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Determining an Optimum Model for Production in Paper Industry: Case Study of Iranian Mazandaran Wood and Paper Industries

[1]Majid Azizi and [2]Mohammad Aghapour
[1]Faculty of Natural Resources,
[2]Faculty of Agriculture, University of Tehran, Iran

Abstract: In current research, Mazandaran Wood and Paper Industries (MWPI) has been studied. With respect to increasing of paper consumption in the country, optimization of the product has been notified due to limitations in wood resources as the most important factor in the production. In the factory, three kinds of products are produced which are printing and writing paper, corrugated medium paper and newspaper paper. Linear programming method has been used in the research. Limitations are wood resources, manpower costs, chemical materials, distribution costs and production capacity. Profit maximization is objective function for three kinds of the products. Results show that with respect to the model, optimum amounts for printing and writing paper and corrugated medium paper have to increase 35 and 18%, respectively. But the amount of newspaper paper has to decrease 13% in comparison with real production.

Key words: Mazandaran wood and paper industries, optimization, linear programming, objective function

INTRODUCTION

Communication technology can play a significant part on the application of printing/writing paper. The average annual consumption of paper in industrial nations is 164 kg for every individual while this figure in developing countries is estimated to be 18 kg and in ours 13.2 kg. On the other hand, the rate of applied paper in 2000 was about 325 million ton and in 2005 about 371 million ton and it will rise to 474 million ton in 2015 which represents one 2.6% of growth in paper consumption. In Iran, as in other countries, the rate of application for varieties of paper products in years to come is increasing. The growth of national population and inherent increase rate of per-capita consumption are two important factors of this phenomenon. Based on per-capita consumption of paper as calculated by FAO for developing countries, the prediction of paper consumption and its shortage based on statistics in 2002, 2004 and 2009 will be described in Table 1 and 2.

It is noted that the per-capita consumption of paper in Iran is on the rise (Table 2). While Iran faces some limitations regarding the most important productive theses of this products (crops) such as wood and forest, it is a dry land with one-third rate of rainfall as compared to the other lands in the world. Iran has a very critically disruptive ecology and a limited biological capability. The forest area of the country covers at present 12.4 million hectare (acre) with 0.2 acre per-capita, while the universal medium of this figure is approximately 0.7 acres. This in itself shows how limited the domestic wood resources is. The problem of time will be, however, more critical if we realize the fact that out of 12.4 million acre of national forests only these of northern part of Iran with an area of about 1.9 million acre are utilizable. This statistics make us understand that the national per-capita of utilizable forests is 0.03 acres; that is to say, it is about 23 time less than the medium universal one. This statistics also shows that the per-capita forests area cover very less than those of medium in the world. MWPI is the most important factory in Iran which uses kinds of wood produced in Sari area and Iranian northern forests and that is known as the only producer of newspaper paper in the country.

Table 1: Estimated demand, production and shortage of paper in years to come

Years	2002	2004	2009
Population (1000 person)	65678.00	69575.0	75329.0
Per-capita consumption (kg)	14.52	16.2	20.1
Demand (1000 ton)	1011.00	1127.0	1574.0
Production (1000 ton)	400-500.00	850.0	1200.0
Shortage (1000 ton)	500-600.00	277.0	374.0

Source: Ministry of Agriculture

Table 2: Prediction of paper per-capita consumption by 2010

Years	2000	2001	2011
Population (1000 person)	63665.4	64601.3	74751.1
Per-capita consumption (kg)	14.2	14.7	20.2
Consumption (1000 ton)	904.0	950.0	1510.0
Production (1000 ton)	440.0	440.0	1170.0
Imports (1000 ton)	464.0	510.0	340.0

Source: Journal of Wood and Paper Industry, Volume 5

Corresponding Author: Majid Azizi, Faculty of Natural Resources, University of Tehran, Iran

Decision making is an integral part and a prerequisite of management and planning. Formulating policies and adequately plan to advance work in producing units not only requires the availability of information about conditions under which production processes in the operation units would be under way, but also, to a large extend, depends on the intelligence and know-hows of planners on how the operators make decision and respond to different policies. Nowadays, mathematical planning, in particular that of linear serves as the most important tools of management science which are applied in an extensive scope.

Considering the availability of restricted sources and the need to assign these sources optimally between a rival's objectives based on economic theories, it seems that there must be a need to extract an optimum model for production based on a unit's weaknesses or limitations. Management, as is commonly known, serves as the most efficient factor for production and marketing of products. It is the passage of time during which the importance of management as a knowledge of applying a mathematical model help managers to identify the bottlenecks and problem by being promoted with the advance of technology. The following causes of this per-capita consumption rise are: (1) World's per-capita growth of population, (2) Economic growth of nations and (3) Relatively little amount of other substituted material in industry and different consumable items.

In their study by employing mathematical planning model, Turkamani and Pourborazjani (1999) identified desirably the program to carry out livestock and agricultural activities jointly and severally and then they were compared with each other on part of their exclusive programs. The results obtained from estimated optimum planning and their comparison with current plans of units under study represent the possibility of the fact that a considerable rise of farmer's and livestock owner's net profit can be made possible. Turkamani and Abdshahi (1997) in their studies tend to draw up a procedure within the framework of a mathematical planning that produces a possibility of considering probable changes of different periods of time in planning agricultural unit. McCauley and Caulfield (1990) specified the effective criteria for selection of an OSB (Oriented Strand Board), factory and developed a mixed integer programming model to determine the optimal location of the OSB sites. The factors affecting this model are access to raw material, transportation costs, access to suitable manpower, factory capacity, cost of production, profitability, market observations and investment-requirements. Faulin (2005) identified different models are proposed to design pig housing facilities. All of them takes the life span of a sow as reference. In this study we approach the problem using a Linear programming model in order to exploit outcomes resulting in a better management of available resources. Dubeau (2005) used multi criteria linear programming models for the problem of formulating diets for growing pigs which not only minimize the feed cost but also that taking into account nitrogen and phosphorous excretions. A combined criterion is minimized within the set of feasible solutions. Recio (2005) developed a mixed 0-1 model for a real farm management, enables crop production to be decided at the beginning of the agricultural year. It will be a medium term planning model more than a scheduling model. It is core of Agri Support a DSS for farm management. Cacchiani (2005) consider the train timetabling problem which aims at determining, for a given set of trains, an optimal timetabling which does not violate track capacity. Researcher proposes a set packing model and describes exact and heuristic algorithms based on the linear programming relaxation. Velasquez (2003) describes a linear programming model of the flower industry supply chain, Since it receives the agricultural raw materials until the flowers are sold to the final customers. This is done by the adequate assignation of resources, answering to market requirements and minimizing production costs. The mathematical model underlines the seasonality presented on the life cycle of the product as well as the seasonality in the consuming process, providing flower growers with a formal tool for decision making processes that improve the general management of resources and all activities of the industry. Abdullah (2003) presented Healthcare facilities have been under medical pressure to control cost. One element that affects cost significantly is staff. Researcher identified a heuristic for emergency departments staff scheduling. It integrates a simulation model and an Integer Linear Program (ILP). Andreas and George (2003) presented a study aiming at optimizing the allocation of human and material resources used in the management of urban solid wastes at the municipality of Thessaloniki, Greece. The results of an extended field survey were used to determine typical profiles for the use of personnel and tracks, which were then subjected to an optimization of the collection routes in the different collection districts. Respectively, a crew rostering model for the deployment of personnel was developed using integer linear programming. It was applied under different scenarios for improving the shift design and the functionality of the system. Drawing on linear planning model, Sultani *et al.* (1999) assessed one of the two systems of modern leaking irrigation and that of sprinkling (stable and unstable) on 128000 acres of lands in Ghazvin area. The findings of research study showed that sprinkling irrigation under special circumstances and other theories have greater deal of net output than leaking one for every land.

We aim by conducting this research study to determine the optimum scales of different products manufactured by MWPI and to obtain the maximum rate of profit. Current research has selected the MWPI as a model unit in order to identify the optimum rate of produced paper in this mill using linear programming to maximize the profits of this productive unit given limited resources such as manpower, chemical substances and above all required lumbers of wood.

Research variables are new profit or revenue of the company, different amounts of required savings to produce various products, price of savings, price of products.

Hypothesis of the research are as follows:

- The optimum amounts of savings are not used in the firm
- The principal aim of firm is to maximize the interest
- The prices of products and savings are fixed during consideration periods

MATERIALS AND METHODS

Linear programming: Linear planning is one of the most advanced tools of managerial science that is used in a very extensive way. Indeed, this science helps managers make more efficient decisions on how to assign limited sources amongst rival's activities by using mathematical models. Providing different possibilities or weaknesses as well as reciprocal relationship between activities, these models, therefore, can evaluate economic results of possible decisions for managers (Kupahi, 1986).

The first step to fabricate a model for a linear programming matter is define decision-making variables. These variables serve as tools that are handled or monitored by the decision-maker the amounts of which identify the answer for a model. Indeed decision-making variables are the same functions from which an optimum response would be chosen. The second step is to specify an objective function that a model has and that must be characterized based on a way in which a manager thinks and construes on a unit under study. The third and last step defines problem limitations.

The response that the solution of a linear planning issue provides, usually consists of a given program or a plan that contains some optimum amount of activities as selected for this purpose. However, the problem for it is that more than ever the number of plans that never break the limits or stipulations of a model exceed than usual. There are good methods to optimally choose one plan out of many and reach a final response. Each of them has a different precision and efficiency. These methods are graphical method, trial and error method, simulation method and simplex method respectively. Among these methods only simplex method is the most efficient one to reach a response.

Linear programming limitations:
Questions that are raised in the form of limitations are serially:

Is there a need to execute J function (for J = 1, 2, 3, …., n) or otherwise? Must we let Xj>0 remain? Each decision is expressed by means of a zero variable and one Yj as follows

$$Z = \sum (CjXj + KjYj) \text{ where } \begin{cases} \text{if},1 & Xj > 0 \\ \text{if } Yj = 0 & Xj = 0 \end{cases}$$

Yj's are dependent variables. Assume that m is an extremely big number and larger than the maximum quantities of all variables Xj (for J = 1, 2, 3, …, n). Then, the following limits ensures if Xj>0, Yj will be necessarily equal to one and cannot reduce to zero

$$J = 1, 2, 3 \ldots, n \; Xj \leq mYj.$$

The only problem that still persistently remains is the fact that if Xj = 0, the quantity of Yj can turn into both a zero and a one. Fortunately, this problem is automatically obviated due to the nature of objective function. The position of Kj = 0 is dispensed with because Yj under, this situation, is elided from model. Only another position is therefore considered and that is Ki >0. If Xj = 0, choose only Yj = 1 from among Yj = 0 and Yj = 1 because in this way we would have a less quantity of objective function.

By this method, it requires from time to time that a very large number of these typical variables should be added such that it would be made impossible to solve a problem from computational point of view.

An experimental model of research: The research has been done at University of Tehran and MWPI factory-Iran, between 2003 to 2005.

The main functions in a linear programming process for a target unit consists of printing and writing, newspaper and corrugated medium papers production given the existing realities.

Each linear planning model presumes that there is no reciprocal connections between model activities or in other words it takes for granted that all functions are independent from one another. In the event there are reciprocal and mutual relationships between some activities, some expressions appear in the forms of multiplication products which have anything to do with non linear programming jurisdiction.

Table 3 shows the rates of these products, costs and returns obtained from any of them in 2003.

Limitations of the model: This model contains four limitations relating to (1) accessible resources, (2) wood shortages, (3) man power and (4) chemical substance with over head charges the ratios of each of which represents the need felt for each product for a targeted source. The amounts on the right, in turn, manifest the maximum accessible resources. These limitations are defined as follow:

Wood limitation: In 2004, about 300,000 ton of the wood have been consumed the 90% of which were used domestically and 10% of which were imported. The reserved or unconsumed amount is about 75000 ton that 10% of which, that is to say, 7500 ton were imported and 67500 ton of which were domestic. Thirty five percent of consumed wood; namely, 168750 ton are used in the production line of newspaper paper. About 5%; that is to say, 112250 ton are used on the production line of printing and writing papers and 60%; namely, 135000 tones are used to produce corrugated medium paper.

$$\sum a_{i1}x_i \leq \text{wood} \quad i = 1,...,n \tag{1}$$

where, x_i is a variable for the amount of wood as i product. a_{i1} = 1 is defined for all products. Wood means the maximum amount of accessible wood/ton.

Manpower limitation:

$$\sum a_{i2}x_i \leq \text{Lab} \quad i = 1,...,n \tag{2}$$

Where, a_{i2} is the number of manpower-day work that is needed to produce one tones of product i. Lab is the maximum manpower that can be accessible based on production volume. This research used manpower cost to produce each unit of each product given accessible statistics (Table 4).

Chemical materials limitation:

$$\sum a_{i3}x_i \leq \text{chi} \quad i = 1,...,n \tag{3}$$

a_{i3} is a chemical need of every unit of product i, chi is the maximum accessible chemical materials.

Table 3: Performances and monetary returns of the different products

Kind of product	Unit	Printing and writing paper	Newspaper paper	Corrugated medium paper
Performance	Ton	4671	57783	82982
Price	Rial (kg)	4100	3800	3020
Monetary returns	Million Rial	19155	220131	250951

Table 4: The manpower cost of any of product

Kind of product	Newspaper paper	Printing and writing paper	Corrugated medium paper
Wages (million rials)	8013	6125	7865
Rate of final price of the product	5	5	5

Source: Data collected from the company

In 2004 total consumption of chemical materials have been 46615 tones, 25% of which have not been consumed by the end of year, 60.9% of which were domestically and 39.1% were imported. The costs of the related chemical compounds of any kinds of produced papers have been used as limitation ratios (Table 5).

Limitation of distribution cost:

$$\sum a_{i4}x_i \leq s \quad i = 1,...,n \tag{4}$$

a_{i4} is the overhead charge as our typical statistics and available information reveal. S means maximum charge of an assigned supply of products in the firm.

Limitation of production: This kind of limitation is involved in limits functions due to the limited capacity of production for any of the products. Here are some potential limited potentiality for any product:

- Newspaper paper: the annual production rate of this paper is 52000 tones with the following details:
  the basic weight of it is 48 g m^{-2}, % of long fiber pulp more than 17%; brightness 58% of ISO standard designation and humidity 6%
- Printing and writing paper: annual production capacity of it is 38000 tones with the following details:
  The basic weight is 50 g m^{-2}, % of long fiber pulp is 40%, brightness 70% ISO, humidity: 6%
- Corrugated medium paper: it is produced annually for 85000 tones and contains the following details:
  The basic weight is 113-127 g m^{-2}; % of humidity 7%

Objective function: This research study has been for its purpose to maximize profits that can be obtained from production cycle of three kinds of printing and writing, newspaper and corrugated medium papers. The objective function as has been designed here is:

$$\text{Max: } Z = \sum_{j=1}^{n} c_j x_j$$

Where:

Z : Total scheduled output or that of fixed elements input that is obtained by deducting variable costs from gross incomes.

C_j : Schedule output of any activity,

X_j: Functions that must be selected.

Table 6 shows the cost price, ex-work price and that of sale of every item of produces. We can calculate the profit gained from each item of product by deducing the cost price from that of sale.

Given the data included in Table 6, one can clarify an objective function for the targeted company as follows:

$$\text{Max } Z = 1020x_1 + 1409x_2 + 1160x_3$$

This function is maximized when it undergoes four limitations such as those of wood, chemical substances, manpower and distribution costs the results of which have been evaluated.

RESULTS

This research study uses a linear programming method to determine an optimum production model for MWPI given the limitations of identified resources the results of which will be dealt with in the present chapter. To solve the said programming problems, we used a linear programming method and LINGO software packages (Table 7).

Table 5: The cost of chemical substances of each product

Kind of product	Newspaper paper	Printing and writing paper	Corrugated medium paper
Chemical substance	45266	37124	25522
Rate of final price of the product	27	15	15

Source: Data collected from the company

Table 6: Cost prices, ex-work prices and sale of any product

Kind of product	Newspaper paper	Printing and writing paper	Corrugated medium paper
Cost price (rials)	4500	7400	2300
ex-work price (rials)	5300	8200	3000
Price of sale (rials)	5520	4809	3460
Profit gained of one kg (rials)	1020	1409	1160

Source: Data collected from the firm

Table 7: The quantities of different products in present and optimum programs

Kind of product	Newspaper paper	Printing and writing paper	Corrugated medium paper
Real production (tons)	57783	4671	82982
Optimum program (tons)	50246	7246	102220
Percent of changes (tons)	13	35	18

DISCUSSION

As it is observed in Table 7, the real production patterns differ from one another from the perspectives of their types and that of scale of products and net income of a unit. In optimum model of production on printing and writing and corrugated medium paper, an order which exceeds its present quantity has been placed (35 and 18%) because these two types of paper uses the limiting material better than other product and provide higher amount of outputs. The level of its production in the optimum model exceeds the present amount. However, the rate of newspaper paper production receded down to 13% because it has a lower net income.

In optimum model, about 237000 ton of wood are expected to effect the production while in the present mode only nearly 225000 ton have been used. This ensures that the rate of production as mentioned above can be enhanced by drawing on the present system. Limited chemical substances for produces are challenging and actually seem critical. The opportunity cost of each additional unit of chemical substances is 7371 rials the value of which calls for the need to make a speedier move towards added effectiveness of this limiting resource more than ever.

The optimum models considering or otherwise the limiting factors, assign the maximum available resources to produce the most profitable products. This problem causes the real earning and optimum earnings vary considerably. The sale price of products is one of the most important parameters, which is presumed stable in linear programming model. For the unit under consideration interferes not so obtrusively in outputs (inputs) market and for that reason it does not seem rationale that once the production model has changed, the sale prices of products also change. Even it does not affect the process to raise the most profitable product as well. The linear programming model, however, augments the incomes of a producing unit theoretically with suggesting of production of the most profitable product without regard to this critical issue. The decision that is made by the unit to produce different products is supported by data collected some past periods of time and viewed by the factory management while the conclusions drawn by optimum models are fed by profile (in an annual cycle). It is therefore possible that any differed actual and optimum income of this unit may be applied because of an imperfect statistical data. To conclusively comment on optimality or non-optimality of resources allocation for a unit, we must draw on both time-series data (annually) and profiled data and simultaneously we should take advantage of a linear planning pattern together with risk. To achieve this purpose one can use price variances, outputs and technical ratios of product in different years, the things that deserve to be used to reveal risk factors and any incredibility. Accordingly, when resource allocation of the unit will be optimum that via changes of price, output and technical rations to benefit of the product during different years, also production model could change with regard to the changes.

CONCLUSION

The function of producing newspaper paper in the present production schedule has been omitted from the optimum model and replaced by that of writing and printing paper, because the profits earned from printing and writing papers are more than those of other products in competition where limited inputs including wood are used. This is also the case for higher rate of corrugated medium paper production. As present program indicates, the varied produces are 145436 ton and will rise to 159712 or nearly 9% in the optimum program.

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