APPLICATION OF THE TRANSHIPMENT MODEL TO DEVELOPMENT OF THE SEED INDUSTRY IN NORTHEAST BRAZIL*

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INTRODUCTION

The importance of agriculture in developing economies is reflected in the share of the Gross Domestic Product (GDP) originating in that sector and in the percent of population working in that sector. Brazil received 19 percent of its GDP from agriculture in 1968, and 60 percent of its population was in agriculture. In contrast, only three percent of GDP came from agriculture in the United States, and only six percent of the population was employed in agriculture [2].

Development of a country's agriculture is dependent on a multitude of factors—not the least of which is availability and use of good seed. Use of high quality seeds increases total yield; allows for more efficient use of fertilizers, pesticides and irrigation because of greater uniformity, better stands and more vigorous plants; usually results in higher quality produce; requires lower planting rates; and usually reduces weed, disease and soil insect problems. Other inputs such as fertilizers, pesticides, technical assistance and credit availability are necessary to achieving a sound agriculture. However, most practices and materials used in crop production have been developed to allow full attainment of the seed's genetic and physiological potential. No agricultural practice can improve crop production beyond the limit set by the seed.

The basic objective of any seed program is to assure an effective supply of good seeds to meet demands of producers. Attainment of such an objective requires large investments in equipment and facilities needed for transporting, drying, processing and storage. Scarce investment resources can be most effectively used if they are employed in a cost-minimizing manner. Optimal geographic location of facilities is an important consideration: So, likewise, is the size of processing facilities. Further, optimum distribution patterns for moving seed from production to processing and on to consumption can result in lowered transportation costs and can also improve the mechanism of seed distribution, assuring delivery of adequate quantities at such time and place as demanded.

Use of good seeds is very limited in northeast Brazil. The bulk of those used to produce feed and food crops comes from each farmer's own production. Two of the more obvious factors contributing to this low use of good seeds are lack of effective production or distribution systems.

The Brazilian Ministry of Agriculture, recognizing the potential contribution of improved seeds to agricultural development, began studies in 1972 to provide the Northeast with the necessary conditions for developing a seed industry. Their proposed program embodies the production, processing, storage and distribution of seeds for seven important crops: corn, beans, rice, cotton, manioc, castor beans and potatoes [7].

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OBJECTIVES

This study was concerned with the efficient operation and location of seed processing facilities for corn, rice and beans[1] and distribution of these seeds in the states of Paraiba, Pernambuco and Alagoas[2] in northeast Brazil. The specific objectives were to:

1. Estimate seed requirements and expected production for 1977-79.
2. Determine optimum shipping patterns from production to processing to consumption based on five *existing* processing facilities.
3. Determine optimum number, size and location of processing facilities to meet expanded *future* needs and to determine associated optimum shipping patterns.

THE MODEL USED

Plant location models have been emphasized in agricultural economics research since the early 1960s and have continued to grow in scope and number as basic models are modified and algorithms are drawn from other fields. Basically, those models which utilize linear programming are concerned with location, size and number of processing plants, and are designed to provide least cost solutions.

In 1961, Stollsteimer [13] presented a model for determining the number, size and location of plants to minimize combined transportation and processing costs. This pioneering study provided the impetus for extensions to multiple product processing [10] considerations of scale and market share restrictions [6, 9, 14]; and transhipment [4, 5].

Hurt and Tramel [3] presented an alternative formulation of the King-Logan transhipment model [4] which permits direct reading of the shipping pattern solution. Recently, Stennis and Hurt [12] developed an approach where the processing cost is inserted as a negative value on the main diagonal of the processor excess capacity submatrix, eliminating the necessity of combining processing cost with either transfer charge from producer to processor or the charge from processor to consumer.

The Hurt-Tramel model and the Stennis-Hurt negative-cost formulation consider the two functions of assembly and processing and associate the economic logic of location theory to empirical analysis required for deriving the optimum number, size and location of processing plants. The model permits simultaneous consideration of the costs of: (1) shipping raw material, (2) processing and (3) shipping the final product.

For this particular application of the model, if we let

i = producing regions ($i=1,\ldots,I$)
j = processing centers ($j=1,\ldots,J$)
k = markets (consuming areas) ($k=1,\ldots,K$)
L_i = location of producing regions i
L_j = location of processing regions j
L_k = location of consuming regions k
X_i = quantity of seed produced at origin i
X_j = quantity of seed processed at plant j
X_k = quantity of seed marketed at market k
X_{ij} = quantity of seed transported from origin i to plant j located at L_j
Y_{jk} = quantity of processed seed transported from processing plant j to market k located at L_k
C_{ij} = unit cost of transporting harvested seed from origin i to plant j located at L_j
C_{jk} = unit cost of transporting processed seed from plant j to market k located at L_k, and
P_j = unit processing cost for plant j.

The problem can be expressed in mathematical terms as follows (where TC is the total cost of harvested seed shipment, processing and processed seed shipment):

Minimize:

$$TC = \sum_{i=1}^{I} \sum_{j=1}^{J} X_{ij} C_{ij} + \sum_{j=1}^{J} X_j P_j + \sum_{j=1}^{J} \sum_{k=1}^{K} Y_{jk} C_{jk}$$

The model is subject to the following constraints:

$\sum_{j=1}^{J} X_{ij} = X_i$ = quantity of seed transported from origin i to all plants j equals quantity of seed produced at origin i

$\sum_{i=1}^{I} X_{ij} = X_j$ = quantity of seed transported from all origins i to plant j equals quantity of seed processed at plant j

[1] These crops were selected because they represent not only 35.6 percent of the cultivated area and 23.6 percent of the value of all crops in the Northeast, but also the major food items in the region. They are of high social importance in providing food and employment, and they require similar processing treatment.

[2] The three states comprise a relatively homogenous area—having similar ecological conditions, using the same varieties of the three crops, using similar cultural practices for these crops, and enjoying a rapidly increasing interchange of products and services.

$$\sum_{k=1}^{K} Y_{jk} = Y_j = \text{quantity of processed seed transported from plant j to all markets k equals quantity of seed processed at plant j}$$

$$\sum_{j=1}^{J} Y_{jk} = Y_k = \text{quantity of processed seed received at consuming region k equals final product demand for region k}$$

where $0 \leq X_{ij}, Y_{jk}$

Since details of the model, including matrix formats for input data and the solution, are given in a recent issue of this *Journal* [12], further discussion of the model is omitted.

SCOPE AND DATA

The study area was divided into 33 micro-regions. These were aggregated on the basis of their historical production into 11 cord seed producing regions, five bean seed producing regions and two rice seed producing regions. Next, groups of micro-regions which were the expected markets for seeds were identified as consuming centers: 18 for corn, 11 for beans and nine for rice.

Regression techniques were used to estimate total requirements for each seed consuming region in 1977-1979. Planted acres were projected, using 1963-73 time series data. Projected areas of each crop were multiplied by the average planting rate to obtain total seed requirements. This estimation of future requirements for seed conformed to results of research by the Bank of northeast Brazil [1], which projected total consumption of corn, beans and rice for 1980.

Production of improved seeds in northeast Brazil is not expected to provide total seed requirements in the near future. Thus, planting estimates provided by the "Seed Program for Northeast Brazil" [8] were used to establish target figures for objectives 2 and 3. These expected quantities of improved seed were used as totals for both production and consumption, and were allocated among the seed producing and consuming regions defined earlier in proportion to their total needs.

Data requirements for objectives 2 and 3 were essentially parallel. Each, for example, required: identification of producing regions, potential processing plant locations and consuming areas; determination of shipping distances and costs; estimation of processing costs; and determination of quantities to be produced in each region and quantities required in each market.

For the second objective (optimum shipping patterns based on *existing* processing facilities), only transportation costs were deemed to be relevant in determining the shipping pattern. There were five existing processing plants, two of which processed all three crops, two processed only corn and beans and one processed only rice. Available information suggested that transportation costs per mile, per unit shipped was constant and equal for all regions. Therefore, a mileage matrix based on the shortest and best routes between the identified producing, processing and consuming areas was constructed and used as the primary criterion for obtaining a solution for objective 2.

For the third objective (optimum, number, size and location of processing facilities to meet *future* needs), additional information was required. Processing costs were developed for three plant sizes (1.25, 2.5 and 5.0 tons per hour). Information on the items of equipment used and their rated capacities was based on recommendations contained in [8], and on information provided by Brazilian seed technology graduates. Cost coefficients, interest on investment, depreciation, insurance, maintenance and repair were adapted from Rostran [11]. Input prices for labor, electricity, etc. were supplied by the State Commissions for Agricultural Planning. Equipment costs and power requirements were obtained from a Brazilian manufacturer and from price and technical specifications in [8]. Transportation cost assumptions were the same as for objective 2.

For objective 3, total supply of improved seed to meet future needs was assumed to be equal to 50 percent of the estimated 1979 total needs for corn and beans, and 80 percent for rice. (These quantities represent approximately the maximum production expected in those areas included in this study, according to information from Brazilian sources.) The allowable producing area was expanded by three micro-regions, assuming that these areas have the capability of becoming producing centers if provided with the necessary physical, technical and financial needs. Each producing region was considered to be a potential processing plant location for objective 3. It was further assumed that the percentage participation of each producing region in the total planted area will remain the same.

Because of seasonality of supply and demand, the year was divided into two six-month periods of plant operation. It was assumed that all seed received by any plant in any period must be processed in that period. One plant may not process simultaneously more than one kind of seed. Priorities of processing were established as follows: corn must be processed first; whenever beans and rice are to be processed, beans will be processed before rice.

RESULTS

Only some results of more general interest are discussed since specific data, situations analyzed and resulting solutions are too voluminous to include here. Emphasis is based on plant location, size and optimum distribution patterns for future seed requirements.

Goals for future production of improved seed were defined as increases over present production of 193 percent for corn, 194 percent for beans and 220 percent for rice. To meet these future processing needs, eleven potential processing plant locations were identified. Plant sizes considered were 1.25, 2.5 and 5.0 tons per hour. It was desired that per-unit processing costs be allowed to vary with volume processed (plant size). Because the optimization procedure is linear, this economies-of-scale non-linearity had to be accounted for by the use of an iterative procedure. After each solution, processing costs were updated to conform with the volume processed at each plant. This procedure was continued until a stable solution was obtained.

The optimum solution specified plants located at nine of the eleven potential locations. No plant as large as the 5.0 tons per hour was required. Only two plants were of the 2.5 tons per hour size, and the remaining seven were of the 1.25 tons per hour size.

Examination of the solution indicated stability in the location of processing plants for corn and beans. For example, the lowest figure in the matrix of marginal costs (relative to corn and beans) was much larger than any processing cost economy which could reasonably be expected in the near future. For rice, however, the solution does not indicate a high degree of stability. The one plant which processed only rice would be eliminated from the solution if only nominal reductions in processing costs at three competing plants could be realized.

Another alternative considered was the exclusion of plants which processed less than 500 tons per year—assuming that such small amounts would not, in a fairly short-run analysis, justify construction and maintenance of a processing plant if the seed could be processed in another region. Excluding two potential plant locations served to increase the capacities of two of the smaller remaining plants to the 2.5 tons per hour size.

IMPLICATIONS AND LIMITATIONS

Stability of the optimum solution in any such study is relevant. Moderate decreases in costs can sometimes cause substantial changes in the location of processing facilities and the attendant distribution pattern. Although the conditions and assumptions of this study were as realistic as possible, changes in supply and demand conditions in the near future are not unlikely. Further, the participation of private enterprise is expected to increase in all sectors of the seed industry in Brazil, modifying the nature and extent of direct government involvement needed.

The greatest difficulty in using transhipment models to determine optimum number, size and location of processing plants lies in specifying a problem which is sufficiently broad in scope to have economic significance, but narrow enough in scope to permit the use of available data. It was not possible, within the scope of this study, to evaluate the influence of such factors as seed production costs and demand variability on optimum shipment pattern and plant location. Thus, the analysis was restricted to processing and transportation, taking as given the quantities of seed to be produced, processed and distributed. Data limitations, especially in terms of demand for seed, were also evident. Due to lack of information about demand, a single criterion was used for all regions. Insufficient information concerning potential producing areas and their capacities also limited the amount of information which could be developed.

The analytical procedure used in this study provides a ready means for adjusting plans to meet changing conditions. With the use of transhipment models and computers, it is possible to provide guides for location and/or relocation of processing facilities. Brazilian government agencies plan to use the findings of this study as an input into their plans for evaluating and determining the optimum number, size and location of seed processing facilities in Paraiba, Pernambuco and Alagoas. The model and procedures can, of course, be extended to other spatial analyses for providing guidance in development planning by either private or government sectors.

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