PRODUCTION SCHEDULING IN A TEXTILE MILL WITH THE AID OF LINEAR PROGRAMMING

BY

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D E C L A R A T I O N

I hereby declare that this write-up is original and a product of my research findings and that I am responsible for any errors of commission or ommission. All articles used have been acknowledged accordingly in the footnotes and Bibliography.

C E R T I F I C A T I O N

This project entitled PRODUCTION SCHEDUL-ING IN A TEXTILE MILL WITH THE AID OF LINEAR PROGRAMMING by Abdu Jibril 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 contribution to knowledge and literary presentation.

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A C K N O W L E D G E M E N T S

This project work marks the end of my one academic session M.B.A. course. Through this medium I wish to acknowledge the assistance rendered me by my lecturers, relations, friends and all those people who in their different ways contributed to my successful completion of the M.B.A. programme as a whole. My greatest gratitude goes to almighty Allah, for giving me the courage and wisdom of writing this very unique project, and bringing it to a successful finish. My thanks also goes to my project Supervisor Dr. J.G. Donli and in particular a thousand thanks to Mr. V. Janakiraman who but for his persistent assistance and help I could not have been able to write the project at all. Many a times when I am confused and about to give up this gentle man from Indis will fill me with encouraging advice, which I follow religiously to the successful finish of this project. To me, he is both a lecturer and a father, because he guided me through the course the way a father guides his son through life.

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/ABDU JIBRIL./

A B S T R A C T

This study, intends to explore the activities of the production line of a textile mill With the aid of a tool of operations research - Linear Programming. The management of the textile mill is facing loss problems and they have attributed some reasons for this, and the intension of this project is to apply L.P. and find out if reasons other than those sited by the management of this company could be found, and to see if the situation of this company can be improved by this application of this O.P. tool.

In carrying out the research, a questionnaire was designed in such a way as to fish out facts about the objective function of the company, the constraints facing the company, and the tec mological coefficients currently prevailing in the company. In the final analysis, fourteen (14) variable and thirteen (13) constraints were identified and the problem which was solved by simplex algorithun presented itself as a twenty-seven (27) by thirteen (13) matrix. This was solve by the computer and conclusions were made.

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A B B R E V I A T I O N

1.	L.P	=	Linear Programming
2.	T.C.	=	Technological Coefficients.
3.	N.T.M.	=	Northern Textile Manufacturers.
4.	Pls	=	Please.
5.	J.Q	=	Jacquard
6.	N	=	Number.
7.	O.P	=	Operations Research.
8.	M/C	=	Machine.

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DEDICATION

This is for Binta and Hafiz.

Chapter One

I N T R O D U C T I O N

1.1 Scope

THE PRESENT study encompasses an overall examination of the production operations of a textile mill, the Northern Textile Manufacturers, which is engaged in the production of blankets and seat upholstery. The company is the largest producer of blankets in black Africa and it has been in operation for over 20 years. Being the first of its kind, it controls the largest share of the market and so it is made up of four fu functional departments to make its operation smooth. The intention is to study the activities in each of the functional departments with their subsections with particular emphasis on the production department. As will be seen later in this project, the production department is further divided into three subsections i.e the spinning section, the wearing section and the finishing section. Incidentally, the company being a manufacturing organisation has its four functional departments and is the busiest. It also has the largets number of workers. The other three functional departmen s are the administrative department, the marketing department and the finance departments.

1.2 Problem

The company has been incurring losses for the past three years, and this, they attribute to the shortage of raw materials. This year however profit was recorded, yet the management is still not satisfied. It is observed that the problem is not only that of shortage of raw material but also poor allocation of available production resources (such as machine hours, the raw material itself, time and money), to its production operations.

The aim is now to apply the mathematical tool of operations research - Linear Programming, to the above problem, with the hope that it might yield findings and insights pointing to a potentially more profitable management of existing facilities in the compnay, thereby leading to maximum profits.

The complexity of the problem stems from the presence of inter-related restrictions. In particular, the numerous processes employed in the production of a great variety of blankets differing in raw materials, yarn type and weight, construction, size, and finish, as well as jacquard design, are subject to capacity limitations. For example if a single change is applied to a certain pattern of production, limitations of machine capacities will force alteration of some other items as well. Such propagation and interacting effects make changes in production pattern quite

complicated to follow. Luckily, a scientific tool exists, that enables the mathematical representation and solution of such interdependent relations, in the form of Linear programming. This tool, we shall apply to the stated problem and see if the situation of the company can be improved through its application.

1.3 Definition and Explanation of Key Terms

Both textile and linear programming are full of terminologies which need be fully explained. Some of these terms are discussed below:

1. Textile Fibres:[1]

A wide variety of fibres are used in making textiles. Some of them are natural fibres, which come from certain plants, animals and even minerals, but some do not occur in nature at all. They are called artificial, or man-made fibres.

Cotton and flax are the most common plant fibres. Like all plant fibres, they are made up of cellulose- the woody substance in plants. Several other plants yield useful fibres, including jute, homp, ramie, and sisal.

Wool and silk are the most important animal fibres. All animal fibres are made up of complicated substances called proteins. Wool comes from sheep. It is a special kind of curly hair.

In its turn, fine threads of silk are spun by the silkworm when it makes a cocoon around itself. The silk is the only fibre that is produced in a long, continuous thread.

There were two main kinds of man-made fibres. Some, such as rayon, are made by processing a natural substance and then re-forming it. Others are made entirely from chemcials produced by man. They are called synthetic fibres. Nylon was the first and is the most important synthetic fibre.

It should be realised that, each kind of fibre has its own particular properties and advantages.

2. Carding and Combing:[2]

Before most fibres can be spun satisfactorily, they must be strainghtened out from their natural tangled state. Also, short fibre must be removed, otherwise the yarn made from them will be weak. Carding and combing machines carry out these operations.

The carding machines, consist of a number of rotating rollers covered with wire 'teeth! The rotating teeth open out and disentangle the fibres. In the combing machines, the fibres are held and combed even straighter by needle-like teeth, in much the samy way as you comb your hair. The fibres leace the machines in the form of a web, which is split into sections and gathered into loose ropes, or slivers for further processing.

3. Dyeing:

The plant and animal fibres used in textile operations have little natural colour. They are mostly off-white or brownish-yellow. They are therefore dyed to add colour to them. Dyeing and printing are the two main methods of colouring fabrics. Dyeing, colours the fibre s throughout in the same colour. The fabric is soaked in dye solution and then steamed to fix the dye.

4. Jacquard Loom:

The machine which weaves the spun yarn into cloth is called a loom. The action of weaving (the weft) between raised and lowered lenghtwise threads (the warp). In the common loom, the sets of warp threads are alternately raised and lowered by a device called a shaft. The threads in each set move together. This arrangement results in a uniform, unpatterned cloth.

A jacquard loom, on the other hand, can weave intricate designs into the cloth. Each warp thread on this loom is moved individually by a separate card, which in turn is held by a harness. A mechanism controlled by perforated cards moves each card up or down, according to the pattern.

5. Roving:[3]

In the operations preceding spinning, several fibre slivers are combined, drawn out through rotating

rollers, and slightly twisted into an intermediate yarn, or roving. The fibres go on to the spinning machines in this form.

6. Slivers:[4]

Slivers are loose ropes of straightened fibres from carding and combing operations.

7. Spinning:

All the natural textile materials[5] except silk, are made up of fairly short, fine fibre. Cotton for example, has fibres up to 2 inches long. Individual fibres are too short, too fine, and too weak to be woven into cloth or blanket. They must first e gathered together, drawn out into slivers, and then twisted tightly together to make yarn. The process of making yarn from raw fibres is called spinning. The fivre to be spun is fed to both the ring frame and the mule in the form of roving. The roving passes through several pairs of rollers, each pair revolving at a slightly higher speed than the previous one. This draws the roving into finer and finer strands of yarn. The yarn is guided onto rapidly rotating bobbins by metal clips called travellers. The travellers move around the bobbins and twist the yarn as they do so in the ring frame.

8 Warp and Weft:

The method of weaving every kind of yarn, both natural and man-made, is basically the same.

One set of threads is passed crosswise under and over a set of lengthwise threads. The crosswise threads are called the weft, and the lengthwise threads are called the warp.

9. Waste Yarm

During the operation of weaving, some of the yarn used in the process are lost and are not useful so far as the operation is concerned. The amount of lost yarn, depends on the quality of the mat3rial used in producing the yarn. At any rate lar e heap of waste yarn is gathered and then sent back to the spinning department where it under goes certain processes and then blended with other fibres, and fed into cards to produce slivers.

10 Weaving

This is the process of interlacing one set of threads with another to form fabrics. Curtains handkerchiefs, and blankets are typical woven products. Various kinds of weave are done. They include among others, twill weave, satin weave plane weave, jacquard weave etc.

11. Yarn

The various p spinning process aim at converting fibres into a continuous length, or yarn, suitable for making into fabrics by weaving or in some other way. All the natural fibres, except silk, are fairly short, and are made into stapple yarn.[6] Very many types of

yarn exist and some of them are continuous filament yarn, textiled yarn, and staple yarn.

1.4 Collection and Assembly of Data

Data for the project was collected using the questionnaire, interview and observation techniques of research methodology. Historical records of plant operations was collected from various sources within the company. For example, general background information about the company, including processes and marketing aspects were gathered by personal interview with the personnel officer and the marketing manager, both of whom have been working with the company just a few years after its formation. Other miscellaneous information that appear in the project were got by observation and discussions with various members of the company's staff-including junior staff. Data on the operations of the spinning section, and the weaving section of the production department were got through the help of the supervisors who rendered a lot of assistance.

Bearing in mind that a meaningful study of so complex a problem must rest on a solid foundation of accurate and reliable data, efforts were made through questionnaire to collect the speed, productivity, and waste factor of each machine on each product. Other information requested include precise numberical values for the total effective capacities in terms of finished goods, after allowances for down time, separation of

direct costs into fixed and variable components, such as heat, light, and power. Unfortunately, such figures were not available. The only data that I therefore, had access to is the one which appears in the next chapter of this project under the sub-heading the company, and the one which is analysed in chapter four.

1.5 Limitations of the Study

Obviously, one of the limitations of this study is my inability to collect accurate statistics as indicated in the preceding subheading, therefore the outcome of the analysis might not give a 100% picture of the position of the company. Though the company management showed open enthusiasm to answer some of the questions put to them, one realises that this research is a highly technical one, and one really can't expect straight forward answers to such technical questions as those posed, since the staff of the company are not well versed in the field. Linear programming is an operations research technique as noted earlier, and the terminologies it contains can only be understood by those who have learnt it. This perhaps is one of the causes of the limitations encountered.

Also because of the methodology used 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.

Due to the present economic crunch we are going through, the firm is not in full production, and in fact some of the blankets it used to produce are now not being produced, and also some of the machines formerly used are no more used. Also workers have been retrenched thus making the facts collected about the company not to be a true representation of the company. This will greatly affect the result which the data analysis will produce.

Another set back is that most of the figures given by the respondents are approximations of the actual figures. figures. And, because my questions are such of the kind that provoke a lot of thought, yet were answered so quickly, the answers are given are rather rushed and therefore subject to possible errors.

Yet another limitation is that at the time of this research, time was at a premium both to me (to enable me finish the study within the limited time at my disposal) and to the company officials who I interviewed (because of their own company operations) and so the study I must admit is not one hundred percent detailed.

Furthermore, the choice of variables and constraints are subjective and subject to challenge in that only those variables and constraints I consider relevant have been taken into consideration.

Also another thing which might be considered as a limitation to 100% thoroughness of the project is the fact that wherever possible, simplication to the problem was effected in a valid manner.

In addition to the 14 blankets under consideration in this project; the company also is producing materials for upholstery and other blankets considered to be less important profit wise. Since the overall production pattern, however, is governed by the 14 main blankets, it is felt appropriate to disregard the minor items, restricting the study to the production of the latter exclusively.

Footnote to Chapter One

1. Lady Plowden, & Co., Margot Chahin & Co, and Jennifer Cochrane; Textiles, McDonald Junior Reference Library 32, B.P.C. Publishing Ltd., 1962; No. 32 P. 10 - 11
2. Ibid; P 14-15
3. Ibid, P 39.
4. Ibid; P 44.
5. Ibid; P 44.
6. Ibid; P. 56.

Chapter Two

FRAMEWORK

2.1 Statement of Objective:

One of the fundamental objectives of any business organisation is profit making. Profit is highly essential for any business to survive and grow. Many business organisations today, are faced with the problem of growth due to the prevailing harsh economic circumstances the country is going through many more have folded up and are out of business for lack of profits. Northern Textile Manufacturers in particular is facing a hard time making profits from its operations due to lack of raw materials and general scarcity of production resources. For this reason, it is desirable for all business concerns in general to do every thing possible to maximise profits in order to remain in business and grow with time, particularly N.T.M.

It is pertinent to note at this juncture however, that this project is not aimed at providing or suggesting every technique available in the literature for profit maximisation but rather, it is aimed at applying the mathematical tool of linear programming to the production line of Northern Textile manufacturers, with the hope of achieving the maximum possible profit from a more profitable management of the available raw materials and other resources at the disposal of the

the management of the company. Stated in clearer terms, the objectives are as follows:

1. Evaluate the present production practices of the company.

2. To identify the major causes that prevent the company from maximising profit especially along the production line.

3. To identify the interacting constraints in the production of various types of blankets and seat covers.

4. To identify the objective function, i.e maximising profit given, the prices of each item produced.

5. To apply the linear programming technique on the problem in order to achieve a systematic and complete solution to the problem.

3.2 Statement of Hypothesis:

The hypothesis is that reasons other than raw material shortage also contribute immensely to the problems of the organisation.

The Reasons in mind are:

i. Poor Management of available resources especially through lack of use of operation research techniques.

ii. Making of wrong decision with regard to the product mix i.e optimum quantities if the various kinds of blankets that will ensure maximum profits.

This project is out to prove or disprove the hypothesis through the application of linear programming. It is hoped that when proved right, the management might adopt the recommendations that will follow for its own benefits and those of its share holders.

2.3 The Company

1. History:

The Northern Textile Manufacturers Limited situated at NO. 5 Independence road, Bompai, Kano, was founded in 1962. The initial idea of its creation was first c conceived by a group of Labanees (led by Mr. Raccah) who were then resident in Kano. They, together with some Japanees national went into a partnership and made the business a reality. While the Labanees provided the initial capital, (amount not disclosed), the Japanees provided the technical support needed to start the business.

The company was registered as a manufacturer of blankets which is what it is producing to date. It started with 80 looms in 1962 and the total production then, was 1,600 pieces of blankets per day. In 1969, the management increased the capacity of the company to 150 looms, i.e by adding 74 looms to its strength. Both sets of machines which are of the same make were produced by the Japanees partners. Still in 1971 another additional 30 looms, were brought, which added up to a total of 184 looms by that same year. Each of these

machines produced a maximum of 25 pieces of blankets per shift, and each machine was manned or supervised by one man. Between 1971 and 1975 therefore, production of blankets had gone up to between 11,000 to 13,000 piece of blankets per day in 3 shifts.

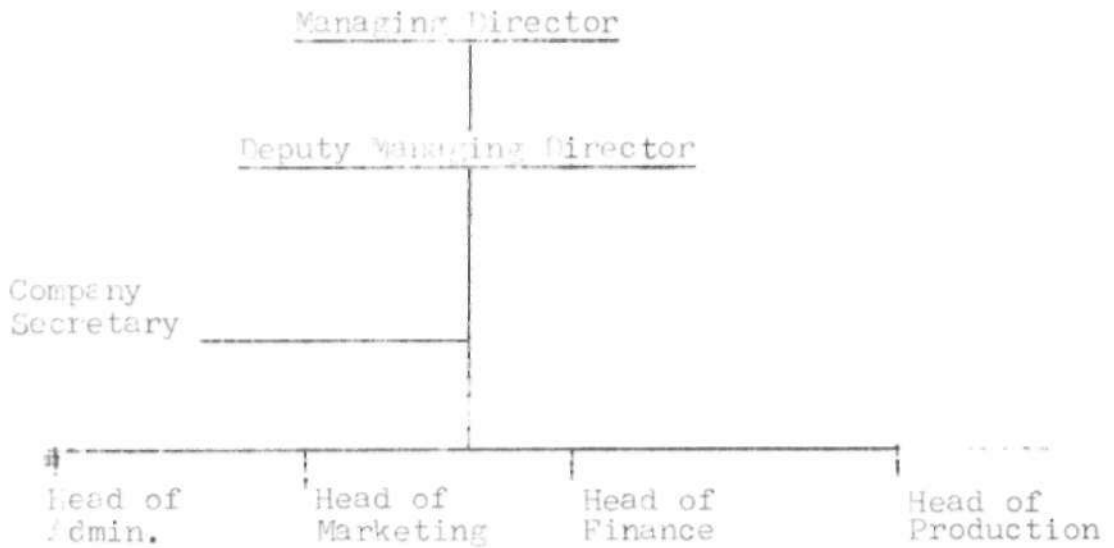
In 1976, the first 80 weaving machines were scrapped because of high cost of labour and maintaince. They were also considered too slow in producing blankets for the management to meet its profit objective. They were therefore replaced by 42 modern and French made machines. These 42 machines have the capacity of making 2 pieces of blankets simultaneously, and each 2 machines can be supervised only by one man. Moreover, each of the machines, can produce 100 pieces of blankets in a single shift of 8 hours i.e (300 pieces in a day). The advantage of these machines to management is obvious.

The rest of the old looms, 104 in number, are also left unused by the management of the company due to high operating costs and the high cost of labor, even though they are still in good working condition. To date they remain idle in the factory premises. It should be noted that all these changes were brought about due to the change of ownership of the company. Earlier in 1974 the original owners had sold the company, 60% to CFAO and 40% to Nigerian Businessmen. The directors today, consist of five Nigerian businessmen (with Abdullah Gashash as Chairman), and four other expatriates

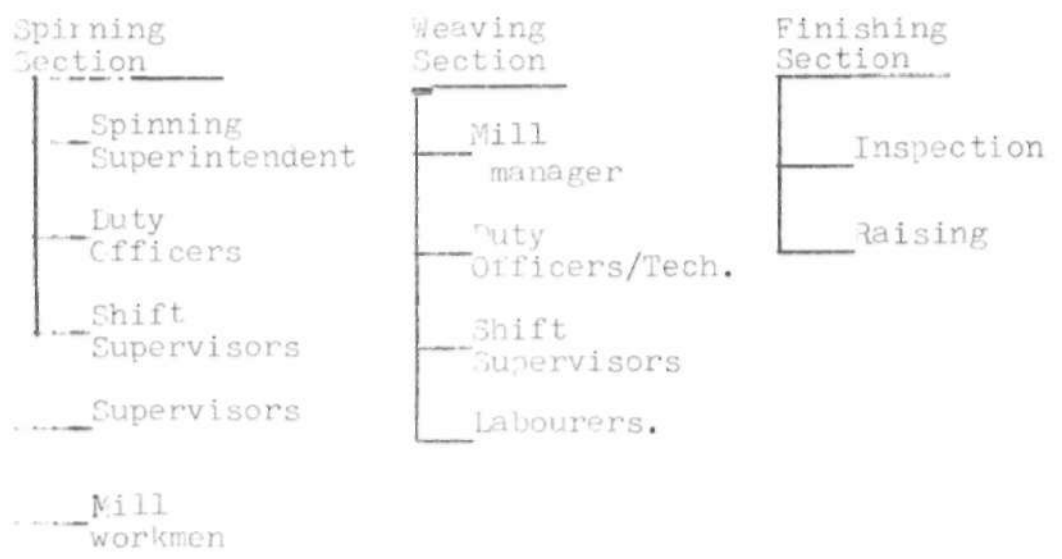
mostly french citizens.

The company started with an initial work force of a few hundreds men in 1962, and by 1978, the figure had risen to a maximum of 1700 men. In 1980 due to raw material shortages and the rising cost of labor, the number of workers in the company was reduced to only 800. Today, the company has only 360 workers, a condition which has been prevailent since 1983. This latter reduction of of workers is as a result of the t retrenchment exercises conducted in the company.

The organisational structure of the company, is such that there are four functional departments i.e Production, Marketing, Finance and Administration all of whom have a head who, are in turn responsible to the managing director and his deputy. There is also a company secretary. The following chart shows the line of authority.



Production Department



As the main line of interest in this thesis is the production line, the production department has been further elaborated to show various sections through which the production process is carried out.

2.3 2 The Process:

The major raw materials needed at Northern Textile Manufacturers are pure cotton, Nylon, waste yarn. Other forms of fibres are also used depending on availability. The Nylon and other forms of fibres are imported from overseas, while cotton is got from Kaduna state. Waste yarn is usually available in the factory, but where it falls short of the factory requirement, additional waste yarn is bought from other textile manufacturers.

These fibres go through several processes in the spinning section, to produce the necessary yarn which is used in the waving section to produce the various types of blanket required. The company amkes both low quality and high quality materials, depending on the raw materials used. Their products include Army and Police blankets, ordinary bed blankets, and very many other kinds of blankets. They also produce all kinds of textile materials of different designs and makes that can be used for car seat upholstery or cushion chairs. The process starts when the raw cotton or other fibres are brought to the factory at the spinning section.

2.3 3 Spinning Section:

This is the department responsible for producing yarn from cotton and other forms of fibres. When the cotton arrives in the factory it is usually brought in a dirty state, in that in transit it must have picked up a few inpurities which make it unsuitable for immediate use. For this reason, the dirty fibre is first dumped into cleaning machines which are refered to as bale braker and scrutcher where it gets separated from the impurities it contains. These machines break up the bales, beat and suck out the dirt, and open out the fibres into their original fluffy state. The cotton fibres emerge from the scrutcher as a continuous fleecy sheet, known as the lap. Only one set of such cleaning machine is available in the factory. This machine has the ability of cleaning out more cotton and other fibres than can be used up at the spinning section on any given workday.

The above activity takes place at about the same time that waste yarn from the factory is being cut into pieces and being made ready for blending with other fibres. This is done with the aid of a pickering machine which processes the waste yarn into loose material similar to other raw fibres. The aim of this process is to avoid loosing the already waste yarn, when it can actually be converted into something useful towards producing more yarn.

Meanwhile the clean cotton so produced from the above activity is transfered to the dyeing section where

it is thoroughly soaked with water and then fed into several containers known as baskets. With the aid of a pressing machine, the soaked cotton is compressed tightly into the baskets until each basket weights exactly 125 kilograms. Each basket, laoded with the thoroughly soaked cotton is transfered into a dyeing machine where the cotton gets dyed into whatever colour is desired.

Using a hydro extracting machine, the cotton is separated from its moisure, by squeesing the latter firmly. This machine turns out a mass of damp fibre but thoroughly rid of any moisure. Because of the dampness of the fibre, the drying machines are used, to dry it. These drying machines have also unlimited capacity, as all the other machines already mentioned.

Depending on the type of blanket to be made, several fibres might necessarily have to be blended together to get the right quality of yarn. The company has four blending rooms with unlimited capacity. At the time this research was conducted, military blankets were being produced and its raw material composes of a thorough blend of fine cotton, polyest nylon, waste yarn and stopping waste. The fibre so produced from such blend makes it possible to get the right quality of yarn needed. It should however be noted that, some other balnkets produced by the company, do not go through all the above

processes. The fibres needed for such blankets just come in a clean state (since they are imported) and are then fed into the carding machines straight a way.

The carding machines are responsible for straightening the fibres (not in either of the two ways already discussed above) and removing unwanted short ones. Fine-quality fibre mixture then emerge from the machine in the form of a filmy web which is gathered into loose ropes known as slivers. These slivers are drawn out by a series of operations into a finer form called roving, in order to make them suitable for spinning. The productivity of the carding machine is reduced by the productivity of the two spinning frames which the company owns to which the latters product goes for further processing. To this end, only 350kg of sliver is produced in 8 hours by each carding machine (there are four in all). One of the four machines is used mainly for processing fibres used for high quality blankets. The other three are used to process low quality fibre used in producing trade blankets.

The silver ten go on to the next set of machines where they are converted into yarn. There are two of such machines. One o is the ring spinning frame which is primarily used for spinning fibre meant for high quality blanket, while the other is the box spinning frame used for spinning fibre meant for low quality blankets.

both machines have the capacity to spin 1050kg. of silver in 24 hours each. The 4 carding machines which can produce over 3000kg. of silver each per day usually have to be stopped at regular intervals to allow the spinning frames to process up all the silver already produced by the carding machines.

2.3.4 Weaving Section:

The yarn leaves the spinning section for the weaving section where it is used to produce many types of blankets. Before weaving, warping is first done, in which the yarn is rolled up in large beams. The warping machine has a total of 90 hours per week. Each high quality blanket requires approximately 7 minutes of warping. Afterwards, the beam is transfered to the looms where blankets are woven.

Generally, two types of blankets are produced in the factory - trade blankets and high quality blankets. The trade blankets include Plmg, DG, BL, Stripped, Mill grey, and twill weave. The high quality blankets include Cellular, Jacquard, tanga and plain, The high quality trade blankets in particular are produced in two different sizes i,e the size for single bed, and king size. Apart from blankets, the company is also producing seat covers. This new diversification is in its test marketing stage. To weave its products, the company has 42 looms all of the same size but of

different mark. 28 of these are ordinary plain or tappet looms. The plain looms only weave trade blankets. This loom has the ability of weaving at most 75 blankets in 8 hours. It can thus produce any number of any kind of trade blanket subject to a limit of 75 blankets in 8 hours. Eight of the fourty two looms are jacquard looms. These looms can weave both the trade blankets and jacquard blankets. The rest of the looms are dobbi looms. In their own case, they can weave any type of cloth or blanket. They are the ones used in making the seat covers as well. The jacquard loom which weaves both jacquard weave and other high quality blankets, does so in 2000 picks/blanket, i.e it does 12 picks per centimeter. However, the jacquard loom can also weave in 2000 picks each 4 stripped blanket, 6 mill grey, 4 bl. The dobbi loom has the same speed for any blanket and it has the ability to weave all kinds of blankets produced by the company.

2.3.5 Finishing Section:

After weaving most textiles must undergo a variety of finishing process before they can be sold. Newly woven blankets leave the loom in a very unattractive state. They are generally harsh to touch, dull and discoloured by inpurities. Recall some of these inpurities were present in the raw fibres and some inpurities are picked up during the weaving and spinning processes. Before any other process takes place, these

impurities are removed first. This is usually done by treating the blankets with a warm solution of soap or other chemicals. After purification the fabric is still drab because the fibres themselves are drab. To make it more attractive, it is coloured by printing and other raising processes (i.e where the blankets are not jacquard weaves).

Afterwards the blankets go through raising processes to give them desirable properties which they do not naturally have. Note cotton, which is the main raw material, is not naturally instrons and so it is made so by calendering. In this process, the material, is passed through two heavy rotating rollers. The instre is only temporary however, because it washes out after some time. The machines in this section can only handle 80 pieces of blankets a day and the company is thinking of purchasing more machines to handle the excess demand.

2.3.6 The Product and Customers:

The company produces two main types of blankets, - the high quality blankets and the trade blankets. The demand for the high quality blankets is throughout the year but minimal. However, the trade blankets are seasonally sold but they represent the bulk of the sales of the company. Sales of the trade blanket depend on the extent of the hamattan, availability of money with the poor masses and yearly crop yields.

The high quality blankets are mainly bought by the rich to decorate their homes.

The company's main customers for the high quality blankets include, U.T.C; Noventis, Kingsway, Hospitals, Institutions, Hotels, Armed forces etc. The customers for the company's trade blankets are chiefly C.F.A.O. (qualitex), SCOA (textiles), individuals, and other companies.

2.3.7 Competitors:

There is one major competitor and this is Chellarams company (Chelco) in Kaduna. It produces all the products that the Northern Textile Manufacturers produces also. It was established several years after NTM was established. The other competitor - Sunflag company does not really pose a threat. It produces imitation of the high quality blankets, which are actually inferior.

2.3.8 Pricing the Product:

Many factors influence the point at which the company fixes the prices of its products. Some of these are as below:

1. Cost of production.
2. Market demand for the products.
3. Agreement entered into, with its competitors.
4. Federal government policies on price setting.

For this reason therefore, prices of each of the products change as situation demands from time to time.

i.e there is no specific price that remains static for long. At the time of this research, the company's products were setting at the following prices:

S I Z E S

S/NO.	Types of Blanket	Single Bed	King Size
1.	SPIN(CH)	₦20.00	₦40.00
2.	SPIN(SS)	₦17.5	₦35.00
3.	Jacquard(SS)	₦21.56	₦45.00
4.	CELLULAR	₦12.5	₦25.00
5.	PLMG	₦10.60	-
6.	D.G.	₦12.60	-
7.	B.L.	₦12.00	-
8.	SRIPED	₦12.00	-
9.	MILL GREY	₦10.60	-

In addition the company makes floor duster which it sells at ₦1.50 each. It is to be noted that the prices could further vary on each blanket depending on the type of finishing process it gets. These prices are fixed in such a way that 25 percent of each price represents the contribution realised on each blanket.

2.3.9 Sales Forecast:

Stipulations on volumes of production must be based on reliable sales forecasts. However, there is no evidence that a sales forecast is made in the company. The company seems to rely on receiving orders from their various customers and then producing accordingly. Nevertheless, after going through their

records of sales for the past year, one official arbitrarily estimated an expected sales of one million (1m) pieces of blanket for the current year. The 1983 figure showed a sales of 938,000 pieces, while the year 1984 was specifically bad with a sale of only 85,000 pieces. Many reasons were advanced to justify the low sale figure for 1984. The break down of the expected sales for 1985 is as follows:

Type of Blanket	Expected Demand for 1985
Trade blanket	500,000 pieces.
High quality Jacquard	100,000 pieces.
Tanga	150,000 pieces.
Plain	150,000 pieces.
Cellular	20,000 pieces.
Floor Duster	80,000 pieces.

Distribution of the company's products is by direct selling to the customer interested.

Chapter Three

LITERATURE REVIEW

3.1 What Linear Programming is:

As business firms and their operations continue to increase in size and complexities, new variables, new problems and new uncertainties have surfaced, all of which make new demands on today's managers. Managers have therefore turned increasingly to new tools and techniques in their bid to cope with the many critical decisions which must be made,

Linear programming is one of the newer tools available to management today. In essence it is a mathematical method of allocating scarce resources to achieve a stated objective, and it is of use whenever both the objective and the environmental constraints which limit the degree of achievement of the objective can be expressed in the form of linear equations and/or inequalities. This linear programming helps management to determine how it can best use the resources of a business to achieve a specific objective such as maximum profit or minimum cost, when the resources have alternative uses. The term "Linear" implies a fixed, definable relationship between the variables in the problem to be solved. This relationship is directly and precisely proportional. For example, linear

means that a 10 percent change in the number of productive hours used in some operation will cause a 10 per cent change in output. The term "programming" simply refers to the orderly process (mathematical technique) by which the best solution to a problem involving limited resources is achieved. In other words, linear programming is an orderly process for solving a particular kind of problem when the variables in the problem are related in a particular kind of way.

3.2 Origin:

The forerunner of linear progeamming theory was contained in a 1920 publication by Wassily W. Leontief. Leonteif, a professor at Harvard University, introduced a quantitative approach for showing the input-out relationship among in industrial and commercial sectors of the American economic system. The full approach to the theory of input-output analysis, considered one of the key sources in the development of linear programming studies, appeared in a book that Leontief published in 1941.

Deciding how many products to transport from each of several sourdes to each of several d destinations was one of the first business applications of the theory of linear analysis. In 1941, F.L. Hitchcock formulated the so-called

"transportation problem" and sketched a proceedure for its solutions. This particular business application of linear programming is considered to be the first important contribution to the solution of transportation type problems. Since them, many other types of industrial and business problems have been solved through the application of linear programming.

The present and most useful development of linear programming is credited to Dr. George B. Dantzig. Dantzig, an American mathematician, developed the basic mathematical foundations of linear progeamming. The influence behind Dantzig's work was the search for a technique capable of solving the immense and complex military planning problems of the U.S. Airforce.

The introduction by Dantzig of linear programming as a managerial tool has resulted in a wide application of this technique to innumerable business and industrial problems. As a result, linear programming, is perhaps, the most widely known and applied of the mathematical tools suitable for multi-variate problems.

Basically, when we speak of variability we mean that the data on which the solution depends is not know with certainty.

3.3 Requirements and Formulation of a Linear Programming Problem :

To be able to apply linear programming in solving a given problem, some basic requirements are necessary.[1]

First, there must be an objective the firm wants to achieve, i.e profit maximisation or cost minimisation.

Second, there must be alternate course of action, one of which will achieve the objective. i.e the firm should be able to allocate its manufacturing capacities in various rations to its different products. e.g in a two-product firm, should the ratio be 50:50? 25:75?, 70:30? some other ratio?

Third, resources must be in limited supply. e.g machine hours, money, etc.

Fourth, the variables in the problem must be interrelated. e.g if profit per product A, is ₦5 and profit per product B is ₦3, total naira profit must and will reflect ratio of product tables to product.

Fifth, the firm's objectives and limitations must be expressed as mathematical equations or inequalities, and these must be linear equations or inequalities. For example objective may be to maximize profit and the limitations might be production resources.

Bearing this in mind, once a problem presents itself as a linear programming problem, its formulation must contain two basic parts which are

in fact common to all linear programming problems. The first part is the objective function while the second part is the constraints set. This second part consists of several resource limitations on which the production process depends. The constraint set is, the system of equalities and/or inequalities which describes the restrictions (conditions or constraints) under which optimisation is to be accomplished. Example of rest ictions as indicated earlier include, machine time, man-hours, materials, contract specifications, etc.

Both these two parts are written as linear expressions, and both are defined in terms of the variables of the problem. In addition, all input variables must be at least equal to zero (i.e non negative). More formally the linear programming problem can be formulated as follows:[2]

Optimise $f(X_1, X_2, \ldots X_n) = c_1x_1 + \ldots + c_n x_n$

subject to

$a_{11}x_1 + a_{12}x_2 + \ldots a_{in}x_n$ (-, , = , -) b_1.

$a_{21}x_1 + a_{22}x_2 + \ldots a_{2n}x_n$ (-, , = , , -) b_2

: : : : : :

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: : : : : :

$a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n$ (-, , =, , -) b_m

with $x_1, x_2 \ldots x_n - 0$.

Having set the problem thus, a solution to the problem is then arrived at, through some mathematical manipulation. The basic proceedures for solving properly constructed linear programs are five in the literature:

1. the graphci approach
2. the algebraic approach
3. the general simplex method
4. the simplex algorithm for maximisation and
5. the simplex algorithm for minimisation.

The graphic analysis is not suited for rproblems involving four or more independent (or decision) variables, and its value for problems contain these decision variable is questionable. The simplex method and simplex algorithm are the best methods of solving today's linear progeamming problems because of the latter's complex nature,

It is pertinent at this juncture to clear the confusion which might be caused because of the overlap in names used. The general simplex method and the simplex algorithm are quite different, the differences lying in the manner in which they are used to solve defined linear programming problems. The simplex algrorithm is the most widely applied and popular technique.

3.4 Purpose of Linear Programming:[3]

As already mentioned, the primary reason for using linear programming is to achieve the best allocation of some commodity or resources. The allocation process involves assigning resources (e.g man-hours, money, machines, raw materials, e.t.c.) to specific activities in such a way that defined objectives are optimized. Because there is only a limited supply of certain productive resources, they must be judiciously assigned subject to specified restraining conditions. For example; the production manager must allocate the available machine time and labour hours in each department, along with the raw materials to the activities of producing the different products which have been scheduled. He is limited by the availability of machines and labor, the amount of row materials on hand, and the number of units required to be produced for each type of product. Another purpose of linear programming becomes glaring where a shipping department manager must allocate the time and capacity of his trucks to deliver specific orders by a given time. He is limited by the number of trucks and the cpacities of each. Also, he must consider the allowable delivery time associated with each order, and hemust deliver the order within that interval.

In each of the above example the objective must be achieved within the limits of the manager's resources capabilities. Management must select the optimum allocation of resources (facilities) to achieve maximum returns. This is the function of the linear programming model.

3.5 Other Characteristics of Linear Programming Problems: 4

Other common characteristics of problems that can be analysed with linear programming are as follows:

1. The quantities of flow of various items into and out of the productive activities are proportional to the level of activity. (For example, doubling the activity level is accomplished by doubling all of the corresponding flows for the unit activity level).

2. There is some way of describing the availability of resources for various combinations. (For example, in preparing an advertsing budget, the allocation dx to market A reduces the amount of money available for use in market B).

3. The decision maker has a choice of input combinations of courses of action, one of which must achieve the desired objective.

4. The problem must be such that it can be expressed in defined mathematical relationships, all of them

In addition, the following are often but not always true.

Raw material is available in unlimited quantities at a fixed cost per unit. (The firm may be buying in a perfectly competitive market or from a monopoly with a fixed price policy).

The output of each activity can be sold in unlimited quantity at a fixed price.

The firm engages in "activities" to transform raw materials into products. These activities require the use of "internal resources" such as machine time or plant space.

3.6 Advantages of Linear Programming:[5]

Linear programming evolved from the inability of simultaneous linear equations to adequately describe a real problem under consideration. Rather than locate the point or (points) at which a given system totally consumed all resources or commodities (money, machine - time, man-hours, e.t.c), the objective become the maximisation (or minimization) of a defined function subject to a system of competing constraints. This introduced a multitude of possible solution points, at least one of which was the optimum set of solution points since total consumption was not always possible (or feasible), the introduction of the inequality better represented the true situation.

As an administrative tool, linear programming has certain distinct advantages. Among these are the following:

1. Insight and perspective into problem situations. Linear programming forces logical organisation and study of information in the same way that the scientific approach to a problem requires. This generally results in a clearer picture of the true problem, which frequently is as valuable and revealing as the answer itself, because it leads more surely to dealing with causes rather than effects; solutions rather than stop-gap expidients.

2. Consideration of all possible solutions to problems. Many management proble s are so complex that difficulty is encountered in p planning any feasible solution, let alone an optimum solution. By using linear programming, the manager makes sure he considers the best solution or solutions as well as any other that he might want to consider.

3. Better and more successful decisions. With linear programming the executive.....builds into his planning a true reflection of the limitations and restrictions under which he must operate.....when (it is) necessary to deviate

from the best program (he) can evaluate the cost or penalty involved.

4. Better tools for adjusting to meet changing conditions. Once a basic plan is arrived at through linear programming, the basic plan can be re-evaluated for changing conditions. Plan can be laid for several sets of conditions to find out how to best prepare for possible future changes. It conditions, change when the plan is partly carried out, changes can be determined so as to adjust the remainder of the plan for best results.

Other advantages include: (1) i proved use of productive factors by indicating the best use of existing favilities; (2) Flexibility in analysing a variety of multidimensional problems; and (3) p provision of an information base from which the allocation of scarce resources can be made.

3.7 Applications of Linear Programming:[6]

In addition to its use in industrial and administrative applications, linear programming has been applied to problems involving agriculture, aircraft, and various military problems. Below are illustrations of a number of the many successful applications of linear programming to real world problems;

(a) Industrial Applications.

Linear programming has been used to solve a variety of industrial problems. In each of these applications the general objective is to determine a plan for production and procurement in the time period under consideration. It is necessary to satisfy all demand requirements without violating any of the constraints. The objective is to maximize a defined return or minimise a defined cost.

Examples of these applications now follow:

i. Production scheduling - alterrate routings. IN this type of problem the quantities of product to be manufactured during a period are fixed; however, there may be several alternat sequences of production process by which a product can be manufactured. Each routing would have a different cost associated with it. Each manufacturing process would have a certain capacity, and the various products would have to compete for this capacity according to particular routing selected for each product. The problem is to produce the required quantity of each product at minimum cost, subject to the constraints on process capacity. For each product, the solution would state how much of the

required quantity of that product was to be produced by each alternative production routing.

ii. Distribution. There could exist certain sources of supply (e.g. ware houses, factories, mines) geographically distributed and certain other location (e.g retail stores, warehouses) where a need exists for the material available at the sources. Depending upon the relative geographical locations, freight rates, and other possible considerations, there is a certain cost associated with transporting a unit of of product from a given source to a given destination. Given these transportation costs, the resources at each source, and the requirements at each destination, the problem is to determine the minimum cost shipping program. The solution would state what quantities are to be shipped from each source to each destination.

iii. Blending probles. These problems are likely to occur when a product can be made from a variety of available raw materials of various compositions and prices. The

manufacturing process involves blending (mixing) some of these materials in varying quantities to make a product conforming to given specifications. The supply of raw materials and the specifications serve as constraints in obtaining the minimum cost material blend. The solution would state the number of units of each raw material which are to be blended to make one unit of product.

iv. Production planning. The production smoothing problem. An industrial concern may have the problem of scheduling its production over a number of future time periods, with the total time span being considered called the "planning horizon" Linear programming aids here too.

In each of these applications, the solution should specify the number of units of each product to be obtained from each of the production or procurement sources in each of the defined time periods.

b. Agricultural applications

The agricultural applications of linear programming deal with somewhat different resources, but the objectives are nevertheless the same - to maximise returns from the allocation activity or

to minimize some defined cost. Two typical problems are described below:

i. The diet (mixture) problem. Assume that the daily requirements of certain substances such as proteins, fat, carbohydrates, vitamins, etc, are given, the contents of these substances in available products are known, and the cost per unit of each product is also known. The problem is to compound a ration that will satisfy the daily requirements of the necessary substances and minimise costs.

ii. Best use of arable land. Assume that crops are to be grown on in plots with arrears of $a_1, a_2, \ldots . a_m$ acres, respectively, where the average yield of the jth crop from ith lot is a_{ij} units per acre (and) the return from one unit of jth crop is p_j naira. The problem is to determine the area in each plot that should be sown in each crop so that a maximum return is obtained under a polity in which no less than b_j unitesare planted in the jth crop ($j = 1, 2, \ldots n$). This particular problem is one involving mixed constraints i.e some of the requirements should be the most, and some, the least.

c. Flight-Scheduling Applications.

Linear programming has been effectively applied to a variety of operational scheduling problems. The most common example of this type of application is the flight-scheduling problem. An example is suppose there are n different types of aircraft that must be scheduled for m routes, and assume that the monthly load transported by an aircraft of the jth type on the jth route is aij units, with an ass associated monthly operating cost of bjj naira. It is necessary to determine the number (xij) of aircraft of the jith type that must be assigned to the jth route to provide this line with aij units (i = 1, 2, ...n;) (j = 1, 2, ...m) of carrying capacity with a minimal total operating cost when it is known that N aircraft of the $_i$th type (i = 1, 2, ...n,) are available (i. e, determine the optimal assignment of aircraft to given routes to provide the necessary carrying capacity with minimal total operating cost).

d. Administrative Applications.

A great number of administ ative problems have in the past been solved using linear programming technique. Some of the problems which lend themselves to being solve by the same technique include the following:

i. Personnel assignment problem. Given a fixed number of persons and jobs, as well as the expected productivity of each person relative to each job, an assignment of persons to job which maximises the average productivity of the assigned personnel can be done using linear programming.

ii. Balancing of production and inventories. A compnay that desire to schedule production according to a reliable sales forecast, with the interest of the plant supervisor being mainly to stabilise his labor force while hoping that inventories will supply the slack, there is need to study the problem with a view to minimizing inventory costs and meeting sales forecast through linear programming.

iii. Policy of the firm. A firm may have access to certain materials of production whose supply, for one reason or another, cannot be increased in the time period in view. These restriction resources limit the opportunities open to the firm. They may be utilized in various ways or not at all, and, depending on what is done with, the resources, expenses,

and profit of the firm will vary. The The problem facing management will be to find the productive programme which will make the profit of the firm as great as possible, subject to the limitation that this programme will not require more than the total available supply of any resource. The production problem becomes one of choosing which productive forces to use and the level at which to use each of them. The use of linear programming is useful here because it states in advance how many different processes need to be used in order to maximize profit.

e. Miscellaneous Applications.

Other application of linear programming include: problem of gasoline blending, structural design, scheduling of a military tanker fleet, minimizing the number of carriers to meet a fixed schedule, the least balast shipping required to meet a specific shipping programme, product distribution, cost cutting in business, fabrication scheduling, profit scheduling, computation of maximum flows in networks, steel production scheduling. Stocks and flows, the balancing of assembly lines, etc.

In addition, linear programming has been used to aid management in maximizing portfolio selections, allocating advertising budgets among competing media to maximize market penetration, and designing containers for maximum storage space to minimize transportation costs.

Footnotes to Chapter Three

1. Levin, R.I. and Kirkpatrick, C.A., Quantitative Approaches to Management; McGraw-Hill Book Company, 1965; P. 199.

2. Brown, R.G. and DeVelle J.B, Qualtitative Methods for Managerial Decisions; AddisonWesley Publishing Company; 1978; P. 63

3. Ibid, P. 70

4. Ibid, PP 71 - 72.

5. Ibid, P. 69

6. Ibid, P. 71.

Chapter Four

DATA ANALYSIS.

In chapter two, we were able to evaluate the present production practices of the company, based on information gathered from interview with the officials. Earlier on in chapter one, we made the assertion that the compony was incurring serious losses from its operations on the production line. We postulated that the problems in addition to those advanced by the management could be caused by poor management of available resources of production. In the same chapter, we said that the aim of the research was to apply the mathematical tool of operations research i.e Linear Programming to the above stated problem with the hope of finding a feasible solution. Chapter three, reviewed the related literature on linear programming in depth, highlighting what it is, its requirement, its characteristics, its advantages and its other areas of application.

In this chapter, attempt shall be made to analyse in detail the data contained in chapter two, and other data collected by means of questionnaire. A copy of the questionnaire is attached to the appendix of this project. In the final analysis, it is hoped that, we

shall come up with a matrix of equations, consisting of operating constraint, on the right side of the equations and a set of values for the technological coefficient for the variables under consideration with an objective function at the bottom of the matrix. The formulation of the problem as will be seen in the matrix shall be phrased as follows: within prescribed machine limitations and sales restrictions, what number of what types of blankets should be produced on what machine so as to meet the objective function from overall mill operations? It is my intention to treat the analysis under the following headings:

1. Objective functions.
2. Raw material constraint.
3. Machine time constraint.
4. Demand consteaints.
5. Mathematical formulation and solution.

4.1 Objective Function:

As indicated elsewhere in this book, the company produces four different kinds of high quality blankets namely: (1) Jacquard (ss), (2) SPDW(ss), (3) SPDW (4) Cellular in 2 sizes, i.e single bed size and King size. Current cost of production for the single bed size for each of the product are as follows: Jacquard (ss) ₦17.25, SPDW(ss) ₦14.00, SPDW(H) 16.00, Cellular ₦10.00. Current cost of production for King size for each of the product is as follows:

Jacquard(ss) 36.00, SPD (ss) 28.00 SPD5(H) 32.00, Cellular 20.00. These are the current costs of production of each of the high quality blankets in the respective sizes mentioned above.

Also the company produces six different types of trade blankets but these are produced in single bed sizes in commercial quantity. These are as follows: (1) BL at cost ₦10.00 (2) DG. at cost ₦10.50, (3) MG. at cost ₦8.50, (4) TG at cost ₦10.00, (5) PLMG at cost ₦8.50 and finally (6) Prints at cost ₦5.00.

From the questionnaire, it is gathered that prices for each of the above listed products are set for a profit of 25% of production costs. This means that 25% of each of the costs of production represents profit to the company for each unit of blanket produced. For example, for Jacquard(ss) king size, the price is ₦45.00 i.e 36.00 cost of production plus 9.00 which is 25% of the cost and which is the contribution from the sale of a unit of Jacquard(ss) king size. A similar calculation holds true for the rest of the blankets. Belwo is a table of contributions for each blanket on 25% of cost of production.

S/N	Types of blanket	Single Bed Size	King Size
1.	Jacquard(ss)	₦4.31	9.00
2.	SPD(ss)	₦3.50	₦7.00
3.	SPD(Bl)	₦6.00	₦8.00
4.	Cellular	₦2.00	₦5.00
5.	BL	₦2.00	-
6.	DG.	₦2.62	-
7.	MG	₦2.13	-
8.	TG	₦2.50	-
9.	PLMG	₦2.13	-
10.	Prints	₦1.25	-

The above figures are the contribution coefficient of the objective function. The respondents to my questionnaire also answered that though they have other objectives such as customer satisfaction, their main objective is to maximise operating profits and at the same time to minimize production costs as far as possible. Happily, linear programming is the perfect tool which can be used to realise both profit maximization objective of a firm and its cost minimization objective simultaneously. This will be proved in due course. The beauty of linear programming is that its objective function can be written such that it aims at cost minimization or profit maximization. In the light of the above

statement the objective function of Northern Textile Manufacturers can be either:

1. (₦9xH of king size jacquard.(ss) + (₦7xaH of king size SPDW(ss)) + (₦8xaH of SPDW(H) king size) + (₦5zaH of king size cellular) + (₦.31xaH of jacquard small size) + ₦3.50xaH of small size SPDW(ss) + ₦4.00xaH of small size SPDW(H) +(₦2.00xaH of cellular small size) + (2.50xaH of BL) + (₦2.62 X aH of DG) +(₦2.13xaH of MG) + (₦2.5xaH of TG) +(₦2.13xaH of PLMG) + (₦1.25zaH of Print) = max profit.

OR

(2) (₦36.00xaH of king size JQ(ss) + (₦28,00xaH of king size SPDW(ss) + (₦32.00xaH of king size SPDW(H) +(₦20.00xaH of king size cellualr) + (₦17.25xaH of small size JQ(ss) + (₦14.00xaH of small size SPDW(ss) + (₦16.00xaH small size SPDW(H)) + (₦10xaH of small size cellular) + (10.00xaH of BL) + (₦10.50xaH of DG) +(₦8.50xaH of MG) + (₦10.00xaH of TG) +(₦8.50xaH of PLMG) + (₦5.00xaH of Print = minimum cost.

The quantity of the various types of blanket to be multiplied by the respective contribution/cost coefficients is to be determined after a series of iterations of the initial matrix (algorithm) for the linear programming problem. They are reffered to as variables, and they assume different values with each successive iteration until the optimum solution is reached at the final.

4.2 Raw Material Constraint:

The raw materials used by the company include waste yearn, waste fibre, dyestuff, nylon, rayon, polypoplene, cotton, and chemicals. As stated in chapter one, the compnay attributed to a large extent raw material shortage as one of the bottlenecks they are facing. It affects the quantity of blankets that can be produced. For this reason, it is being treated as a constraint for the company in the problem formulation. Though some are easily available, especially those used for producing trade blankets, others needed for high quality blankets are in short supply. Even those that are claimed to be easily available more often than not present a problem to the company.

For the period under review (a month), average raw material availability is at most 24,762.8kgs. This figure represents raw material available for the production of both high quality and trade blankets. This figure also represents to the company the limit of the use of raw material and is a constraint for all kinds of blankets. As for chemical total availability for our time frame is at most ₦12,500.00 worth. This also represents a general constraint for all the blankets. Of the 24,762 kilograms, 14857.7kgs is available for the production of high quality blankets

and 9,905.1 kilog ams is available for teade blankets production. Both figures represent constraints on their respective types of blankets. Now with this available raw material, at least about 2000 pieces of king size jacquard blankets, 1500 pieces of small size jacquard blankets, 5000 pieces of both king size and small size spdw(22), 4150 pieces of both king size and small size SPDW(4) and 4500 pieces of cellular can be produced.

As for the trade blankets about 5000 pieces of each is produceable by the company for the period under review.

Each type of king size blanket weights roughly 4.8Ibs. or 2.16kg. while the other small sizes weigh approximately 1.25Ibs or 56kg. It is also gathered that wastages of some of the raw material is encunter for many reasons. Because there is no accurate record on these wastage, I have assumed a 10% loss for the month .

4.3 Machine Time Constraint.

The company has at its disposal a total of 42 looms, comprising of 8 jacquard looms, 6 Dobbi looms and 28 tappet looms. These machines vary according to the type of fabrics or blankets that they can produce. For example, only jacquard p looms can weave jacquard blankets but in addition the Jacquard

looms can also weave other types of fabric. The tappet looms are used to weave only trade blankets as they cannot weave any other type of blanket, while the Dobbi looms have the advantage of weaving just any kind of fabric except jacquard materials. This is the basic difference. Other differences lie in the fact that tappet looms are normally operated while both jacquard and dobbi looms are automatic.

Presently, the company operates in two shifts of 8 hours each, for 5 working days in a week. This means that in one month the total available gross machine time is 16 hours x 20 days = 320 hours. Break time each day is 40 minutes. Occasional stoppage due to breakdown, NEPA and other reasons have been estimated at 90 minutes a day on the average. Total stoppage period of machines per day therefore becomes 130 mnutes. The net machine time per month therefore becomes (320 x 60 minutes) - (130 x 20) = 16600 minutes. The above computation is for only one machine. This implies that for 8 jacquard machines total available time is 16600 minutes x 8. Available time for the other types of machines can be arrived at through similar calculations i.e

(a) 28 tappet looms, available time is atmost (16680 x 28) minutes.

(b) 6 Dobbi looms, available time is atmost (16680 x 6) minutes.

Each of the machine is capable of producing two hundred blankets each a day except the tappet looms which are manually operated. They produce about 150 peices of blankets a day. For a month, both the Jacquard looms and the Dobbi looms are capable of producing at least 6000 pieces of blankets each while the tappet looms produce at most 4500 pieces. This goes to say that each trade blanket takes roughly 960 minutes = 150 or 6.4 minutes to produce while the high quality king size blankets take about 960 minutes ÷ 200 or 4.8 minutes to produce.

The machines used in the finishing section (i.e sewing machine), also have 16680 minutes in a month. Each blanket depending on its size and the type of finishing it is being given takes roughly 3 to t minutes on the finishing machines. There are 12 sewing machines.

4.4 Demand Constraint:

Demand for blankets is fairly uniform throughout the year but skews to greater heights during the last two months of the year. Based on this fact, we assume that the total demand for the month under our consideration is approximately 130,000 pieces for all the blankets. This goes to say that the company expects to sell a total of at least 130,000 peices during the month and this therefore serves as a condition of production. Of this figure it is

estimated that at most 69% or 89700 pieces will be the various kinds of high quality blankets while 31% or 40300 pieces will be the various kinds of trade blankets. These latter figures represent production condition for the two major types of blankets for the period. Of this amount, the high quality blnakets are estimated to have the following individual demand:

i. Jacquard weaves (all sizes) = 34583 pieces.
ii. SPDW(H) " = 18333 "
iii. SPDW(SS) " = 19583 "
iv. Cellualar weave " = 19500 "

The trade blankets are expected to have the following demand breakdown:

i. PLMG blankets = 9000.
ii. Print = 5000.
iii. MG,BL,DG AND TG = 26,300

All these figures are conditions in that during production for the month, these figures must not be exceeded.

Finally the company considers the high quality blankets to be the most important and this reason explains the high expectation for the sales forecast of the blankets. They are considered most important because they have the highest profitability hence the company expects to maximise their own profit by

producing more of the high quality blankets than the trade blankets. The management also expects to minimize production costs from high production of this set of blankets.

In the next subheading, we shall be able to verify whether profit maximization or cost minimization can be achieved through greater production of the high quality blankets alone.

4.5 Mathematical Formulation and Solution:

As indicated earlier on, formulation of the problem within the framework of linear programming shall be phrased as follows: within the prescribed machine limitations, sales forecast, and raw material constraint, what number of what type of blankets should be produced so as to maximise profit from overall mill operations.

The processes through which each blanket passes have already been highlighted in chapter two. And in this chapter, we indicated which machiens are responsible for weaving each type of blanket. Each blanket or a certain group of blankets take different amount of inputs, and it takes a fixed amount of inputs to make each unit of output (blnakets). For example, to, make one unit of an output-say Jacquard blanket, requires certain amount of raw material of a specific type, and it has to go through the Jacquard loom and

the quantity of that type of blanket depends on the sales forecast for it. These input output relationships are to be formulated in the form of matrix equation. To be able to do this, each type of blanket, which we shall hence forth be refering to as variables will have to be represented by letter X_k where k assume the variables , 1, 2, 3, 4.....14, depending on which type of blanket is being reffered to.

SC; Let X_1 represent king size Jacquard(SS) blanket.

X_2 " " " SPDW(SS) "
X_3 " " " SPDW(H) "
X_4 " " " Cellular "
X_5 " smal size Jacquard(SS) "
X_6 " " " SPDW(SS) "
X_7 " " " SPDW(H) "
X_8 " " " Cellular "
X_9 " " " BL "
X_{10} " " " DG "
X_{11} " " " MG "
X_{12} " " " TG "
X_{13} " " " PLMG "
X_{14} " " " Prints "

Our objective functions will therefore be as below if we represent the company names of the various types of blanket with the letter X_k, where k takes value 1, 2, ...14, as explained above.

1. Profit Maximizing Objective function:

$9X_1 + 7X_2 + 8X_3 + 5X_4 + 1.31X_5 + 3.5X_6 + 4X_7 + 2X_8 + 2X_9 + 2.62X_{10} + 2.13X_{11} = 2.5X_{12} + 12,.13X_{13} + 1.25X_{14}$ = Maximum profit.

OR

2. Cost Minimizing objective function:

$36X_1 + 28X_2 + 32X_3 + 20X_4 + 17.25X_5 + 14X_6 + 16X_7 + 10X_8 + 10X_9 + 10.5X_{10} + 8.5X_{11} + 10X_{12} + 8.5X_{13} + 5X_{14}$ = Minimum cost.

The following inequalities are devivable from the response got for my questionnaire.

1. Raw Material Constraints:

$2.\ 16(X_1 + X_2 + X_3 + X_4) + .56\ (X_5+X_6+X_7+X_8) \leq$ 14857.7kg.

$.56\ (X_9 + X_{10} + X_{11} + X_{12} + X_{13} + X_{14}) \leq$ 9905.1kg.

2. Machine time Constraints:

tappet loom $6.4(X_9+X_{10}+X_{11}+X_{12}+X_{13}+X_{14}) \leq 467,040$ minutes.

JQ Loom $4.8(X_1+X_2+X_3+X_4)+3(X_5+X_6....+X_{14}) \leq$ 133,440 minutes

Dobbi Loom $4.8(X_2 X_3 + X_4) + 3(X_6 + X_7 + \ldots\ldots X_{14}) \leq$

100,080 minutes

Finishing D/C $5(X_1 + X_2 X_3 + X_4) + 3(X_5 + X_6 \ldots\ldots X_{14}) \leq$

200,160 minutes

3. Demand Constraints:

$$X_1 + X_5 \leq 34,583.$$

$$X_2 + X_6 \leq 19583$$

$$X_3 + X_7 \leq 18,333$$

$$X_4 + X_8 \leq 19,500$$

$$X_9 + X_{10} + X_{11} + X_{12} \leq 26,300$$

$$X_{13} \leq 9,000$$

$$X_{14} \leq 5000$$

4.5.1 Formulating the Matrix

The task of solving the linear programming problem is aided by the use of a simplex tableau one for each iteration (evaluatory step) of the algorithm itself. A tableaux for the basic maximisation problem must consist of about five columns[1] i.e

1. contribution of current solution variables
2. solution set
3. Technological coefficients.
4. Constraints
5. Variable leaving solution locator.

The basic tableau which is also referred to as the initial basic solution appears below: Note since the problem present itself as a maximisation problem, the objective function that is used is the profit maximisation one. It will be appreciated that such a gigantic problem will be cumberson and boring to solve manually. For this reason, the computer is used snd the solution appears in appendix 2. Based on this solution we draw an inference which appears in the next chapter.

The interpretation of the figures presented by the computer in appendix 2 appears in appendix 3 where I manually presented it in a tabular form for the benefit of those who might use the information in this book, The table which signifies the final matrix to the problem formulated on page 66 reads thus:

i. Produce 26531.61 pieces of small size high quality Jacquard blanket at a profit of ₦114351.24.

ii. Produce 17687.68 pieces of Black trade blankets at a profit of 46341.72.

Total maximum profit arising from this operation will be ₦160692.9

Added to this, there will be enormous amount of resources of time and market demand left un-utilised.

Basic Solution.

Contribution of current solution variables	Solution set of blankets	Technological Coefficients														Constrainrts	Variable leaving solution locator
		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}		
	S_1	2.16	2.16	2.16	2.16	.56	.56	.56	.56	0	0	0	0	0	0	14,857.7Kg.	
	S_2	0	0	0	0	0	0	0	0	.56	.56	.56	.56	.56	.56	9,905.1 ,,	
	S_3	0	0	0	0	0	0	0	0	6.4	6.4	6.4	6.4	6.4	6.4	467,040min	
	S4	4.8	4.8	4.8	4.8	3	3	3	3	3	3	3	3	3	3	133,440 ,,	
	S_5		4.8	4.8	4.8		3	3	3	3	3	3	3	3	3	100,080 ,,	
	S_6	5	5	5	5	3	3	3	3	3	3	3	3	3	3	200,160 ,,	
	S_7	1	0	0	0	1	0	0	0	0	0	0	0	0	0	34,583 pes.	
	S_8	0	1	0	0	0	1	0	0	0	0	0	0	0	0	19,583 ,,	
	S_9	0	0	1	0	0	0	1	0	0	0	0	0	0	0	18,333 ,,	
	S_{10}	0	0	0	1	0	0	0	1	0	0	0	0	0	0	19,500 ,,	
	S_{11}	0	0	0	0	0	0	0	0	1	1	1	1	0	0	26,300 ,,	
	S_{12}	0	0	0	0	0	0	0	0	0	0	0	0	1	0	9,000 ,,	
	S13	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5,000 ,,	
	Xo	-9	-2	-8	-5	-4.31	-3.5	-4	-2	-2.5	-2.62	-2.13	-2.5	-2.13	-1.25	Maximum Prfts	

This, we might attribute to the fact that data collected is in complete and as I earlier explained in chapter I, there were a lot of limiting factors that hinder a 100% thoroughness in this project. It is withing these limitations that data was collected and were still able to prove that the company could overcome its losses problems through the use of linear programming with the limited data at hand. It is hereby suggested that had the management agreed to release some of the information needed (which they refused to "because it is company secret") findings would have been made that would indicate even greater profits.

Despite the encouraging result got, it is felt ridiculous to suggest to a compnay of this size to produce only two types of blankets. Therefore making a deeper analysis, the initial basic solution is changed in such a way as to produce a minimum of 1000 pieces of each type of blanket, and the resources for doing this, is removed from the right hand constraints. This is doen in consideration of the company's customers. It will also be advsntageous to the company since it will give the company product width. The result of this further analysis appears in appendix 4 and interpreted manually in appendix 5. The result shows a profit of about ₦140,000 i.e a loss of a

little over ₦100,000. This loss we fill is justified to give the company the advantage of having a large product width as mentioned above.

This study shows that the actual problem of the company, is the poor management of available resources rather than its shortage, since this analysis shows us that profits could be made. In the final analysis, conclusion are drawn, and recommendation are made in the next chapter. Also, the program used in the computer for this analysis is shown in appendix 6.

Footnote to Chapter Four

1. Brown, K.S. and Revellen, J.B., Quantitative Methods for Management Decision; Addision Vesley Publishing Company; 1978, P. 94.

Chapter Five

CONCLUSION AND RECOMMENDATIONS

In view of the widespread occurence of linear programming problems, standard machines codes are now available for the automatic solution of such problems and other similar ones on the major high-speed electronic computers on the market. It is one of these computers that was used to solve the problems formulated in the preceeding chapter, and solution was reached in a matter of minutes for a problem that could have taken weeks or even months to solve.

One striking thing that the solution showed is that, the company can actually make a remarkable profit under optimal production as compared to the little profits or even losses which it gets under current operations. It must be realised however, that the problem for which this solution is botained was formulated with data which is surrounded by a few limitations as indicated in chapter one, and under a few assumptions. Also that no account has been taken of scheduling difficulties, changes in machine assignment, changeovers to the production of different styles of blanket, advantageous location of production facilities, seasonal variables,

deviation of actual order from forecasts, and similar realistic contingencies. The result which appears in appendix one and on which I am basing my conclusion cannot therefore be implemented in 100% detail, but it should be appreciated that it is sufficiently valid to constitute a valuable guide for broad policy decisions. To this extent I must say the project has met one of its aims.

It may well be noted that, some items which have the highest profits when taken by themselves such are X_1, X_2 and X_3, appear in the optimal solution program in no amount at all. This circumstance is due to the fact that the amount to be produced of each item for maximum revenue may not be maximised individually. Rather it is constrained in an interlocking fashion with all other items so as to satisfy simultaneously all sales forecasts, raw material and machine limitations, while striving for maximum profit.

In conclusion, a number of valuable lessons were learned from the results of the present study.

1. The establishment of quantitative data for operational characteristic is an accomplishment in its own right.
2. The figures emerging from the linear programming solutions furnished quantitative measures for

a highly complex system of interacting effects.

3. Critically limited processing steps as well as redundant capacity were clearly brought to light.

4. Guiding lines were crystallised for increasing overall profits by rendering future sales efforts more selective.

5. The linear programming approach proved itself capable of furnishing guidance for setting up production target, evaluating merchandising plans and capital investments, and improving efficiency in the utilization of resources of production for actual mill output.

6. Striking evidence was brought home of the great potential benefits to a manufactuirngg business especially Northern Textile Manufacturers, from the services of an operations research team of mathematically trained and competent scientists. Only such people can uncover such vital information, such as the one this project has uncovered.

The insights revealed through this project should stimulate management's interest to the extent that definite plans should be formulated for continuing such studies and infact extending there crope. For this reason I make the following recommendations.

So long as the objective of the company remains profit maximisation or cost minimization or both, a mere frequent use of tools of operations research becomes inevitable for the company. It should therefore hire the services of a team of competent operations research experts to do the job for them. Particularly since linear programming has proved to b be as useful to the company's problem as we have described above, (i.e judging by the results obtained in appendix 1), a few more cases can be tested to see if the company can benefit from it. In the first place, the company should try as much as possible to avoid much of the limitations that this project faced. This should therefore increase vastly the size of the problem beyond that obttained in this project, This can be done in three directions.

1. All productive processes involving possible machine limitations should be included. The exception might be that, the machine processes, such as warping, which top management would never allow to hold up production or become a bottleneck will not be included. Want processes should be commited in the latter category will be determined by consultation with mannagement. This expansion will increase the number of rows in the table and will therefore naturally increase the complexity of

the problem.

2. Many more sales restrictions which face the company should be taken into consideration and should be set up somewhat differently. Maximum and minimum sales restrictions should be set up for most of the styles individually based on available forecastes, and with a much finer breakdwon than the one that was obtained in this project. In addition, several "cross restrictions" may also be set up, such as a restriction on the combined total of king size blankets of all styles. This could be done on the fact that King size blankets supply a limited market, in which the variable styles are competing with one another. These restrictions could be set up as a flat percentage range above and below the corresponding sales forecasts. The percentages would be determined by an examination of the historical variations of actual sales from forecasts. This expansion will also further add to the rows of the table.

3. As we have seen above, one and the same type of blanket may be represented by more than one column of our table, whereever we have a choice among different machines at the same stage of process. It is planned to include henceforth

all of the feasible combinations of machine selection. This will grwatly expand the number of columns to be dealt with.

These extensions described above are expected to provide a very realistic picture of the Northern Textile Manufacturers' operations. The results should closely relfect the impavt of all the factors included in the linear programming formulation.

Note that so far, the determination of optimum production goals within the restrictions imposed by mill e uipment and market conditions have been dealt with exclusively. An additional advantage of the lineat programming approach when applied to actual operations shall not be described and recommended.

A definite production pattern could be decided upon for a given period by management based on all realistic factors, such as seasonal fluctuations, inventory situation, deviation of ordersreceived from the forecasts e.t.c. This working program will differ obviously from the one obtained as a yearly average target (just as the situation in this project). A linear programming problem can now ve set up in which the total volume for each style of blanket is no longer allowed to vary in some range but is set equal to a fixed pre-established number, which will differ, in general, from the one which has resulted from the

earlier general optimisation. As before different machine choices for the same styles will be carried as separate columns in the table with correspondingly different profit coefficients.

Having prescribed a fixed, pre-established composition of mill output, a new linear programming solution will now show us the best allocation of styles to machines combinations so as to accomplish the specified true mill output at minimum total cost. Since all data on costs and machines productivities have already been collected for the earlier problem we formulated in this project, the present optimisation of actual mill operations would require only a minor amount of additional efforts and machine time. This is therefore an outstanding example of the possible" side advantage" of linear programming, and is highly recommended that the company should try its hand on it.

During the course of this research, it was discovered that there are other areas which could be interesting to investigate. One is the determination of sales restrictions which will adequately reflect each of the seasonal periods. It is realised that annual forecasts (and hence implied average for a month, provides us with only a general picture because a strong seasonal variations exist. These

fluctuations differ for the various groups of blankets. It is likewise virtually certain that with the hiring of experts in the field of operations research, new areas will continue to be explored as they bring themselves to attention.

Linear programming in the context of textile mills in Nigeria in general is headed for a long and eventful course if explored to the fullest.

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APPENDIX I
QUESTIONNAIRES

Master of Business Administration Research Questionnaire on "Study of the Production Activities of a Textile Mill with the Aid of Linear Programming".

1. Sir, I understand that you produce both high quality blankets and trade blankets.

   Yes/NO

2. If answer is yes, please list the important high quality blnakets you produce.

   a.
   b.
   c.
   d.
   e.

3. Please specify how many sizes of each you make

   a. Single bed size
   b. double bed size
   c. king bed size

4. Also list the more important trade blankets you make.

   a,
   b.
   c.
   d.
   e.
   f.

5. Please specify the different sizes in which you make them.

   a. single
   b. double
   c. King size.
   d.

6. What is the cost of producing each high quality blanket you listed above, Please write answer in order as in (2) above.

   a.
   b.
   c.
   d.
   e.

7. What is the cost of producing each trade blanket you listed above? Please arrange answer in order as in in (4) above.

   a.
   b.
   c.
   d,
   e.
   f.

8. If your profit is a constant percentage of cost of production, be specify the answer.

   a. 100%
   b. 75%
   c. 50%
   d. 25%
   e. others (P.ease specify).

.....

9. Which of the following is the compnay's objective.

   a. To maximize profit
   b. To mnimize cost
   c. Both (a) and (b)
   d. None
   e. Others (Please specify)

.....

.....

10. What are your basic raw materials?

   a.
   b.
   c,
   d.
   e.

11. -re the raw materials easily available?

   Yes/NO

12. If no, why?

   a. Restriction on importation
   b. Effect of draught
   c. Other reasons (Please specify)

.....

.....

13. How much of the raw material listed in (10) are available for the production of trade blankets in a month? Express answer in weight Please.

.....

14. How much of the raw material listed in (10) are available for the production of high quality blankets in a month? Express answer in weight if possible:.....

15. What is the weight of each type of trade blanket?

a.
b.
c.
d.
e.

16. What is the weight of each type of high quality blankets? Include as the sizes please.

a.
b.
c.
d.
e.

17. How much of the raw material is wasted during production process or for other reqsons?

a. 30%
b. 20%
c. 10%
d. 5%
e. Nothing.

18. What types of machines (loom) do you use for weaving?

a.
b
c.
d.

19. Please indicate what differentiates one machine from another?

.....

.....

20. How many shifts do you operate daily?

a. One shift
b. Two shifts
c. Three shifts
d. Four shifts.

Please specify the duration of each shift.

21. Please tick the correct reason below why your machines stop working each day.

a. After work
b. During breaktimes
c. Occassional technical faults on the machine.
d. N.C.P.A. failure
e. When an operator is not around
f. Others.

Please specify average time lost each day due to above reasons.

22. The machines are also l'ee on saturdays and sundays?

Yes/NO

23. How long does it take to produce each type of high uality blankets?

a.
b.
c.
d.
e.

24. How long does it take to produce each type of trade blanket?

a.
b.
c.
d.
e.

25. What other machines do the blankets go through?

a.
b.
c.

26. What is the time available on each of the machines in (25) above?

.....

27. How long does each blanket take on each of the machines in (25) above?

.....

28. What is the expected total demand for all the blankets for the month.

.....

29. Please breakdown the figure in (28) above in to the aggregate demand for:

a. High quality blankets
b. Trade blankets.
c.

30. Please go further and breakdown the figures in (29) above into the different types of blankets.

a. For high quality
   i.
   ii.
   iii.
   iv.
   v.

b. For trade blankets.
   i.
   ii.
   iii.
   iv.
   v.
   vi.

31. Please specify any other constraints that the company faces in their production process?

32. In waht ways do these constraints in (31) affect the production process?

33. Which of the blankets are considered most important by the company?

a.
b.
c.
d.
e.

34. Why are they considered most important?

a. High profit
b. Low cost
c. high demand
d. Readily available raw materials.

APPENDIX II

```
p        0        r        0
2.16
p        9        r        1
.56
p        4        r        0
.2592593
max. profit:     160692.9


3.857143
3.857143
3.857143
3.857143
1
1
1
1
0
0
0
0
0
0
1.785714
0
0
0
0
0
0
0
0
0
0
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0
26531.61
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0
1
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1
1
1
1
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1.785714
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0
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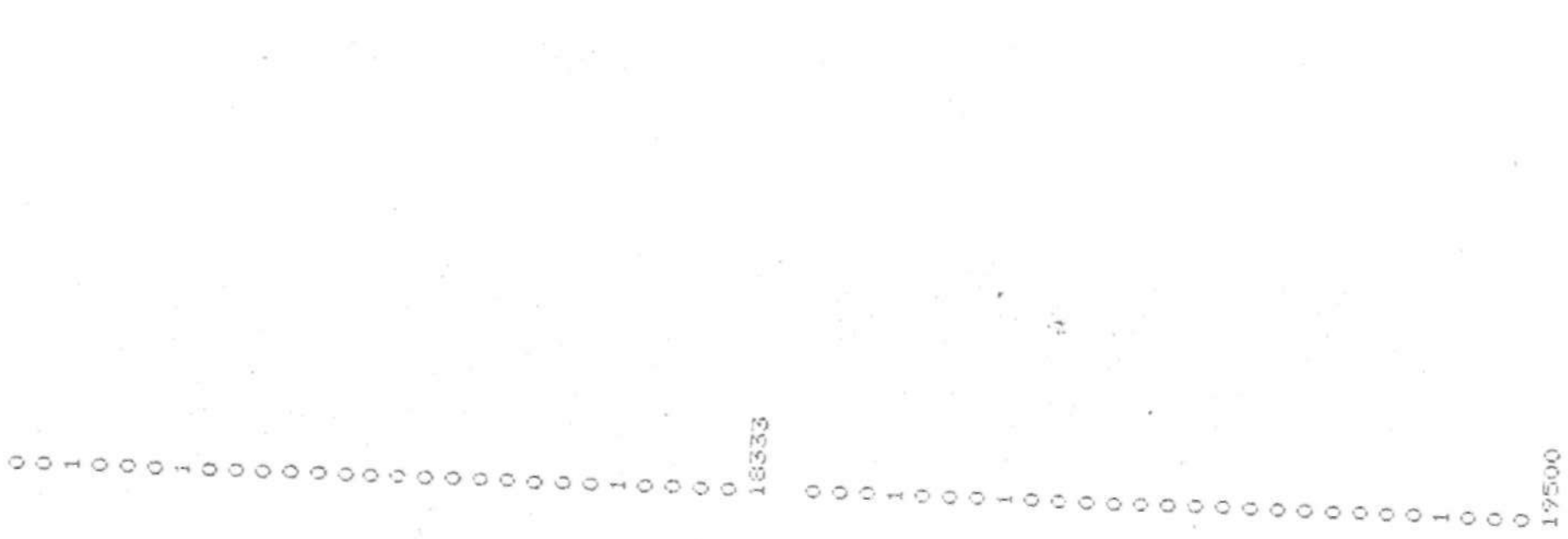
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353838.9
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-6.771429
-6.771429
-6.771429
0
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0
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782.1429
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4.8
4.8
4.8
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3
0
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0
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0
-5.357143
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1
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0
0
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0
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47016.96

-6.571429
-6.571429
-6.571429
-6.571429
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0
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0
-5.357143
-5.357143
0
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67502.14

-2.857143
-3.857143
-3.857143
-3.857143
0
-1
-1
-1
0
0
0
0
0
0
-1.785714
0
0
0
0
0
1
0
0
0
0
0
0
8051.393

0
1
0
0
0
1
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0
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0
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0
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1
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0
0
0
0
0
17583

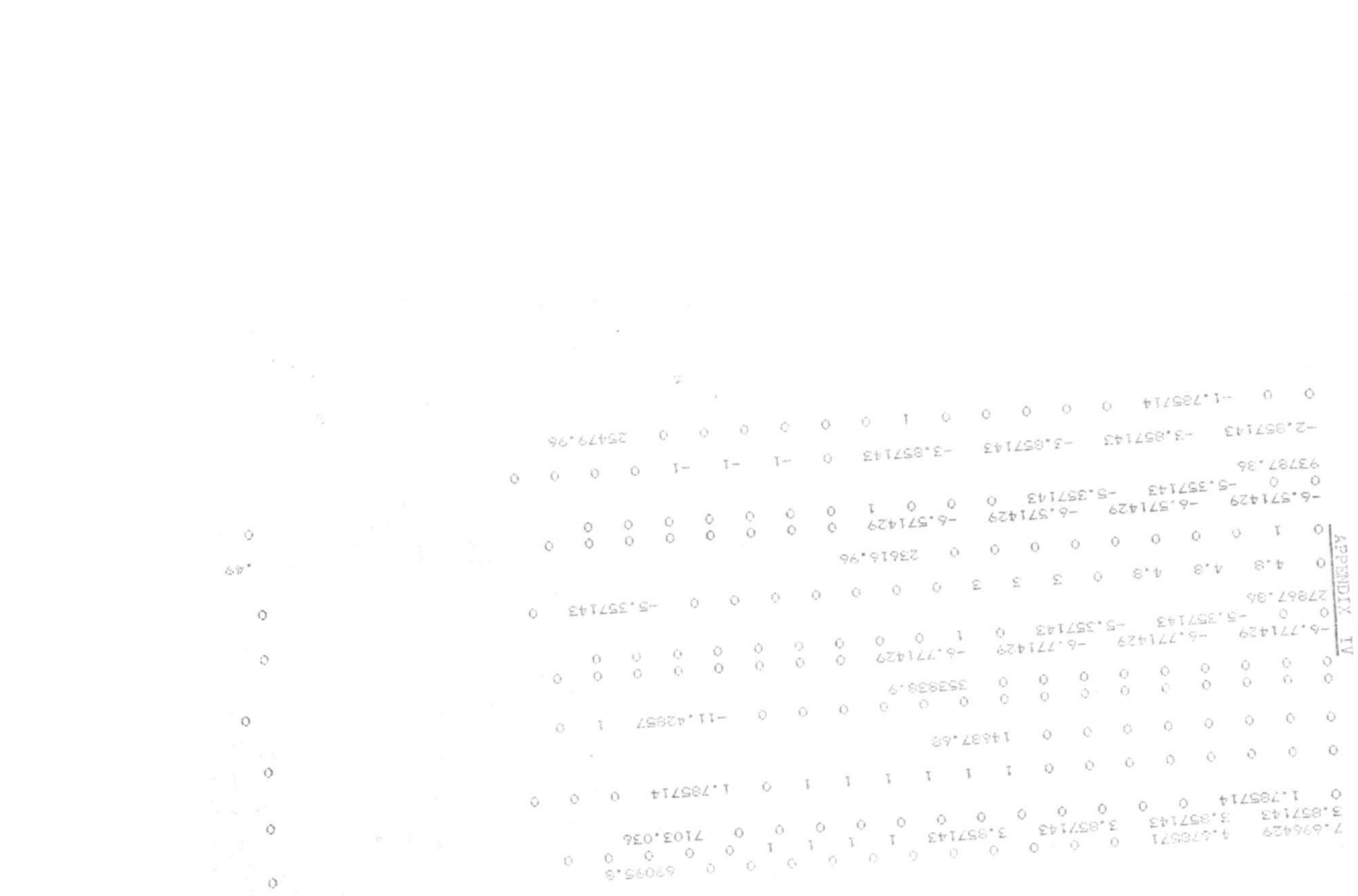

18333
17500

```
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 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
-1
-1
 0
-1.785714
 0
 0
 0
 0
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 0
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 0
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 1
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 0
8612.321

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9000
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1
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0
0
0
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0
0
0
0
0
1
5000

7.624286
9.624286
8.624286
11.62429
0
.81
.31
2.31
.12
0
.49
.12
.49
1.37
7.696429
4.678571
0
0
0
0
0
0
0
0
0
0
0
160692.9



```
0   1   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   1   0   0   0   0   0   17583

0   0   1   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   1   0   0   0   0   16333

0   0   0   1   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   1   0   0   0   17500

0   0   0   0   0   0   0   0   0   0   0   0   -1   -1   0   -1.785714   0   0

0   0   0   0   0   0   1   0   0   9612.321

0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0
0   0   0   0   0   1   0   8500

0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0
0   0   0   0   0   0   1   4500

7.624286   9.624286   8.624286   11.62429   0   .81   .31   2.31   .12   0   .49
.12   .49   1.37   7.696429   4.678571   0   0   0   0   0   0   0   0   0   0
0   69095.8
```

APPENDIX VI

```
100         REMark Simplex-rao2j
110          REMark data
112 CLS:PAPER 0:INK 4
120 INPUT "How many products ?"; it
130 INPUT "How many constraints ?"; pr
140 DIM D(it+pr,pr)
150 FOR n= 0 TO it-1
160 FOR m=0 TO pr-1
170 PRINT ; "For product"; n+1;", constraint";m+1;"technological
180 INPUT D(n,m)
190 END FOR m
200 END FOR n
210 FOR n=0 TO pr-1
220 PRINT "Resources available for constraint";n+1;" ?"
230 INPUT D(it+pr,n)
240 END FOR n
250 LET D(it+pr,pr)=0
260 FOR n= 0 TO it-1
270 PRINT  "Profit per product ";n+1;" ?"
271 INPUT b
280 LET D(n,pr)=-b
290 END FOR n
300        REMark Slack variables
310 FOR n=it TO it+pr-1
320 FOR m=0 TO pr
330 LET D(n,m)=0
340 END FOR m
350 END FOR n
360 FOR n=1 TO pr
370 LET D(it-1+n,n-1)=1
380 END FOR n
400       REMark Find Pivot
420 LET p=0
430 LET q=D(0,pr)
440 FOR n=1 TO it+pr-1
450 IF D(n,pr) <=q THEN
460 LET q=D(n,pr)
470 LET p=n
480 END IF
490 END FOR n
495 PRINT "p";p
500 LET r=0
510 LET s= 1E20
520 FOR n=0  TO pr-1
525 IF D(p,n)=0 THEN GO TO 570
526 IF D(p,n)<0 THEN
527 IF D(it+pr,n)<0 THEN GO TO 530
528 IF D(it+pr,n)>0 THEN GO TO 570
529 END IF
530 IF D(it+pr,n)/D(p,n)<s THEN
540 LET s=D(it+pr,n)/D(p,n)
550 LET r=n
560 END IF
570  END FOR n
575 OPEN £5,ser1
580        REMark Pivotal row
581 PRINT p: PRINT r
582 PRINT £5,  "p ", p,: PRINT £5, "r ",  r
585 LET pivot=D(p,r)
586 PRINT pivot
587 PRINT £5, pivot
590 FOR n=0 TO it+pr
600 LET D(n,r) = D(n,r)/pivot
610 END FOR n
```