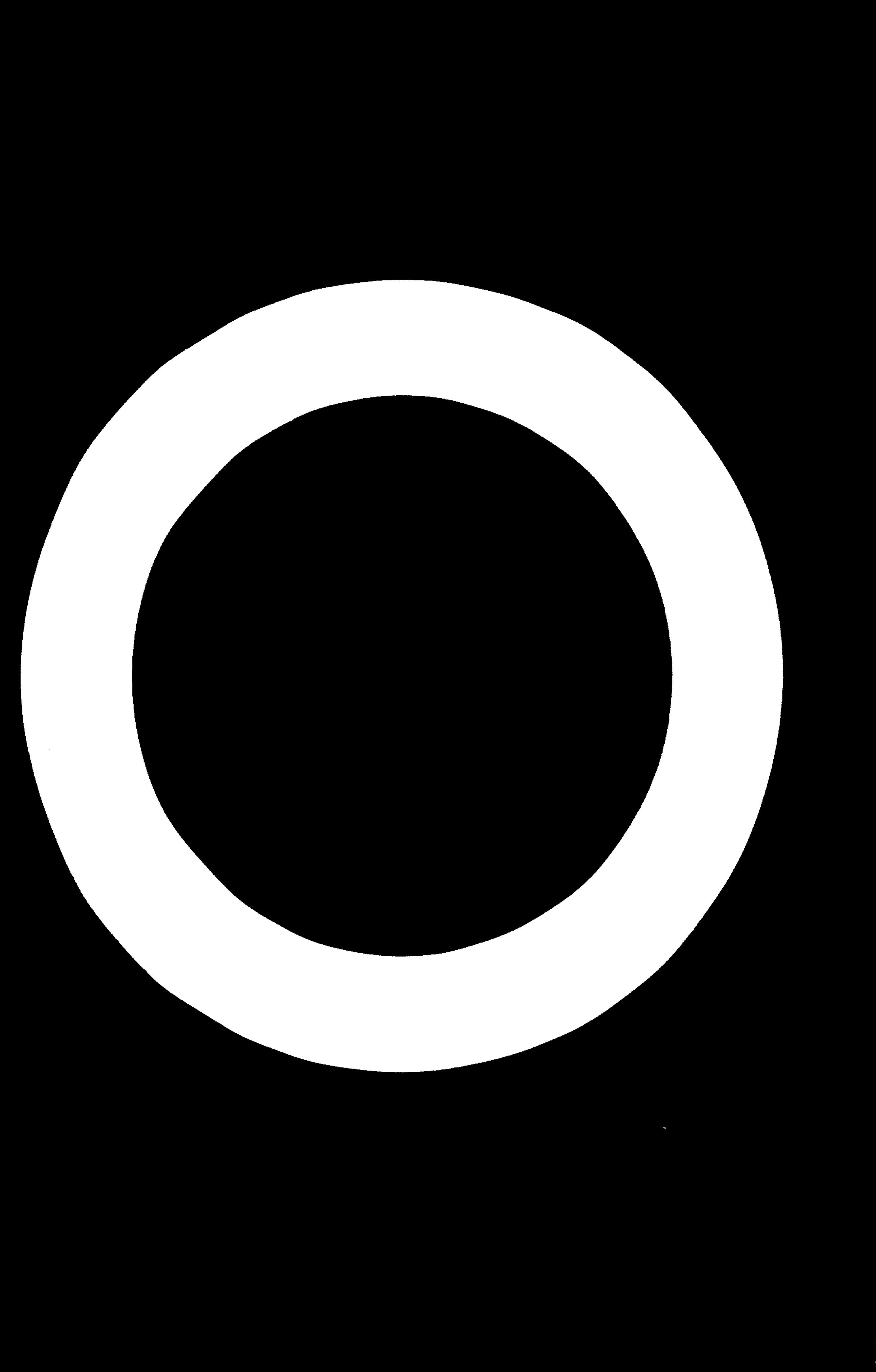
SUMMARY

This study aims at investigating the utility of applying activity network analysis to the implementation of projects in developing countries. The study is divided into two main parts: a case study and general observations.

The case study examines the implementation of the project of building a cement factory in the Republic of Sudan. The study covers the period from the initial contemplation of the project up to its completion. Critical path computations were made using estimated and actual duration times for the project activities. An analysis of delays, their causes and costs was conducted, and the corrective measures which were actually taken were reviewed.

Based upon the results of the case study and the author's experience with developing countries, general observations were made about the peculiarities of delays in developing countries. Recommendations were then presented for measures to improve the performance in project implementation in developing countries. They include measures which would prevent or minimize delays, and the design of information and decision-making systems. The author also recommended steps which the United Nations Industrial Development Organisation (UNIDO) could take in order to help developing countries with their implementation problems.



CHAPTER (1)

INTRODUCTION

1.1 The Background

The application of modern mathematical techniques to the solution of management problems of developing countries has so far been restricted due to a number of factors. Foremost among these are:

1. Overemphasis of the technical, rather than the managerial aspects of industrial problems by those who attempt to solve them. For example, faced with the problem of a bottleneck in a production process, a decisionmaker in a developing country will be more inclined to add new machinery rather than improve the utilization of existing ones.

2. Lack of interest and faith on the part of decision-makers in the potential benefits of modern techniques.

3. Lack of adequate and accurate information concerning the problems under study. This has prompted decision-makers to rely more heavily on their intuition and rules of thumb for the solution of their problems.

4. Scarcity of personnel experienced in the development and use of these techniques.

5. Absence of a common language for communication between decisionmakers and specialists.

6. Unavailability of computing facilities which can handle large-scale problems.

7. The widespread assumption that management problems of developing countries are nonquantifiable, or that the quantitative aspects of the problems are too simple to warrant the use of modern techniques.

In the author's opinion, it is the lack of skill on the part of management more than the lack of modernity of the equipment that accounts for the slower rate of growth of industrial organizations in most developing countries. A great deal of benefit can be gained if management is educated in the new concepts and techniques.

The application of modern mathematical methods to managerial problems of industry, better known as Operations Research (O.R.), can benefit industrial concerns in developing countries in many ways. For example:

1. They can help managers in stating their goals and objectives more explicitly so that they are better able to establish clearer policies and guidelines for their own decisions and for their subordinates to be guided by.

2. They may assist in outlining the range of possible alternatives to solve specific problems and the limitations on the solutions.

3. They can be used for evaluating the quantifiable consequences of alternative policies, strategies or courses of action against criteria derived from the objectives of the organizations, and for selecting the optimum alternative(s). Criteria of choice may be given as tangible quantities such as profits, costs, sales or production volumes or as intangible quantities such as risks or variabilities involved. A test of the sensitivity of the optimum choice to changes in the factors governing the choise can also be provided, which would indicate the desired level of accuracy in determining the values of those factors. Given a specific range of variation in the values of the operating factors, sensitivity analysis will provide the range of variation to be expected in the values of the criterion variables. This again helps in reconsidering the decision and in setting provisions to adjust the system once deviations in the values of the factors occur.

4. They can assist in determining the costs of satisfying the noneconomic objectives of the firm (such as the political or social objectives), so that policymakers can decide how far they can afford to choose non-economic alternatives. At the same time, mathematical methods can be useful in finding out the most economical way to achieve a noneconomic objective.

Even if the information available to tackle a management problem in a developing country is meagre, it would still be more advantageous to use it in a rational way than to discard most of it and resort exclusively to intuition and experience.

Perhaps a realistic approach would be to seek the application of simplified managerial tools which are compatible with the accuracy and availability of the data of the problems which they tackle, and then to sharpen the tools and increase their sophistication as more data become available, people become more experienced in the models, and positive results emerge from these applications.

A very important management area which largely escaped the attention of specialists and managers alike is the area of industrial project implementation. A great mass of literature has been written about planning and multitudes of techniques have been devised in order to improve the planning process, whereas implementation has generally been taken for granted as a series of routine operations which can best be performed by strictly adhering to a given schedule. In practice, this has not been true. Many projects which were meticulously planned, both technically and economically, suffered considerable losses as a result of failures in their implementation.

The term, "Implementation of an industrial project", is referred to here as the sequence of steps taken in order to complete the construction of the project and to put it into operation at a specified percentage of its normal capacity. The starting point may be after the occurrence of any one of the following events:

1. The initial decision to consider the project. This implies a very broad definition of implementation, encompassing most of the planning stages as well as the process of executing the plans. It only excludes the stages which lead to the initial contemplation of the project. In a planned economy, this would be the economic planning studies at the national level, which point at the need for investment in projects such as the one under consideration.

2. The completion of the economic and technical studies of the project and the final preparation of tenders. This includes feasibility studies and the choice of the production processes.

3. The choice of the most suitable bids and the finalization of agreements with suppliers and contractors. The stages which follow from this point on are generally characterized by the execution of plans already laid down. In other words, the decision content of these stages becomes less and the action content becomes more prominent. This is the most widely accepted starting point in the definition of "implementation", as it marks the dividing line between two distinctive stages. It should be noted, however, that it does not mark a precise point in time, since most projects involve more than one tender, and one of them might be in the process of execution while another one is still in the study stage.

Several people consider project implementation to be synonymous with the construction of the project. This is a very narrow definition because other activities, such as putting the project to work, are just as important as construction itself, and keeping them out of consideration might expose the project to serious delays, a situation which is illustrated in the case study in this paper.

The definition of "implementation" which will be adopted in this study is the most general one, starting with the contemplation of the project and ending with the development of production output to a specified percentage of capacity. This definition permits a greater latitude in analyzing the sources of delay in the total cycle of the project. It will be seen that all the activities along the total cycle are amenable to the same type of mathematical treatment adopted in this study, which is the use of a very simple mathematical tool known as "activity networks".

It might then be worthwhile to attempt to apply simple mathematical tools, such as network analysis, to problems of project implementation in developing countries as a test of the potential use of such techniques in these countries. Such an attempt would suggest ways in which the problems encountered in these applications should be tackled, and indicates how the use of more sophisticated models may be explored.

Two study strategies are possible: the first is to conduct an extensive study, collecting general data about a large sample of projects; and the other is to carry out an intensive study of one or two cases, and following through with as much detail as possible. It is the belief of the author that the latter approach is more rigorous, since the results of a detailed study of a specific case can serve as a guideline for outlining the needed points of emphasis in a larger survey.

The country chosen for the study was the Sudan. The economy of the Sudan is representative of the economies of developing countries in their initial stages of development, and perhaps an industrial project established in the Sudan would meet with a large number of the problems typical of those countries.

1.2 Objectives of the Study

The object of the study is essentially to apply activity network analysis to an industrial project which has been recently completed or which is about to be finished, in the Sudan. The purpose of this application is to find out whether this technique could have improved the implementation of the project and prevented some of the delays which did occur. Another goal of the study is to determine ways in which the implementation of industrial projects in developing countries may be improved. This is accomplished by focusing on the following aspects:

1. the critical path of activities toward the completion of the project,

2. common sources of delay,

3. ways in which these delays may be anticipated and avoided and

4. costs of delay and the basis for decisions connected with project implementation.

1.3 Sudanese Industry

Most of the Sudanese industrial concerns are small size, relying heavily on manual work, and owned by families or partnerships. The traditional industries are leather tanning, textile, ivory products and a limited number of food-processing small-scale plants. Most of these concerns are around Khartoum but some are around other populated cities like Atbara. A few medium-sized plants, employing over 200, have been recently established or are under construction to produce textiles, cement, fertilizers, canned fruits, tanned leather, shoes, cardboard paper and dairy products. A number of these factories are government owned and operated. In order that the government be able to control the operations of its industrial investments, it established the "Industrial Development Organization", which is under the "Ministry of Industry".

The government also has controlling interest in other concerns. It affects this control mainly through the appointment of government representatives on the boards of the companies.

Most of the products of Sudanese industry are locally consumed. Distribution to remote regions of the Sudan is rendered difficult by the vastness of the land (one million square miles), and the inadequacy of the means of transportation.

Engineers, chemists, accountants and other professionals are provided by the University of Khartoum. Cairo University — Khartoum Branch also graduates a number of accountants every year. On the other hand, other than Khartoum Technical Institute, there is no school for the training of the needed technicians, and Sudanese industrial concerns have to take up the task of training their technicians and the workers.

No management or engineering consulting firmsoperate in the Sudan, other than a consulting firm, in Khartoum, which advises the companies on their labour and legal problems.

Another difficulty which Sudanese industrial concerns face is the lack of an industrial base. As a result of that, industrial companies have either to import their intermediary products or establish an industry which is integrated vertically, and both alternatives may not be economically desirable, with the result that the cost of material becomes relatively, and sometimes considerably, higher than that in more industrialized countries.

Labour costs are not generally in a better position than material costs, because although the hourly wages are much less than those earned by their counterparts in industrially-developed countries, the productivity is so low that it offsets most of the advantages of low wages. Added to the fact that the labour content of small- and medium-scale industries is high, the labour cost per unit of product is thus generally higher than what it is in comparable industries in developed countries.

A number of factors also contribute to the increase in the cost of equipment per unit of product. Among which are the costs of transporting this equipment from overseas, the reduced equipment utilisation and the low level of maintenance.

In addition to that, neither the government nor the consumers have any organization which establishes any control over the quality of the finished products. Besides, the government sometimes provides protection for local industry against importation. All this leads to a lack of pressure on the industrial companies to improve the quality of their products.

Increased production costs, reduced quality, inadequacy of the means of transportation, and the absence of capital for sales promotion are among the main causes behind the inability of Sudanese industrial concerns to export their products.

This means that the problems which a Sudanese manager faces are most challenging, and that Sudanese industry needs the best-trained of managers.

The Sudan is a country with vast natural resources, inhabited by people who are dedicated to their country and to world peace, and who have great ambitions toward industrial development.

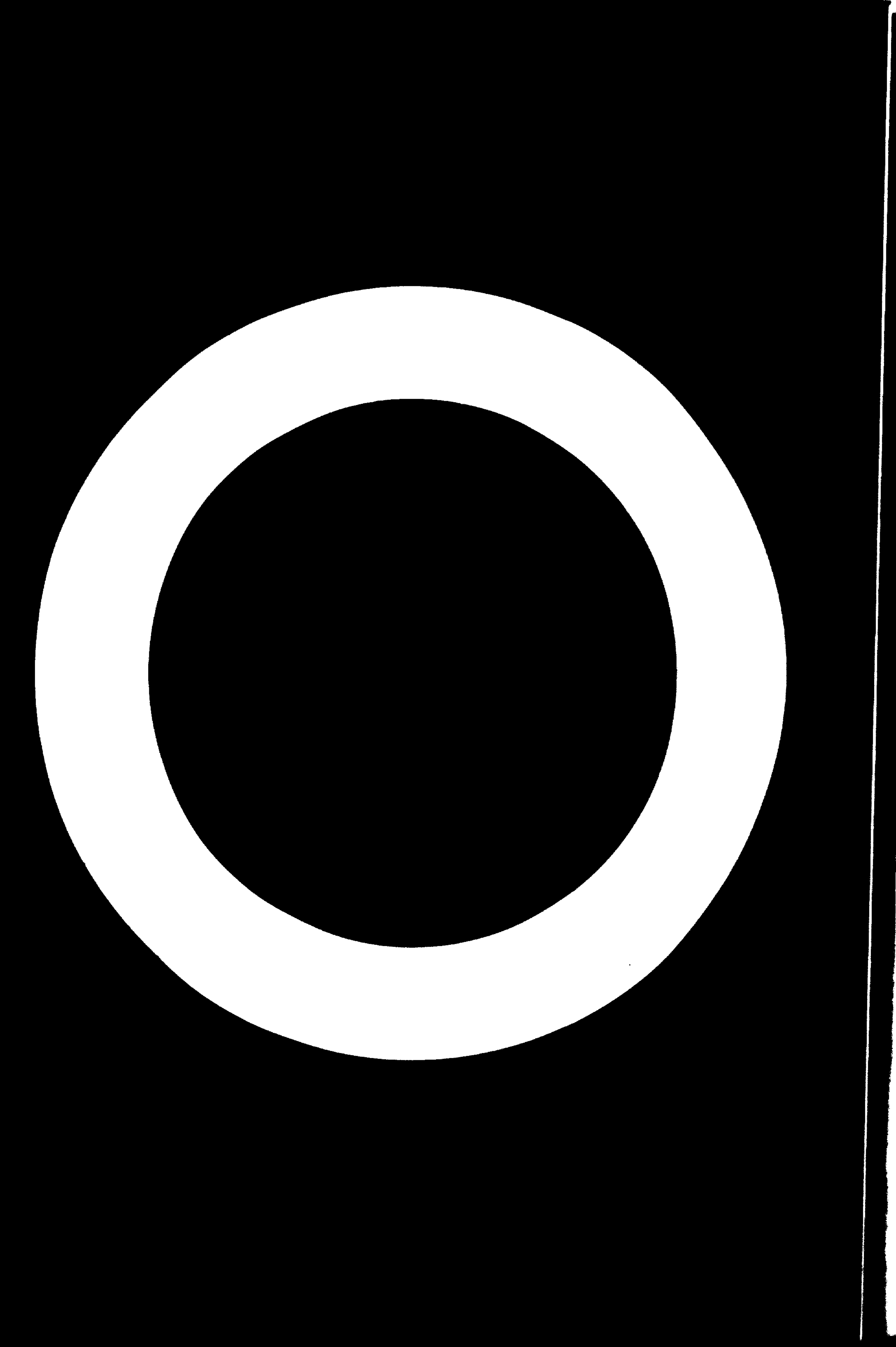
It is under this environment that modern management techniques can be most helpful.

It can be concluded that the problems of industrial companies in the Sudan contain most of the elements of problems of industry in a developing country, and a great deal can be learned about these problems by studying cases of implementation of industrial projects in the Sudan.

PART I

CASE STUDY

A CEMENT-PRODUCING PLANT



CHAPTER (2)

THE APPROACH

2.1 Selection of the Case

The range of choices for case studies was not a wide one and several factors contributed to that. As stated by a high official at the Ministry of Industry, projects started before the establishment of the Ministry were not given adequate analysis and preparation, and those created afterwards had not yet reached a significant stage in their implementation. He also pointed out the serious lack of data in old projects. The author believes that the official's statement is generally, but not literally, true. There are a number of projects which were given sincere efforts in planning and which demonstrated a satisfactory degree of success. However, the number of such projects is small, perhaps only because the total number of projects which can lend themselves profitably to the kind of analysis proposed in this study is small. Besides, very few factory owners and managers were willing to disclose information about their plants. The author visited a number of plants whose owners were kind enough to encourage the study, but the author found that the sizes of the operations were less than could be useful for the purposes of the study.

The author was finally fortunate to receive the help and encouragement of the Chairman of the Board of the Nile Cement Company, in Khartoum, to conduct the study on the project of establishing the company's plant at Rabak. The plant is approaching completion, but the experience which the company has gone through until it reached the present stage is illustrative of many of the problems of industrialization in developing countries, and is indicative of some of the approaches to solve them.

The present Chairman of the Board of Directors, who is actually the original promoter of the project, has made available to the author many of the studies which were conducted in preparation of the project, in addition to company files and publications. He has also given much of his precious personal time to inform the author about aspects of the history of the company which were not covered in the records.

The author decided that it would be wiser to take advantage of the available mass of facts, data and information about that project and study them in depth, than to scatter efforts on a number of superficial studies.

Data about the sequence of activities performed or are still required to be performed from the start of the project to its actual completion have been collected, which included both the planned and actual duration times of most of the activities. Information was also gathered about the details of the activities and the prevailing circumstances under which they were performed. This included the causes of delays and how they were treated. The data have been updated until the time of writing this report, in October, 1968.

2.2 The Cement Industry in the Sudan

In order to clarify the context in which the present cement project was contemplated, a brief review of the cement industry in the Sudan is in order. That, in turn, requires a glance at the economy of the Sudan.

The Sudan is a predominantly agricultural country. Its possibilities in this direction are almost without limit. The agricultural producing capacity which has been limited in the past due to water shortage is being met by the construction of dams, two of which have been recently constructed: the large Roseires and Kashm El Girba dams.

In addition to increasing the agricultural output of the land, the government is also interested in industrial development. A number of plants are presently under construction and others are being planned as an integral part of an industrial development plan.

Although over 90% of the exports are agricultural or animal products, with very little, if any, added industrial value, the country now realizes that in order that it may acquire the foreign currency needed for development, more industrialized products will have to be exported. This puts a pressure on the efforts toward industrialization.

The ambitious plans of the Sudan government for the improvement of agriculture and the development of industry cannot materialize without the establishment of large construction projects. Such projects do not only include dams, irrigation systems and buildings of industrial plants, but a host of other important constructions as well. To name a few, one can mention water supply and sewage systems, highways, bridges, airports and office buildings, which are examples of projects directly related to the development plan, but there are also housing developments, schools, hospitals and commercial buildings which become more needed as development progresses.

All of this reveals the increased need for cement as one of the main raw materials used in construction. At the time the present cement project was contemplated (in 1959), only one cement factory existed in the Sudan. Located in Atbara, that factory produced 150,000 tons of cement per year, which was about half of the expected demand for 1968.

In 1959, the two major dams referred to above had not been started, and since together they were estimated to require about 320,000 tons of cement, the projection of demand for cement in the following years was estimated to be rising sharply. Even now, at the time this report is being written, October, 1968, when the two dams have already been completed, the demand for cement is still rising, whereas the local production has not increased since then.

It was estimated that a great deal of savings and a conservation of valuable foreign currency could be effected if the added demand on cement were to be satisfied by local production rather than importation. This is why a group of Sudanese businessmen, headed by the enterprising present Chairman of the Board, contemplated the establishment of a company which they later called, "The Nile Cement Company", which is the subject of the present study.

CHAPTER (3)

PROJECT DESCRIPTION

3.1 Sources of Data

The data and information about the project have been extracted from the following sources:

1. Report on the Technical and Economical Feasibilities of a Portland Cement Factory at Rabak, Blue Nile Province—Sudan. Prepared by F.H. Kocks K.G. — Consulting Engineers, Coblenz-Germany, March, 1961.

2. Report on the Choice of Location of a Portland Cement Factory Near Rabak, Blue Nile Province—Sudan. Prepared by F.H. Kocks K.G. — Consulting Engineers, Coblenz-Germany, April, 1962.

3. The Complete Story of the Rabak Cement Plant. A statement prepared by the Chairman of the Board of Directors of the company and distributed over the shareholders, April, 1968. (In Arabic).

4. Company File: Gist of the Problem of the Project.

5. Company File: Financing.

6. Company File: Raw Materials.

7. Company File: Tenders.

8. Interviews with the Chairman of the Board.

The source of information about an activity is referred to by its serial number, followed by the page number wherever applicable, both between brackets. Hence, [1:80] means page 80 of the Report on the Technical and Economical Feasibility. In the few cases where no exact statement about a certain date or a duration time of an activity is given in any reference, an estimate of these quantities is made which checks with all other data of the project. In such cases, the word "Estimated" takes the place of the reference number.

3.2 Project General Information

The company was incorporated in January, 1961, under the name, "The Nile Cement Company (NCC)", with an initial capital of L.S. 1,000,000 ($2,800,000), to produce cement at an annual capacity of 100,000 tons of cement. The factory was to be located at Rabak, on the Kasti-Sinnar Railway line, about 65 kilometers north of Nyfer, a site which was believed to be rich in limestone (see Appendix 4, Figs. 6 and 8).

As perceived by the principal promoter of the project, the three basic constituents of the project were:

1. Its feasibility from both the technical and economical points of view. The main question to be asked here was, "Can cement be produced according to standard specifications at a cost competitive with imports and other local output?". The principal promoter sought the advice of a well-known specialized consulting firm called F.H. Kocks K.G., to obtain an answer to this question. He believed in the complexity of the production process and the need for precision in the construction phase of the project, and consequently he put a heavy emphasis on the reputation of the company he wished to contract with for construction. As an illustration of the degree of complexity of the production process, a flow diagram of production is presented in Fig. 5, Appendix 3.

2. The availability of raw materials: As was mentioned before in this report, many projects in developing countries suffer because most of their materials are imported. The main raw materials for this project are: limestone, clay, gypsum and oil. The quantities needed per year of each material to produce the annual rate of 100,000 tons of cement are:

limestone	180,000 tons
clay	26,000 tons
gypsum	3,000 tons
fuel oil	10,500 tons
diesel oil (for power)	2,600 tons

Clay is found in inexhaustible quantities along the White Nile and the Blue Nile valleys. Gypsum is best procured from Port Sudan, and oil is imported at a relatively high cost. However, the most crucial raw material is limestone, because of the quantities needed and the special qualities required in it. The promoter of the project resorted to several specialized agencies to help him with the problem of the identification of the most suitable site for mining for limestone. Among those agencies were the Geological Survey Department (G.S.D.) in the Sudanese government and Mackey and Schnellman. It is safe to say that limestone has been, and perhaps still is, one of the most awkward problems faced by the project.

3. Financing the project: The principal promoter sought several means of financing the project. They were mainly:

   a. Stock issue: to the public and the government.

   b. International financing: two organizations were approached:

      The International Finance Corporation (under the International Bank for Reconstruction and Development) and

      IMPRESIT: a consortium of Italian concerns participating in the construction of the Roseires Dam.

   Unfortunately, for reasons which will be explained later, no final agreement was reached with either source of international financing.

   c. Government or government-sponsored loans.

   d. Another important source of financing, for equipment purchases, is the credit terms of equipment suppliers.

Again, financing has been another difficult problem, and it has not been completely solved by the time this report is being written.

3.3 Definition of Terms

Project: A complex undertaking, by an organisation or a subdivision in an organisation, which consists of many interrelated activities aimed at attaining a specified goal. The organisation may be a company, a government agency, an educational institution, a military establishment, a charitable society, or any similar entity.

Activity: A distinct and time-consuming sequence of actions aimed at accomplishing a task or a series of interrelated tasks in a project. An activity has definite starting and ending points.

Event: A point in time marking the beginning or ending of one or more activities.

Critical Path: That particular sequence of activities which decides the length of time from the starting point of the project until its ending point (the total project completion time). A delay in any activity along this path will cause a corresponding delay in the total project completion time.

Total Slack or Float: The length of time which the ending of an activity may be delayed without increasing the total project completion time.

Free Slack or Float: The length of time which the ending of an activity may be delayed without delaying the start of any activity in the project.

Slack Activity: An activity whose total slack is not equal to zero.

Slack Path: A sequence of activities which are not on the critical path.

Subcritical Path: A slack path whose slack is minimum or is close to zero.

The above terms are used in the study of projects with activity networks.

It is obvious that both the total slack and the free slack for activities on the critical path are equal to zero.

For any project, precedence relationships exist between activities. "Activity A precedes activity B" or "A is a predecessor of B" means that A will have to be finished completely before

B can start. At the same time, other activities may have to precede B and A may be the predecessor of activities other than B.

Although the size and complexity of an activity is determined arbitrarily, depending on the degree of detail required in the analysis, an activity must not be defined so that half of it is not preceded by a certain activity and the second half is. In such a case, the activity should be divided into two distinct activities.

The definition of "project" as given in this section applies to the construction of the cement plant at Rabak, Sudan. An analysis of the project through activity networks can thus be conduoted.

An activity network is a graphical presentation of the activities of the project as a network.

A network is simply a set of nodes and branches (links). In activity networks the nodes are generally circles and the branches are arrows, whose directions represent the precedence relationships among activities and events.

The presentation of a project by an activity network may be done in any of two different methods:

a. activities are represented by circles and events by arrows and

b. activities are represented by arrows and events by circles.

It is the latter form of presentation which is followed in the present study.

Regardless of the form, all activities and events must emerge from a single node indicating the start of the project, and converge into another one marking its end.

An explanation of the uses of activity networks and an application of them to the cement project is given in the next chapter.

3.4 Description of Activities

Since activities are represented by arrows, each activity will be identified by the two numbers given to its terminal events. Hence, for any activity i-j, i is the starting event and j the ending one. The activities are so numbered that for any activity i-j, j is greater than i, and for any activity u-v preceding i-j, i is equal to or greater than v. These rules have been established for the purpose of the analysis which follows the construction of the network.

Table (1) below gives a list of the project activities, together with essential data about them.

Column (1) is a listing of activity numbers according to the code numbers of their terminal events. Activities have been ordered so that any activity following another one is listed after, but not before, that one. Also, all the activities starting from a certain event are listed in an uninterrupted sequence.

Column (2) is a brief description of each activity. A detailed description is given in the following section.

The actual starting dates of the activities are listed under column (3).

The immediate predecessors of each activity are given under column (4). Since if activity x-y precedes u-v and u-v precedes i-j, then x-y precedes i-j, then the mere mention that u-v precedes i-j after the knowledge that x-y precedes i-j implies that x-y also precedes i-j. That is why predecessors which are not immediate, that is, predecessors of predecessors, are not mentioned in column (4).

Column (5) gives the planned duration times of the activities. Part of this information has been mentioned explicitly in consultants' reports on feasibility studies, in company files, in the chairman's statement to the shareholders, or during his interview with the author. The data which could not be extracted

TABLE (1)
PROJECT ACTIVITIES AND DATA

(1) Activity Number	(2) Activity Description	(3) Actual Starting Date Month/Year	(4) Preceding Activity	(5) Planned Duration Months	(6) Actual Duration Months	(7) Reference Page
0-1	Contemplate project, make initial estimate of expenses, and sell idea	10/59	none	2	2	8
1-2	Acquire government approval of project and incorporate company	12/59	0-1	1	1	8
1-4	Seek technical assistance for initial raw material feasibility studies	3/60	0-1	6	6	8
2-3	Open bank account and allocate initial funds	1/60	1-2	1	1	8
2-4	Acquire permission to mine for raw materials	7/60	1-2	2	2	8
2-5	Study potential sources of financing	2/60	1-2	3	3	5;8*
2-6	Issue and sell common stock	1/60	1-2	2	2	5;8
2-7	Appoint Board of Directors	1/60	1-2	1	1	8

* Semicolons are used to separate between reference numbers, while commas are used to separate between page numbers of the same reference, and colons are placed between a reference number and its page numbers.

(1)	(2)	(3)	(4)	(5)	(6)	(7)
3-8	Seek technical assistance for feasibility studies: technical and economical	7/60	2-3	5	5	8
4-8	Conduct initial feasibility studies: raw materials	9/60	1-4 2-3 2-4	2	2	3:3;6
8-9	Feasibility studies: technical and economical	12/60	2-6 3-8 4-8	3	3	1:VII,113
9-10	Prepare equipment tender and invite offers	3/61	8-9	3	3	Estimated
9-11	Revise feasibility studies: raw material	1/62	8-9	9	23	3:3;6
9-12	Finalize plant location study	1/62	8-9	3	3	2
9-13	Acquire approval for public connection of utilities and power network to site	6/61	8-9	2	2	3:5,25
10-14	Contractors prepare preliminary offers	5/61	9-10	8	8	7;8
11-57	Finalize raw material study	12/63	9-11	6	58*	3:36;6
13-55	Expedite construction of utilities and connection of power line to site	4/65	9-12 9-13	8	9	3:5,25

(1)	(2)	(3)	(4)	(5)	(6)	(7)
14-19	Study plant and equipment bids	2/62	10-14	2	7	8
15-17	Acquire land and prepare site	1/65	9-12	2	2	2;3:13
15-18	Negotiate and finalize agreement with international financiers	5/61	2-5 9-11 9-12	8	Discont. 11/62	5
17-20	Construct temporary and supplementary power units	5/65	15-17	6	6	3:25
17-21	Construct utilities (water and drainage) within site	3/65	15-17	4	4	3:15,16,25
18-51	Acquire government approval on international financial arrangements		15-18	2	—	5
19-22	Negotiate with bidders and make preliminary agreement	9/62	14-19	2	3	7
20-52	Install power connection to quarry	6/65	17-20	5	5	3:25
22-23	Acquire import licence for equipment	12/63	19-22	1	1	Estimated
23-24	Finalize and sign equipment agreement (including design of civil work)	1/63	2-7 22-23	2	2	3:8
24-27	Suppliers produce first consignment of equipment	3/63	23-24	8	24	1:80;3:39

(1)	(2)	(3)	(4)	(5)	(6)	(7)
24–28	Recruit executives	5/65	23–24	2	2	3:13
25–26	Finalize plant layout and design of buildings	3/63	9–12 23–24	2	7	3:39
26–29	Finalize and sign civil work contract with equipment supplier	10/63	25–26	2	11	3:8;7
27–30	Suppliers ship first equipment consignment	3/65	24–27	1	1	3:15
28–34	Train executives	7/65	24–28	12	12	3:16
29–31	Issue and sell additional common stock	3/66	26–29	3	3	3:19;5
29–32	Suppliers produce second equipment consignment	9/64	26–29	14	23	1:80;3:39
29–33	Suppliers produce third equipment consignment	9/64	26–29	14	23	1:80;3:39
30–36	Clear first equipment consignment at customs, inspect and transport to site	4/65	27–30	1	3	1:80;3:27,28
31–50	Install rail, track and platform of branch railway	6/66	29–31	6	12	3:25;Estimated
32–40	Suppliers ship second equipment consignment	4/66	29–32	1	1	3:15;Estimated

(1)	(2)	(3)	(4)	(5)	(6)	(7)
33–41	Suppliers ship third equipment consignment	4/66	29–32	1	1	3:15;Estimated
34–38	Recruit professionals	7/66	28–34 29–31	2	2	3:17
34–39	Recruit technicians	7/66	28–34 29–31	2	2	3:28
35–36	Contractors construct buildings and foundations (Schedule I)	3/65	15–17 26–29	4	4	3:13,27
35–37	Company constructs other civil work (Schedule I)	3/65	15–17 26–29	4	4	3:13,27
36–50	Contractors construct buildings and foundations (Schedule II)	7/65	35–36 30–36	6	6	3:13,27
37–50	Company constructs other civil work (Schedule II)	7/65	35–37	6	6	3:13,27
38–48	Train professionals	9/66	34–38	6	6	3:[illegible],66
39–48	Train technicians	9/66	34–39	6	6	3:28,[illegible]
40–49	Clear and inspect second equipment consignment and transport to site	5/66	32–40	1	3	1:80;3:27,28
41–50	Clear and inspect third equipment consignment and transport to site	11/66	33–41	1	3	1:80;3:27,28

(1)	(2)	(3)	(4)	(5)	(6)	(7)
42-43	Install power connection to housing	7/65	17-20 35-37	4	4	3:25
44-45	Negotiate and finalize government loan agreement	6/66	2-6 29-31	1	1	3:61
46-47	Erect first equipment consignment	7/65	17-21 30-36 35-36 35-37	3	3	1:80;3:27
48-53	Recruit workers	3/67	38-48 39-48	3	3	3:28,66
49-50	Erect second equipment consignment	9/66	40-49 42-43 44-45 46-47	4	4	1:80,3:27
50-54	Erect third equipment consignment	12/66	31-50 36-50 37-50 41-50 49-50	5	5	3:39
51-52	Seek further financing	7/66	44-45	6	28*	3:63
51-55	Procure purchased raw material	11/67	44-45	9	9	3:25
53-55	Train workers	6/67	48-53	6	6	
54-55	Settle disagreements with contractor	5/67	50-54	0	16	3:49-59
55-56	Test and adjust erected plant	9/68	13-55 51-55 53-55 54-55	2	2*	3:60

(1)	(2)	(3)	(4)	(5)	(6)	(7)
56-58	Carry out pilot production	11/68*	20-52 51-52 55-56	2	2*	3:60
57-58	Prepare raw material resources for exploitation	10/68*	11-57 20-52 51-52	1	1*	3:60
58-59	Develop production to full capacity	1/69*	57-58 56-58	2	2*	3:60

from these sources were estimated by different means. One of the methods was to take actual duration times as the planned duration times in the activities where no delay was observed to have occurred. Where delays were reported the total length of the delays in each activity was subtracted from its actual duration.

The actual duration times, in column (6), are obtained by subtracting the actual starting date from the actual ending date of each activity. In very few cases estimates had to be made of the actual durations, based on the starting or ending dates of connected activities.

In column (7) the source of information is mentioned, using the reference code given in section 3.1 above.

3.5 Detailed Explanation of Activities

Only activities in Table (1) which are not self-explanatory are explained here.

0-1 The project was first contemplated by the principal promoter, who is the present Chairman of the Board of Directors, in October, 1959. He launched a campaign to sell the idea to the public and potential investors, which resulted in the cooperation of 200 promoters.

1-2 The government's approval of the project was given, on the basis of a proposed list of names for membership in the Board of Directors, for an initial capital of L.S. 1,000,000. The company was incorporated under the name, "The Nile Cement Company".

1-4 Technical assistance for initial raw material study was sought by the chief promoter from the Geological Survey Department (G.S.D.) of the Sudanese government. The emphasis was on the determination of the mining areas for limestone, the assessment of the quality of the limestone, and the estimation of the size of pure limestone deposits.

2-3 Opening an account in the bank in the name of the company and allocating initial funds for the exploratory stage.

2-4 An application was submitted to the Mining Department for permission to mine for raw materials. The permission was granted after consideration by the Mining Council.

2-5 Potential sources of financing were explored after initial estimates of the financial requirements of the project were made.

2-6 An issue of L.S. 1,000,000 worth of common stock was initially made. It was sold as follows:

The Public	L.S. 404 640
Industrial Bank (Govt.)	438 360
Industrial Development Organization (Govt.)	157 000
	1 000 000

2-7 A board of directors was formed with the principal promoter as chairman.

3-8 The promoter sought technical assistance in Germany from specialized consulting firms. He finally contracted with F.H. Kocks K.G. for the technical and economical feasibility studies.

4-8 The G.S.D. made a general survey of the mining area in Nyfer Er Rugaiyeg, 65 kilometers south of Rabak (see Fig. 8, Appendix 4). They took surface samples and submitted their first report which showed their initial estimate of the total deposits of suitable limestone in the area to be 14.17 million tons, which were sufficient to supply the factory for 100 years. They indicated, however, the presence of dolomite and high magnesia but suggested difficulties were surmountable.

8-9 Kocks conducted their feasibility study and submitted their report in March, 1961. It included the following studies:

a. calculation of raw material requirements and location;

b. estimation of transportation requirements of material and personnel and evaluation of different means of transportation;

c. plant location (Rabak site recommended);

d. process analysis of production (Fig. 5, Appendix 3);

e. equipment requirements and factory layout;

f. equipment of the limestone quarry and the claypit;

g. storage facilities;

h. power station;

i. labour requirements;

j. construction costs;

k. time schedule of construction;

l. demand for cement in the Sudan and economic considerations;

m. comparison with competitive suppliers; and

n. financial requirements (fixed and working capitals).

9-10 Another aspect of the study was the preparation of the equipment tender. The company called for offers with a closing date in June, 1961.

9-11 The International Finance Corporation (IFC), which was interested in financing the project, contracted with Mackey and Schnellman (M & S) for conducting further raw material studies in collaboration with G.S.D. Their report was moderately optimistic but reserved.

9-12 IFC also requested that the plant location study be revised. Kocks undertook the revised study. They compared three sites and recommended the Rabak site again.

10-14 Six companies (will be denoted by A, B, C, D, E and F), representing 3 European countries were interested and were preparing equipment offers. They all submitted their offers at the deadline, except Company F.

11-57 Raw material studies were conducted intermittently, with no continuity. The limestone deposits were irregular in quality, and a great difficulty was faced in determining the pattern of pure deposits. Extensive sampling and analysis was needed. The British Institute for Geological Sciences' Overseas Division, was finally helping in the study.

13-55 An application was submitted to the government for the construction of water and sewage systems and for the installation of a connection from the power network to the factory site.

14-19 The study of plant and equipment bids: an activity which was to take only two months ended up by lasting for seven months. After the offers had been submitted in February, 1962, except for that of Company F, the government (which was then a military regime) put pressure to cancel the tender. The chairman of the board (who was at the same time managing director), resigned from the company in March, 1962, together with all members of the board. A new board was then appointed, whose first job was to consider the offers submitted by all six companies in September, 1962. The new board was more inclined toward Company F, against the advice of Kocks, the consultants, and IMPRESIT, the potential financiers.

15-17 Land was purchased in Rabak and foundations were prepared on the basis of the plant layout finally approved.

15-18 Negotiations with international financiers were an effort which unfortunately did not end up by any agreement. However, the history of negotiations is an interesting study by itself, in addition to the fact that the estimation of the costs of delays will not be complete without consideration of the lost opportunity of less costly financing. It has been previously mentioned that the Nile Cement Company (NCC) sought the financial participating of the International Finance Corporation (IFC) as far back as May, 1961. The IFC, after studying the preliminary report on feasibility studies, reported in November, 1961, that they were willing to consider an investment up to 50% of the project cost, but not to exceed 3 million U.S. dollars, provided the preliminary investigations proved the project's feasibility to IFC's satisfaction and an agreement could be reached between the NCC and the IFC on the terms and conditions of investment. They proposed that 25% of the funds provided by them should be in shares and 75% in debentures, with the intention to sell shares to the public when they were able to buy them. IFC also proposed a minority capital participation by a foreign industrial partner acceptable to all the parties concerned, to help the company in the proper management of the plant. IMPRESIT, the consortium of Italian companies previously mentioned, was an acceptable partner to IFC. IMPRESIT proposed to advance the NCC with L.S. 500,000 to be paid back in cement in quantities equal in value to the loan plus 8% annual interest. The cement was supposed to be used for the constructio[n] of the Roseiris Dam undertaken by IMPRESIT. The conditions of IMPRESIT were: (1) that cement be of a quality which permitted underwater durability;

(2) that production be started by October, 1963; and (3) that NCC accept a representative of theirs as a member of the board.

The IFC proposed a capital structure as follows: IFC 30% (in equity), government 30% and public (shareholders) 40%. They also proposed a loan of L.S. 700,000 at 7%, payable over 9 years and after 4 years grace.

In order to satisfy IFC as to feasibility, the plant location study was revised (activity 9-12). Also, the IFC commissioned Mackey and Schnellman to revise raw material studies together with GSD (activity 9-11). The reluctance of the government to approve the IFC loan and the slow progress of raw material studies resulted in the withdrawal of the IFC offer. Together with it, and as a result of the NCC's decision on the bid, the IMPRESIT offer was cancelled. This almost completely erased any hope for international financing.

International financing was, however, one alternative means of financing, and other means were simultaneously explored, specifically, government and government-supported loans, and other local sources. This is why activity 15-18, and the succeeding activity 18-51, are only an alternative path to activity 44-51, and any one is a sufficient, but at least one is a necessary, condition for proceeding beyond event 51.

19-22 The NCC, as a result of government pressure, selected Company F, which caused the resignation of Kooks, and the withdrawal of IMPRESIT. Actually the consultants had advised that Company F's offer (and that of Company E) be excluded from consideration because they were incomplete and were not prepared in accordance with the disposition given. They also doubted the capability of the company on the basis of its reputation.

23-24 The equipment agreement specified dates for the supply of equipment in different shipments, and stated that the contracting company furnish designs of buildings and other civil work connected with the plant.

24-27 The first equipment consignment included raw mix homogenization, gypsum crusher, cement silos and packing plant, and laboratory.

25-26 The plant layout was finalized on the basis of the contractor's actual designs of machinery and equipment.

26-29 The civil work contract with equipment suppliers included the construction of foundations and the buildings to house the equipment.

27-30 Suppliers were responsible for delivering each equipment consignment to Port Sudan.

28-34 The executives were trained in the contracting firm.

30-36 The NCC received the equipment at Port Sudan, performed preliminary inspection, cleared it through the customs and transported it to the plant site at Rabak. This final step could not be conducted in the rainy season from June to October.

31-50 Transport of raw material was one of the main considerations in the plant layout study. Three means of transporting limestone from the quarry to the plant (65 kilometers) were considered, and the means selected was by installing a branch railway between the quarry and Rabak.

38-48 Engineers were trained at the contracting company abroad.

39-48 Technicians were trained at the cement factory in Atbara.

35-37 Civil work which was not taken up by Company F was bid for by several companies, from which a few were selected. This included housing, internal company power network, drainage, the water system, etc.

51-52 About half a million Sudanese pounds were needed to finance the remainder of the construction costs of the plant. Several sources have been sought: the IFC which again showed some interest, the government, and private local financing. The capital was raised to L.S. 1,250,000. There were still shares with a value of L.S. 133,195 unsold. Until the writing of this report, this problem was still unsolved.

51-55 Purchased raw material was either imported, such as oils and sacks, or purchased locally, such as gypsum.

54-55 A disagreement between the NCC and Company F about whether the equipment contract covered the testing of equipment under load. An agreement was reached in March, 1968, but was disputed again in May, 1968. The NCC finally agreed to bear more expenses than it originally figured out.

57-58 This includes the final plan for exploiting the limestone quarry and the arrangement for transportation.

CHAPTER (4)

ACTIVITY NETWORK ANALYSIS

4.1 Uses of Activity Networks

Network analysis is a very useful tool in analysing project activities for the purpose of deriving useful information and making various decisions connected with the projects. Although the graphical presentation of the network is not essential to the development of the required information, its main advantage is that it gives a clear view of the interrelationships among the activities. Also, by performing the computations on the graphical network, a solution is provided against which table calculations, especially when manually-performed, can be checked.

The basic uses of the activity network analysis can be summarized in the following statements.

1. In order that the network be constructed, the individual activities in the project have to be spelled out and their interrelationships indicated, especially their precedence relationships. This step by itself is of great benefit in ensuring that no activity is neglected in the planning of project implementation.

2. Finding the total project duration. Estimates of the total project duration which do not take into consideration the complicated precedence relationships of the activities are apt to be erroneous. This has been demonstrated in this project, where the initial estimate of the total project duration was quite different from that obtained with the use of the critical path method, even though the two estimates drew upon the same basic data.

3. Determination of the critical path. Once the critical path is known, it is possible to concentrate effort in the activities along that path, in order to guard against any delay in the final project completion time. This means that special attention may be given to the control of the performance of the critical activities.

4. Determining subcritical paths. The paths along the project which have very small slacks are no less important than the critical path. If activities along such a path are delayed, in their start or during their execution, more than the total slack of the path, then a delay in the final completion time of the project will be inevitable. The knowledge of the critical path and the closest subcritical paths helps in ensuring that no delay will occur in the project completion time. Also, information about subcritical paths is required when a reduction in the total project duration is considered.

5. Reducing the total project duration. With the knowledge of the activities whose durations can be reduced, and the cost of the reductions, it is possible, with the use of CPM, to determine the minimum cost programme (or schedule) which will shorten the total project duration by a certain period of time. Such a programme will specify the activities whose duration will be shortened, and the amount of reduction.

6. Determining the cost-duration relationship, the optimum project duration and the minimum duration. Computing the minimum cost to gain a specific reduction in project duration, over a range of project durations will give the cost-duration relationship for that range. If the benefit accruing from savings in the completion time along the same range is known, the optimum project duration can then be determined. It is that duration for which the gain from shortening the project duration minus the cost of the reduction is maximum. It is also possible with the knowledge of the above information to compute the minimum project duration, or that duration beyond which no reduction is possible by any means.

7. Scheduling the project implementation. That is, determining the start and finish dates of the various activities. The start and finish times of activities on the critical path are dictated by the sequence; however, there is usually a great deal of latitude in determining the starting times of slack activities. Network analysis helps in setting these times so that the project is not delayed, nor are other restrictions on

the project, such as capacity restrictions of certain resources, isolated. The scheduling of activities thus involves the distribution of slack.

8. Optimizing the utilization of limited resources. Suppose that a number of activities require the use of a certain resource which has a limited capacity, such as a piece of equipment or manpower with specified skill. Such a resource will have to be allocated so that the project will not be delayed. If delay is inevitable, then the allocation should be such that the total cost of delay and resource use is minimum. Certain approaches in network analysis help in finding the optimum allocation of scarce resources over project activities, and the optimum implementation schedule for that allocation.

9. Once a timetable has been set for the implementation of a project, control can be effected on the implementation process by following up the execution of the various activities. Not only is network analysis a helpful tool in locating deviations from the set schedule, but it is also very useful in determining appropriate courses of action once delays are observed.

4.2 Drawing the Network

Two networks have been drawn for the project, the two being identical in all respects except for the duration times of the activities. The first network represents the planned durations of the activities, while the second represents the actual duration times.

The networks have been drawn according to the activity-on-arrow rather than activity-on-node presentation. In this case, the activities have been represented by arrows and the events by nodes. There is no reason for the author to choose this form of presentation other than the fact that arrows depict the passage of time involved in an activity while nodes indicate end points, a presentation which conforms more to the concepts of activities and events.

In activity-on-arrow networks dummy activities are introduced in situations such as the following when activity A precedes both activities C and D, and when D is preceded by another activity B, where there is no precedence relationship between C and B, then a dummy activity E is introduced between A and D to indicate the precedence of A to D without implying any precedence of B to C. The following diagram illustrates the point.

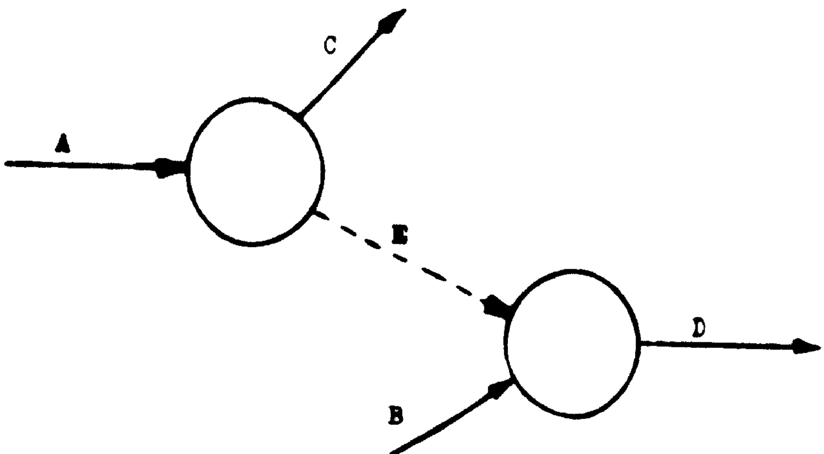


Figure (1): Dummy Activities

Needless to say, more than one activity can be in the place of A, B, C or D. Dummy activities are represented by dotted lines in order to distinguish them from actual activities; their duration is, of course, zero.

The two networks for the planned and actual durations are presented in Appendix A(1), Figs. (3) and (4), respectively.

It must be noted that activities 15-18 and 18-51 are alternatives to activities 29-31, 31-44, 44-45 and 45-51. The completion of any one of the two sequences is sufficient for the start of event 51. This fact has been taken into consideration in the critical path computations, especially those for the actual network.

4.3 The Critical Path

The computations leading to the determination of the critical paths of the planned and actual durations are presented in Appendix A(1), together with an explanation of the procedure. These computations are based on the data given in Table (1). It will be noted that in Tables (4) and (5), the dummy activities have been listed in order to streamline the procedure and guard against errors.

The networks portrayed in Figs. (3) and (4) in Appendix A(1) show the critical paths as sequences of double-lined arrows.

The critical path according to the planned duration times is:

0-1-4-8-9-10-14-19-22-23-24-28-34-38 (or 39)-48-53-55-56-58-59

The critical path according to the actual duration times is:

0-1-4-8-9-10-14-19-22-23-24-25-26-29-32-40-49-50-54-55-56-58-59

4.4 Observations and Comments on the Critical Paths

1. The total project duration as determined from planned activity durations is 68 months (5 years and 8 months), while the actual project duration is 113 months (9 years and 5 months). The duration times of the "actual" network are in effect the actual times only for the activities performed until the time of writing this report, and estimated from there on. The two durations are to be compared with the initial expectation of 24 months for the period between the time equipment is ordered and the time full capacity operation is attained.* The great

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* Information about the expected total project duration is found in references [1:80], [3:5], [5] and [8].

discrepancy among the three figures indicates the following:

a. A lack of realism in the initial estimate of the project duration. To start the project in October, 1959, and to expect by March, 1960, that the project will end in late 1962 or early 1963 is being unrealistic. In addition to the fact that the minimum time to sign agreements with equipment suppliers (activity 23–24) is 31 months from the start of the project, this time has been underestimated, or more precisely, neglected. Even when this time is disregarded, there still remains a minimum of 37 (68 minus 31) months from the time the agreement is signed until full capacity is attained. This is a vivid demonstration of the potential benefit of CPM. Had it been applied in the initial estimates of the project duration with the use of the data then available, a more realistic estimate of the project duration would have been obtained.

b. Even though a CPM estimate based on planned durations would have been closer to the actual duration, the difference between the two is still large enough to raise some questions. A more detailed treatment of this discrepancy will follow in the next chapter; however, it may be noted at this point that the data reveal that either the initial estimates of the activity durations were inaccurate or the controls over the implementation process were inadequate.

2. The critical path for planned durations is partially different from that for actual durations. The difference lies in the activities between events 24 and 55. However, it may be remarked that the actual critical path had a slack of 2 months in the planned network, between events 24 and 55. Hence, it was the subcritical path for that network. On the other hand, the critical path according to estimated durations turned out to be a path of 39 weeks of slack between nodes 24 and 34, and 32 weeks between nodes 34 and 55, in the actual-durations network. This implies the need for considering the subcritical paths along with critical paths, during the implementation stage of a project.

3. Another point worthy of examination is the extent to which the duration times of critical (and subcritical) activities are under the control of the company. A rough dividing line is

whether the company itself is responsible for the execution of the activity in question or some other organisation is responsible. Other considerations influencing the degree of control of the company over the activity durations are also important, and will be treated somewhere else in this report. Here we find that out of 21 critical activities in the planned network 16 were under company control, whereas out of 23 critical activities in the actual network 14 were under company control. This means that most of the critical delays occurred in activities for which the responsibility of execution laid outside of the company.

CHAPTER (5)

ANALYSIS OF DELAY

5.1 Delayed Activities

Out of the 65 activities of the project, 18 suffered from delay. These are listed in Table (2) below. Delays can be classified according to whether they are:

a. critical or noncritical: Critical delays are those which result in a delay in the final completion time of the project. Delays in critical activities are thus critical delays.

b. avoidable or unavoidable: Avoidable delays are those which could have been prevented if certain actions had been taken (or avoided), essentially by the company, but also more generally by other parties interested in the project, such as the government.

c. company-caused or outside-caused: Depending upon whether the activity has been performed by the company or subcontracted.

d. slight or major: Slight delays are those which extend the finish time of an activity beyond the latest allowable finish time by only a negligible amount.

e. starting or implementation: Delays may occur in the starting time of an activity or in its performance time. Again, delays during performance may be in the form of slow progress or interruptions and temporary stoppages.

f. procedural or physical: Procedural delays are those which occur in activities connected with paperwork, studies, legal actions, negotiations, etc., whereas physical delays are those which occur in activities involving physical steps leading to the final construction of the project. In general, delays can be classified in more detail according to the type of activity or sequence of activities they hit; for example, feasibility studies, financing efforts, manufacturing of equipment, etc.

TABLE (2)

DELAYED ACTIVITIES

(1) Serial Number	(2) Activity Number	(3) Activity Description	(4) Planned Duration (Months)	(5) Actual Duration (Months)	(6) Delay (Months)	(7) Actual Total Slack (Months)	(8) Planned Total Slack (Months)
1	9–11	Revise feasibility study (raw material)	9	23	14	16	19
2	11–57	Finalize raw material study	6	58	52	16	37
3	13–55	Expedite construction of utilities and connection of power line to site	8	9	1	82	38
4	14–19	Study plant and equipment bids	2	7	5	0	0
5	15–18	Negotiate and finalize agreement with international financiers	8	Discontinued	—	—	21
6	18–51	Acquire government approval on international financial arrangements	2	—	—	—	21
7	19–22	Negotiate with bidders and make preliminary agreement	2	3	1	0	0
8	24–[illegible]	Suppliers produce first consignment of equipment	8	24	16	14	9
9	25–26	Finalize plant layout and design of buildings	2	7	5	0	2

(1)	(2)		(4)	(5)	(6)	(7)	(8)
10	26–29	Finalize and sign civil work contract with equipment suppliers	2	11	9	0	2
11	29–32	Suppliers produce second equipment consignment	14	23	9	0	2
12	29–33	Suppliers produce third equipment consignment	14	23	9	4	7
13	3[illegible]–36	Clear first equipment consignment at customs, inspect and transport to site	1	3	2	11	9
14	31–50	Install rail, track and platform of branch railway	6	12	6	16	13
15	40–49	Clear and inspect second equipment consignment and transport to site	1	3	2	0	2
16	41–50	Clear and inspect third equipment consignment and transport to site	1	3	2	4	6
17	51–52	Seek further financing	6	28	22	22	15
18	54–55	Settle disagreements with contractor	0	16	16	0	2

With a delay in the total project completion time of 45 months (113 - 68 = 45 months = 3 years and 9 months) so far, a close examination of the nature of delays and their causes is essential. It will also provide information and insight which may help in the avoidance of future delays.

5.2 Critical Delays

The more obvious type of critical delay is that associated with the activities which are on the critical path of the actual-duration network. A list of these activities is given in Table (3) below.

TABLE (3)

CRITICAL DELAYS

Serial Number	Activity Number	Description	Delay Months
1	14–19	Study plant and equipment bids	5
2	19–22	Negotiate with bidders and make preliminary agreement	1
3	25–26	Finalize plant layout and design of buildings	5
4	26–29	Finalize and sign civil work contract with equipment suppliers	9
5	29–32	Suppliers produce second equipment consignment	9
6	40–49	Clear and inspect second equipment consignment and transport to site	2
7	54–55	Settle disagreements with contractors	16
			47

It will be observed that the sum of delays in these critical activities is 47. Recalling that the total slack in the planned network of this path is two months, we find that the actual total delay is 47 - 2 = 45 months, which confirms the data given above.

Although delays in the second and sixth activities in Table (3) are significant in themselves, they are slight compared to the other activities, and consequently they are not going to receive the same degree of attention in this study given to other critical delays.

The fact that critical delays are those which control the actual length of the project does not foreshadow the realization that if these activities were not delayed, the project would still have suffered from considerable hinderances due to other delays. For example, sequence 9-11 and 11-57, with a total delay of 66 months is only absorbed by 37 months of total planned slack in activity 11-57, leaving 29 months of delay to influence the project completion time.

In order to find out whether the delay in an activity, or a sequence of activities, could have been a cause of delay in the project, we may compare the delay in the sequence with the total slack of its activities. If the delay in a single activity is greater than the total slack of the activity then this activity is one which might have controlled the project duration had the duration of other activities remained unchanged. We will call this type of delay "subcritical delay". If the delay in one activity is less than its total slack, but the cumulative delay in a sequence is greater than the total slack of the last activity in the sequence then the sequence has suffered from a subcritical delay. Of the 18 activities in Table (2), only activities numbered 13-55, 30-36, 31-50 and 41-50 have not suffered from either critical or subcritical delay. Their delay is actually uncritical, implying that if each of these activities started at its earliest start time, and was delayed in its implementation time by the actual amount it did, the completion time of the project would not be any later than the planned, provided that all other activities are not delayed. This classification will help us in identifying the activities which should have received extra attention from management. They are primarily those listed in Table (3), but also, to a slighter degree, all other activities in Table (2) except the four activities whose delays are uncritical. It should be noted, though, that a number of the subcritical delays may have been the result of the lack of pressure to finish the project at the originally planned date.

5.3 Other Classifications of Delay

A categorization of a certain delay as to whether it is avoidable or not depends upon the causes of the delay. Causes of delays will be treated in the next section, and it will then be possible to identify avoidable and company-caused delays, and to determine whether the delay occurred in the start or the implementation of the activity. The emphasis will be on delays which are not slight; that is, those which exceed two months. The reason is that the total delay is caused by the accumulation of a small number of long delays, and the cumulative effect of slight delays is negligible in proportion to the total delay.

It is obvious from Table (3) that the critical delays occurred in procedural as well as physical activities, and that other than in the first two activities, retardation took place in activities performed outside of the company. As will be seen later, this does not imply that the company had no control on these operations.

5.4 Causes of Delays

Starting with critical delays (Table 3), we observe that they occurred first in activity 14-19, "Study plant and equipment bids". The time of this coincides with the time the government (the former military regime) interfered with the decision of the Board of Directors concerning the selection of the best bidder. For some reason, the government was in favour of company F, against the advice of all consultants, and the discretion of management, and in spite of the fact that company F had not submitted any offer by the closing date of the bid. In order to allow company F to enter the bid, the government put pressure on the company to cancel the submitted offers and reopen the bid. The board resigned and another was appointed, which then submitted to government pressure and repeated the cycle, finally selecting company F's offer. The government's interference cost the company five months of delay and the choice of an unpreferred offer.

Delays in activities 25-26, 29-32 and 54-55, totalling 30 months, have been caused, or at least partially caused, by company F. The most prominent and most unwarranted delay resulted from the introduction of activity 54-55, "Settle disagreements with contractors", which was naturally not anticipated in the original plan of the project, as evidenced by the fact that its planned duration was zero.

The three serious delays mentioned above can be attributed to the choice of an incapable company, and the signing of an inadequate contract with the company. The contract did not spell out in detail the responsibilities of company F, the penalties to be imposed on it for failure to carry out its responsibilities, and the allocation of costs among the NCC and company F. This gave rise to slackness on the part of company F and disputes between the two sides.

Critical activity 26-29, "Finalize and sign civil work contract with equipment suppliers", was delayed by 5 months, delaying the project completion by an equal amount. This confirms the chairman's opinion that the signature of that contract had been postponed for too long. This was a joint responsibility of the NCC and company F.

These facts, however, do not minimize the importance of other subcritical delays, the most important of which can be classified under two broad categories:

a. Raw material studies: the success of the whole project rests upon the existence of pure limestone deposits, in quantities sufficient to supply the plant, when working at full capacity, for a period at least equal to the economic life of the project. Until the present time, this problem has not been completely solved. Samples of deposits have been taken from various areas around the location of the proposed quarry, but none have so far proved to be completely satisfactory, and those which have been considered as satisfactory, have not yet proved to be in sufficient quantities. Therefore, although activities 9-11 and 11-57 do not present themselves in the network as critical activities, the following facts have to be reckoned with:

activity 11-57 has already used up its slack in a late start, and

the actual time for its completion is partly estimated and is subject to great uncertainties.

These facts indicate a possibility that the raw material studies may still cause a delay in the final project completion time.

b. Financing efforts: activities 15-18 and 18-51, connected with the negotiation and finalization of international financing agreements with IFC and IMPRESIT and the acquisition of government approval of them were shown on the networks as alternatives to local financing schemes, and therefore as not essential to the completion of the project. In reality, the termination of efforts to reach agreements with international financiers harmed the project in three ways:

(1) It left the problem of financing still unsolved. Indeed, activity 51-52, "Seek further financing", would still be needed, but the amount of additional financing would have been less and the probability of obtaining it higher.

(2) It raised the cost of financing, as the terms of IFC and IMPRESIT were better than those of local financiers.

(3) It deprived the company from an important source of technical assistance (raw material studies and management know-how).

Besides, it increased the foreign currency burden on the government. The disruption of the negotiations came as a result of:

The failure of the company to produce cement at the expected time. This resulted in the loss of interest of IMPRESIT, which needed the cement for dam construction according to a specified schedule. The withdrawal of IMPRESIT, coupled with the NCC's choice of company F, and the dragging of the project caused the IFC to lose faith in the management of the project at that time.

> The inability of the company to demonstrate the existence of pure limestone deposits in adequate quantities, even though the IFC showed ample interest in investigating the raw material situation, and went as far as investing in this research by hiring a consulting firm.

All these considerations point to the failure of the company to support raw material research on a continuous and consistent basis as the main reason behind its inability to find a solution to this problem at an early stage of the implementation process, and its present financial difficulties. Cooperation with the G.S.D., as a local agency, for these studies was desirable, but complete reliance on it at some later stages of the study was unwise because of its limited capabilities.

Company F tended to put the blame on NCC because of its lateness in the construction of the facilities on the site. However, it is obvious from both the planned and actual networks that construction activities are not part of any critical path, and that their delay has not caused any hindrance to the completion of the project.

It is the opinion of the author that the planned activity durations are exaggerated rather than underrated, since many of the activities could have been accomplished in a proportion of the time allotted to them had they not been subjected to the impedances they encountered. Examples are in raw material studies, financing efforts, and erection of equipment.

5.5 Corrective Measures

Inasmuch as delays have started with appointment of the new board in March 1963, no attempt to rectify them has been made until the original promoter of the project returned as chairman of the board and managing director of the company in March 1965. He had already inherited many problems. The steps that he took can be summarized as follows:

a. Construction work: He made a reassessment of the situation, and determined the amount of work that had to be done in order to meet deadlines beyond which the company had to pay penalties to company F. As hardly any work had been accomplished for the preparation of the site, he initiated tasks leading to the connection of electricity, the construction of temporary power unit, the transportation of the first equipment consignment to the site, and the purchase and importation of other raw material.

Financing: As a result of a re-evaluation of the capital requirements of the project, the chairman of the board discovered an increase of about one million Sudanese pounds in the capital needs (from L.S. 2.5 million to L.S. 3.5 million), as a result of the increased prices of raw materials, increased wages, accumulated unpaid interests, and their complications. He then resumed his contacts with the IFC to revive the opportunity for international financing, and received initial encouragement subject to a proof of the existence of adequate limestone. Further research into this area was halted due to the absence of response from G.S.D. When the IFC finally gave up on financing the company, the chairman turned to the government for local financing. The government instructed the Industrial Board, the Industrial Development Organization, and the Commercial Bank to provide loans for the company, but only a portion of the promised funds were actually delivered. That left the financial problem still unsolved.

c. Raw material studies: After the G.S.D. had demonstrated its lack of interest in pursuing its limestone studies, the company planned a two-stage study, the first aiming at discovering satisfactory limestone deposit in quantities just sufficient to supply the plant until the second stage of the study is completed, which aims at discovering acceptable limestone in the quantities required. The company met with initial success in the first stage. For the second stage, a representative of the British Institute for Geological Sciences took a good sample of the deposits, together with all the previous raw material studies, back to his home office for closer investigation. The report was expected by the company by the time this report was written.

d. Staffing: The chairman took immediate steps toward hiring the executive, professional, technicians and workmen for the project, and charting training programmes for all these categories.

e. Equipment production and installation: A follow-up of the production of equipment was made, but it was restricted by the nature of the equipment contract. Also, installation of equipment and its testing was interrupted several times due to disputes about the interpretation of the contract.

In summary, efforts to accelerate the project completion were impeded by the original behaviour of the project implementation.

5.6 The Cost of Delays

The cost of delay is the cost of opportunities lost as a result of the delay. In general, opportunity costs have been classified as those of.

a. tied-up capital,

b. lost earning opportunity, and

c. immobilized scarce resources.

Applying the basic concept of opportunity cost to the project under consideration, we find that had there been no delay in the execution of the project:

(a) The company would have earned income corresponding to full capacity production during the period of delay.

(b) It would have saved in construction costs.

(c) It would have been able to take advantage of better financing opportunities.

In the opinion of the author, no additional account should be given to the cost of tied-up capital in addition to the loss of earning opportunity of that capital, expressed in item (a) above; otherwise, such a cost would be counted twice in two different ways.

a. Lost Earning Opportunity

This can be computed as follows:

1. Find the earnings lost for every year of delay by subtracting the total annual expenses, not including depreciation or the cost of capital, from the total annual revenue, assuming that the project has been working at full capacity during these years.

2. Determining the worth of the net earnings at a certain point of time using an appropriate discount rate. That point may be the beginning of the project, its planned end, or its actual end. For the purpose of this study, the accumulated lost earnings at the actual completion time of the project will be computed.

Revenue:

The factory price at the Atbara plant is 105.00 Deutsche Mark (D.M.) per ton, and it is believed that an addition of D.M.5 to that price to account for savings in transportation to buyers from the Rabak plant is reasonable. The selling price of cement at the Rabak plant can then be expected to be D.M. 110 per ton [1:107]. Using a transfer rate of D.M. 11 for each Sudanese pound (L.S.), the price of cement will then be L.S. 10/ton.

For 100,000 tons per year, the total revenue will be L.S. 1,000,000/year.

Expenses: [1:105]

Raw Materials	
Limestone and clay	D.M. 13.60/ton
Gypsum	1.20
Gas oil for rotary kiln	19.80
Diesel oil for power plant	7.30
Total raw materials	D.M. 41.90/ton
Labour	4.70
Overhead (other than machinery and capital cost)	3.00
Total expenses	D.M. 49.60/ton

or about D.M. 50/ton

This is equal to 50/11 = L.S. 4.55/ton. Total annual expenses = 4.55 X 100,000 = L.S. 455,000.

Earnings:

The lost earnings per year of delay are then equal to

1,000,000 - 455,000 = L.S. 545,000

Taxes have not been taken into account because of the government's policy of encouraging new industry.

b. Increase in Construction Costs

By increasing the project implementation period, a company pays wages and salaries to the workers and employees engaged in implementation for a longer period, and incurs greater expenses for the equipment and services it uses. Besides, it will probably pay more for materials and services as the trend of price and wages is generally on the rising side.

In one of the reports of the project [5], it was estimated that the capital cost of the project has increased from L.S. 2½ million to L.S. 3½ million, or by the amount of one million, as a result of delay. Apparently this estimate was based partly on the accumulated interest on the capital borrowed, and partly on the increased cost of the project. It is again the author's opinion that the accumulated interest on capital, as well as the cost of capital, should not be counted as part of the cost of delay, since such interest would have been paid out of the lost earnings which had already been counted as costs. The increase in capital needs as a result of accumulated interest will be taken into account in the following items.

The exaggeration of the estimate of one million pounds by including the increased cost of capital is offset by the fact that that figure was reached when the delay was only 20 months.

An increase of 15% in the construction costs (other than the costs of equipment and machinery which come under the contract with company F, but including the cost of transportation equipment) due to increased wages and prices would be a [illegible] was made estimate. Such costs were estimated at L.S. [illegible] million [illegible] or about L.S. [illegible]. Therefore, the increase in construction costs is [illegible] X [illegible] = L.S. [illegible].

In addition, if we consider the overhead to be a fixed cost incurred by the company whether it produces or not, then the L.S. [illegible] mentioned above represents the additional wages, salaries and expenses incurred by the company during the years of delay. Hence, the increase in construction cost per year of delay due to idle resources is:

3.[illegible] X 100,[illegible]/11 = L.S. 28,[illegible]

c. Financing Opportunities Foregone

The cost of this item is hard to assess. Two excellent financing opportunities (IFC and IMPRESIT) were lost to the company as a result of its slow rate of achievement. As a result, the company resorted to local financing with different interest rates and terms of payment (payment to IMPRESIT would have been in cement). The main outcome of this lost opportunity is the persistence of the problem of financing which has continued to plague the company and may still threaten to result in more delay. An important effect of cumulative interest is the increased capital needs of the project, which further complicates the problem of financing. The extent of the combined effect of all these factors is again difficult to estimate. Therefore, only items (a) and (b) in the cost of delay are going to be taken into consideration, with due recognition of the importance of item (c).

d. The Total Cost of Delay

From the above analysis

Total Annual Costs:	
Lost earnings	L.S. 545,000/year
Increased construction cost due to idle resources	28,000
	L.S. 573,000

The compounded sum of these costs over 45 months (3 years and 9 months) of delay, at the interest rate of 10% (which represents the normal rate of interest in the Sudan for such projects), constitutes the value of the cumulative of these costs at the actual completion time of the project, according to the present expectation of that time.

This is equal to:

573,000 X 4.3 = L.S. 2,463,900 *

To that figure should be added the increase in construction costs as a result of increased prices and wages.

Total cost of delay = 2,463,900 + 120,000 = L.S. 2,583,900

Comparing this figure to the original estimated capital cost of L.S. 2.5 million, we find that the cost of delay is very high indeed, especially when we take into consideration the resulting financing problems.

As the author believes that the project could have been planned and implemented to be completed at least 15 months ahead of the planned period, the total delay should be counted, in his opinion, as 45 + 15 = 60 months. Therefore, the cost of delay should be:

573,000 X 6.1 + 120,000 = L.S. 3,615,300

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* To find the compound worth of a series of equal annual payments, over n years at the rate of interest i, the annual payment is multiplied by the sinking fund factor $\frac{(1+i)^n - 1}{i}$.

The factor in this equation is obtained by interpolating for $n = 3\frac{3}{4}$ between n = 3 and n = 4.

e. The Cost of Delay to the Government

In addition to the liability of the government as an underwriter of the company's debts, it incurred the following losses in its foreign currency resources:

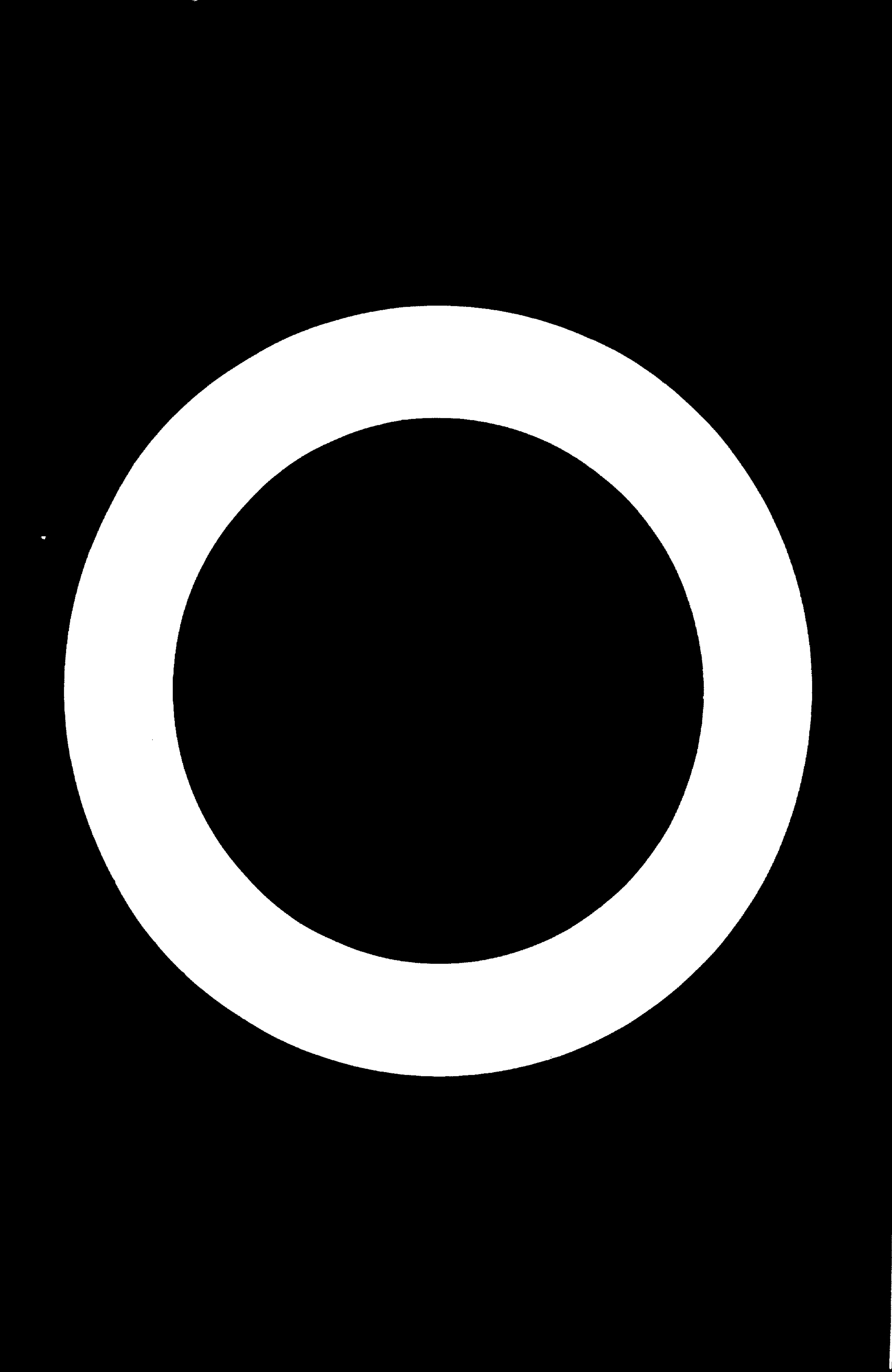
1. The importation of cement equal to the production of the company (100,000 tons/year) during the years of delay. Annual cost is: L.S. 1,000,000.
2. The additional interest paid to foreign financiers (in this case, company F).

f. Incidental Costs

In addition to these costs, company F claims the amount of L.S. 134,000 for increased costs due to design and implementation errors, and for disputed activities (see activity 54-55). These additional costs could be traced to inadequate contracting and inadequate implementation by both company F and the management of NCC during the military regime. The present management believes that it can cut down these claims to about L.S. 30,000.

PART II

GENERALIZATIONS



CHAPTER (6)

PECULIARITIES OF DELAYS IN DEVELOPING COUNTRIES

6.1 Definition of Delay

A delay in the occurrence of an event is the period by which the actual occurrence time of the event exceeds its anticipated (or planned) occurrence time. This difference may be due to an underestimation of the required time, or to a stretch in the actual time. If the event in question marks the end of an activity, a sequence of activities, or a project, then the study of delay should include a consideration of both the planned and actual durations of the activities. In a developing country, errors in estimating the planned durations, as well as inefficiencies in implementation, are apt to be causes of an observed delay.

It is thus clear that delays are determined by comparing actual implementation times with times which are estimated as appropriate to the company and the country in question, and not with any foreign or international standards, which may not be realistic as far as the particular project is concerned. However, international and foreign standards are often useful as guidelines for estimation, references for economic comparisons, and standards for which actual achievement is sought.

6.2 Common Causes of Errors in Estimation

A number of factors contribute to the observed errors in estimation, most important among which are:

a. The general inexperience of the people engaged in project planning as to the total needs of the projects in terms of activities and resources, as a result of their limited knowledge of the industry in question.

b. The lack of knowledge of planners about the techniques of project planning.

c. The limited interest of management and planners in rigorous and scientific planning.

It must be noted here that errors in estimating project duration may go both ways, although they are usually on the under-estimation side.

6.3 Common Causes of Delay

a. Activities under Company Jurisdiction

Absence of or inadequacy of planning.

Inability to foresee difficulties which could be anticipated.

Low productivity and inefficient use of resources, partly due to the low skill of the people and partly due to outdated practices.

Scarcity of resources, resulting in a long lead time for their replenishment, replacement, development, expansion or acquisition, in addition to a higher cost of doing that. This applies more specifically to capital equipment, human skills and raw materials.

The high rate of uncertainty associated with the timing of the accomplishment of any act, or the availability of any resource.

The frequent need to go through a multiplicity of channels of communication for decisions and approvals.

The effect of the "Psychology of Delay". As soon as delay is known to have occurred in a critical activity, people working on other activities which may not be so critical tend to feel uncompelled to complete their tasks on time, with the result that further delay may be caused by this attitude, which again causes others to slacken their pace. This chain reaction may continue until a general atmosphere of tardiness dominates the implementation of the project.

Confusion of political with economic goals. This has been amply demonstrated in the case study previously presented.

f. **Activities Performed Outside Company**

i. Performed by the government

Red tape government procedures

Too much interference with company operations and decisions

ii. Performed by subcontractors

Ambiguities in some of the clauses of the contract which may yield to different interpretations and may cause disputes between the two parties to the contract

Failure of the contract to specify responsibilities, liabilities, penalties, exact specifications and schedules

CHAPTER (7)

DELAY PREVENTION AND CORRECTION

7.1 Allocation of Responsibilities

In order that delays in project implementation be avoided before they happen, and quickly remedied after they occur, a clear definition of responsibilities must be made. Whether a project is public or private, once the board of directors is formed, it constitutes a management group which should be held responsible before the government or the shareholders (or both in mixed projects), for the success of the construction and operation of the project. If the government feels that a public or mixed project is of such a nature that its close supervision is needed, then this should be reflected in the composition of the board more than in its relationship with the board after its formation.

For responsibilities to be meaningful, the goals and objectives of the project must be clearly defined. This will make it possible to establish the project's measures of success, and accordingly the management of the project will know what it is responsible for.

Once objectives and responsibilities are determined and made known to everybody concerned, the government (and perhaps also the shareholders), must give as much freedom of action to management as possible within the legal, social and economic structure of the nation.

7.2 Preventive Measures

The following actions are suggested as measures which are likely to help in preventing the occurrence of delays. They are all based on the proposition that the more effort is put in planning the less is needed for implementation.

a. The development of a detailed list of all the activities required to complete the project. The list should specify precedence relationships among the activities. (This is the first step in the application of network activity analysis. For a comprehensive list of the benefits of this technique, see Section 4.1).

b. The determination of estimates of activity durations based on a careful study of all the available relevant information. This may require efforts to improve the skill of the planners, or the use of outside consultants, or both measures.

c. The application of the Critical Path Method (CPM), or PERT, in order to find the minimum project duration, the critical path(s), the subcritical path(s), and different activity slacks.

d. Setting a schedule for the starting and completion times of activities. This task involves the distribution of total slack among slack activities, and the allocation of resources for minimum cost, waste and delay.

e. The establishment of a cash flow budget for all the years of project implementation, to ensure that the financial needs of the project will be provided for at the right times.

f. The precise specification of the tender requirements.

g. The careful charting of contracts between the company and the subcontractors.

h. A proper selection of the personnel in charge of the project at all levels, letting the technical and performance aspects of the choice dominate the political aspects.

i. The installation of a motivational system which will encourage the people working on the implementation of the project to complete it in the shortest possible time. This will involve the setting of an incentive plan coupled with penalties for delays.

j. The establishment of an information system which takes charge of storing relevant information for use in the future, in order to improve the efficiency of project planning and implementation and avoid the repetition of errors.

7.3 Establishing Controls over Implementation

The preventive measures suggested above can only be of value when coupled with a control system which will ensure the application of the measures, and which will enable management to correct delays as soon as they occur, in order to minimize their effect.

A control system will involve the following:

a. A feedback system which gathers and develops information about:

starting and target dates for all activities

day-by-day reporting of the current status of implementation

the availability of the different resources and their degree of use by the project. Also, any shortage in the resources.

alternative courses of action which may be resorted to in cases of emergencies.

b. An effective decision-making system. With an efficient information collection system, which provides the required information at the right place at the right time, it will be possible to move the point at which decisions are made against problems of bottlenecks and unexpected occurrences as far down as the managerial hierarchy as realistically possible. This, in turn, will help in guaranteeing a quick response to the problems.

c. An efficient communication system built into the system in order to ensure quick transfer of information and instructions.

d. A system of follow-up of the work of subcontractors. It is often advisable for the company to send a team of its engineers and technicians on training programmes in the plants of the companies supplying the machinery and equipment. These people can also follow-up on the schedule of manufacture of equipment. When process quality control is needed for the equipment, the company representatives can also do that at the suppliers' plants.

e. Last, but not least, the management team should continually show interest in the speed at which the project is implemented. They could do that by the consistent and fair application of the systems of rewards and punishments.

CHAPTER (8)

INFORMATION SYSTEMS AND DECISION-MAKING

8.1 Introduction

It was mentioned in the last chapter that control required the existence of efficient information, communication and decision-making systems. In this chapter, we will discuss how to design these systems.

8.2 The Information System

The main function of this system is to collect, process, and store the information required for planning the implementation of the project, for following up the progress of implementation, and for making the appropriate decisions. The information given below is either required for or developed during the process of implementation. It is listed according to its main usage

a. Preparation of the Initial Study for Bidding Purposes

i. Feasibility Studies

Product information: quality characteristics, performance characteristics

Market information: acceptability of product quality, potential market, expected annual sales, seasonality, long range trend, sales price, distribution channels, transportation means, export potential

Production process: economic choice of process, machinery, equipment, raw materials, spare parts needs, manpower requirements, with emphasis on skills

Raw material supplies: sources (local or imported), assurance of delivery, seasonality, load time, prices, terms of payment

Plant location

Plant layout

Capital requirements

Cash flow budget

Production economics

The general economic desirability of the project (versus competition: both local and foreign, also compared with other channels of investment)

Other social and political values of the project

ii. Preparation of the Tender

Clear specification of minimum requirements in machinery, equipment, process and information from suppliers and subcontractors

Unambiguous definition of the terms of contracts

iii. Contracting

Legal terms

Liabilities, penalties

b. Planning of Implementation

In order to plan implementation realistically, the following information is needed

Activities, their precedence relationships and durations. In order to develop this information, the company could use consultants or draw upon the experience of other companies in the same country, government planning agencies, foreign companies, or United Nations data and statistics. It may also draw upon its own experience.

The procedure for applying network analysis to project implementation. (To be used for finding the slacks, critical path(s), minimum project duration, and for scheduling of project activities).

c. Controlling of Implementation

Effective control of the implementation process requires the availability of certain information, and continuous feedback of other information. Examples:

Implementation schedule

Available resources and their current usage

Standards of performance on the main tasks of the various activities

Reporting on actual performance as compared with standard

Day-by-day (and sometimes even hour-by-hour) reporting on the current progress of implementation

Estimated expenses of tasks and activities

Actual expenses as compared with estimated

Immediate reporting of any irregularities, unexpected occurrences, trouble spots, bottlenecks, etc.

d. Making Rational Decisions in the Face of Implementation Problems

All the planning and feedback data listed above are needed when problems occur in implementation and decisions are to be made to select the appropriate courses of action. In addition, the following information is often required:

Any additional resources which may be available and their costs

The cost of delay

8.3 The Communication System

An adequate communication system is required to convey information connected with implementation speedily and accurately. Such a system may be conveniently classified into two interrelated parts: an internal system and an external system. The internal system transmits reports from lower to higher levels (and sometimes horizontally) and hands instructions in the opposite direction. In the design of a communication system, the following factors must be taken into consideration:

a. Information characteristics

Amount of information: this involves the number of reports, their size, frequency and the type of information they include

Speed of communication: information may be classified according to the required speed of its transmission

Accuracy of transmission: another dimension according to which information must be classified is the accuracy at which it is to be received at the other end of the communication channel

Storage requirements: information should be identified as to whether it should be filed or not

b. Characteristics of communication channels

Means of communication: it can be verbal or written. Verbal communication may be face to face, by telephone or through a third party. Written communication may be through standard reports, special reports, memoranda, letters or cables.

The cost of each communication channel

The limitation on its capacity

Its speed

Its accuracy

c. Design of communication system

The selection of the appropriate communication channel and its capacity depends of course on the characteristics of information transferred. More than one channel could be used to convey the same piece of information, for example, by telephone for speed, and then by memorandum for confirmation and file, or by cable for speed, followed by a letter for details. The following guidelines may be helpful in designing a communication system:

In order to save time, information should be conveyed simultaneously rather than in series as much as possible.

Standard reports should be resorted to wherever repetitive reporting is needed.

The required information should be available at the appropriate destination at the right time, in the proper accuracy. The absence of information may be of a very high cost. However, minimization of redundancy and cost is desirable both economically and in order to avoid the crowding of communication channels and the confusion of people.

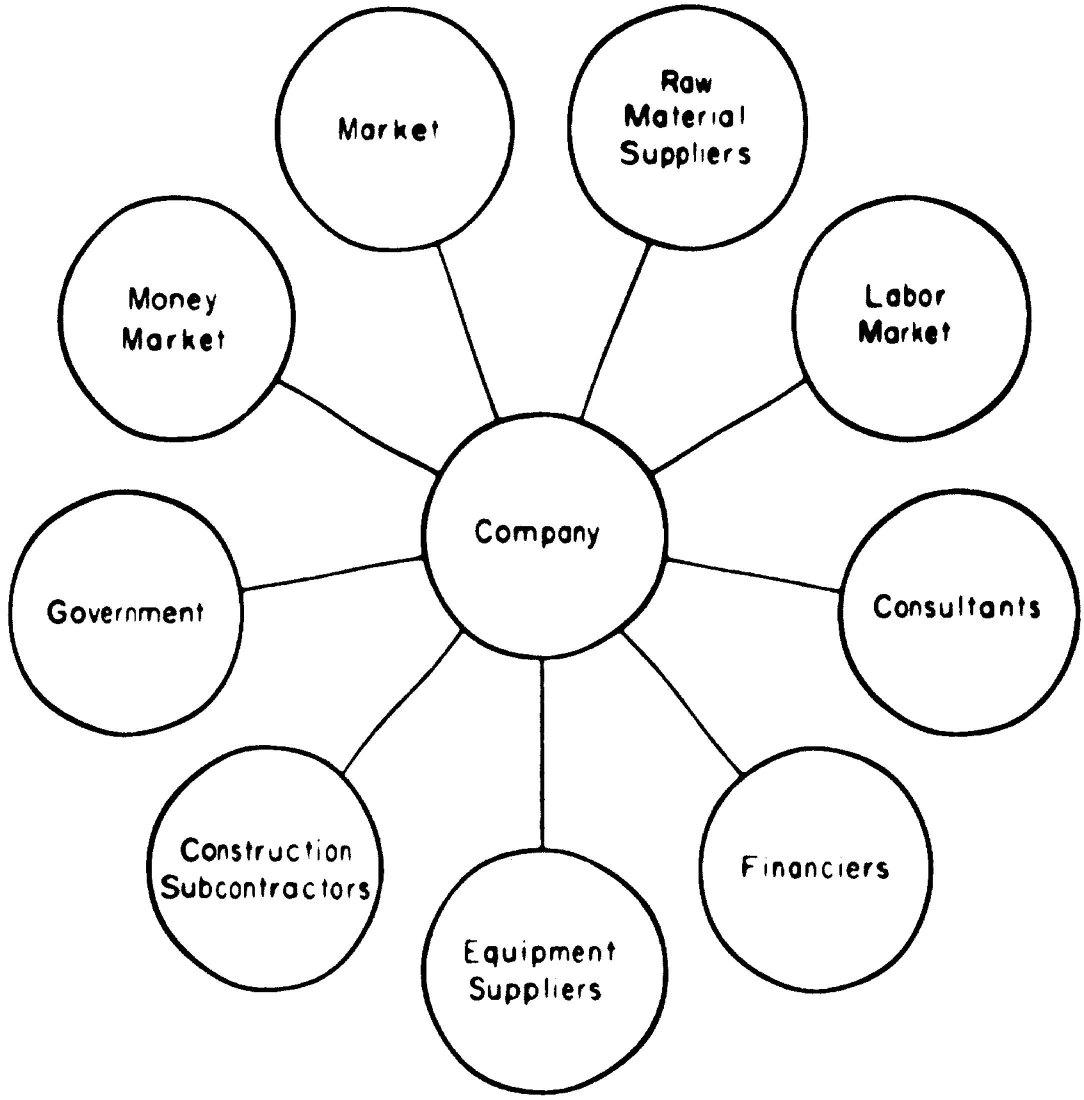


Figure 2: The Company and its Environment

The extent of the external communication system may be appreciated with the consideration of Fig. 2, which shows the relationship of the company with its environment.

8.4 The Decision-Making System

Decisions are required whenever a non-routine problem is encountered during the implementation process. A few questions will have to be settled in order that decisions be made in the best interest of the project.

a. The objectives of the organization

It is true that the first thing the organization wants accomplished is the implementation of the project, but of prime importance here is the time-cost trade-off; also, the recognition of any non-quantifiable factors such as the social and political considerations. Once objectives and the measures of their achievement are defined and made known, it will be possible to push the location of decision-making a few levels downwards.

b. The location of decision-making

It is always advantageous from the point of view of speed to locate the points of decision-making as far down the managerial hierarchy as possible. However, a few factors are of influence in this respect.

The weight of the decision: whether it is strategic and involving major company policies or tactical and relating only to operational problems

The skill, experience and reliability of the people in charge

The speed of communication

The loading of higher management. As top management becomes more busy and the speed of communication slows down, more decisions will have to be delegated to lower echelons.

The level at which information related to decision-making is available

The departments of the organization affected by the decision

Once decisions are made, they must be transformed into instructions, requests or any other appropriate action immediately, and appropriate controls must be used in order to ensure their implementation.

CHAPTER (9)

CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

As a result of the findings of this study, reinforced by similar experiences in developing countries, the author concludes that the application of network analysis, as a simple and modern management technique, can be of great benefit for the implementation of projects in developing countries. Even if data are not accurate or complete, the findings reached in the process of following the systematic approach required in network analysis can be useful in planning a project, preventing delay in its implementation, and minimizing delay whenever it is unavoidable.

The author thus sees an important role for the United Nations Industrial Development Organization (UNIDO), in improving the performance of companies in developing countries on project implementation. Two main courses of action are recommended for the UNIDO, which may open the way for other alternatives. They are: disseminating useful information, and offering training programmes.

9.2 Information Dissemination

The UNIDO could organize efforts toward the development of bulletins and manuals which could serve as guides and educational media to people working on project planning and implementation, for the main purpose of improving the efficiency of project implementation in developing countries. Examples of such publications are:

a. A manual on project planning, to cover the following subjects:

Definition of project objectives

Collection of information (see section 8.2: Feasibility Studies)

Making decisions related to the planning of the project, such as selection of the production process

Determination of the resources required and their costs

b. A manual on contract writing, with special emphasis on international contracts. This would be involved with:

The expression of technical specifications

Legal aspects of contracts

Points which should not be overlooked by a contracting company

c. A manual on project implementation:

Determination of activities, their durations, costs and resource requirements

Application of network analysis, CPM and PERT

Scheduling project activities

Allocation of resources

Making decisions related to implementation, with consideration of the cost of delay versus the cost of accelerating implementation. An important example is the determination of the optimum of the project duration.

Determination of the cost of political and social decisions, for the guidance of policy-makers

d. A manual on activity networks. The emphasis in this manual would be on the technique of drawing the network, finding activity slacks and the critical path. Naturally, CPM and PERT would be the central theme of this manual. Other topics which should be included are the cost-duration relationship and the optimum allocation of resources. The manual should be oriented toward use in developing countries. This could be reflected in extended explanations and the choice of examples.

e. A guide to activity estimation. Comparative data about the duration and cost of typical activities may be compiled by the UNIDO. Examples are the duration and cost of the construction of

a square meter (or a square foot) of a building

a kilometer (or a mile) of an asphalt or concrete road.

Also the training period of a professional or a technician in a specific industry, or the time required for specific government procedures, such as customs formalities, may be estimated. In case this task proves to be difficult to accomplish, the UNIDO may offer help to governments, industrial companies or planning agencies in developing their own standards.

9.3 Training Programmes

A very powerful means which the UNIDO can use for propagating information and educating people about project implementation is short training programmes. Such programmes could be arranged in collaboration with governments to be offered nationally or regionally to industrial planners, employers in industrial companies engaged in project planning or implementation, and government officials connected with industrial projects. A two- or three-week full time or residential course would be preferable. In case this is not possible, an equivalent period in part time instruction would be the second choice. Topics which may be covered are:

a. How to conduct a feasibility study; the areas to be covered in the study

b. How to prepare a tender and how to write contracts with suppliers and contractors

c. Preparing a project network

d. Critical path calculations

e. Time-cost trade-off calculations

f. Project scheduling

g. Organization of the project: division of responsibilities, selection of personnel, determination of the systems and procedures

h. Determination of the cost of delay

i. Control of implementation

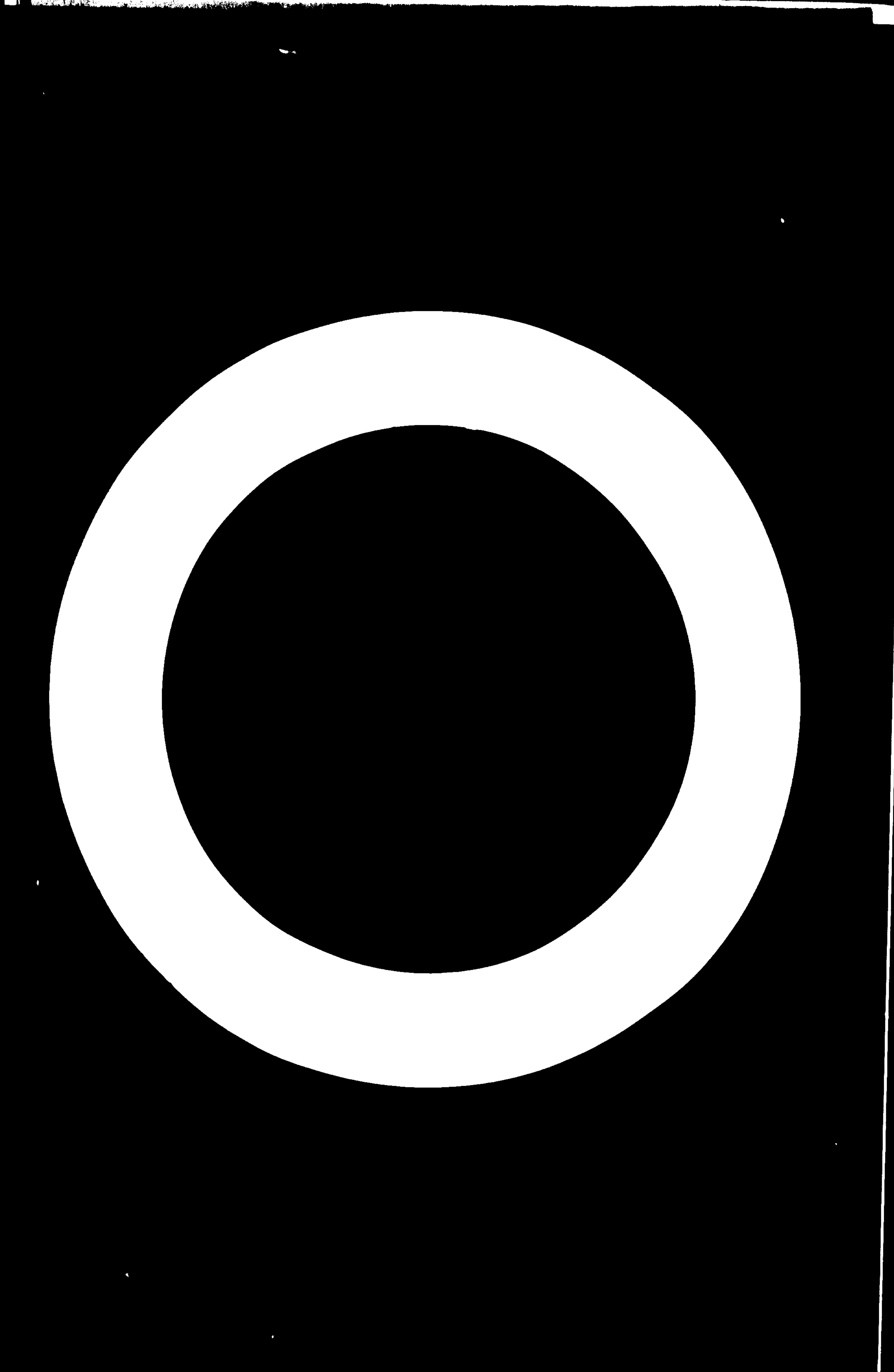
j. Decision-making in the face of implementation problems

It is obvious that the manuals and guides suggested by the author can be of great value in these training programmes.

The training programmes can also be a vehicle for inviting co-operation with the UNIDO in comparative studies which may be conducted about implementation characteristics, information and problems in developing countries.

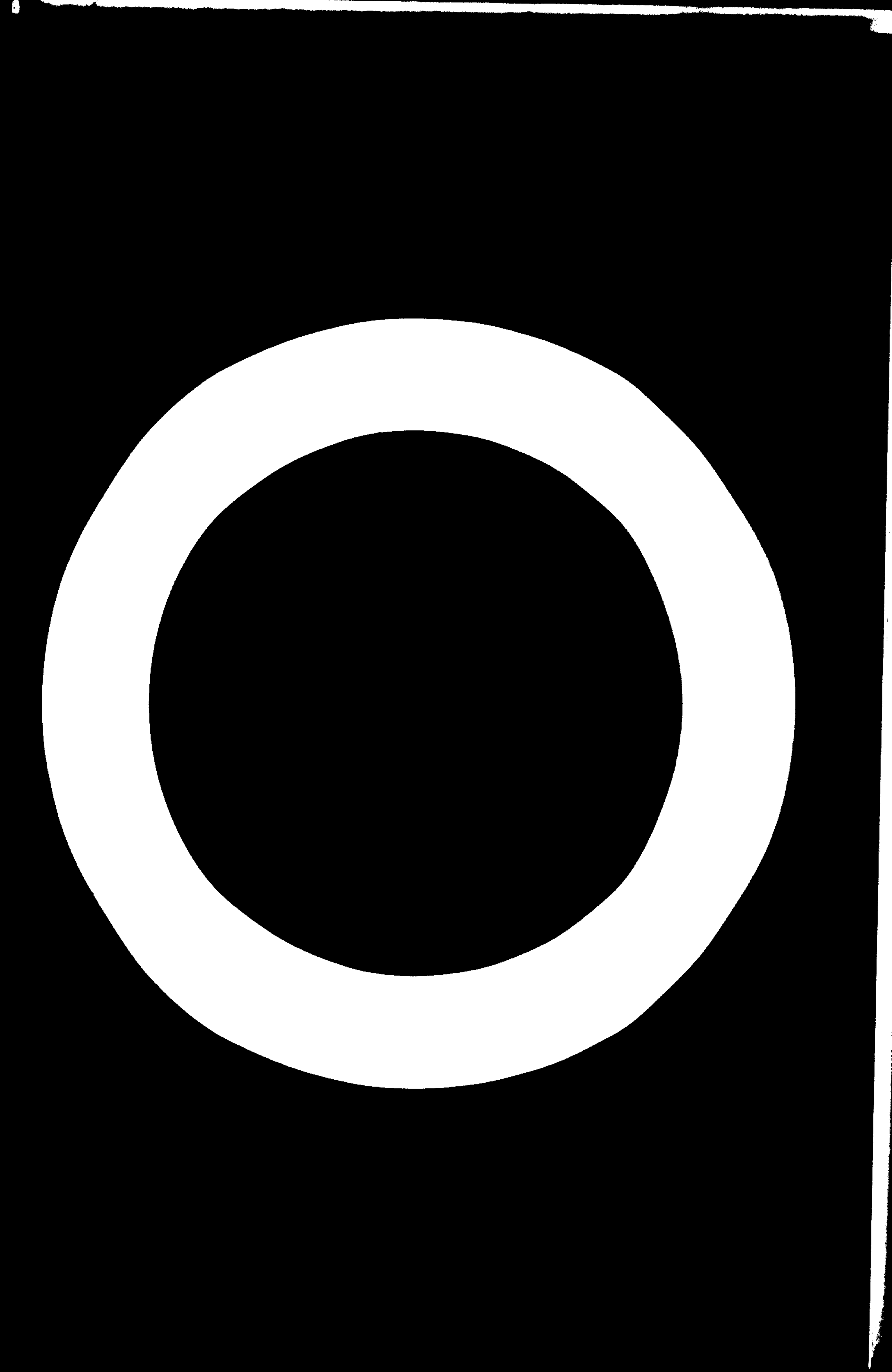
PART III

APPENDICES



APPENDIX A1

PROJECT ACTIVITY NETWORKS



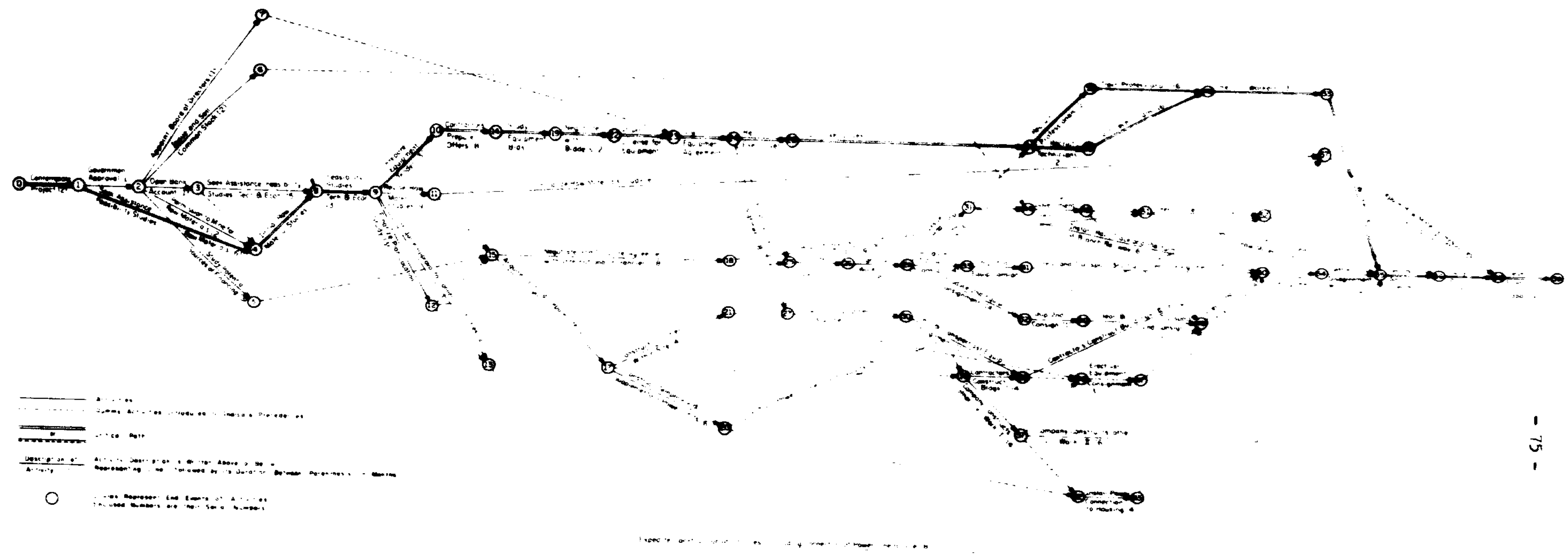


Figure 3 Project Activity Network; Planned Duration Times of Activities

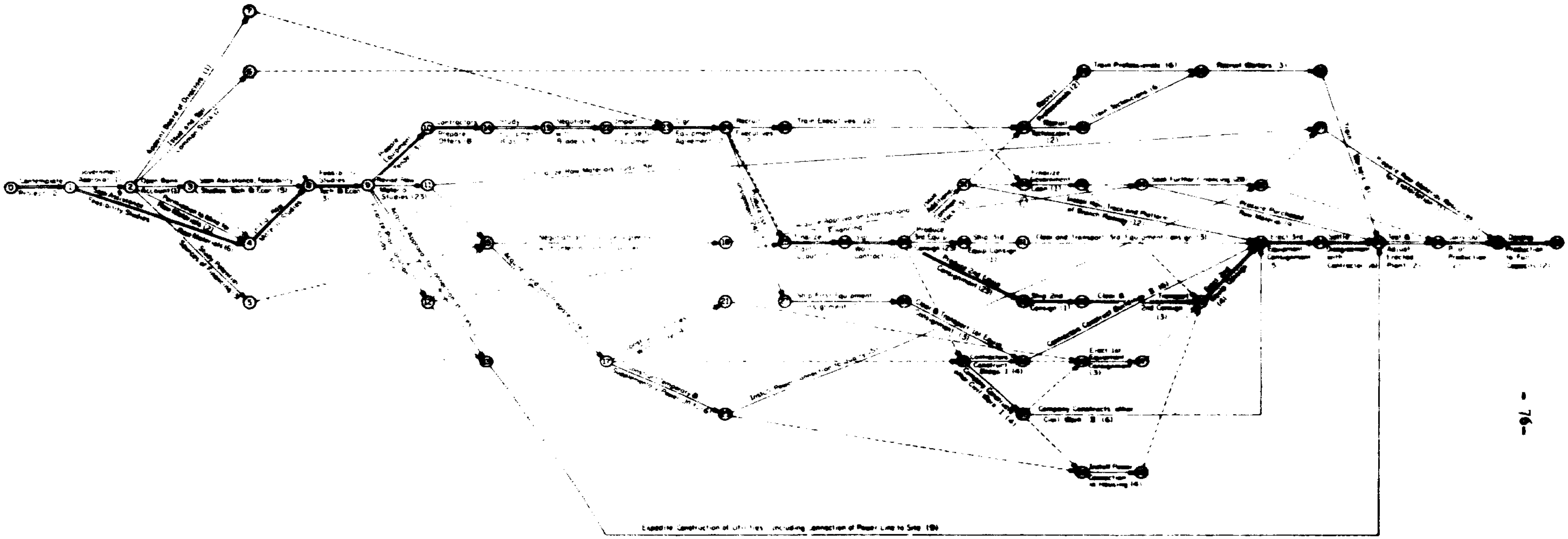
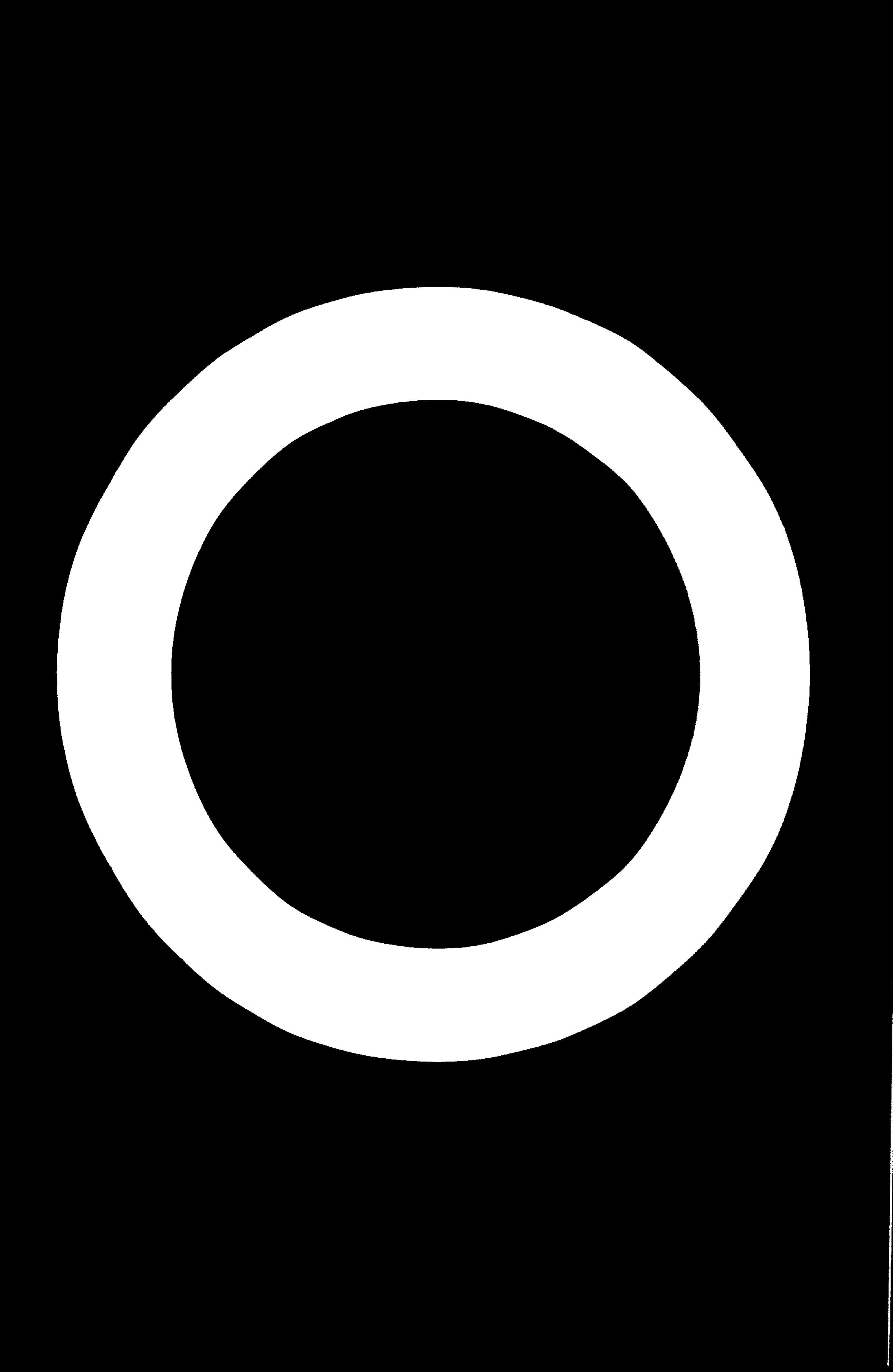


Figure 4 Project Activity Network; Actual Duration Times of Activities

APPENDIX A2

CRITICAL PATH METHOD



A2.1 Definition of Symbols

i–j = activity whose beginning event is i and ending event is j

t or t_{i-j} = single estimate of activity duration time

ES or ES(i–j) = earliest activity start time

EF or EF(i–j) = earliest activity finish time

LS or LS(i–j) = latest allowable activity start time (that is, latest start time which will not delay the project completion time)

LF or LF(i–j) = latest allowable activity finish time

T_E or $T_E(i)$ = earliest event occurrence time

T_L or $T_L(j)$ = latest allowable event occurrence time

TS or TS(i–j) = total activity slack (or float)

FS or FS(i–j) = activity free slack (or float)

A2.2 Computation of Slack and Critical Paths

Explanation of the computational procedure of the Critical Path Method (CPM) is made in connexion with Tables 2 and 3. The procedure is:

Step (1): Listing the activities

a. List the activities according to their predecessor and successor events, and write their duration times under t.

b. Introduce the dummy activities along with the real activities, giving them a duration time equal to zero, and list all their predecessor activities.

c. All activities merging into a single activity (i–j) should have i as their second number, and all activities bursting from a single activity (i–j) should have j as their first number.

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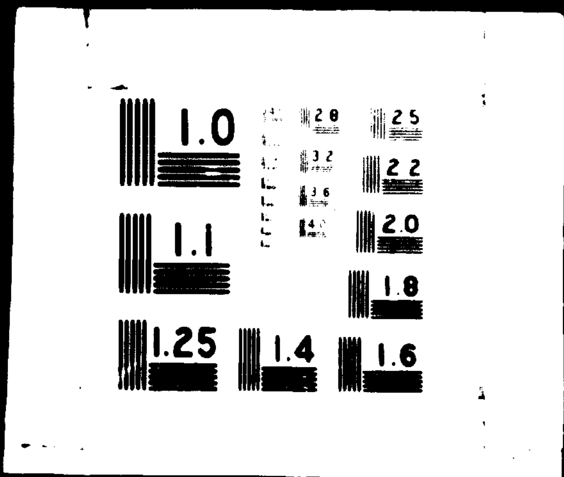


d. In order to ensure that no event is forgotten:

every successor event which is listed as a predecessor is checked, except for the last event,

bursting events which branch out into more than one activity are denoted by b succeeded by the number of branching activities, and

merging events which are the meeting points of more than one activity are denoted by m succeeded by the number of merging activities.

The procedure listed under (d) was followed in the author's rough calculations and is not shown in Tables 1, 2 or 3.

Step 2: Forward Pass Computations (Earliest)

a. Put $T_E(0) = 0$.

Which means that the starting time of the project is defined as zero.

b. $ES(i-j) = T_E(i) \quad \text{all } j$

That is, the earliest start of all activities succeeding an event is the T_E of the event.

c. $EF(i-j) = ES(i-j) + t_{i-j}$

The earliest finish time of an activity is equal to its earliest start time plus its duration.

d. $T_E(i) = \max_{\text{all } h} EF(h-i) = ES(i-j) \quad \text{all } j$

In words, this means that an earliest event occurrence time is the latest of the finish times of its preceding activities. This value of T_E is then used to determine ES of succeeding activities.

Step (3): Backward Pass Computations (Latest)

a. Put $T_L = T_E$ for terminal event.

This is a convention and it implies the earliest project finish time without any adjustment in activities.

b. $LF(i-j) = T_L(j)$

That is, latest allowable finish time of an activity is equal to the latest allowable occurrence time of the succeeding event.

c. $LS(i-j) = LF(i-j) - t_{i-j}$

Which is simply the fact that the latest start time of an activity is equal to its latest finish time minus its duration t.

d. $T_L(j) = \min_{\text{all } k} LS(j-k) = LF(i-j) \quad \text{all } i$

That is, the latest allowable occurrence of an event is the earliest of the latest start times of all its succeeding activities. This value of T_L is then used to define the LF of all preceding activities.

<u>Step (4)</u>: Determination of Slack

a. $TS(i-j) = LS(i-j) - ES(i-j) = LS(i-j) - T_E(i)$

$= LF(i-j) - EF(i-j) = T_L(j) - EF(i-j)$

That is, the total slack of an activity is equal to the latest start (or finish) time of the activity minus its earliest start (or finish). It is equal to the amount of time that the activity completion time can be delayed without affecting the earliest start or occurrence time of an activity or event on the network critical path.

b. $FS(i-j) = ES(j-k) - EF(i-j) \quad \text{any } k$

$= T_E(j) - EF(i-j)$

The free slack of an activity is thus the earliest occurrence of its ending event (earliest start of succeeding activities) minus its earliest finish time. It is equal to the amount of time that the activity completion time can be delayed without affecting the earliest start or occurrence time of any other activity or event in the network.

The critical path in the network, according to the definition given for T_L of the end event of the network, is the path on which the activities have zero slack. If T_L is defined as greater than its T_E, the minimum slack will be positive, whereas if $T_L < T_E$, the minimum slack will be negative, which implies that in order to reach the required T_L, some activity durations will have to be shortened.

TABLE 4

CRITICAL PATH ANALYSIS OF PROJECT NETWORK

PLANNED DURATION TIMES

Activity		Earliest		Latest		Slack	
Number	t (mons.)	ES	EF	LS	LF	TS	FS
0-1	2	0	2	0	2	0	0
1-2	1	2	3	3	4	1	0
1-4	6	2	8	2	8	0	0
2-3	1	3	4	4	5	1	0
2-4	2	3	5	6	[illegible]	3	3
2-5	3	3	6	38	41	35	0
2-6	2	3	5	8	10	5	0
2-7	1	3	4	28	29	25	0
3-4*	0	4	4	8	8	4	4
3-8	5	4	9	5	10	1	1
4-8	2	8	10	8	10	0	0
5-15*	0	6	6	41	41	35	16
6-8*	0	5	5	10	10	5	5
6-44*	0	5	5	52	52	47	33
7-23*	0	4	4	29	29	25	25
8-9	3	10	13	10	13	0	0
9-10	3	13	16	13	16	0	0
9-11	9	13	22	32	41	19	0
9-12	3	13	16	38	41	25	0
9-13	2	13	15	52	54	38	0

* Denotes dummy activities

10–14	8	16	24	16	24	0	0
11–15*	[illegible]	22	[illegible]	41	41	19	0
11–5[illegible]	6	[illegible]	28	59	65	3[illegible]	27
12–13*	0	16	16	54	54	38	0
12–15*	0	16	16	41	41	25	6
12–25*	0	16	16	33	33	17	15
13–5[illegible]	8	16	24	54	62	38	31
14–1[illegible]	2	24	26	24	26	0	0
1[illegible]–17	2	22	24	41	43	19	0
15–18	8	22	30	43	51	21	0
17–20	6	24	30	43	49	19	0
17–21	4	24	28	46	50	22	0
17–35*	0	24	24	45	45	21	11
18–51	2	30	32	51	53	21	7
19–22	2	26	28	26	28	0	0
20–42*	[illegible]	30	30	49	45	1[illegible]	9
20–52	5	30	35	59	64	29	15
21–46*	[illegible]	28	28	50	50	22	13
22–23	1	28	29	28	29	0	0
23–24	2	29	31	29	31	0	0
24–25*	0	31	3[illegible]	33	33	2	0
24–27	8	3[illegible]	[illegible]	40	48	9	0
24–28	2	31	33	31	33	0	0
25–26	2	31	33	33	35	2	0
26–29	2	33	35	35	37	2	0
27–30	1	39	40	48	49	9	0

28-34	12	35	45	33	45	[illegible]	[illegible]
29-31	3	35	38	48	51	12	0
29-32	14	35	49	37	51	2	0
29-33	14	35	[illegible]	42	56	7	0
29-35*	[illegible]	35	45	45	45	[illegible]	0
30-36	1	[illegible]	41	49	[illegible]	9	0
31-34	[illegible]	38	38	45	45	10	7
31-44*	[illegible]	38	38	52	52	14	[illegible]
31-50	[illegible]	38	44	51	57	13	11
32-40	1	45	[illegible]	51	[illegible]	[illegible]	0
33-41	1	47	50	56	56	7	0
34-36	2	45	47	45	47	[illegible]	0
34-39	2	45	47	45	47	[illegible]	0
35-36	4	35	39	46	50	11	2
35-37	4	35	39	45	49	10	[illegible]
36-45*	0	41	41	5	5[illegible]	9	0
36-50	6	41	47	51	57	[illegible]	8
37-42*	[illegible]	39	39	[illegible]	49	10	[illegible]
37-46*	[illegible]	39	39	56	56	11	2
37-50	6	39	45	51	57	12	[illegible]
38-48	5	47	53	47	53	[illegible]	
39-48	6	47	53	47	53	0	0
40-49	1	50	51	52	[illegible]	2	[illegible]
41-50	1	50	51	56	57	6	4
42-43	4	39	43	49	53	10	0
43-49*	0	43	43	53	53	10	8

44–45	1	38	39	52	53	4	0
45–49*	0	39	39	53	53	14	12
45–51*	0	39	39	53	53	14	0
46–47	3	41	44	50	53	9	0
47–49*	0	44	44	53	53	9	7
48–53	3	53	56	53	56	0	0
49–50	4	51	55	53	57	2	0
50–54	5	55	60	57	62	2	0
51–52	6	39	45	56	62	15	0
51–55	9	39	48	53	62	14	14
52–56*	0	45	45	64	64	19	19
52–57*	0	45	45	65	65	20	0
53–55	6	56	62	56	62	0	0
54–55	0	60	60	62	62	2	2
55–56	2	62	64	62	64	0	0
56–58	2	64	66	64	66	0	0
57–58	1	45	46	65	66	20	20
58–59	2	66	68	66	68	0	0

TABLE 5

CRITICAL PATH ANALYSIS OF PROJECT NETWORK

ACTUAL DURATION TIMES

Activity		Earliest		Latest		Slack	
Number	t (mons.)	ES	EF	LS	LF	TS	FS
0–1	2	0	2	0	2	0	0
1–2	1	2	3	3	4	1	0
1–4	6	2	8	2	8	0	0
2–3	1	3	4	4	5	1	0
2–4	2	3	5	6	8	3	3
2–5	3	3	6	67	70	64	0
2–6	2	3	5	8	10	5	0
2–7	1	3	4	34	35	31	0
3–4*	0	4	4	8	8	4	0
3–8	5	4	9	5	10	1	1
4–8	2	8	10	8	10	0	0
5–15*	0	6	6	70	70	64	30
6–8*	0	5	5	10	10	5	5
6–44*	0	5	5	80	80	75	53
7–23*	0	4	4	35	35	31	31
8–9	3	10	13	10	13	0	0
9–10	3	13	16	13	16	0	0
9–11	23	13	36	29	52	16	0
9–12	3	13	16	34	37	21	0

9-13	2	13	15	96	98	84	1
10-11	8	26	[illegible]	16	[illegible]	0	0
11-15*	0	36	36	70	70	34	0
11-57	58	36	[illegible]	52	110	15	0
12-13*	0	16	16	95	96	82	0
12-15*	0	[illegible]	16	77	70	54	20
12-25*	0	16	16	37	37	21	21
13-55	9	16	25	96	107	82	82
14-19	[illegible]	24	31	[illegible]	51	0	0
15-17	2	36	38	70	72	34	0
15-18	Cancelled						
17-20	6	36	[illegible]	74	78	34	0
17-21	4	38	42	75	79	37	0
17-35*	0	38	38	74	74	36	17
18-51	Cancelled						
19-22	3	31	34	31	34	0	0
20-42*	0	44	74	[illegible]	78	34	15
20-52	5	44	49	104	109	60	10
21-46*	0	42	42	79	79	37	23
22-23	1	34	35	34	35	0	0
23-24	2	35	37	35	37	0	0
24-25*	0	37	37	37	37	0	0
24-27	24	37	61	52	75	14	0
24-28	2	37	39	76	78	39	0
25-26	7	37	44	37	44	0	0
26-29	11	44	55	44	55	0	0
27-30	1	61	62	75	76	14	0

28-34	12	39	51	78	[illegible]	39	7
29-31	3	55	58	71	74	16	0
29-32	23	55	73	55	78	[illegible]	0
29-33	23	55	78	59	82	[illegible]	0
29-35*	0	55	55	74	74	19	0
30-36	3	62	65	76	79	11	0
31-34	0	58	58	90	90	32	0
31-44*	0	58	58	80	80	22	0
31-50	12	58	70	74	86	16	16
32-40	1	78	79	75	79	0	0
33-41	1	78	79	82	83	[illegible]	0
34-38	2	58	60	90	92	32	0
34-39	2	58	60	90	92	32	0
35-36	4	55	59	75	79	20	6
35-37	4	55	59	74	78	19	0
36-46*	0	65	65	79	79	14	0
36-50	6	65	71	80	86	15	15
37-42*	0	59	59	78	78	19	0
37-46*	0	59	59	79	79	20	7
37-50	6	59	65	80	86	21	21
38-48	6	60	66	92	98	32	0
39-48	6	60	66	92	98	32	0
40-49	3	79	82	79	82	0	0
41-50	3	79	82	83	86	4	4
42-43	4	59	63	78	82	19	0
43-49*	0	63	63	82	82	19	19
44-45	1	58	59	80	31	22	0

45–49*	0	59	59	82	82	23	23
45–51*	0	59	59	81	81	22	0
46–47	3	65	68	79	82	14	0
47–49*	0	68	68	82	82	14	14
48–53	3	66	69	98	101	32	0
49–50	4	82	86	82	86	0	0
50–54	5	86	91	86	91	0	0
51–52	28	59	87	81	109	22	0
51–55	9	59	68	98	107	39	39
52–56*	0	87	87	109	109	22	22
52–57*	0	87	87	110	110	23	7
53–55	6	69	75	101	107	32	32
54–55	16	91	107	91	107	0	0
55–56	2	107	109	107	109	0	0
56–58	2	109	111	109	111	0	0
57–58	1	94	95	110	111	16	16
58–59	2	111	113	111	113	0	0

APPENDIX A3

FLOW CHARTS

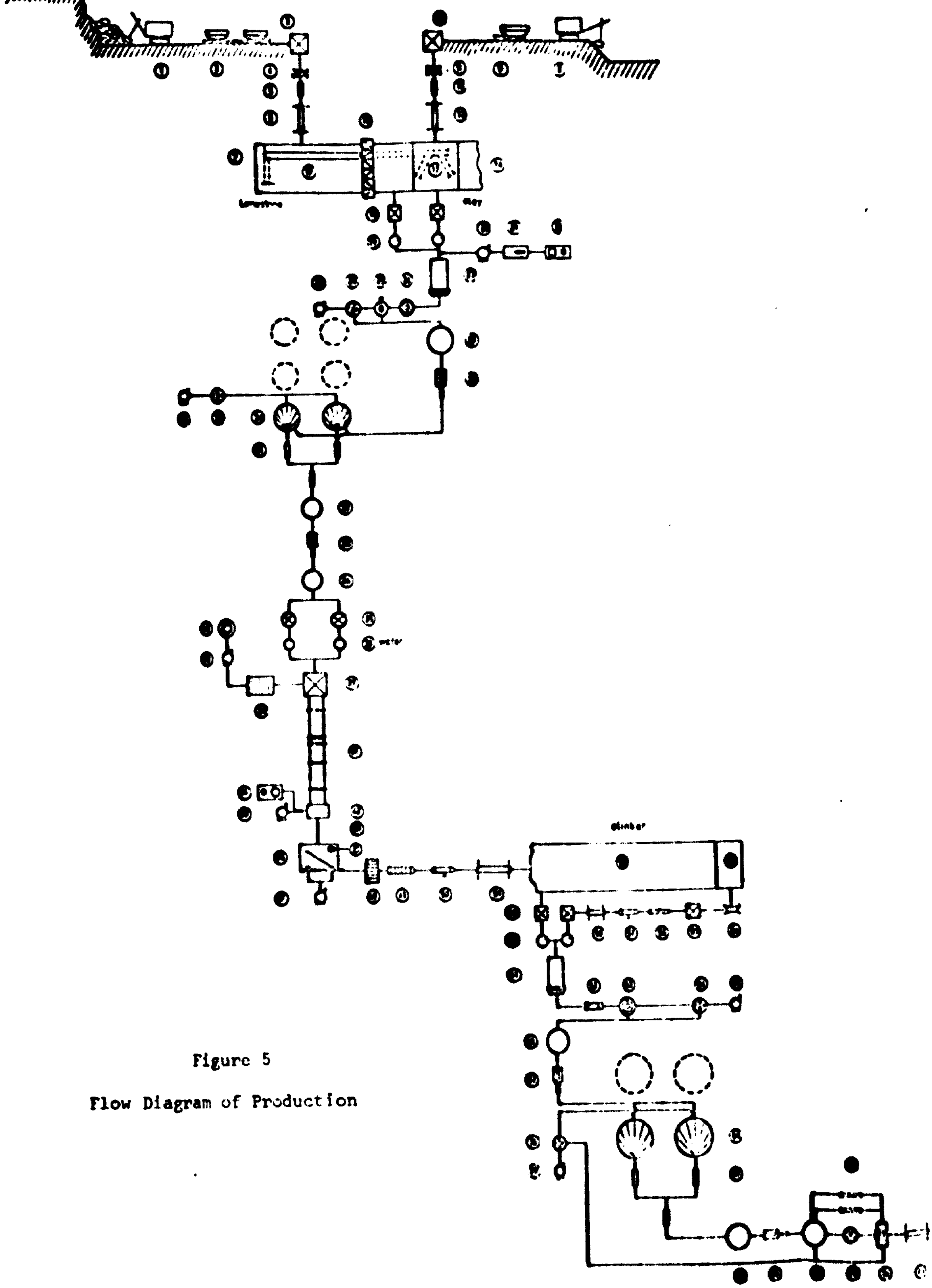


Figure 5

Flow Diagram of Production

Detailed details on these depend on the type of machinery chosen in the final planning of the cement factory

LEGEND

Extraction of Limestone and its Preparation

- power shovel 75 t/h
- rolling stock of narrow gauge arranged for tub tipping
- feeding hopper
- hammer crusher 75 t/h
- electro-magnetic oscillating channel 75 t/h
- belt conveyor vertical 75 t/h
- belt conveyor reversible and portable with swing arm 75 t/h

Extraction of Clay and its Preparation

- power shovel 15 t/h
- rolling stock of narrow gauge arranged for tub tipping
- feeding bin
- hammer crusher with drying plant
- electro-magnetic oscillating channel 15 t/h
- belt conveyor vertical 15 t/h
- belt conveyor horizontal

Storage of Raw Materials

- double beam cranes way
- storage bin for limestone
- storage bin for clay

Grinding Plant for Raw Mix

- two feeding hoppers
- two plate feeder discharges
- blower
- oil burner with oil basin
- oil tank designed for one day's supply with pre-heating device
- tube mill for dry grinding
- airstream separator
- cyclone fan
- bag filter
- blower
- intermediate silo
- pump, type "Fuller"

Silos destined for the Homogenisation of Raw Mix

- two silos with pneumatic homogenisation installation and pneumatic silo discharge
- three pneumatic compressed air conveyors
- feeding hopper
- pump, type "Fuller"

Rotary Kiln Plant

- feeding hopper for the rotary kiln
- two segmental wheel gates
- two granulating dishes
- feeding mill
- dust extraction plant equipped with electric filters
- blower
- chimney
- rotary kiln
- front of furnace
- blower
- oil tank designed for one day's supply with pre-heating device
- clinker cooler, type "Fuller"
- chimney for exhaust air
- blower for the cooling air
- clinker crusher
- apron conveyor
- weigh-belt feeder
- belt conveyor vertical

Clinker Storage

- storage bin for clinker

Crushing Plant for Gypsum and Storage of Gypsum

- storage bin for gypsum
- hammer mill
- intermediate silo
- oscillating conveyor channel
- weigh-belt feeder
- belt conveyor vertical

Cement Grinding Plant

- two feeding hoppers
- two plate feeder discharge
- tube mill for cement
- bucket elevator
- centrifugal separator
- bag filter
- blower
- silo
- pump type "Fuller"

Cement Silo Plant and Packing Department

- two silos with pneumatic silos discharge
- two pneumatic compressed air conveyors
- silo
- pump, type "Fuller"
- silo
- segmental wheel gate
- packing machine
- belt conveyor
- bag filter
- blower
- two screw conveyors for the silos destined for the dosing of raw meal
- bag filter
- blower

THE NILE CEMENT CO LTD
KHARTOUM - SUDAN

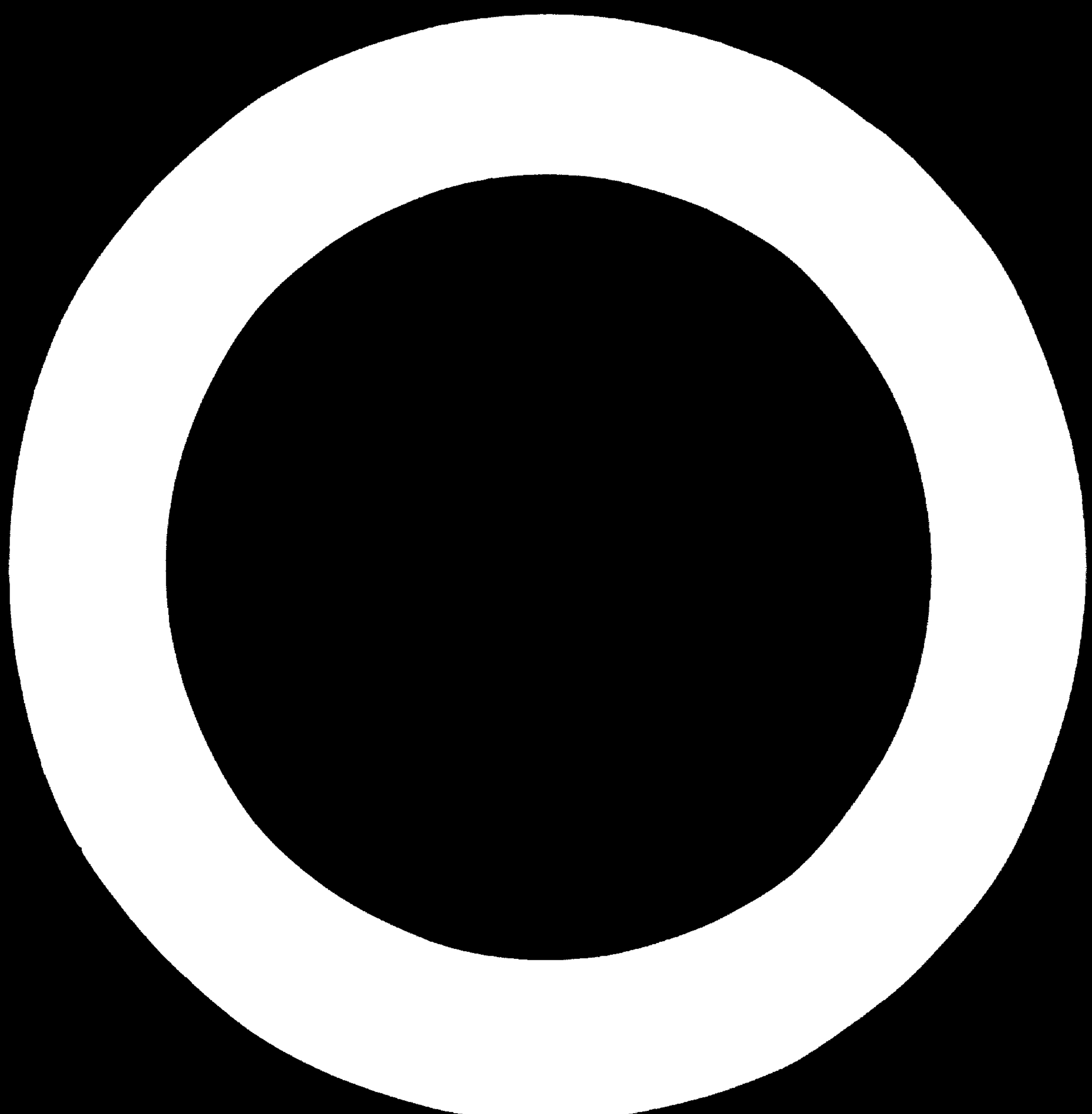
FLOW DIAGRAM OF THE PRODUCTION

[illegible]

F.H. KOCKS K.G.
CONSULTING ENGINEERS
COBLENZ - GERMANY

Figure 5 cont.

Flow Diagram of Production



APPENDIX A4

PROJECT MAPS

SUDAN

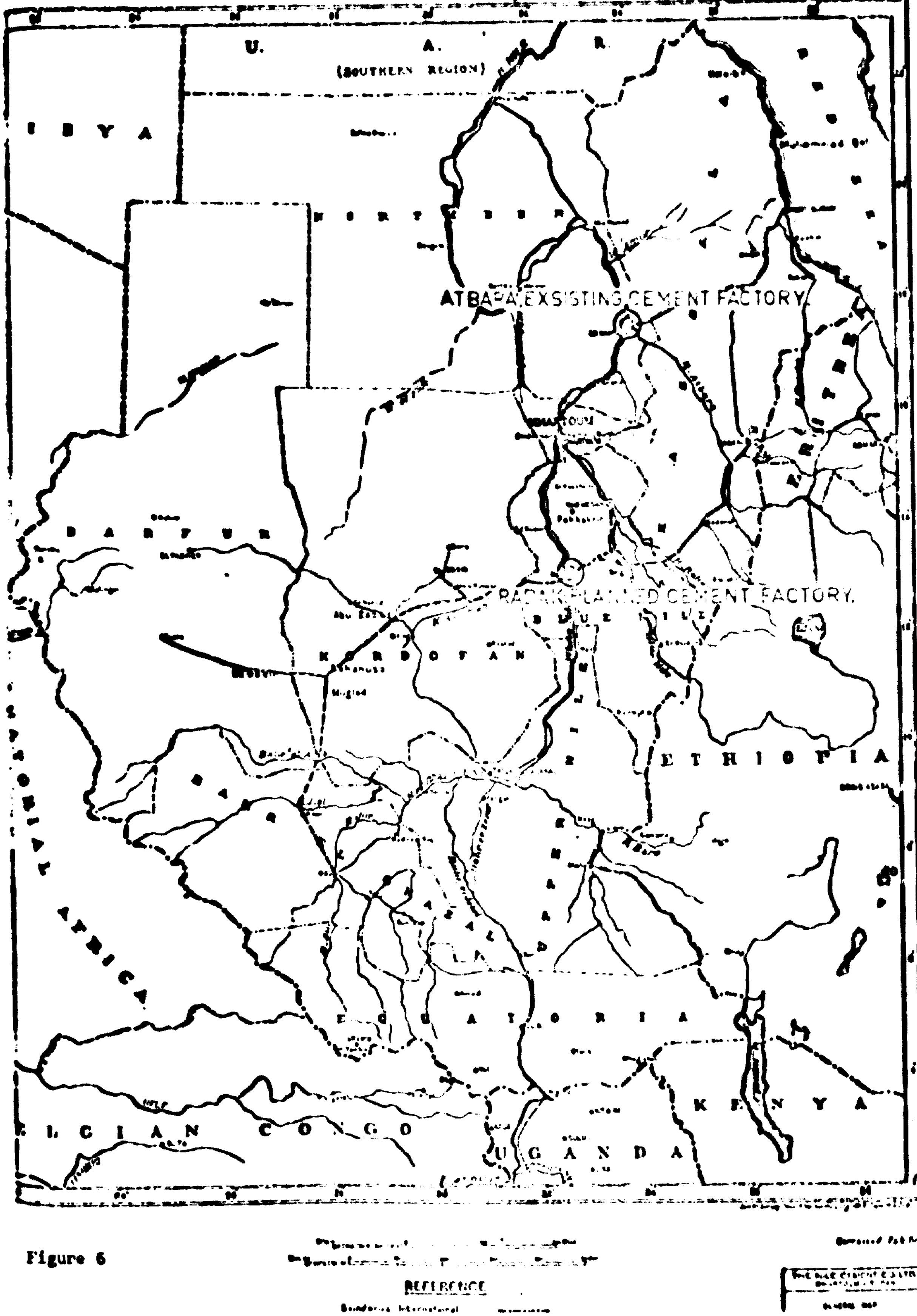


Figure 6

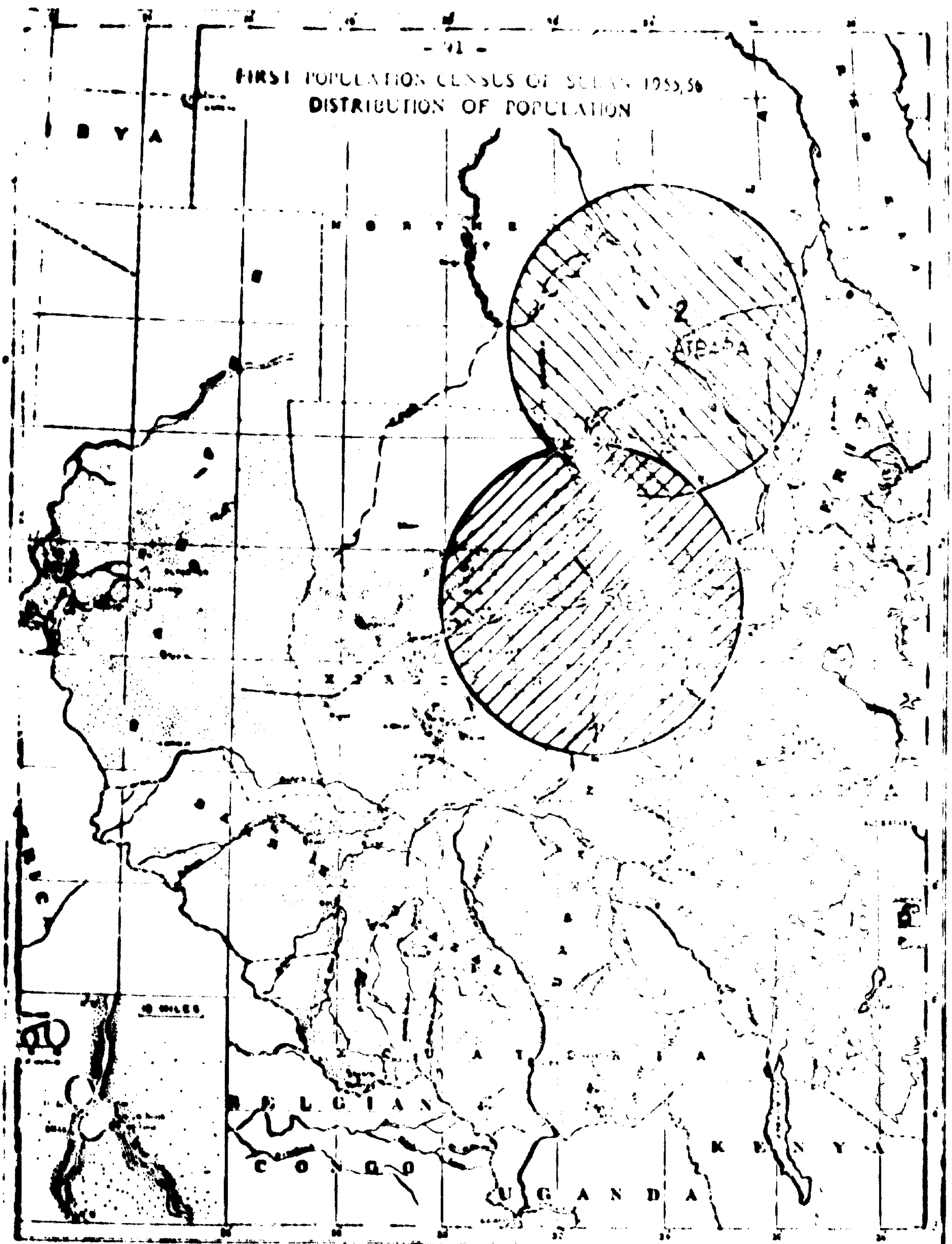
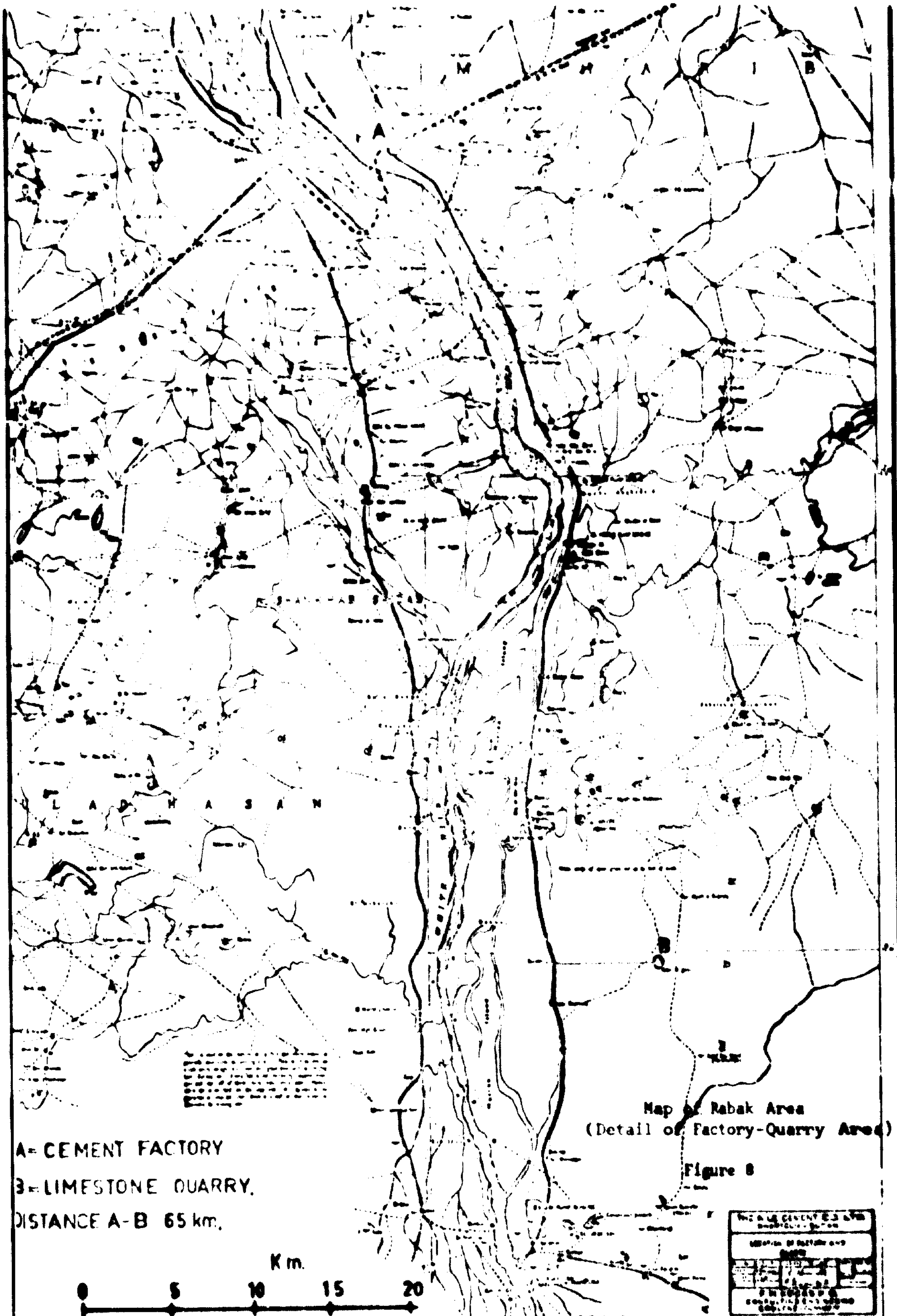


Figure 7

CIRCLE	CENTRE.	RADIUS.	POPULATION.
1	RABAK	300km	3,7 Mill
2	ATBARA	300km	1,2 Mill.



Map of Rabak Area
(Detail of Factory-Quarry Area)

Figure 8

APPENDIX A5

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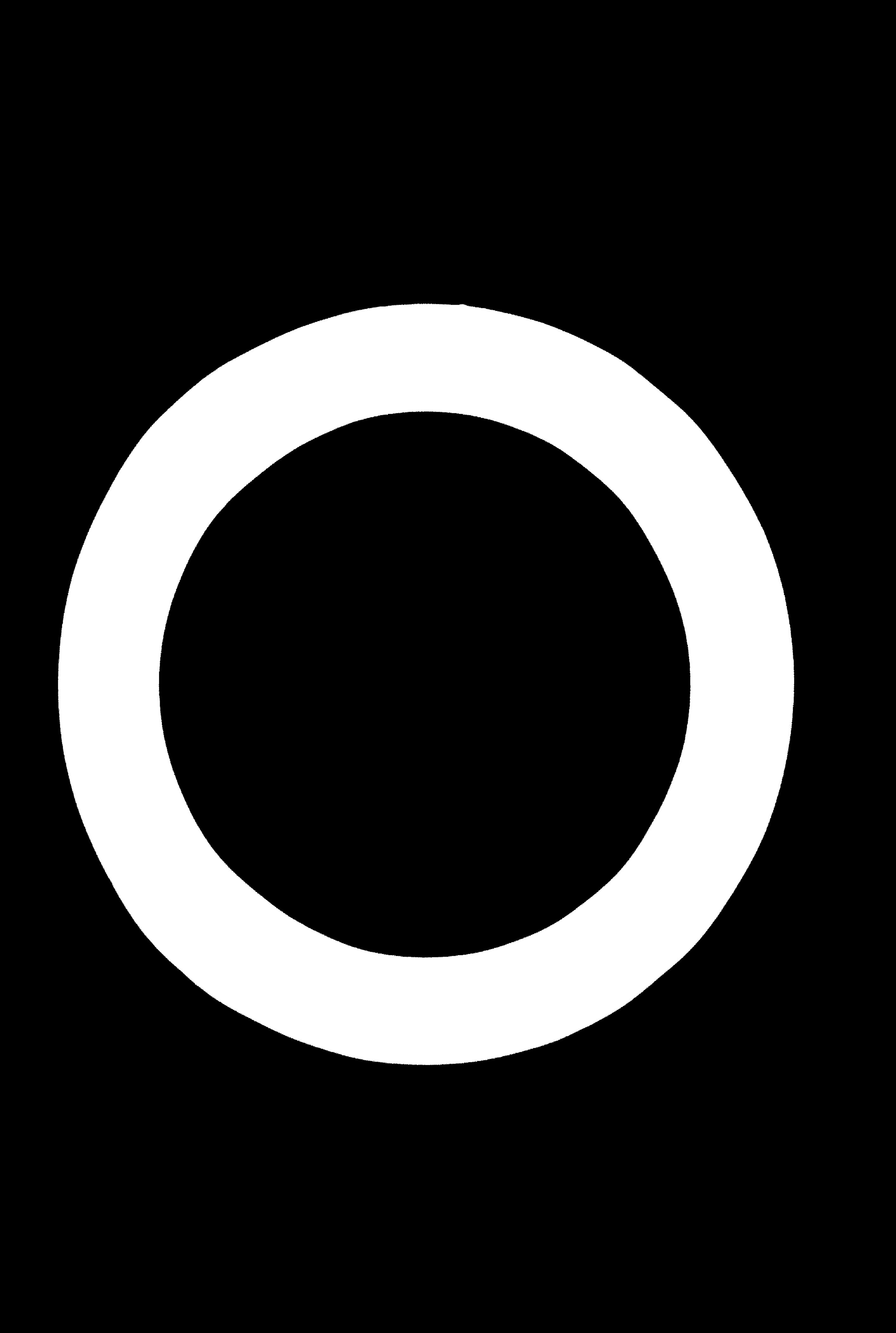

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