APPLICATION OF OPERATIONS RESEARCH IN THE STUDY OF THE ANNUAL GENERAL MAINTENANCE PRACTICE OF THE CEMENT COMPANY OF NORTHERN NIGERIA (CCNN) LIMITED SOKOTO

BY

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DEDICATION

This Project is dedicated to my family and friends for their love, patience, continous support and encouragement.

DECLARATION

I hereby declare that, this research Project to be my own personal work under the able guidance of my Supervisor. It is original and any other person's work referred to, has been acknowledged in the footnotes and bibliography.

MUHAMMAD RABIU SAIDU

9th October 1987
Date

CERTIFICATION

This Project report entitled APPLICATION OF OPERATIONS RESEARCH IN THE STUDY OF THE ANNUAL GENERAL MAINTENANCE PRACTICE OF THE CEMENT COMPANY OF NORTHERN NIGERIA (CCNN) LIMITED, SOKOTO, by Muhammad Rabiu Saidu meets the regulations governing the award of the degree of Master of Business Administration (MBA) of Ahmadu Bello University, Zaria, and is approved for its contributions to knowledge and literary presentation.

Chairman, Supervisory Committee	Date
Member, Supervisory Committee	Date
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ABSTRACT

Cement is literally the Cornerstone of today's building and civil engineering industries throughout the world. The demand for cement in Nigeria far exceeds the supply from the local industry. The local industry has a total installed capacity of 5.42 million tons per annum. As at 1984, the total local cement production is 3,010,000 tons (See Appendix 1.1) as against the annual demand of 7,000,000 tons (Business Concord, 1987).

It is therefore imperative that all feasible cost reduction measures are used in running the industry. This will improve operations efficiency, improve its profitability and allow for further re-investment. This will bring about the necessary expansion and growth in the industry to meet our cement requirement, which will result in some savings of our meagre foreign exchange earnings.

The Cement Company of Northern Nigeria, Sokoto was established by the former Northern Region, in partnership with a German firm in 1962. The company started production in 1967. Since that time, the company has been operating at a loss. Business

organisations that are not profitable need to be studied in order to solve their problems.

This study is aimed at exploring the possibilities of applying operations research technique (Pert Network analysis) in the kiln shut dov/n maintenance practice of the company to reduce its operation costs, It is hoped that, the study will assist CCNN as well as other cement companies in the country in planning and scheduling of their kiln shut down maintenance practice at optimal cost.

The data for the study was collected from the company's maintenance and production records and interviews with company executives. A Pert Network Diagram was drawn, the critical path and the normal cost associated with the critical path was determined. The cost implication of crushing some activities within the critical path in relation to plant downtime costs was analysed. The optimum crew size was also determined; and suitable recommendations made.

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DEFINITIONS AND EXPALNATION OF TERMS

1. Cement

Cement in its various forms is produced for different uses under different environmental conditions. The main raw materials for cement production are limestone (calcium carbonate - $CaCo_3$) and gypsum (calcium sulphate - $CaSO_4 \cdot 2H_2O$). The major components of cement are calcium, aluminites and alumino ferrites.

2. Clinker

An intermediate product obtained after crushing, burning and cooling the primary raw materials (limestone) into fine powder and at a specified temperature.

3. The Kiln Subsystem

This is the nerve centre of a cement factory. It is within this unit, that the raw meal is heated and clinker produced. As long as this sub-system of the cement factory is working, the cement making process can be said to be continuing. The shut-down of the kiln can therefore be likened to the shut-down of the factory. In most factories like CCNN Ltd. Sokoto, the annual kiln shut down maintenance is synonymous with the plant annual general maintenance when all items of equipment are checked and repaired where necessary.

4. Clinkering or Sintering Temperature:

This is the temperature (about 1500 ^{o}C) to which the fine limestone powder is heated to produce clinker.

5. Raw Meal

The raw material (about 75% calcium carbonate) crushed to sizes of between 20mm to 60 mm fed into the kiln.

6. Fiddle Factor

This is defined as the ratio of raw meal fed into the kiln to the clinker produced.

7. Plant/Equipment downtime:

This is the time period when a plant/equipment for used in a production process is not available for production due to breakdown or lack of raw materials.

8. Downtime Costs

These are costs associated with plant/equipment downtime. These costs include profit loss due to loss of production, costs from the payment of idle time of operators and other staff associated with the affected equipment; repair costs in the form of wages and salaries of the repair crew as well as costs for spare parts used, etc.

9. Blending

The mixing of different grades of the primary raw materials to get the specific grade for processing to raw meal.

10. Plant Maintenance

The whole range of work activities dealing with formulating adequate and appropriate repair and maintenance policy for all equipments and plant items so as to ensure optimum plant performance at optimum costs to the organisation. (Starr, 1964).

11. Plant Reliability

This deals with developing and designing plant items whose performance are consistent and as far as possible failure free.

12. Calcination or Decarbonation Temperature

This is the temperature (about 900^{o}C) at which the primary raw material, calcium carbonate (limestone) decomposes into calcium oxide (free lime) and carbon dioxide.

13. Stockout Costs

These are costs incurred due to shortage of stocks (such as finished products, raw materials, spare parts, etc.) needed for effective running of the plant. These costs include plant downtime and start-up costs, cost incurred due to the loss of consumer goodwill, etc.

14. System

According to Starr (1964), A System can be defined as a collection or conglomeration of activities, functions or components that can be bounded within the boundaries of the system and also possess common interdependences,inter-relationships and interactions.

Chapter One

GENERAL INTRODUCTION

1.1 The Study

According to Carrol (1977), "Management of the maintenance function has provided numerous opportunities for cost savings." The complex equipments used in modern production like the cement industry makes it essential that a proper planning and scheduling of plant maintenance be embarked upon by the industries. Steps in upgrading the maintenance function include scheduled preventive maintenance based on the expected lifetimes of critical parts, use of operations research in the maintenance function to determine the optimal composition and development of crews, and the use of costly test equipment to keep an even-more costly production equipment in working order.

The Cement Company of Northern Nigeria (CCNN) started production in 1967 after the initial design problems were rectified. Since that time to date, the company has been operating at a loss. Business organisations that are not profitable (private or public) need to be studied in order to solve their problems.

This project aims at studying and analysing the activities involved in the annual general (Kiln shut-down) maintenance practice of the CCNN with particular emphasis on the Kiln production sub-system.

Operations research technique (PERT Network analysis) will be used to determine the optimum time within which the kiln shut-down maintenance could be carried out; the optimal maintenance crew size and utilization as well as the optimal total maintenance and repair costs.

1.2 Justification of the Study

The CCNN Ltd. Sokoto is a member of the Cement Manufactuers Association of Nigeria (CMAN). This Association has a common forum, where all problems related to the industry, and research findings are discussed and exchanged among members.

The Cement industry is the backbone of the construction industry. A viable construction industry is a necessary pre-requisite for the industrial development of any nation. A study of this nature if successfully carried out therefore will not only help the CCNN reduce their operations costs and thus improve their profitability but also other members in the cement manufactuers Association of Nigeria and by implication accelerate the industrial take-off of this country. A study of this nature is therefore worthwhile.

1.3 Objective and Scope of the Study

The CCNN Ltd., Sokoto has been operating at a loss since the start of its operations in 1967. The study is aimed at finding ways of improving the annual kiln shut-down maintenance practice of the company through the application of operation research (PERT Net-Work Analysis). Thereby reducing its operation costs and improve its viability.

The scope of the project will involve the following:

1. Identifying and analysing the various activities involved in the annual kiln shut-down maintenance practice of the company and establish their relationship.
2. Draw a PERT network diagram, identify the critical path and the critical activities.
3. Determine those activities within the critical path whose times could be reduced and the cost implication in relation to plant downtime costs of such a reduction to the company. Thus determining the optimal kiln shut-down maintenance function.
4. Analyse the various data collected, such as the kiln production figures, stoppages and percentage of time utilization as well as maintenance and repair costs, diesel and libricnts, and kiln oil consumptions per annum for production purposes.

1.4 Statement of Hypothesis

As stated earlier, good management of the maintenance function has provided numerous opportunities for cost savings in terms of plant down time costs. The CCNN Ltd. has been operating at a loss during its twenty years of operations while some cement companies in the country are profitable (See Appendix 1). It can therefore, be reasonably assumed that, the problem of the company is mostly unsystematic and diversifiable, that is, it is caused by factors unique to the company. One of these factors, indeed the most important factor is poor maintenance function. In other words, the problem of the company is caused at least partly, it not entirely by ineffective maintenance practice. This study is based on that premise.

1.5 Limitations of the Study

(a) Due to the data collection methodology, the accuracy of the final results obtained from the analysis will depend very much on the degree of accuracy and reliability of the personnel who obtained and recorded most of the historical data as well as on the accuracy of the information collected during personal interviews and discussions with top executives and the maintenance staff of the company.

(b) Only the 1986 kiln shut down maintenance records were available. These cannot be said to be a true representation of what always happens during the kiln shut down annual maintenance of the company.

(c) Some documents and published information such as direct Vs. overhead costs of manufacture, and complete financial statements of the company were not made available to the researcher. In the words of the Public relations Officer (PRO) of the company, "they are classified documents, not for public consumptions". The study therefore has to be conducted within 'company secrets' constraints.

(d) That, the routine preventive maintenance of all items of plant and equipment are carried out regularly as per instruction mannual of these equipments.

(e) For the purpose of historical veritification of the results, it is assumed that variabilities observed in the past data can also be expected to occur in the future.

1.6 Research Methodology:

All the data collected for this study are obtained through personal interviews, observations and study of historical records. For example the data on 1986 kiln shut down maintenance schedule, kiln

production figures and stoppages and maintenance crew size were obtained through interviews with the production manager, the Assistant Technical Manager as well as records kept in their departments.

The 1986 monthly salary and wages of staff of the company, the 1982 to 1987 (six months) maintenance and repair costs were obtained from the records kept by the finance department.

The company background information was obtained from an interview with the General Manager and records of briefs by previous management kept in their Archieves (courtesy of the company's PRO).

Information on the cement factory components or sub-systems and the cement making process was obtained from observations (The researcher was conducted round the whole plant), interviews with the production manager, the Assistant Technical Manager, and the UNIDO Technical Assistant team members as well as records kept by the company.

The data on kiln shut-down maintenance was analysed through the use of PERT network analysis and PERT cost and the results compared with computed plant downtime costs and other related information. The rest of the data was analysed using tables.

To achieve the objective of the project, the study is divided into five chapters, with chapter one dealing with General introduction. Chapter two dealing with background information of the CCNN, its historical background, structure and functions. Chapter three focuses attention on literature review, plant maintenance, operations research with particular emphasis on PERT Net Work and PERT Cost Analysis, and review of related researches. Chapter four deals with the analysis and interpretation of data, while chapter five ends with conclusions and recommendations.

Chapter Two

THE COMPANY

2.1 Back ground Information on the Company

The Cement Compan, of Lorthern Nigerian (CCNN.) is situated at Kalambaina, five kilometres, .orth-.est of Sokoto city. It was established in 1962 by the Nothern Region through the Northern Region Development Corporation (NRDC) now New Nigerian Development Company (NNDC) in partnership with a German firm, Ferrostall A.G. of Essen.

Construction work on the plant started in 1963 and was completed in 1965. However, due to the initial design problems, which had to be rectified, production could not start until 1967. The plant was originally designed and constructed to handle .et cement process manufacturing. But due to the nature of the primary raw materials and environmental conditions of the plant location, it had to be converted to a dry cement process. The designed capacity was 100,000 tons of cement per annum. However, actual production up to 1970 was only 20% of the installed capacity.

In 1974, the Board of Directors commissioned United Nations Industrial Development Organisation (UNIDO) to look into the problems of the company. In its report, it highlighted four major problems facing the company as:

1. Poor financial structure.
2. Lack of enough spare parts and proper maintenance.
3. Poor Technical Management.
4. Inadequate power supply.

A committee set up by the Board that studied the report, recommended a new capital structure, resuscitation and expansion of the plant. In addition the company should also accept the Technical Assistance proposal from UNIDO. The report of the committee was accepted by the Board. After a series of negotiations with the Federal Government, Technical partners and the CONN, a 60 million naira Euro-dollar loan was secured for the resuscitation and expansion of the plant. A contract for the resuscitation and expansion of the plant was signed with a German Consortium in 1980. The resuscitation work was completed in 1982. The expansion with a planned capacity of 500,000 tons per annum was completed in 1985 and was commissioned by the then Head of state Major General Muhammadu Buhari in May, 1985. The Technical partners were also appointed as Managing agents. The Technical Assistant Trust Funds agreement with UNIDO was signed in Lagos on 14th January, 1987 by the CCNN, UNIDO and Federal Ministry of Industries.

The Technical Assistant agreement with UNIDO provides for the deployment of UNIDO experts in the

various aspects of the Cement manufacturing process. At present, there are sixteen number UNDP team in the factory working side by side with the Nigerians and about ten more are expected very soon. The main function of the team is to work with the Nigerian staff, to identify loopholes in the operations of the plant, recommend and implement the recommended solutions. And above all, ensure that by the end of the contract period, 1989, which is renewable at the discretion of the GCNL, capable Nigerians are train to handle the running of the factory profitably.

The ownership and composition of the shareholders of the company has varied over the years. However, the present shareholders of the company with their relative shareholding are as follows:-

The Federal Government of Nigeria	31.53%
The NNDC Ltd.	25.42%
The Sokoto State Government	22.37%
The Kano State Government	10.54%
The Kaduna State Government	8.47%
Ferrostall A.G. of Essen, Germany	1.70%
Total	100%

Source: General Manager's brief to the Board of Directors, 20th March, 1987.

The staff strength of the GCNL rose from 240 in 1984 to 780 today. The breakdown of the staff according to departments is:-

Administration	65
Security/Cooks/Gardeners	86
Production	276
Quarry	43
Laboratory	27
Technical:	
Mechanical	102
Electrical	72
General	40
Finance:	
Accounts	17
Stores	30
Procurement	14
Sales	8
Total	780

Source: General Manager's brief to the Board of Directors, 20th March, 1987.

2.2 Organizational Arrangement

The company from 1962 to date has undergone many organizational changes. In fact right now NISER, in a consultancy arrangement is appraising the organization with a view of coming up with a suitable organizational structure.

Presently, the company has a Board of Directors with ten members including the chairman. The chairman

and two other members are appointed by the Federal Government. The NNDC Ltd. and Sokoto state government appoints two members each, while Kano state government, Kaduna state government and the Technical partners appoint a member each.

After a reorganization of the company in 1985 in preparation for the take over of the management of the company from the managing agents, a General Manager was appointed. He is assisted by two deputy General Managers, Technical and Administration and commerce. He is responsible to the Board for the day-to-day running of the affairs of the company. Directly under the deputy General Manager Technical are two departments, the Technical and Production. While Deputy General Manager Administration and Commerce heads Administration, Finance, Sales and procurement departments.

The Technical Manager is responsible for the coordination and planning of all the maintenance functions and repairs activities of the plant. He is assisted by Assistant Technical Manager. The Technical department is divided into the Mechanical, Electrical and General services sections, the sections are headed by a Chief Mechanical Engineer, a chief electrical Engineer and General services

engineer respectively.

The Production Manager is responsible for the quarrying of the primary raw materials, the actual production process, quality control and packaging of the cement product. The department is divided into quarrying and crushing of raw materials, raw materials blending and grinding, kiln burning and clinker handling, cement grinding, cement packaging and quality control sections. The production manager is assisted by assistant Production Manager and has working directly under him, the Quarry Manager, Production Engineer and Laboratory Chemist.

The Procurement department is in charge of the purchase of spares and other raw materials needed for the continous operations of the company.

The Personnel Manager, whose activities is overseen by the company Secretary is responsible for the employment and placement of personnel as well as matters related to benefits for the employees' welfare and training. In addition, he is responsible for the security, gardeners and cooks. He has working under him, a Personnel Officer, a Security Officer and head of services (labourers, cleaners, etc) to assist him in the performance of his duties.

The Financial Controller heads the finance department. He is responsible for the procurement and disbursement of funds of the company. The department is divided into the Accounts and the stores sections. He has under him the Chief Accountant and Stores Officer each responsible for the accounts and stores respectively.

The Sales Manager is in charge of the sales department. He is mainly concerned with implementing the company's sales policies (the company operates in a sellers market, there is little or no marketing that is done to sell the company's product). (See Appendix 2.1 for the details of the Corporate Organizational chart).

2.3 The Plant.

2.3.1 The Cement Making Process:

Cement is the basic requirement of most construction works ranging from the most humble village mosque to the sophisticated dams and bridges in and around the cities. It is used in the construction of rain-water catchment dams, irrigation channel linings, vast hydro-electric projects, harbour works, new towns development, airports and road net-work constructions.

The cement manufacturing process can be divided

into two broad categories, the wet process and the dry process cement manufacturing. The two processes differ in the way the primary raw materials are handled up to the calcinating stage. The details of the cement making process vary widely. No two works are the same and there may well be differences within a single works as new kilns and their associated equipment are added to those already existing. However, regardless of the variations in detail, all methods of cement production involve the same fundamental stages as follows:[1]

1. The primary raw materials are reduced to fine particles, so that it can be mixed properly.
2. The raw materials are blended and mixed to produce a raw feed mix (raw meal) of uniform chemical composition containing cacium curbonate (about 74.5%), silica, alumina, iron oxide and other compounds in the required proportions.
3. The blended raw meal is heated to the point where all moisture is driven off as steam or water vapour.
4. The dried mix is heated to decarbonation or calcinating temperature of about 900°C. At this temperature, the calcium carbonate in the mix is dissociated into calcium oxide (free lime) which remains in the mix and carbon dioxide which

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1. Anomymous (1985), The West African Portland Cement Company Limited Silver Jubilee Special publication, p.10.

is driven off as gas.

5. The mix is further heated to form calcium silicates, aluminates and alumino ferrites which are the principal components of grey cement (Portland cement). This process is completed in the rotory kiln at a temperature of about 1500°C to produce Clinker.

6. The Clinker is cooled to a temperature of between 60°C and 150°C for convenient handling. The clinker may be sent directly to the grinding mill or stockpiled.

7. The clinker after addition of gypsium to control the setting time of the finished product is ground to a specified finess.

8. The finished product (cement) is stored in silos for a relatively short time before being bagged and despatched to the market.

2.3.2 The Major Production Units and their Functions

The CCMM factory (See Appendix 2.2), has two production lines, the old resuscitated line of 100,000 tons of cement per annum installed capacity and the new added line with an installed capacity of 500,000 tons per annum. Due to the problems of breakdowns of old equipments, the old line is hardly in use.

The major production units of the two lines and their functions are basically the same. But below is the description of the main production units and their functions of the new line.[2] (See appendix 2.2) for the flow diagram.

2.3.3 Crushing Plant, Sampling Station and Stockpiling Equipment (Blending Hall)

The raw material is transported from the quarry to the primary crusher by dump trucks. The primary crusher, with a capacity of 550 tons/hour, crushes the material into pieces of sizes between 20 - 60 mm. The crushed material is transported to the blending hall by a belt conveyor system. The blending hall (mixing beds) have two major functions namely, prehomogenizing the raw materials and to provide sufficient stock pile. The storage capacity of the piles is 48,000 tons. Before mixing, a sampling station is located by the crushers which takes samples continuously from the material stream arriving from the crusher to ensure raw materials quality.

2.3.4 Raw Material Reclaiming and Grinding Plant

The raw materials are reclaimed from the stockpiles and transported via a belt conveyor system at a rate of 250 tons/hour to the raw mill bins. In the raw mill, the material is ground into fine

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2. Anomymous General Manager's brief to the Board of Directors., p.10

powder and its moisture content reduced to below 1%. The product, raw meal is the intermediate product that is fed into kiln after homogenizing in the silos. The nominal rated output of the raw mill is 150 tons/hour.

2.3.5 Raw Meal Transport and Homogenizing

The raw meal is transported via air slides and bucket elevator into the homogenizing silos. The silos have a useful capacity of 9,000 tons, sufficient to last about 3 to 5 days at full kiln production. The silos are aerated from the bottom and the material is circulated by the rising air to ensure homogenity of the calcium carbonate content. The calcium carbonate content should not vary by more than $\pm$ 0.25%.

2.3.6 Preheater and Kiln Plant

The fine homogenized raw meal is fed via a closing system to the suspended preheater which utilized the hot waste gases of the rotary kiln. As the raw meal decends, it is heated to decarbonation temperature of about 900°C as it enters the kiln. At this temperature, decarbonation takes place. The mix, calcium oxide, silicates and ferrites is burnt to clinker at a temperature of about 1450°C.

From the kiln, the clinker enters the planetary cooler tubes which are attached to and rotate together with the kiln. The clinker is cooled to a temperature of about 120°C and larger lumps are cru shed to sizes below 30mm. It is then conveyed pneumatically to the open clinker storage system. The rated output of the kiln is 1600 tons/day and the capacity of the clinker storage is 18,000 tons. The fiddle factor of the kiln is about 1.6.

2.3.7 Cement Mill

The clinker from the storage system is transported by Pan conveyors and bucket elevators to the mill feeding bins. Gypsum, the second component of the cement primary raw materials is fed via separate feeding bin and bucket elevator. The clinker and gypsum is mixed in the ratio of about 95% and 5% respectively. The mix, ground to a certain finess produces cement. The finished product (cement) is transported by air slides to the cement pumps. The cement mill of two compartment has a rated capacity of 52 tons/hour per compartment.

2.3.8 The Packing Plant and Storage Silos

The cement is transported by cement pumps by means of compressed air into two cement silos via pipelines. The cement silos have an average storage capacity of about 4600 tons each. The packing plant

is accommodated within the cement silos. Each silo contains two packing lines with a capacity of 1000 bags per hour. Each of the silos is also equipped with a bulk loading facility for loading on to waiting trucks for onward delivery to the market.

2.3.9 Dedusting System

To control environmental pollution, all air flow gases (kiln waste gas, raw mill air flows, etc) within the plant are dedusted. For this purpose several dust collection equipments have been installed. The two types of dedusting system are:-

1. Electrostatic precipitator
2. Air pulse filters.

Both systems are capable of cleaning exhaust gas up to a purity of 99.98%. This means that the maximum dust content of the exhaust gases is below 120mg./mm^3. This level of dust content conforms with international standards.

2.3.10 Condition of the Plant

The plant is generally in a satisfactory condition. However, there is a lot of improvement (like providing access to lubrication points, bearings coverage belt system rollers, etc) to make, if the plant is to produce at a continous optimal level.

Chapter Three

LITERATURE REVIEW

3.1 Plant Maintenance

Machines may be viewed as being made up of a sequence of components each of which performs a function. The number of individual mechanical and electrical components required to perform correctly in sequence (series) is larger than one might think. If any one of them fails to function correctly due to either breakdown or faulty adjustment, the system as a whole fails to function correctly. Thus, the reliability of a plant (system)depends upon the number of components and their arrangement. (Buffa, 1973).

Since the time of James Watt and George Stephenson, the complexity of macinery has grown at a pace which is still accelerating. With the Advert of the computer and advance control engineering, the Technology of production process has leapt forward. As a consequence of this, the capital cost of plant and machinery has increased enormously, making it necessary to ensure the maximum effective utilization of that plant. The pattern of development in the capital intensive industries such as the cement industries has therefore been, the increased use of two

and three working shifts (CCNN operates 3 x 4 shifts work schedule), and this leaves little or no time for essential repairs, lubrucation and regular maintenance. Most work of this kind would previously have been carried out while the machinery was shut down during the evening or at weekends. With continous operations becoming a necessity due to increased awareness and improvement of the tastes of the consumer, high demands on business to produce higher quality and higher volumes of goods and services at a very fast rate, Some definate maintenance strategy must be developed. According to Buffa (1973) we can view this problem as one of maintaining the reliability of the entire production system and this could be done by:

1. Increasing the size of repair facilities and crews so that average machine downtime is reduced, because maintenance crews are less likely to be busy when a breakdown occurs.
2. Utilizing preventive maintenance where practical so that critical parts are replaced before they fail.
3. Providing for slack in the system at critical stages so that we have parallel paths available. This means excess capacity, so some machines can be down without affecting the delay costs

to any great degree.

4. Making individual components within a machine or the machines within the system more reliable through improvements in engineering design.
5. Decoupling successive stages of the production system by inventories between operations. The resulting independence of operations localizes the effect of a breakdown, so operations preceeding and following the machine that is down are less liekly to be affected.

The choice of which strategy/strategies to be used depend on the circumstances the organization finds itself in but ultimately the objective of any choice is that of reducing operations cost to a minimum. According to (Moski, 1970), overwhelming evidence in all industries points to the fact that, a well conceived and properly executed plant maintenance programme results in minimum overall maintenance costs and maximum return on the investment in productive facilities for any given level of plant utilization.

3.1.1 What is Plant Maintenance?

As indicated earlier, Starr (1964) defined Plant maintenance as the whole range of work activities dealing with formulating adequate and appropriate

repair and maintenance policy for all equipments and plant items, so as to ensure optimum plant performance at optimum costs to the organizations.

3.1.2 Types of Maintenance Systems

All maintenance systems can be grouped into four categories depending on the degree of complexity of the activities carried out, in carrying out the maintenance function. All the systems are however highly inter-related and usually one or more systems are used in conjunction with each other by an organization. The four main categories are:-

1. The Breakdown/corrective maintenance system.
2. The Routine or Running maintenance system.
3. The Preventive maintenance system.
4. The planned maintenance system.

3.1.2.1 Breakdown/Corrective Maintenance System

Breakdown maintenance is work which is carried out after a failure, while corrective maintenance is work undertaken to restore a facility to an acceptable standard. This is also referred to as repair maintenance, it is usually applied in cases where equipments can be allowed to run until they fail or deteriorate before repairs are affected.

Organization that practice only this system of maintenance eventhough they may have made advance provision in the forms of spares, materials and equipment don't have any planned and organized programmes for maintenance. Repairs are just carried out as they occur. This makes definite maintenance policy difficult if not impossible. Breakdown maintenance is in the long-run not economical as the only system to be used by an organization. If many unanticipated breakdowns occur at the same time chaos could result. Finally, because breakdown maintenance is usually carried out under emergency conditions, the quality of the repairs may be very low and the running times of machines before the next breakdown will consequently be short.

3.1.2.2 Routine Running Maintenance

Routine or running maintenance is work which is carried out while the facility (plent or machinery) is in service. This system calls for constant check-up of plant items on a regular basis by either setting up a pattern to be followed regularly during fixed time intervals and/or by issuing instructions to be followed on a maintenance card which can be used as a check list. Routine maintenance, usually carried out according to plant operations mannual taking into consideration, local

operations conditions is normally simple, economical and highly effective in preventing fault development.

3.1.2.3 Prentive Maintenance

This is work, that is directed at the prevention of failure of a facility (Plant or machinery). This is applied in situation where the average time and cost of preventive maintenance is less than the average time and cost for repair after breakdown; And where high facility reliability is absolutely necessary. That is, the failure of such facility may lead to disruptions of service and/or serious consequences for the organizations. For instance forced ventalation units in mines.

It is usually carried out by detecting and replacing weak parts with new parts before they breakdown, so as to ensure the reliability of the equipment. For this reason, preventive maintenance is inevitably associated with high maintenance costs.

3.1.2.4 Planned Maintenance

This is maintenance which is organized and carried out with forethought, control and records. According to Harding (1977), Planned maintenance implies the examination of all means of repairing, lubrucation, servicing and overhauling of machinery so that in the long run, the machinery has minimum

down time due to failure. Planned maintenance will include activities carried out when:-

(a) The machine is running, such as planned lubrication, certain servicing and for minor unplanned repairs;

(b) The machine is shut down for a planned service.

(c) The machine is shut down for a pre-recogonized breakdown.

(d) Modifications to the design of the machine is done and/or is to be made in order to increase its reliability.

An effective planned maintenance system therefore calls for elaborate and accurate preparations and data recording in order to have adequate feeback for future actions. Due to the attention and thoroughness in its implementation, failures in between service times are usually minimal.

However, it should be noted that, for all practical purposes, the maintenance systems discussed above could be grouped into two main categories, the breakdown and/or planned maintenance systems. Thus for the purpose of this project, we will differentiate all types of maintenance systems and policies as either breakdown or planned with the latter being the focal point on which the project revolves.

3.1.3 Importance and Characteristics of Maintenance

If a machinery is run without maintenance service, it will breakdown sooner or later, and continue to breakdown at closer intervals of time. When a machine breaks down these costs occur: machine down time costs and possible loss of potential sales; idle direct and indirect labour, delays in other processes that may depend for material supply on the machine that is down, increased scraps, customer dissatisfaction from possible delays in deliveries and the actual cost of repairing the machine (Buffa, 1973),Thus, proper maintenance of plant items ensures a longer life, a high salvage value for equipments but above all reduce if not completely eliminate costs associated with breakdowns. This is a major contributing factor in the need to maximise returns on capital especially in developing economy where investment capital is usually very hard and/or costly to procure. Effective plant maintenance raises the question of the need to have adequate stocks of required spare parts and the right calibre of maintenance crew. This is, especially important in an age when technological changes are very rapid and an equipment can easily be made obsolent through careless decisions and lack

of effective maintenance planning. A good strategy of prevention of breakdowns demands that, whenever a failure occurs, then reasons for that failure must be examined and determined; evaluating the characteristics of every unit of equipment, particularly its critical points of weakeness, to determine what preventive maintenance steps are necessary to prolong its life; and recruiting, selecting and maintaining a good crop of workforce such as electricians, machinists, fitters, etc.

The maintenance function usually has a constrasting objective with those of production activities. While the latter aims for a continous, higher volume of production, better quality of products and possibly scrap reduction, the former on the other hand tries to identify faults and device means of rectifying the faults, prevent their occurance to the bearest minimum within the shortest time possible. Thus, in a production oriented industry, the idea is always to keep production going at minimal interference from the maintenance department. This calls for effective maintenance programmes. Effective maintenance programm brings about such intangible benefits like safety, better house keeping, better reliability of delivery through

more accurate scheduling, and a higher quality of product. Maintenance service should therefore not just be considered as a'necessary evil' which consumes a sizeable portion of the organization budget but as an important activity which deserves serious attention from top management.

3.14 The Scope of the Maintenance Function

The maintenance function extends beyond machinery and equipments maintenance to include factory maintenance as well. This includes buildings, grounds, factory services such as power plants, heating and ventilating systems, plumbing system and general house keeping. For a piece of equipment, maintenance activities and functions include manufacture and fabrication of parts, lubrication and oiling of the equipment, planning and scheduling workloads by making planned and shut-down plant overhauls. It also include preventive and corrective measures,that is, detecting and correcting possible failure before they occur; breakdown repairs etc. For the purpose of this project the maintenance function service will be limited to 'process' maintenance which involves carrying out maintenance work such as breakdown and planned preventive maintenance services on different equipments and of machinery within the CCNN.

3.1.5 Maintenance Objectives and Policies

Specific objectives of a planned maintenance system varies from organisation to another and is very much dependent on the type of business that a firm is engaged in. For example the specific objectives of maintenance service required by a hotel business is customer satisfaction. This is different from those required by other enterprises like a chemical industry, a hospital etc. In general, however, the ultimate objectives of a planned maintenance service is "maximum availability of facilities for 'production' activities." These are usually spelt out in the form of cost and operational objectives. A consensus should therefore be reached between management and the maintenance department by clearly defining expected results and the ways and means through which these results could be achieved within the context of the overall business needs and goals (PRIEL, 1974).

Should the facilities be repaired and maintained regularly on a scheduled basis or should we wait for equipment and facilities failure? The answer is of course dictated by the characteristics of the facilities and the relevant costs. Thus the maintenance policies of a firm are not only dependent on the nature of the business but more on the specific

conditions prevailing in the firm - such as size of the enterprise, variability and length of machine running times, availability and cost of spares, etc. as well as, on the personal concepts and views of policy makers. These conditions have a direct bearing on important factors like the allocation of the workload in the firm, the need for constant check - up of plant items, maintenance budget, etc. To have an effective maintenance policy therefore, needs the integration of the maintenance policy with the overall policies of the organisations, such as those dealing with production, marketing, finance, personnel, etc. This is important because a balance needs to be struck between operational objectives such as those dealing with the performance and appearance of equipments and cost objectives which may require the maintenance crew to operate within a limited budgeted expenditure.

3.1.6 Choice of a Plant Maintenance Policy.

As indicated above, the choice of a maintenance policy is dictated more by the characteristics of the facilities (breakdown time distribution) and relevant costs. Eventhough other important factors such as personal concept and views of top management and the nature of the business play a part.

3.1.6.1. Breakdown Time Distribution

To formulate any general policies concerning maintenance service require data on the breakdown time distribution of the equipment. Breakdown time distributions show the frequency with which machines have maintenance-free performance for a given number of operating hours, and are ordinarily shown as distributions of the function of breakdowns that exceed a given run time. These distributions differ depending on the equipment. For example, a simple machine would tend to breakdown at nearly constant intervals following last repair. That is, it exhibits minimum variability in breakdown distributions. While more complex machines would exhibit greater variability. This implies that the periods and number of breakdowns for simple equipments can be predicted with reasonable accuracy. However, the more complex an equipment, the more difficult it is to anticipate and predict its failure. For such cases, management will need to rely more on accurate data on past behaviour or resort to the use of more advanced decisions making tools to forecast likely times of equipment failures (Buffa, 1973).

3.1.6.2 Maintenance Costs

In adopting a maintenance policy, maintenance costs are of prime consideration. Maintenance costs are basically either directly or indirectly related

to the type of maintenance service offered. Direct maintenance costs (cost of spares, and direct labour, etc.), are common to all maintenance services and differ only in magnitude depending on the peculiar circumstances and whether a breakdown or a planned maintenance service is adopted. For example, a particular maintenance service may involve simple lubrication, repairing or adjusting of a part of an equipment or it may involve complete replacement of one or more units with new units. While indirect maintenance costs usually involve such costs as idle labour, that is wages and salaries of the production crew, losses from loss in profit due to possible loss of customer goodwill, etc. Thus, it is very important for an organisation to make a careful analysis of the possible costs to be incurred if a breakdown or planned maintenance service policy is to be adopted.

3.1.6.3 Which Maintenance Policy?

In formulating a plant maintenance policy, an organization should consider both its internal and external environments. In other words, an organization needs to consider such factors as its production process, the availability of skilled personnel, etc. the general economic conditions within which it operates before deciding on a

breakdown or a planned maintenance policy. However, as mentioned earlier, both of these systems may need to be employed at the same time or over time. A planned maintenance service is best suited for simple equipments with low variabilities in their breakdown time distributions and in situations where the total down time costs for a breakdown service outweigh the total costs for effecting a planned maintenance service. While if the reverse is true or if it takes the same or less time to repair an equipment, a breakdown rather than planned maintenance service is adopted. What is important however, is for every organisation to strive to achieve a balance between the two in order to achieve maximum plant performance and operational efficiency at minimum costs.

3.1.6.4 Which Maintenance System?

In adopting a maintenance system, an organisation should start with a careful analysis of its needs. That is , the organisation should clearly define its maintenance objectives and policies. Based on these, a maintenance system or a combination of systems which satisfies its needs is selected. Indeed as mentioned earlier, no

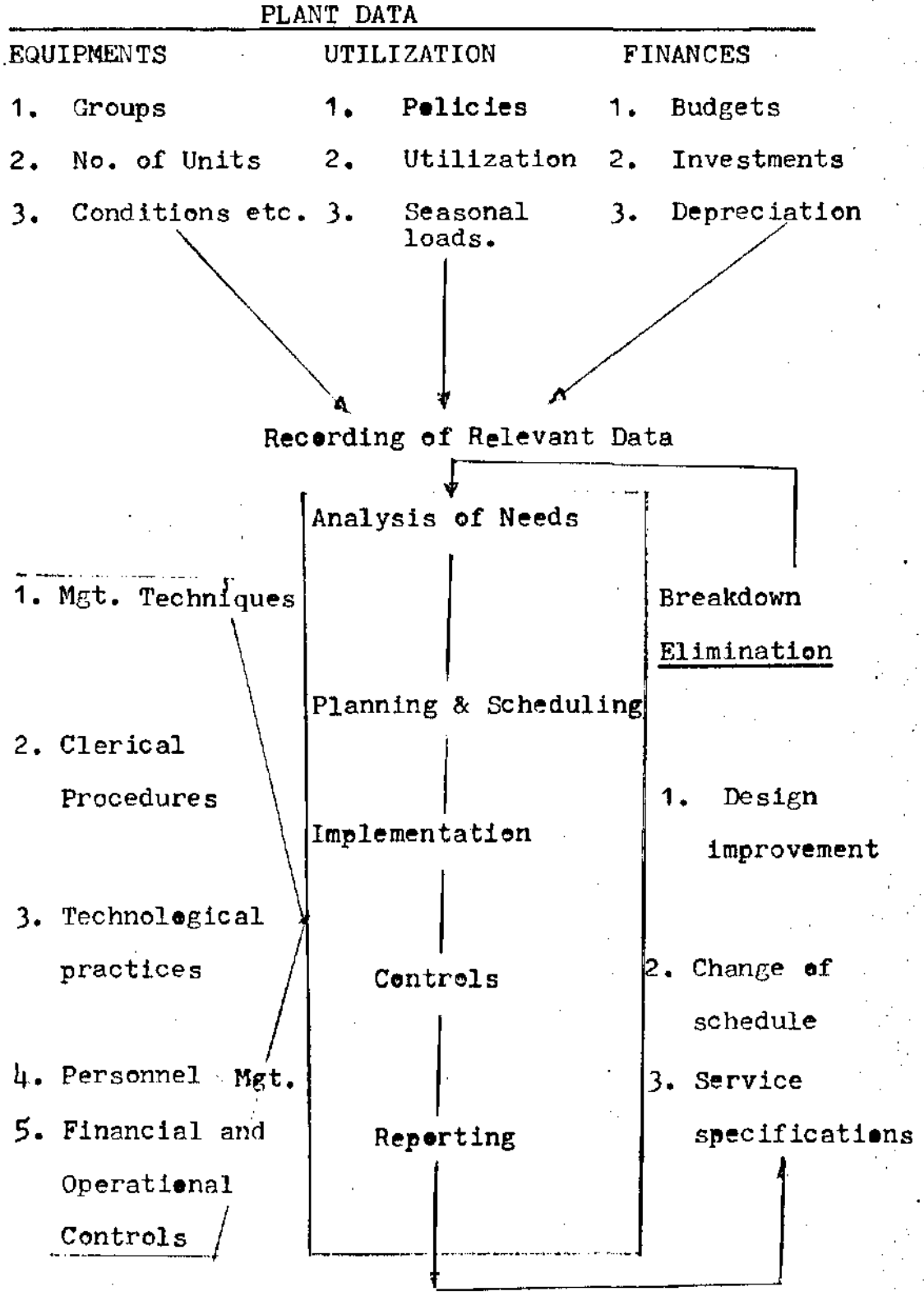
single maintenance system is often used in isolation. For example, a breakdown maintenance system is usually used not as a complete system by itself but in conjunction with other systems in order to solve specific problems. Whichever system or a combination of systems is used, there is a need to draw up detailed guidelines or policies on planning, implementation evaluation and controlling the system to make it effective and efficient.

According to Wanka (1984),

> To solve these problems and meet these requirements, various 'ideal' plant maintenance systems have been proposed and one of such is the 'loop of systematic action.' For a system to be effective and efficient it should take into account all activities connected with the maintenance function and these activities should be identifiable even in the smallest maintenance department.

Fig. 3.1.

The Loop of Systematic Action



Adopted from: WANKA, A.Y. , MBA Project, 1984,p.30.

3.2 Operation Research

Managers must manage effectively and efficiently to succeed. Managing involve making decisions and this needs sound informations. There are many sources for such information - indeed, a manager's performance depends very much on his skill at locating and exploiting sources of information. They must, therefore, be continually on the look out for worthwhile information sources. For many years, these sources lie within the subject matter of economics, accountancy, commercial law, industrial relations, production techniques, human relations, etc. In addition managers take into account the organisations' objectives and policies. However, managers have become increasingly aware that their performance can be improved by a more careful study of the way they run their operations. They began to question the consequences of the existing and alternative methods of operating. And to obtain answers to these questions, management needed to research into the operational side of the business. So operational research came into being. See Fig. 3.2.

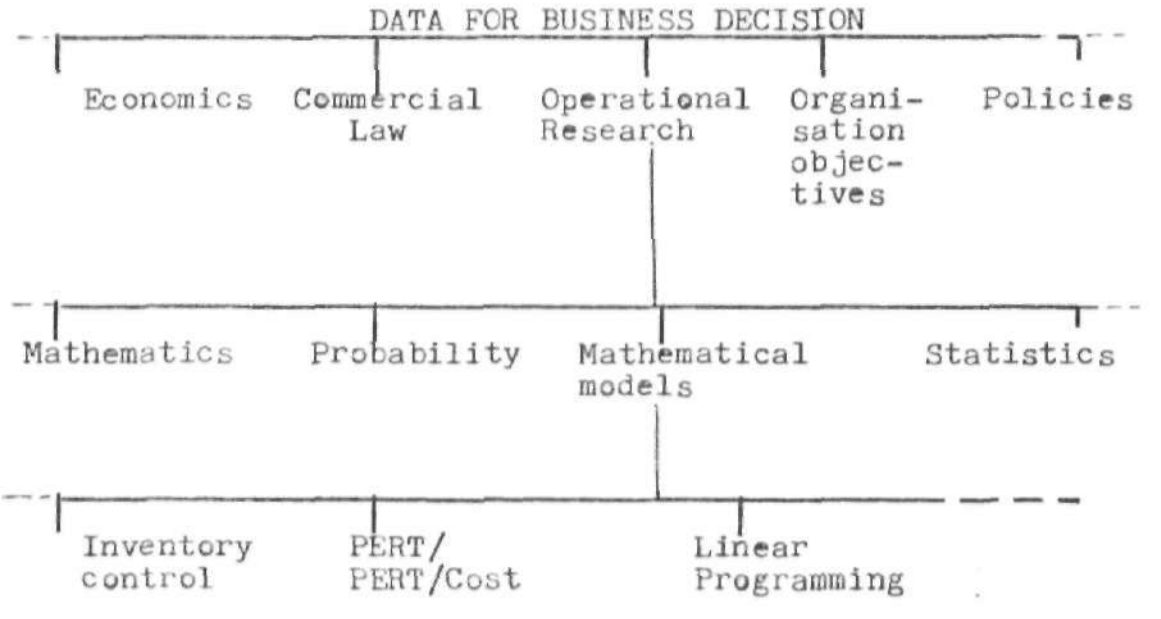
Operational research uses any technique that helps in the analysis of operations. According to Herper (1975), these techniques can be grouped into:

(a) Quantitative Techniques: These involve the careful measurement of operational requirements and returns, for valid measurements enables objective comparisons to be made between alternatives.

(b) Non-Quantitative Techniques: Not all operating factors are quantifiable. It is not possible, for example to measure how one kind of organization structure compares with another. Nevertheless research is possible and operational research workers often use anologies with non-business situations to enable them to find more effective operational methods.

(c) Cybernetics:- This is a theory of control and effective control is, of course, essential for effective operations.

Fig. 3.2



The place of Operational Research in the business situations. Adopted from Harper (1975), page 4.

However, the main area of interest of this project is the mathematical models of the quantitative techniques with particular reference to PERT (Programm Evaluation and Review Technique) analysis and PERT/Cost.

3.4 PERT Network Analysis and PERT Cost

As indicated earlier the maintenance function is of great significance to the management of complex industrial enterprises. For this reason a number of Techniques are used to ensure an effective and efficient performance of this functien, such techniques are; method study, work measurement, and Pert Network Analysis and Pert/Cost.

3.4.1 Method Study

This is an analytical method which finds considerable application in the maintenance function. It is used as an analytical tool and as a means of synthesis, some of its uses are:

1. The examination and improvement of methods of repairs by the use of different sequences of activity, the provision of special tools and jigs with which to work, and the elimination of unnecessary activities.
2. The elimination of recurring failures by change of design.

3. The comparison of job specifications for existing and new machinery, and assessment of the usefulness of new machinery.
4. The examination of production processes, leading to the elimination of unnecessary processes and the consequent reduction of maintenance.
5. Examination of the schedule in order to isolate key costs which cause the major part of total maintenance cost.
6. The synthesis of new job specifications for key costs areas after their elimination by re-design.

3.4.2 Work Measurement

Here all maintenance jobs are timed and rated and standard times deduced for them or alternatively they are estimated from a standard data. From this, it is possible to:

(a) Produce incentive scheme for maintenance workers.
(b) Carry out time analysis for breakdowns and so be able to forecast shut times with some degree of accuracy,and
(c) Dovetail the otherwise indepedent activities of fitters, greasers, electricians, plumbers,

and builders, all of whom may need to work together on a breakdown or major overhaul.

3.4.3 Pert in Maintenance Planning

When a repair or a major overhaul is to be carried out, then the conditions may well favour the use of Pert as a planning and progressing technique. The use of this technique helps to give:

(a) A Clearer Definition of Tasks:

Rigorious logical analysis is a fundamental characteristics of network analysis and results in clearer definitions of tasks, responsibilities and work sequence. The effect is two fold:

(i) A better initial plan.

(ii) Better control

(b) Better Use of Resources:

A regular consideration of float (slack) time available provides opportunities to make greater use of existing resources. This should lead to more extensive use of existing resources and consequently the saving of money that would other wise have been invested in extra resources. This raises the question of flexibility of resources. The more intensive utilization can only be achieved either if the resources are very flexible (e.g. pair of hands) or the work is suited to more

specialized and less flexible resources. As the trend in both plant and brain power is at present for increased specialization, the savings from better utilization need more careful planning if they are to be achieved; this in itself may be a justification for using the technique.

The technique when used also helps in overcoming these problems:

(a) Where total time must be reduced to a minimum without incurring extra expense, and

(b) Where a number of activities are closely interrelated.

Despite the existence of many techniques in the study and analysis of the maintenance function of industrial enterprises as indicated earlier, this project is going to be concerned only with Pert NETWORK ANALYSIS and PERT/Cost.

3.4.4 What is PERT?

Programme Evaluation and Review Technique (PERT) is a management control tool for defining and integrating what must be done to accomplish program objectives on time. It is a technique for focussing management attention on dangersignals that require remedial decisions, and on areas of effort for which

trade-offs in time, resources or technical performance might improve capacity to meet major deadlines.

PERT recoganizes that, the successful achievement of a programme's objectives requires a plan that identifies special events or progress bench marks to be achieved in sequence based upon scientific interdepedences among those events. Three factors influences progress toward objectives, namely, Time, Resources, and Technical performance requirements. Time is a variable that can be saved or spent in applying resources to meet program objectives. Responsible planners and technicians estimate the time necessary to move from event to event.

3.5 Functions Performed by PERT

The original application of PERT focused its attention on time, performance requirements, and the interrelation of various events. The most modern improvement in PERT is called "PERT Cost" wherein not only time, but also cost of each event and for each activity is brought into the program picture. PERT systematically performs the following functions:-

(a) It states the sequence and interrelationships of significant finite events; that is, progress bench marks in the plan to achieve end objectives under planned application of resources to meet specified performance.

(b) It measures the relative uncertainty for completing activivies that link different events in the flow plan or network based upon the technician's estimate of time and range of time necessary to complete each activity.

(c) It synthesizes network and time data to provide the combined impact of such data on capacity to meet program deadlines.

(d) It reveals the relative criticalness among different areas of effort required to meet end objectives. It pintpoints, on one hand, the critical activities which may require remedial discussions, and on the other hand, activities where slack exists and where some delay will not hamper ability to meet end-objective deadlines.

(e) It provides top management with the integrated summary picture of total progress and progress outlook on a continuous basis.

(f) It stimulates the time impact of proposals for change and optional courses for remedial decision on the outlook for meeting end-objective deadlines.

3.5.1 Pert Cost

There are very few activity times that cannot in practice be reduced - at a cost. Eventhough virtually all activity times can be continually reduced by accepting a progressively higher cost, there comes a point where technical factors impose a final limit. The time taken for a concrete to harden for example cannot be reduced below a set limit no matter how much one is prepared to pay. Similarly the sheer physical limit to the number of people who can work on a small unit imposes a minimum activity time which in practice cannot be reduced. The technique of using network diagram to reduce the project completion time at a cost is known as PERT/Cost.

There are many advantages of reducing the project completion time. Among them are:-

(a) Earlier completion may result in possible contract bonuses.

(b) The existing estimated project completion date is beyond the contract date and will result in lateness penalties.

(c) Facilities can be released more quickly for transfer to further profitable work.

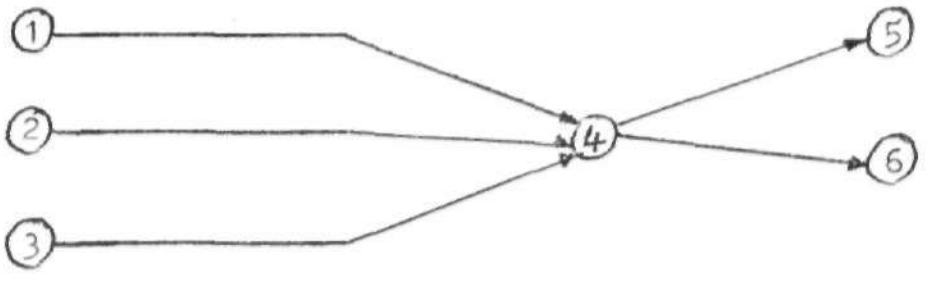
(d) Idle time of facilities in sub-critical paths can be reduced.

(e) Company reputation is enhanced and its competative position improved.

3.5.2 Construction of Pert Network

The technique employed by Pert is to represent a project (such as maintenance service or major overhaul) by a network or arrow diagram in which constituent activities of the project are shown as interconnected arrows. The diagram defines the sequences and interrelationships between the activities. The intersection points of the arrows are known as events or nodes and the rule in drawing the diagram is that all the activities entering an event must be completed before any activity leaving that event can be started. Thus in Fig. 3.3, activities 1 - 4, 2 - 4 and 3 - 4 must all be completed before either activity 4 - 5 or 4 - 6 can start.

Figure 3.3 ACTIVITIES



Activities are defined by their preceeding event and succeeding event numbers. Where two activities running in parallel start and finish at the same event, a dummy activity is inserted to enable a distinction to be made between them

Figure 3.4



A dummy activity is sometimes also necessary to represent parts of a project in logical form Activities may include such items as: obtain finance; procure neces-ary spare parts from suppliers; order materials from stores, etc.

By discussion with executives concerned with various aspects of the project, a network diagram is built up. It has been found that, the construction of the diagram, including the necessary prior consultation, is itself worthwhile as it brings to light unforeseen difficulties and introduces a degree of rigour into planning which has hitherto been lacking. It will be noted that, at this stage

no question has arisen of the time required for activities or for the total project. The network simply establishes the inter-dependency of activities within the network, and thus the sequences in which they must be carried out.

3.5.3 Analysis of the Network

With the completion of the network, the duration of activities are estimated. The estimated time for each activity is shown against the corresponding arrow and for all dummy activities the time is zero. Against each event are shown two times, the earliest time (T_E) by which that point on the diagram can be reached and the latest time (T_L) by which it must be reached, if the total project is not to be delayed. The earliest time to reach an event is in fact the time taken by the longest path from the start of the project to the event, since all activities arriving at the event must be completed before the state of affairs represented by the event is achieved. The value of earliest time for the start event (T_{E1}) is zero. While the earliest time (T_{E_2}) of the event preceeding the first event is given by the relation:

$$T_{E_2} = T_{E_1} + AT_1$$

where AT_1 is the time taken to complete the start event. The remaining events in the network are examined in the same manner.

Note:

Before calculating the earliest time at any event, it is essential to calculate the earliest time for all preceeding events. For example in Fig. 3.5 events, 1, 2, and 3 must be completed before event 4. Alternatively the earliest times are determined and the highest figure selected; that is 7 days; and this is the earliest time for event 4.

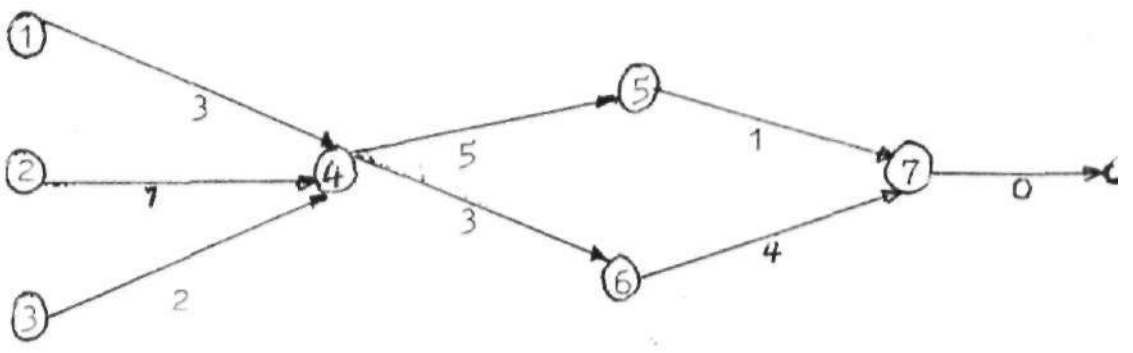


Fig. 3.5

The earliest times by which events must be reached if the project time is to be unaffected are calculated by working backwards from the last event in the project, in this case event 7. Thus the latest

time for event 5 is 14 - 1 = 13 days and for event 6 is 14 - 4 = 10days. Before calculating the latest time for any event, it is essential to calculate the latest time for all subsequent events. The lowest of these times is selected. Thus for activity 4 the latest time is 7 days.

3.5.4 Critical Path

It is clear that there is a critical sequence of activities through the diagram upon which the overall project time depends and this path is readily identified as running through those events which individually have identical T_E and T_L values. Critical activities are those for which $T_E = T_L$ at both the preceeding and succeeding events and for which the succeeding event time less the preceeding event time is equal to the activity duration. In the example given above , the path which satisfies the condition is 2 - 4 - 6 - 7; and is called the critical path.

All activities not lying, on the critical path contain 'total float (total slack) and some also contain free float(slack). Total float is the period by which an activity may be delayed or extended without increasing the overall project time. Free float is the period by which an activity

may be delayed or extended without delaying any subsequent activity.

During the planning of a project, knowledge of the critical path shows which activities should receive special attention and is usual to divert resources from the non-critical to the critical activities. The critical sequence can also be subjected to examination and where appropriate the critical activities can be overlapped to achieve a further reduction in the project time. Re - analysis and review are repeated until a satisfactory working plan is achieved.

3.6 Review of Related Researches

It is worthwhile to note the findings and recommendations from similar researches conducted in certain companies. This will help guide the research as well as show what problems these companies have that are in common with the CCNN and in what ways are these companies different, so that CCNN can learn from their achievement and failures as highlighted in the researches.

Two similar researches, the application of operations research on the maintenance practices of two different companies, the Ashaka Cement Company,

Bauchi state and the Nigerian Railway Corporation (NRC) Zaria were conducted by Ado Yakubu Wanka (1984) and Usman A. Saleh (1986) respectively. While the approach of these studies is different from this one (The two researches used simulation and Queeing Techniques), some useful information can be derived from them. Both researches focuses their attention on the problems of equipment (plant) down time and its attendant costs, the optimal maintenance crew size and effective utilization, some of the key variables of interest to this study.

The findings and recommendations of interest of these two researches are:-

1. The general concepts and views of most top management in various organizations as regards plant maintenance services are far from uniform. While some managers, advocate less frequency in maintenance services through the application of breakdown maintenance policies, others view the objectives and aims of maintenance service as one of prolonging the operating life of all plant items and equipments. This later view will inevitably call for a planned and systematic approach to the provision of effective

maintenance policies which will necessarily be preventive in nature. However, even those who advocate planned maintenance service are not unified in their approach as to which form it should take, that is, whether routine or purely preventive maintenance (Saleh, 1986).

2. No matter which maintenance policies are adopted for a particular plant, there is a need to plan and obtain maximum production volume at minimum costs by ensuring that the plant is in a constant state of optimum operating efficiency. This will require the use of all possible techniques and measures available within the resources of the organization. Specifically, this study has shown that operations research techniques have very high potential applications in industrial system. They can be used to have a better understanding of the operations of an industrial system and thus increase the operating efficiency of the plant by helping to formulate effective plant operations and maintenance policies (Saleh, 1986).

3. The main causes of down time in the Cement plant are power failure, mechanical breakdowns

and maintenance, "operational reasons," Electrical/process control repairs, refractory and bricking repairs (Wanka, 1984).

4. The three causes of locomotive down time in the NRC are material failure, maintenance and operational lapse. The maintenance and operational lapse are attributable to the ineffectiveness and inexperience of a large proportion of the maintenance team since most of the team members are not well educated and only rose to their reasonably high positions through long service with the organization (Saleh, 1986).

5. The manpower problem of the NRC is not shortage but could be that of having too many unqualified and inexperienced staff and inadequate educated, experienced and motivated personnel (Saleh, 1986).

Among the recommendation made by the two researchers that are of interest are:-

1. The use of generators in the cement plant to safeguard against stoppages due to power cut and increased use of planned maintenance rather than repairs on a breakdown basis (Wanka, 1984).

2. The management of any organisation should strive for a balance between the different maintenance policies and systems and it should always be prepared to shift this balance depending on its organization's specific and peculiar needs and also on its external environmental variables (Saleh, 1986).

3. There is a need for intensive training of the maintenance staff, in house, and in Universities and Polytechnics. This will serve as a motivator to the staff and the staff will be better qualified for the performance of their job (Saleh, 1986).

Another study of interest is the one conducted by Umar Faruk Bello (1985). Faruk Bello studied the Management Practices of the Cement Company of Northern Nigerian (CCNN), the very company in which this research is being carried out. At the end of his study, Bello concluded that,"the organising function of management of the CCNN seems to be satisfactory, the staffing and directing need improvement but the major problem areas are planning and controlling as these are areas where the company's management is most deficient." Bello also noted that,

the measures provided for the control of the quality of machines for effective performance, periodic inspections, taking appropriate maintenance measures to prevent faults or breakdowns are hardly implemented considering the incessant breakdowns which continue to bedevil the company and pose the single most important obstacle to its success.

Among the most important recommendations made by Bello are:-

1. "Supervisors should be taught how to perform their jobs more effectively. All managers who supervise subordinates should be given intensive training on how to observe and record the performance of their subordinates and the appropriate approach that would be helpful to subordinates without causing resentment. Their knowledge of the job should be deepened so that they can effect correction. Professional control staff such as inspectors of new machinery, maintenance staff and Auditors should be specifically trained on how to minimise costs to the company. In fact it is the view of this researcher (Bello) that the company should specially study the causes

of the machine breakdowns that has been causing the company so much loss. Measures should be taken to prevent such costly mistakes, including the replacement of the inspecting consultants, or maintenance crew responsible for their incompetance.

2. The owners of the company should consider looking into the membership of the Board of Directors of the company to identify members who have no knowledge of or an experience in business, and replace them. The board and management should be allowed to perform their duties without political interference. Strictly, business considerations should guide the operations of the company, if it is not to be turned into another civil service establishment.

Chapter Four

ANALYSIS AND INTERPRETATION OF DATA

4.1 Schedule of Activities and Network Diagram

The schedule of activities and their sequence was drawn up using the information provided in Appendix 4.1 and the information collected from the Assistant Technical Manager. For example, activities 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 37 and 38, their time duration and their sequences were based entirely on the information provided by the Assistant Technical Manager. While the remaining activities, their sequence and time duration was based on the information in Appendix 4.1.

In some instances, where the activities time overlapped as in the case of activities 15 and 16 29 and 30, and 35 and 36, the researcher assumes the activity that starts earlier as the predecessor to the activity that starts later eventhough they may finish at the same time and in some cases the later finishing earlier.

Based on the information from Appendix 4.1 and the Assistant Technical Manager and above assumptions, the schedule of October 1986 kiln

shut down maintenance and repairs activities and their times was drawn up as shown in Table 4.1.

Based on the schedule drawn up, the Pert Network diagram of the kiln shut down maintenance and repairs for October, 1986 was drawn as shown in Fig. 4.1. The activities times in hours were computed and tabulated as shown in table 4.2.

The various paths and their times from Fig. 4.1 were determined and the critical path determined from these paths.

Table 4.1

Kiln Shut-down Maintenance and Repairs Activities and their Sequence

Event	Activity	Predecessor	Time(hrs)
1.	Shutdown process	-	12
2.	Cooling down of the kiln	1	48
3.	Opening of the kiln door	2	2
4.	Provision of light in the kiln	3	2
5	First Inspection of the kiln and estimating the extent of brick damage	4	24
6	Ordering and collecting of materials from the store	5	12
7	Transporting of material to kiln site	6	6
8	Loading of materials on the platform.	7	6
9.	Clean all already knocked down bricks and rubbles in the kiln	5	96
10	Second inspection of the kiln	9	12
11.	Gathering of crew for the 2nd and final cleaning of the kiln	10	24

Table 4.1 cont.

Event	Activity	Predecessor	Time(Hrs)
12	Brick work in the kiln	8, 17	168
13	Welding of plates on cooler elbows	11	96
14	Check all planetary coolers. Ensure anchors are welded in readiness for casting	13	24
15	Casting of cooler elbows	14	120
16	Casting of cooler lifters (Patch work)	15	48
17	Brick work in hot gas generator	11	96
18	Check and patch up burner pipe	13	24
19	Clean the backend of the kiln so that probe can go in easily	17	24
20	Check crusher hammers, baskets and lubricants	-	72
21	Check belt conveyors, reclaimer system	20	192
22	Check belts, double pend flaps (bearings)	-	48
23	Check raw mill inlet flange and liner plates	22	96

Table 4.1 cont.

Event	Activity	Predecessor	Time (Hrs)
24	Check precipitator (Electrodes and Plates)	-	48
25	Screw conveyors/ cooling tower	-	96
26	Check bucket elevator drives	-	72
27	Check discharge of raw mill silo	26	48
28	Replace kiln rotary feeder	-	72
29	Dismantle inlet seal	28	144
30	Check clinker transport	29	24
31	Clean raw water reservoir	-	48
32	Check raw water non-return Valves	31	192
33	Check cranes and Hoists general	-	192
34	Check compressors, fitters, lub., etc	-	264
35	Check panels (general)	-	336
36	Replace gear motors	35	48
37	Running Tests	12,16,19, 21,23,25 27,30,32, 33,34, and 36	72
38	Close kiln door and start (light up)	37	12

SOURCE: Schedule of Kiln Shutdown Repairs October, 1986. See Appendix 4.1.

FIGURE 4.1

NETWORK DIAGRAM FOR KILN SHUT DOWN MAINTENANCE AND REPAIRS

OCTOBER 1986.

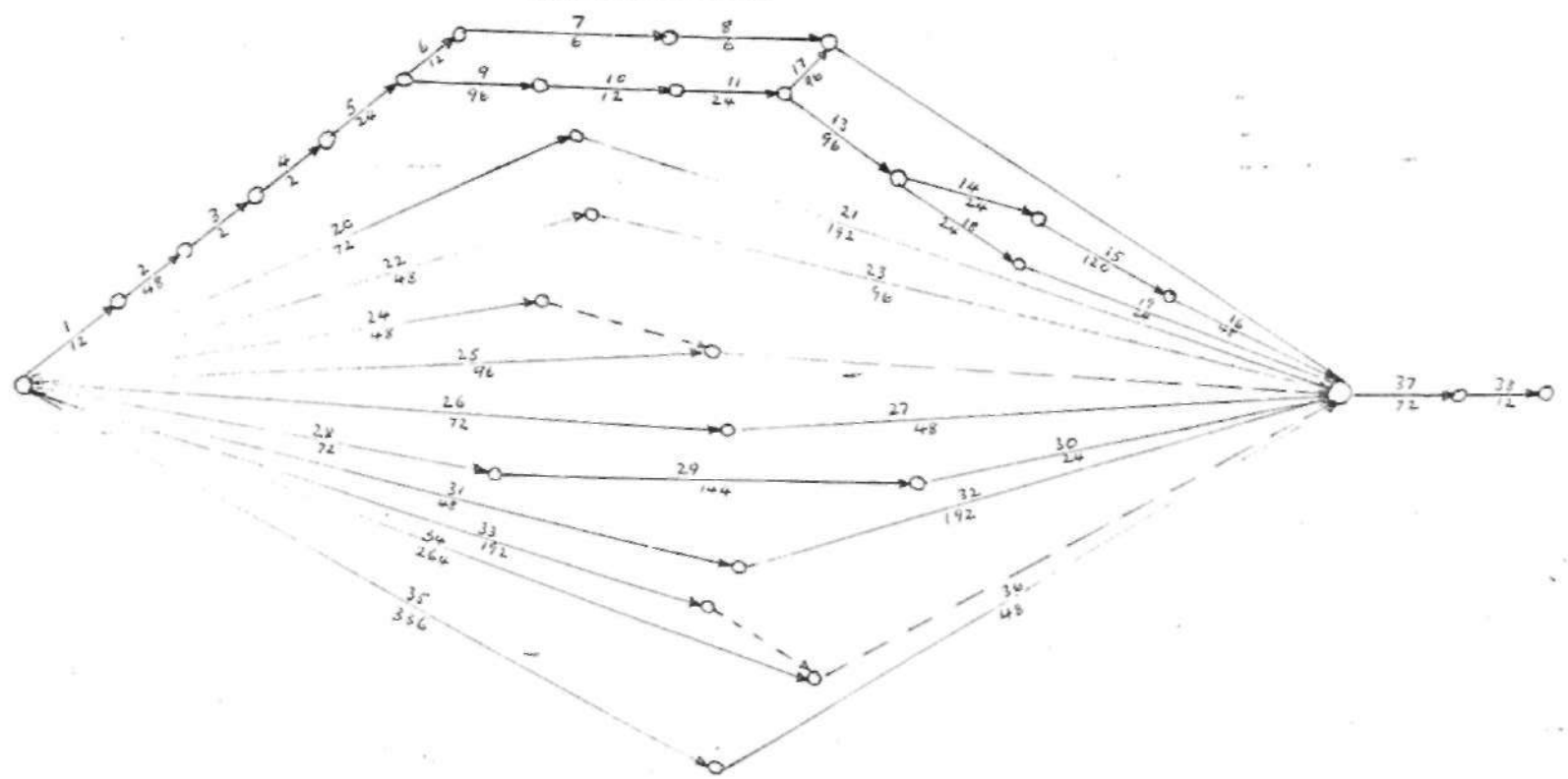


Table 4.2

Table Showing Activities and their Times in Hours Computed from Figure 4.1

Activity	Early Start	Early Finish	Late Start	Late Finish	Slack
1	0	12	0	12	0
2	12	60	12	60	0
3	60	62	60	62	0
4	62	64	62	64	0
5	64	88	64	88	0
6	88	100	316	328	228
7	100	106	328	334	228
8	106	112	334	340	228
9	88	184	88	184	0
10	184	196	184	196	0
11	196	220	196	220	0
12	316	484	340	508	24
13	220	316	220	316	0
14	316	340	316	340	0
15	340	460	340	460	0
16	460	508	460	508	0
17	220	316	244	340	24
18	316	340	460	484	144
19	340	364	484	508	144
20	0	72	244	316	244
21	72	264	316	508	244

Table 4.2 cont.

Activity	Early Start	Early Finish	Late Start	Late Finish	Slack
22	0	48	364	412	364
23	48	144	412	508	364
24	0	48	460	508	460
25	0	96	412	508	412
26	0	72	388	460	388
27	72	120	460	508	388
28	0	72	268	340	268
29	72	216	340	484	268
30	216	240	484	508	268
31	0	48	268	316	268
32	48	240	316	508	268
33	0	192	316	508	316
34	0	264	244	508	244
35	0	336	124	460	124
36	336	384	460	508	124
37	508	580	508	580	0
38	580	592	580	592	0

The Paths - Computed from Figure 4.1

1-2-3-4-5-6-7-8-12-37-38 = 364 hrs.

1-2-3-4-5-9-10-11-17-12- 37 - 38= 568 hrs.

1-2-3-4-5-9-10 - 11 - 13 - 14 - 15 - 16-37-38 = 592.hrs

1-2-3-4-5-9-10-11-13-18-19-37-38 = 448 hrs

20 - 21 - 37 - 38 = 348 hrs

22	-	23	-	37	-	38	=	228 hrs.
24	-	37	-	38			=	132 hrs
25	-	37	-	38			=	180 hrs
26	-	27	-	37	-	38	=	204 hrs
28	-	29	-	30	-	37 - 38	=	324 hrs
31	-	32	-	37	-	38	=	324 hrs
33	-	37	-	38			=	276 hrs
34	-	37	-	38			=	348 hrs
35	-	36	-	37	-	38	=	468 hrs

The Critical Path is 1-2-3-4-5-9-10-11-13-14-15-16-37-38=592hrs.

4.2 Normal Labour Cost Associated with the Net-Work Diagram(Figure 4.1).

According to company records, the average gross salary of a factory worker (Production, Mechanical, Electrical, etc) is N2881 per annum.

∴ Gross salary of a worker per hour (Assuming one year = 365 days).

$$= \frac{N2881}{365 \times 24} = N0.3289.$$

Activities 1 to 19

Appendix 4.1 simply implies that, activities 1 to 19 are performed by production. The researcher therefore assumes that all the staff in the production department are involved in these activities. According to company records, there are 276 staff in the

department (See staff strength and distribution in chapter 2).

But Labour cost = Number of staff x Duration of the job x the rate per hour.

∴ labour cost for activities 1 to 19

= 276 x 508 x ₦0.3289

= ₦46,114.4

Activities 20 to 34

According to the Assistant Technical manager of the company, for the maintenance and repairs activities represented by Appendix 4.1, The Mechanical section was divided into twenty groups, with a group consisting of about five workers.

Based on the labour cost of a worker per hour, the composition of a group, the labour cost of the following activities are calculated as follows:

Activity	20	=	0.3289	x 72 x	15*	=	₦355.2
,,	21	=	0.3289	x 192 x	15	=	₦947.2
,,	22	=	0.3289	x 5 x	48	=	₦78.9
,,	23	=	0.3289	x 5 x	96	=	₦157.9
,,	24	=	0.3289	x 5 x	48	=	₦78.9
,,	25	=	0.3289	x 5 x	96	=	₦157.9

*The researcher assumes that, the notation 02/04 in Appendix 4.1 implies groups 02, 03 and 04. Thus making a total of fifteen staff.

Activity	26	=	0.3289	x	5	x 72	=	₦118.4
,,	27	=	0.3289	x	5	x 48	=	₦78.9
,,	28	=	0.3289	x	5	x 72	=	₦118.4
,,	29	=	0.3289	x	5	x 144	=	₦236.8
,,	30	=	0.3289	x	5	x 24	=	₦39.5
,,	31	=	0.3289	x	5	x 48	=	₦78.9
,,	32	=	0.3289	x	5	x 192	=	₦315.7
,,	33	=	0.3289	x	5	x 192	=	₦315.7
,,	34	=	0.3289	x	5	x 264	=	₦434.1

Activity 35 and 36

Appendix 4.1 simply says Electrical. Therefore the researcher assumes that, all the electrical staff are involved in activities 35 and 36. Since there are 72 staff in the electrical. The researcher assumes that, all the 72 staff are involved in the electrical repairs.

∴ The labour cost of activities 35 and 36

= 72 x 0.3289 x 384 = ₦9093.4

Activity 37

The researcher assumes that all the mechanical and electrical staff are involved in the running tests. That is, everybody is busy checking his own area of operation.

∴ labour cost of activity 37

= 214 x 72 x 0.3289 = ₦5067.7

Activity 38

The researcher assumes, only the production workers are going to be involved in activity 38.

∴ labour cost of activity 38

= 276 x 12 x 0.3289 = ₦1089.3

∴ Total normal labour cost associated with figure 4.1 which is equal to the sum of all the labour costs associated with all the activities

= ₦64,877

4.3 Crushing of Activities Along the Critical Path

Since running tests can not be conducted until all the mechanical, electrical and production jobs are completed. The crushing of activities along the critical path to reduce the time has to conform with this constraint. Thus, the shortest time for the activities along the critical path cannot be less than the time taken by electrical to complete their assignment, which is 468 hrs.

Due to physical constraints, not all the activities' time can be reduced, by increasing the labour force. Those activities whose time can be reduced by increasing labour force along the critical path are: 9, 11, 13, 15 and 16. The activities' time can be reduced by increasing the labour force

as follows:

Activity	9	by	48	hrs.
,,	11	by	12	hrs
,,	13	by	48	hrs
,,	15	by	8	hrs
,,	16	by	8	hrs.

Total reduction of time = 124 hrs.

The implication of reducing the critical path; time by 124 hrs is that, path 1-2-3-4-5-9-10- 11-17-12 -37-38 has to get its time reduced by at least 100 hrs. This reduction is possible by increasing the labour force of the following activities along the path. 9, 11, 17 as follows:

Activity	9	by	48	hrs.
,,	11	by	12	hrs
,,	17	by	48	hrs

Total reduction of time 108 hrs.

The increase in the labour force can be affected by transfering all the mechanical workers to assist the production workers. Since the smallest slack for the Mechanical group is 244 hrs. Which means their job can start 244 hrs later and still be able to complete their assignment in time.

4.3.1 The New Paths After Crushing Activities 9,11,13,15 and 16 Along the Critical Path

1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 12 - 37 - 38 = 364 hrs.

1 - 2 - 3 - 4 - 5 - 9 - 10 - 11 - 17-12-37-38 = 460 hrs.

1 - 2 - 3 - 4 - 5 - 9-10-11-13- 14-15-16-37-38 = 468 hrs.

1 - 2 - 3 - 4 - 5 - 9-10-11-13-18-19-37-38 = 340 hrs

20 - 21 - 37 - 38 = 348 hrs

22 - 23 - 37 - 38 = 228 hrs

24 - 37 - 38 = 132 hrs

25 - 37 - 38 = 180 hrs

26 - 27 - 37 - 38 = 204 hrs

28 - 29 - 30 - 37 - 38 = 324 hrs

31 - 32 - 37 - 38 = 324 hrs

33 - 37 - 38 = 276 hrs

34 - 37 - 38 = 340 hrs

35 - 36 - 37 - 38 = 468 hrs

The New Critical Paths are:

1-2-3-4-5-9-10-11-13-14-15-16-37-38 = 468 hrs.

35 - 36 - 37 - 38 = 468 hrs

4.3.2 Cost Due to Crushing of Activities Along the Critical Path

The only cost that changes after crushing some activities along the critical path and path 1-2-3-4-5-9-10-11-17-12-37-38 is the cost associated with activities 1 to 19. This is due to the change in time duration.*

*All assumptions made in the calculation of the normal cost apply in this calculation.

This new cost is given by:

Number of people invole x the new time x rate per hour.

= 276 x 384 x ₦0.3289

= ₦34,858.0

∴ The new labour cost associated with the network diagram shown in Fig. 4.1 after crushing some activities is:

₦53,348.0
==========

4.3.2 Down Time Costs

The downtime costs are costs associated with possible loss of profit due to non-production, cost of salary payment of idle labour, costs associated with loss of customer goodwill due to delay in order, repair costs, etc.

The relevant costs and computable due to a delay in affecting repairs.

= Salary payment of idle labour force (all staff in the factory) + possible loss of profit due to non-production ± the savings made as a result of redeploying of staff in the crushing exercise.

Total annual salary for the company for 1986 (See Appendix 4.16).

= ₦3,322,971.

∴ Total hourly company payment (Assuming one year = 365 days)

$$= \frac{3,322,971}{365 \times 24} = \underline{\underline{₦379.33}}$$

According to the production Manager, the cost of producing one ton of cement is about ₦165.0 while the selling price as at 1986 is ₦200,00

∴ Profit per ton = ₦35.0

The total cement production for 1986, is 308,683 (See Appendix 4.9)

∴ The Gross Profit the company should make for the year = 308,683 x ₦35.0

= 10803,905

∴ The supposed profit per hour = ₦1233.32

Savings made as a result of crushing some activities is:

₦11529

∴ The gain that proper deployment of staff for the activities in the maintenance and repairs represented by Fig. 4.1 to the company is:

= ₦1233.32 x 12*4 + ₦379.3 x 12 + ₦11529

= ₦214,494.

---

*12 hrs were saved from the redeployment exercise of the mechanical staff to help in the production staff activities (1 to 19).

4.5 Staff Utilization

While the researcher is not in a position to compute staff utilization for production and Electrical, the idle working hours of the groups in the mechanical section could be computed before and after the redeployment to production in order to increase the labour strength of the group and thus reduce the time (See tables 4.3 and 4.4).

Table 4.3

Table Showing Mechanical Staff's Useful Time, Idle Time and Idle Time as a % of Useful Time Computed From Fig. 4.1, Appendix 4.1

Group	Time Taken to Complete given Assignment	Idle Time	Idle Time As a % of Useful Time
02/04	264	244	92.4
05	144	364	252.7
06	144	364	252.7
07	120	388	323.3
08	240	268	116.7
18	240	268	116.7
20	456	52	11.4
Total	1,608	1,948	
Average	230	278.3	121.0

There are a total of 45 staff involved in the activities. Out of the total of 3,556 hrs they are suppose to be working, they are idle for 1,948 hrs.

In other words the correct number of staff that could be kept fully employed:

$$= \frac{1608 \times 45}{3556} \text{ Staff}$$

$$= 20.4 \triangleq 20 \text{ staff.}$$

In other words 45 - 20 = 25 staff, are redundant during the exercise.

∴ Redundant workers as per the schedule of maintenance and repairs of kiln shut down (Appendix 4.1) is 25

From the analysis of staff utilization, and evidences drawn from what Mr. Zdenko (1987) stated on the staffing position; it is clear that the company is overstaffed. For instance, according to the schedule of October, 1986 kiln shutdown maintenance and repairs programme. Twenty five out of the forty five mechanical staff involved were redundant or could be utilized somewhere else. Mr. Zdenko (1987) also indicated, in his own words that, "it is evident that, there are so many electrical people, although stoppages for mechanical reasons are more often than electrical ones. Also in his comments on the number of people in the chemical and shift control staff. He stated "The number of people in the chemical and shift control section are too many."

The time utilization after redeployment of each of the nine groups is the sum of the time taken to do their job plus the time they were redeployed to help the production works as the case may be. This total, subtracted from the time to reach the test period (384 hrs) mark their idle time. The idle time is calculated as as a percentage of time utilization. See table 4.4 below.

Table 4.4

Group	Time taken to complete given assignment	Time of deployment to production	Total Useful time	Idle Time	Idle Time as a % of useful time
02/04	264	108	372	12	3.2
05	144	124	268	116	43.3
06	144	124	268	116	43.3
07	120	124	244	140	57.4
08	240	124	364	20	5.5
18	240	124	364	20	5.5
20	456	-	456	(72)	(18.75)
Total	1608	728	2336	352	
Average	230				15.1

Since there are a total of nine groups of five number each. On the average, 15.1% of the time of the

total number of the nine groups (45) are idle. In other words 15.1% of the 45 staff are redundant.

∴ Redundant workers ≈ 7.0

4.6 Annual KILN Stoppages Data

The annual kiln stoppages data due to mechanical and electrical faults, bricking repairs and technological problems (blockages along the lines) and similar problems that could be attributable to lapses in planned maintenance obtained from kiln stoppages data of the company (Appendix 4.10 to 4.14) were summerized and tabulated in table 4.5.

From the table, the average kiln idle time per annum is 2405.6 hours with an average of 307.2 hours per month and idle time as a percentage of utilization time of 37.72%. The down time costs as a result of these stoppages per annum is staggering.

For example the downtime costs for 1986, using the average figure is:*

Gross factory labour cost per hour x number of idle hours + potential loss of profit per hour x number of idle hours = (₦379.33 x 2405.6 + ₦1233.32 x 2405.6)**

= ₦3,879,390.8

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* Repair costs, loss of customer goodwill due to delay in delivery of order, etc, were not taken into consideration in the calculation.

** See item 4.3.2, calculation of downtime costs.

From appendix 1.2, the highest loss incurred by the company was in 1982 which stood at N2,333,000. This indicates that, the down time costs as a result of lapses in planned maintenance for 1986 far outweigh the highest loss ever incurred by the company by about N1,546,390.

As observed by Mr. Zdenko, (1987), "if precautions are taken by checking every day, or every shift if it is necessary, all points lubricated, for changes in noise pattern, unusual vibrations, abnormal heat of some bearings, many serious damages would be prevented." In his other comments, he also indicated lack of proper trained and experienced Nigerian staff to handle the plant as another cause of the incessant stoppages of the plant.

Table 4.5

Summary of Annual Kiln Stoppages Data

Year	Total Kiln Idle Time (Hrs)	Monthly Average of Kiln Idle Time (Hrs)	Monthly Average of Kiln Idle Time as a % of Utilization Time
1982	1767.2	294.5	40.0
1983	1320.6	165.1	22.8
1984	2953.6	369.2	50.0
1985			
1986	4202.7	350.2	39.4
1987*	1783.9	356.78	36.4

Table 4.5 cont.

Year	Total Kiln Idle Time (Hours)	Monthly Average of Kiln Idle Time (Hrs)	Monthly Average of Kiln Idle Time as a % of Utilization Time
Total	12,027.7		
Average	2405.6	307.2	37.72

4.7 Kiln Annual Production Data

The Kiln annual production data, indicating the total number of tons of clinker produced per annum, the monthly average, the annual monthly average of kiln time utilization as a percentage of rated time and the percentage of rated capacity used were summarized from Appendix 4.2 to 4.8 and tabulated in table 4.6 below.

It is interesting to note that, on the average, 100,524 tons of clinker is produced with a kiln utlization time of only 43.1%. In other words if the kiln's time is 100% utlized:

$\frac{100254 \times 100}{43.1}$ tons of clinker would have been produced or 232,607.9 tons of clinker.

But note the average cement production per annum (See Appendix 4.9) is 308,683 tons. That is 100,524 tons of clinker is equivalent to 308,683 tons of cement (assuming all things remain constant, no cement mill breakdowns, etc).

$$\therefore \quad 232{,}607.9 \text{ tons of clinker} = \frac{308{,}683 \times 607.9}{100{,}524}$$

$$= 714{,}278.22 \text{ tons}^*$$

$$\therefore \text{ Loss of production due to kiln idle time}$$

$$= 714{,}278.22 - 308{,}683$$

$$= 405{,}595.22$$

$$\therefore \text{ Loss in potential profit due to kiln idle time in 1986} = ₦405{,}595.22 \times 35$$

$$= ₦14{,}195{,}832.0$$

This low kiln time utilization is as a result of stoppages due to lapses in planned maintenance and repairs, and poor technical management. This results

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*The figure is higher than the rated capacity of the factory. The researcher believes the error is due to errors in the compilation of the data by the staff of the company.

indicate a potential loss to the company of about ₦14.2 million.

Table 4.6

Summary of Annual Kiln Production Data

Year	Total (Tons)	Monthly Average (Tons)	Monthly Average of Kiln Time Utilization (%)	% of Kiln Rate Capacity
1982	22,119	3,686.5	50.7	37.6
1983	58,087	4,840.6	57.4	57.9
1984	45,822	3,818.5	47.3	41.8
1985*	106,703	5,043.5	23.75	23.4
1986	274,707	22,892.2	47.7	47.2
1987**	95,706	11,903.3	31.46	24.5
Average	100,524	8,697.15	43.1	38.7

SOURCES: Computed from Appendix 4.2 to 4.8

4.8 Annual Production Maintenance Cost of Plant Per Ton of Clinker Produced.

The annual production maintenance cost of plant per ton of clinker produced which consists of cost of maintenance and spares, cost of kiln oil consumed, the factory labour cost and the cost of diesel and lubricants consumed were computed from Appendix, 4.15, 4.16 and 4.17, and 4.2 to 4.8. The figures are

*Figures are sum of the old and new line production figures for the year.

**Only 5 months production figures are available.

summarized and tabulated in table 4.7 below.

Table 4.7

Annual Production Maintenance Cost of Plant Per Ton of Clinker Produced

Year	Maintenance and spares Cost (₦)	Kiln Oil Consumption (₦)	Labour Cost (₦)	Diesel and Lubricants consumption (₦)
1981/82	12.6	1.34		1.7
1982/83	4.8	6.67		3.25
1983/84	13.2	13.35		5.2
1984/85	6.7	4.5		2.9
1986	7.2	5.8	12.1	2.7
1987	12.75	7.3	16.0	3.48
Average	9.54	6.5	14.0	3.2

SOURCES: Computed from Appendix 4.15, 4.16 and 4.17, and Appendix 4.2 to 4.8.

Studying the table, except for possibly the figures for diesel and lubricants consumptions, all the other figures show no discernable pattern or trend. This clearly indicates that, there is no consistency in the maintenance practice of the company. In other words, there is no planned maintenance operating in the company.

In the words of Mr. Zdenko, (1987) "Machineries and Equipment with defects are not repaired in industry-wise manner, but mostly only provisionally due to lack of many spares and consummables but at the same time because of lack of any preventive maintenance .... most of the long stoppages for lining, maintenance and overhauling the machinery could be attributed to the management lack of planning and supervision."

Chapter Five

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The Cement Company of Northern Nigeria has not been successful throughout its twenty years of operations as indicated by the losses it has kept incurring during this period. In line with the objective of the study, scope and hypothesis, data was collected from the company and analysed. Based on the analysis of the data, general discussions with top management of the company and the researcher's personal observations, the following conclusions are arrived at. It should be noted that, conclusions 1, 2, 3, 4, 5 and 6 are general in nature to similar companies like the CCNN, while the rest are specific to it.

1. There is no general concensus among top executives in various organizations as regards to plant maintenance services policy. While some advocate planned maintenance, others are of the view that equipments should be maintained/repaired only after their breakdown. Even those who advocate planned maintenance, only give a lip service to it.
2. No matter which maintenance policies are adopted for a particular plant, there is a need to plan

and obtain maximum production volume at minimum costs by ensuring that all items of plant are in constant state of operating efficiency. This will require the use of all cost saving devices/techniques within the resources of the organization. Specifically this study has shown that operations research techniques such as PERT Network analysis and PERT cost have very high potential applications in the planned maintenance function of industrial organizations.

3. Technical agreements signed between government agencies/industries and technical experts from the Industrial nations are in most cases to the disadvantage of the Industrial/Government agencies. In other words, in most cases the Technical partners from abroad always stand to gain from these agreements.
4. There is little or no monitoring of the signed technical agreements between the foreign experts and the Nigerian industries to ensure compliance by the technical experts in the implementation of these agreements.
5. Where the foreign technical partners fail to perform there is little or no effort made by the Nigerian partners to claim damages.

6. Companies with government's having controlling shares are often saddled with a Board of Directors whose members have little or no knowledge of business or the operations of the companies and as such end up being a liability rather than an asset to the management of these companies.

7. There is very poor planning and scheduling of maintenance and repairs activities in the CCNN. For instance with proper planning and scheduling the company could have saved about ₦214,494 from the October, 1986 kiln shut down maintenance and repairs activities alone in terms of idle labour cost. This poor planning and scheduling also results in a potential loss of about ₦3,879,390 due to kiln stoppages in 1986. These stoppages result in kiln idle time which results in a potential profit loss of ₦14,195,832 in 1986 due to non production.

8. The company is overstaffed, in other words, there are many redundant workers. For instance analysis of the mechanical staff utilization in October 1986 kiln shut down maintenance and repairs activities indicated that twenty five out of the forty five staff are redundant.

9. Many of the Nigerian staff in the company are not properly trained and inexperienced to handle the cement plant operations.

Going through some of the records of the company and discussions the researcher had with some top executives of the company, the following conclusions could also be drawn.

1. The company is faced with inadequate power supply from NEPA which contributes to about 19.2% of kiln stoppages.
2. The company is faced with the problems of lack of spares and consumables to carry out their maintenance and repairs activities whenever the need arises.
3. The company is faced with poor financial structure. The small revenue made by the company normally goes into the payment of interests.
4. There is no serious organized formal training in the company, eventhough one of the cardinal points of the UNIDO technical agreement is to train Nigerians to take over the industry at the end of their contract agreement.

5. There is poor communication between top management and operatives as a result operatives often do things the way they 'think' they should be done not necessarily how they should be done.
6. Employee services like transportation, canteen facilities,etc. are inadequate and in some cases completely absent. This result in workers discontent and incessent complaints.

5.2 Recommendations

While some of the recommendations are applicable to many industries like the CCNN, others are very specific to the company. The General recommendations are:-

1. Top management in organisations should agree on the type of maintenance system to be adopted by the company. In this regard, planned maintenance and repairs system is the best and its implementation should be persued vigorously.
2. Management of complex industries should employ operations research techniques such as PERT Network analysis and PERT cost, simulation and queing in their planned maintenance function and operations for effective staff utilization and conservation of their meagre resources.

3. Where governments are the controlling share holders of business enterprises, care should be taken in the appointment of Board of Directors. Only people with sound business backgrounds or who are conversant with the operations of the companies should be appointed as Board members in order to help the management of these organizations succeed.
4. Only competent people from government or industries should draw up any technical agreements with foreign partners. Specific provisions should be incorporated in these agreements for review of foreign partners performance and where they are found wanting, they should be held liable, in addition to the termination of the agreement.
5. The Federal Government should look into the flight of vital industries like the cement factories which are necessary for the industrial take off of this country and come to their aid in the procurement of necessary spare parts and consumables from abroad.

Specific recommendations to Cement Company of NOrthern Nigeria CCNN Soketo are:

1. The company should utilize the UNIDO expert team to draw up a comprehensive planned preventive maintenance and repairs of all items of equipment in the factory.
2. The company should employ PERT Network analysis in their planned maintenance and repairs functions. This study shows that its application in the October, 1986 kiln shut down maintenance alone, an idle labour cost savings of ₦214,494 could have been made and more than half of the forty five staff of the mechanical section could have been utilized somewhere else.
3. An organized formal training of both the senior and junior staff should be embarked upon by the company using the UNIDO Technical expert team, and some experienced Nigerians as tutors and coordinators of the program.
4. The company should embark on staff rationalization to save the cost of redundant labour.
5. To supplement the inadequate power supply, the company should provide and ensure proper maintenance of big stand by generators to at least ensure an un-interrupted kiln operations due to power failures.

6. The management of the company should look into some of the key management functions like planning, controlling and motivation to ensure a contented work force and a smooth operation of the company.
7. The owners of the company through the Board of Directors should restructure the management and financial structure of the company to make it more viable.
8. Employee services like transportation, canteen facilities, a resident doctor or health clinic services should be improved where already available and established where they don't exist.
9. The CCNN should liase with Cement Manufacturers Association of Nigeria in order to establish a foundary and improve its fabrication workshop facilities in order to meet some of their spare parts and consumables requirement locally. The presence of the cement experts from UNIDO can be exploited in this regard.

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APPENDIX 1.1

LOCAL CEMENT PRODUCTION STATISTICS (1984)
(MILLION TONNES)

No.	Company	Installed capacity	Actual 1984 Production	% Capacity Utilisation
1.	Ashaka Cement Co. Ltd.(Bauchi)	0.75	0.62	83%
2.	Bendel Cement Co. Ltd. (Ukpilla)	0.45	0.05	11%
3.	Benue Cement Co. Ltd. (Gboko)	0.90	0.67	74%
4.	Calabar Cement Co Ltd.	0.40	-	-
5.	Nigerian Cement Co. Ltd. (Ukalagu)	0.72	0.12	17%
6.	The Cement Co. of Northern Nig. Ltd. (Sokoto)	0.60	0.05	8%
7.	The West African Portland Cement Co. Ltd.	1.60	1.50	94%
	T O T A L	5.42	3.01	56%

SOURCES: Anonymous, The West African Portland Cement Company Limited, Silver Jubilee Special Publication, December, 1985, page 17.

APPENDIX 1.2

PROFIT AND LOSS STATEMENTS OF CCNN LTD. SOKOTO FOR THE YEARS 1967-1985

Accounting Year	Profit
31st May 1967	(727,000)
,, ,, 1968	(1,177,000)
,, ,, 1969	(1,270,000)
,, ,, 1970	(1,026,000)
,, ,, 1971	(496,000)
,, ,, 1972	(432,000)
,, ,, 1973	(630,000)
,, , 1974	(817,000)
31st October, 1977	(677,000)
,, ,, 1978	(743,000)
,, ,, 1979	(459,000)
,, ,, 1980	(9,000)
,, ,, 1981	(176,000)
,, ,, 1982	(2,333,000)
,, ,, 1983	(1,026,000)
,, ,, 1984	(2,031,000)
9 months of 1985	(1,557,000)

SOURCES: Anonymous (1987) CCNN Annual Company Accounts.

APPENDIX 1.3

THE NIGERIAN CEMENT COMPANY LTD NKALAGU, ENUGU, ANNUAL ACCOUNTS 1975 - 1980 YEAR ENDED: 31st MARCH

Business Results

	1975 ₦'000	1976 ₦'000	1977 ₦'000	1978 ₦'000	1979 ₦'000	1980 ₦'000
Fixed Assets	9,672	16155	26691	30255	33841	35883
Capital Employed	-	-	17819	18722	24319	23028
Paid up share capital	8400	8400	8400	12600	12600	12600
Profit before taxation	5549	7134	7238	2655	2325	1663
Profit after taxation	3346	4339	3686	1162	1659	845

SOURCES: Anonymous, Nigeria Company Handbook and guide to Operating Business in Nigeria, A.J.M.S Published, 1980, page 144.

APPENDIX 1.4

The West African Portland Cement Co. P.O. Box 1001 Lagos

Business Results, Year Ended 30th November.

	1974 ₦'000	1975 ₦'000	1976 ₦'000	1977 ₦'000	1978 ₦'000	1979 ₦'000	1980 ₦'000
Fixed assets	18180	33912	96967	146364	158896	159189	164
Current Liabilities	(3830)	7485	13111	18130	1724	48026	545
Paid up share capital	700	12500	18000	30500	35650	35650	356
Turnover	19617	26590	31316	29577	51607	74757	754
Profit before tax	2758	5128	7256	7902	9252	10279	105
Profit after tax	2008	3499	4656	7902	9252	10279	105
Earnings per share	14.3k	14.0k	12.9k	12.9k	13.0k	14.4k	14.
Dividen per share	8.1k	5.4k	5.4k	4.9k	6.7k	7.2k	7.2

SOURCES: Anonymous, Nigeria Company Handbook and Guide to Operating Business in Nigeria, A.J.M.S. Publication 1980, page, 208.

APPENDIX 1.5

THE ASHAKA CEMENT COMPANY LTD. BAUCHI

Business Results

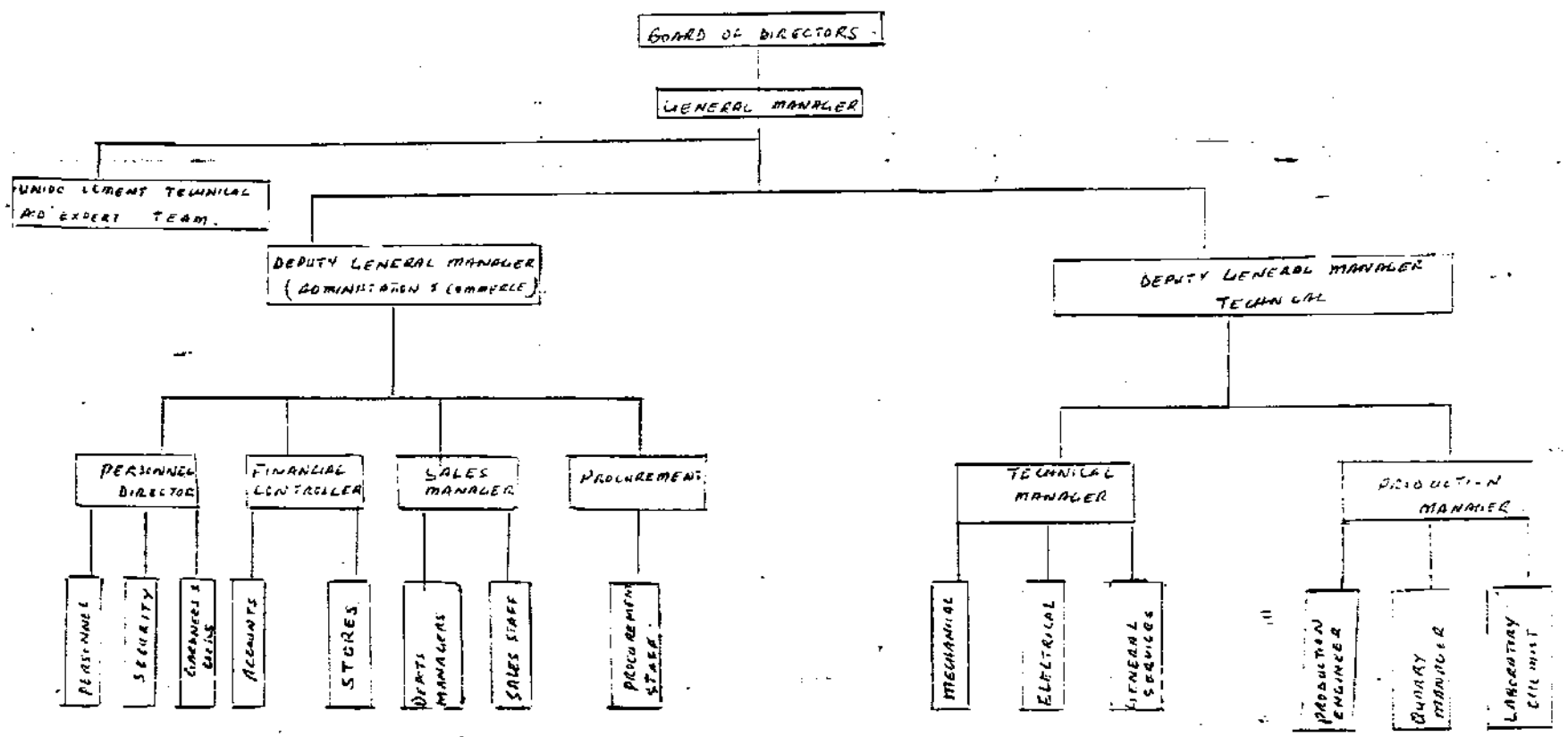
	1980	1981
Profit before tax	8,100,000	14,500,000

SOURCES: WANKA, A.Y. (1984), M.B.A. Project, page 5.

APPENDIX 2.1

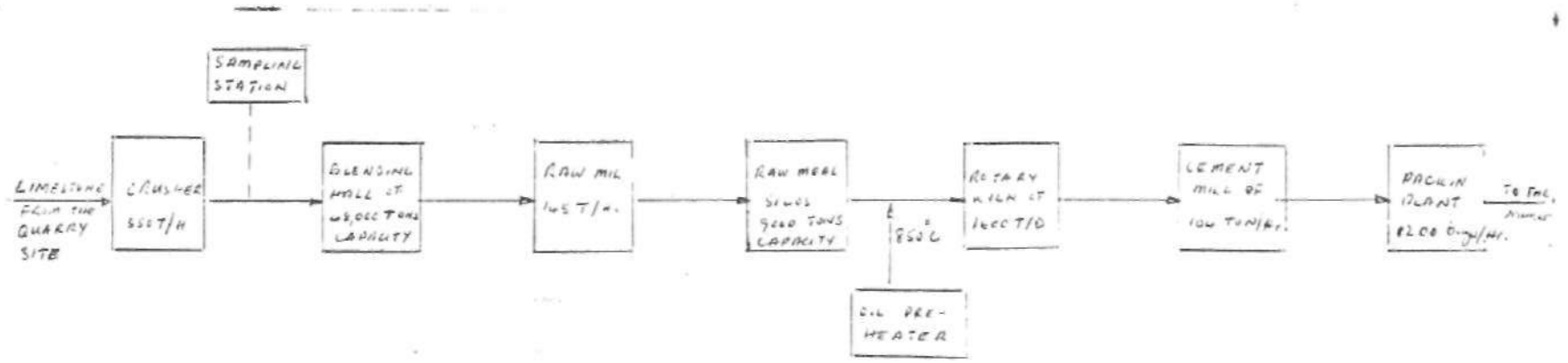
CEMENT COMPANY OF NORTHERN NIGERIA LTD.

CORPORATE ORGANIZATION CHART.



APPENDIX 2.2

THE MAJOR CEMENT PRODUCTION UNITS – 'NEW LINE'



SCHEDULE OF KILN SHUTDOWN REPAIRS

APPENDIX 4.1

DATE: 01 OCTOBER, 1986

REPAIR ITEMS	DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	REMARKS
		SEPTEMBER									OCTOBER												
KILN "T" REPAIRS		28	29	30	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	
01. PRODUCTION																							
SHUTTING DOWN PROCEDURE = 12 hrs.																							
01 COOLING DOWN																							
02 REMOVAL OF COATINGS AND BRICKS																							
03 BRICK WORK IN THE KILN																							2.86 + 2.62 + 3.40 = 8.88 m
04 WELDING PLATES ON COOLER ELBOWS																							
05 CASTING COOLER ELBOWS																							
06 CASTING COOLER LIFTERS (PATCH WORK)																							
07 PATCH UP BURNER LANCE																							
08 BRICK WORK IN HOT GAS GENERATOR (DUST MIXER)																							
02. MECHANICAL																							
GROUP 02.14:																							
01 CHECK CRUSHER (HAMMERS, BASKET, [illegible])																							
02 BELT CONVEYORS, RECLAIMER SYSTEM																							
GROUP 05																							
03 CHECK BELTS, DOUBLE FEND FLAPS (BEARINGS)																							
04 RAW MILL INLET FLANGE AND LINER PLATES																							
GROUP 06																							
05 PRECIPITATOR (ELECTRODES & PLATES)																							
06 OIL/GAS BURNERS/COOLING TOWER																							

NOTES: KILN STOPPED ON SEPTEMBER 28TH AT 17:5[illegible] '86

CEMENT COMPANY OF NORTHERN NIGERIA LIMITED

APPENDIX 4.1 Cont.

SCHEDULE OF KILN SHUTDOWN REPAIRS

DATE: 01 OCTOBER, 1986

	REPAIR ITEMS	DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	REMARKS
			SEPTEMBER									OCTOBER												
	KILN 1 REPAIRS		28	29	30	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	
	2																							
	GROUP 07																							
07	CHECK DISCHARGE OF RAW MEAL SILO																							
08	BUCKET ELEVATOR DRIVES																							
	GROUP 08																							
09	REPLACE KILN ROTARY FEEDER																							
11	DISMANTLE INLET SEAL																							
11	CHECK CLINKER TRANSPORT																							
	GROUP 10																							
10	CHECK RAW WATER NON RETURN VALVES																							
10	CLEAN RAW WATER RESERVOIR																							
	GROUP 12																							
12	CHECK CRANE AND HOISTS (TUNNEL)																							
	GROUP 13																							
13	CHECK COMPRESSORS, FILTERS, LUB, ETC																							
	02. ELECTRICAL																							
01	CHECK PANELS (GENERAL)																							
02	REPLACE GEAR MOTOR (09.51.01)																							

NOTES

KADUNA REFINERY & PETROCHEMICALS CO. LTD. ZARIA, NIG.

3084

APPENDIX 4.2

KILN PRODUCTION DATA FOR THE 'OLD LINE'

1982

Months	Tons of Clinker Produced	% of rated Capacity	Utilization of Time (%)
July	3,774	51.5	63.9
August	2,839	41.6	28.0
September	1,901	31.1	30.2
October	1,574	20.8	31.4
November	5,796	17.2	74.7
December	6,235	63.5	76.2
Total	22,119		
Monthly Average	3,686.5	37.6	50.7

SOURCES: Anonymous (1987), Cement Company of Northern Nigeria (CCNN) Ltd. Annual Production Data.

APPENDIX 4.3

KILN PRODUCTION DATA FOR 'OLD LINE'

	1983		
Months	Tons of Clinker Produced	% of rated Capacity	Kiln Utilization of Time (%)
January	4,622	50.6	54.9
February	5,315	58.2	72.1
March	7,001	76.7	82.3
April	4,917	53.9	65.2
May	3,791	41.5	48.2
June	7,431	81.4	86.4
July	4,374	47.9	47.3
August	-	-	-
September	6,586	72.2	70.6
October	6,112	67.0	67.3
November	2,828	31.0	34.1
December	5,110	56.0	60.3
T O T A L	58,087		
Monthly Average	4,840.6	57.9	57.4

SOURCES: Anonymous (1987) CCNN Ltd. Annual Production Data.

APPENDIX 4.4

KILN PRODUCTION DATA -'OLD LINE'

1984

Months	Tons of Clinker produced	% of rated Capacity	Kiln Utilization of Time (%)
January	3,581	39.2	43.4
February	6,687	73.3	90.1
March	5,322	58.3	58.0
April	4,181	45.8	50.1
May	4,762	52.2	54.2
June	1,763	19.3	19.6
July	4,386	48.1	58.0
August	2,475	27.1	30.2
September	2,256	24.7	26.2
October	5,722	62.7	71.6
November	2,644	29.0	35.3
December	2,043	22.4	30.8
TOTAL	45,822		
Monthly Average	3,818.5	41.8	47.3

SOURCES: Anonymous (1987) CCNN Ltd. Annual Production Data.

APPENDIX 4.5

KILN PRODUCTION DATA - 'OLD LINE'

1985

Months	Tons of Clinker produced	% of rated capacity	Utilization of Time (%)
January	4,176	45.8	54.6
February	5,247	57.5	73.4
March	4,270	46.8	46.0
April	1,860	20.4	18.5
May	2,979	32.6	30.7
June	1,872	20.5	28.5
July	-	-	-
August	2,313	25.3	37.0
September	6,354	69.6	71.8
October	4,782	52.4	58.8
November	-	-	-
December	1,152	12.6	21,8
TOTAL	35,005		
Monthly Average	2,917.1	32	31.9

SOURCES: Anonymous (1987) CCNN Ltd. Production Data.

APPENDIX 4.6

KILN PRODUCTION DATA - 'NEW LINE'

1985

Months	Tons of Clinker produced	% of rated Capacity	Utilization of time (%)
January	-	-	-
February	-	-	-
March	8,705	17.9	20.9
April	20,97	4.3	8.0
May			
June			
July	7,414	15.3	19.5
August			
September			
October			
November	35,005	72.1	71.4
December	18,477	38.1	36.0
TOTAL	71,698		
Monthly Average	7,169.8	14.8	15.6

SOURCES: Anonymous (1987), CCNN Production Data

APPENDIX 4.7

KILN PRODUCTION DATA - 'NEW LINE'

1986

Months	Tons of Clinker produced	% of rated capacity	Utilization of Time (%)
January	16,710	34.4	34.8
February	34,143	70.3	26.7
March	19,189	39.5	42.1
April	33,708	69.4	72.2
May	17,303	35.6	37.9
June	15,528	32	35.5
July	35,644	73.4	73.45
August	28,284	58.3	61.7
September	35,225	72.6	84.3
October	15,546	32.0	35.8
November	23,427	48.3	56.2
December	4,604	9.5	11.9
TOTAL	274,707		
Monthly Average	22,892.2	47.2	47.7

SOURCES: Anonymous (1987) CCNN Ltd. Annual Production Data.

APPENDIX 4.8

Kiln Production Data - "New Line"

1987

Month	Tons of Clinker produced	% of rated capacity	Kiln Utilization of time(%)
January	-	-	0
February	19,333	39.8	46.7
March	43,497	89.6	92.0
April	28,708	59.1	61.2
May	23,501	48.4	51.8
June	-		0.0
July	-		0.00
August	-		0.00
TOTAL	95,706		
Monthly Average	11,903.3	24.5	31.46

SOURCE: Anonymous (1987) CCNN Ltd Annual Production Data.

APPENDIX 4.9

1986 CCNN Monthly Cement Production Figures

Month	Cement Production (Tons)
January	30,928
February	26,917
March	24,430
April	31,754
May	30,437
June	22,350
July	32,190
August	28,608
September	25,066
October	16,692
November	18,300
December	21,011
TOTAL	308,683

SOURCES: Anonymous (1987) CCNN Ltd. Sokoto Cement production data.

APPENDIX 4.10

Monthly Stoppages of Kiln - 'old Line 1982

Month	Number of Idle Hours	Kiln Idle Time as % of Utilization Time
January		
February		
March		
April		
May		
June		
July	257	34.5
August	445.4	59.7
September	396.1	55.0
October	327.2	43.9
November	171.5	23.8
December	170.0	22.80
Total	1767.2	
Monthly Average	294.5	40.0

SOURCE: Anonymous (1987) Kiln Stoppages Data from Company Records.

APPENDIX 4.11

Monthly Stoppages of KILN - 'Old Line'

1983

Months	Number of Idle Hours	Kiln Idle Time As a % Utilization Time
January	334	44.8
February	172.3	25.6
March	125.1	16.8
April	245.1	34.1
May	59.9	8.1
June	46.9	6.5
July		
August		
September		
October		
November	167	23.2
December	170.3	23.0
TOTAL	1320.6	
Monthly Average	165.1	22.8

SOURCES: Anonymous (1987) CCHN Ltd. Kiln Monthly Stoppages Data.

APPENDIX 4.12

Monthly Stoppages of Kiln - 'Old Line"

1984

Month	Number of Idle Hours	Kiln Idle Time as % of Utilization Time
April	357.3	49.6
May	340.1	45.7
June	-	-
July	302.8	40.7
August	458.4	61.5
September	439.3	61.0
October	161.5	21.7
November	453.3	60.5
December	440.76	59.1
TOTAL	2953.46	
Monthly Average	369.2	50.0

SOURCE: Anonymous (1987) /KILN Stoppages Data from Company Records.

APPENDIX 4.13

Stoppages of KILN - 'New Line'

1986

Month	Number of Idle Hours	Idle Time as A % of Utilization Time
January	58.2	7.8
February	117.4	6.1
March	325.5	43.7
April	167.5	23.3
May	434.6	58.3
June	476.3	66.1
July	170.7	22.9
August	273.9	37.5
September	90.3	12.5
October	472.7	63.3
November	314.8	43.7
December	650.4	87.5
TOTAL	4202.7	
Monthly Average	350.2	39.4

SOURCE: Anonymous (1987) KILN Stoppages Data from Company Records.

APPENDIX 4.14

Monthly Stoppages of KILN - 'New Line

Month	1987 Number of Idle Hours	Idle Time as a % of Utilization Time
Jnauary	744	No data Available.
February	336.7	50.0
March	77.7	10.4
April	272.3	37.8
May	353.2	47.4
June		
July		
August		
September		
October		
November		
December		
TOTAL	1783.9	
Monthly Average	356.78	36.4

SOURCE: Anonymous (1987) KILN Stoppages Data from Company Record.

APPENDIX 4.15

Annual Production Maintenance Cost of the Plant

Year	Maintenance and Spares (N)	Diesel and Lubricants (N)	Kiln Oil (N)
1981/82	278,054	37,889	29,750
1982/83	281,424	188,739	387,578
1983/84	605,632	238,654	612,088
1984/85	711,548	306,582	481,831
1985	622,133	272,136	622,418
1986	1,928,896	748,044	1,585,853*
1987**	1,220,000	333,000	705,960*
TOTAL	6,917,687	2,458,044	5,131,438
Average	988,241	351,149	733,063

SOURCES: Anomynous (1987) CCNN Annual Accounts.

*The figures were calculated using the average ratio of kiln oil to diesel and lubricants consumption for the years 1982/83, 1983/84, 1984/85 and 1985.

**Records for six months was the only data available.

APPENDIX 4.17

1987 Grosss Monthly Salary Payments

Month	Production	Services	Administration
January	108,685	75,990	88,973
February	110,869	73,294	92,633
March	116,839	95,558	85,491
April	129,338	117,556	98,313
May	122,750	101,209	114,134
TOTAL	588,481	463,607	479,544
Monthly Average	117,696.2	92,721.4	95,908.8

SOURCES: Anonymous (1987) CCNN Ltd. Annual Accounts.