Tropical Agricultural Research Vol. 9 1997, 126-136

A Model for Determining the Number and Location of Fruit Processing Plants

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ABSTRACT. *Locating a processing plant is a crucial policy decision which has to take into account various factors so as to enhance the competitiveness of a firm particularly in a market economy. Processing is an important value addition activity that enables converting surplus mangoes, the fruit considered in this study, into pulp and thereby eliminating the wastage. They also create new demand for more diversified agricultural products thereby increasing farmers income. Further, increased production of fruits and vegetables will provide impetus for rapid growth of processing industries. Wrongly located processing industries would lead to high transportation and other infrastructural costs. Hence, the appropriate strategy is to aim at large output, so as to establish a market for processed mango pulp. In this direction, an attempt has been made in this paper to determine the number and location of processing plants. The study was carried out to determine the number of processing plants required for mangoes to minimise the total cost of transport and processing. The results indicate that 3 plants each located at Srinivaspur, Chintamani and Kolar would be ideal.*

INTRODUCTION

Agro processing industries help in increasing income and employment opportunities for rural poor. Besides, they lead to gainful utilization of locally available resources and help in checking the rural exodus. They also create new demand for more diversified agricultural products, thereby increasing farmers' income. Increasing the availability of fruits and vegetables assumes greater significance from the point of view of providing both balanced diet and earning foreign exchange. Further, increased production of fruits and vegetables will provide impetus for rapid growth of processing industries.

In India, there are more than 3,500 fruit and vegetable processing units with a capital investment of over Rs. 250.00 crores. It has been estimated that as a result of processing of various kinds of fruits and vegetables, there has

been a value addition to the tune of about Rs. 12,000.00 crores per annum. This sector accounts for about 19% of the industrial output, 7% of industrial investment and provides employment to 19% of the industrial work force (Kapur and Nagaraj, 1983).

However, out of the total production of fruits and vegetables in India, the processing industry utilizes barely 1% as compared to 83% in Malaysia, 78% in Philippines, 70% in Brazil, 65% in the U.S.A., 46% in Canada, 40% in U.K. and 30% in Australia. It has been estimated that the postharvest losses in fruits and vegetables account for about 30% of total production which is valued at Rs. 6000.00 crores per annum (Pandey, 1994).

Studies on location models are important as they help in deciding *ex ante* the best location of a processing plant, so that the costs of sourcing raw material and transportation are reduced to the minimum (Kloth and Blakley, 1971; Trychniewics and Tosternd, 1973; Byrkett *et al.*, 1976; Kumbhare and Sirohi, 1981).

The result of the present study also corroborate the findings of Stollsteimer (1963) who arrived at the number, size and plant location based on the minimum combined costs of processing and transportation. Warrack and Fletcher (1970) worked on a location model wherein 40 sites and towns were selected as potential plant locations. Gupta and Arora (1988) showed that the transportation cost for processing soybean in Uttar Pradesh could be reduced by 12.38% by adopting a location model.

METHODOLOGY

The task here is to simultaneously determine the number, size and location of plant/s that minimize the combined transportation and processing costs involved in assembling and processing of any given quantity of raw materials. In the present study the location of processing plants for mango was worked out for Kolar district, a predominant mango growing area in Karnataka.

Stollstemier's (1963) model of Linear Programming was used to minimise both the processing and transportation costs. The model can be algebraically stated as :

$$Minimize \ : \ TC = \sum_{j=1}^{J} P_j X_j \left[L_K + \sum_{i=1}^{I} \sum_{j=1}^{J} X_{ij} C_{ij} \right] L_K$$

Subject to:

$$\sum_{j=1}^{J} X_{ij} = X_i$$

Quantity of raw material available at origin i per production period for j plant.

$$\sum_{i=1}^{I} X_{ij} = X_j$$

Quantity of raw material processed at plant j per production period for i plant.

$$\sum_{i=1}^{I} \sum_{j=1}^{J} X_{ij} = X_t$$

Total quantity of raw material produced and processed.

where,

TC = Total of processing and transportation cost.
P_j = Unit processing costs in plant J located at L_j.
X_{ij} = Quantity of raw material transported from origin i to plant j located at L_j.
C_{ij} = Unit cost of transporting material from origin i to plant j located with respect to L_j.
L_K = One locational pattern for j plants among the (L_j) possible combinations of locations for J plants given L possible locations.
L_j = A specific location for an individual plant (j = 1.....j)

Assuming TPC are constant for any number of plants.

$$TPC = P \sum_{j=1}^{J} \sum_{i=1}^{I} X_{ij} = P_X$$

P = Constant unit processing cost
P_X = Total quantity of material to be assembled and processed
TPC = Total processing costs

Potential plant sites

Potential plant sites in the region were identified where mangoes are grown extensively. In addition, factors such as infrastructural facilities,

availability of incentives and concessions were taken into consideration for determining the future plant locations.

The assumptions involved in using the model are stated below :

1. To transport mangoes from a production centre to processing centre, the transport cost per truck (9 tonne capacity) was considered at Rs. 30.00 per kilometer, based on the rate prevailing during the period of study, April 1996.

2. There are no economies of scale in plant location and hence plant costs are independent of plant locations.

3. Mango being a seasonal fruit, the duration of its processing was considered at 80 days in a year. However, the same processing plant and machinery can be used to process papaya, guava, tomato *etc.*, so as to keep the plant working round the year, and

4. Out of the total production of mangoes in the region, it is assumed that about 10% will be available as raw material for processing.

Data base

The primary data were collected during April 1996 from 10 randomly chosen mango processing units located in Bangalore and Chittoor from among 50 units. The establishment cost of processing plants was obtained by considering all investments. The secondary data pertaining to the establishment cost were also obtained from Karnataka State Agro Industries Corporation (KAIC) Ltd., Bangalore. Transportation costs were computed based on the information obtained from sample farmers.

The total cost of installing a processing plant of 1000 MT was arrived at Rs. 7.5 million (Table 1). The life span of the plant was taken as 10 years. Further, the fixed processing costs were calculated for 80 days assuming different capacities of the processing plant.

Table 1. Details of investment cost for setting up a fruit processing plant (1000 tonnes capacity per season for 80 days).

Particulars	Rs (million)
1. Land (3 acres with water facility)	0.7
2. Building:	
a) Administrative building (RC) - 20 × 80 m (Packing space, administrative office, residential quarters)	0.7
b) 9 Ripening sheds - 20 × 100	0.9
c) Sheets 80 × 30 m for 3 buildings	1.2
d) Processing hall 100 × 30 m	0.6
e) Fruit cutting hall 20 × 40 m	0.2
Sub total	2.7
3. Machinery:	
a) Boiler - (1.5 – 2 ton capacity)	0.8
b) Reforming section	0.15
c) Cooling tank	0.025
d) Electrical hoisters - 2	0.1
e) Retarders - 5	0.05
f) Craters - 30	0.06
g) Trailers - 5	0.02
h) Hot pulp overhead tank	0.1
i) Cattles - 300 lts capacity	0.35
j) Roto pumps - 5	0.15
k) Cold pump tanks	0.015
l) Pulpers - 2	0.2
m) Cutting tables - 7	0.07
n) Can sterilizers	0.025
o) Lab equipment	0.02
p) Generator (82 5 kv capacity)	0.05
q) Krushi tractor to transport the stone and waste	0.065
r) Jeep (office use)	0.3
Sub total	2.98
Total:	
1. Land	0.7
2. Total building	3.6
3. Total machinery	2.98
4. Additional equipment for multipurpose processing	0.22
Total	7.5
Means of fiance:	
Loan (75%)	5.625
Margin money (25%)	1.875
Total	7.5

Projection of quantity proposed for processing

At present, less than 1% of the total production of mangoes produced in Srinivaspur region is subjected to processing, whereas, in the neighbouring district of Chittoor in Andhra Pradesh about 30 to 40% of mango production goes for processing. In the present study, a conservative estimate of 10% of the total production has been taken as being available for processing, keeping in view the rising demand for processed products. Processing costs of mango pulp only and not the other forms were considered in the present study.

RESULTS AND DISCUSSION

The principle of optimisation of plant locations and plant capacities is based on minimisation of the combined costs of transportation and processing.

Optimal location of processing plant

In Srinivasapur region of Kolar district, during the year 1994 – 95 the total quantity of mangoes produced was 98,000 tonnes. Of this, 10% (9860 tonnes) was assumed as the surplus available for processing in the proposed locations.

To study the optimal location pattern of processing units, five potential areas were considered based on production. The areas considered are Srinivasapur, Chintamani, Kolar, Mulbagal and Bangarapet taluks of Kolar district.

The optimal location pattern in the Kolar district with a range of one to five plants is specified in Table 2. The result of the analysis showed that, if there is to be only one plant for the whole of Srinivasapur region, the transportation costs will be relatively high but processing cost will be at minimum. Obviously, the location of this plant would be in the most intensive production region (Srinivasapur) where both transportation and processing costs together accounted for about Rs. 0.5 million.

The analysis revealed that the total cost (TTC + TPC) in two plant locations, one at Srinivasapur and another at Chintamani would work out to Rs 0.579 million. It could be seen that the total cost of three plants would be Rs. 0.616 million with the least transportation cost. All these plants are in the most

intensive production regions of Srinivaspur, Chintamani and Kolar with a daily capacity of 41.08 tonnes of raw mangoes in each plant. However, by setting up plants at all the five production sites *viz.*, Srinivasapur, Chintamani, Kolar, Mulbagal and Bangarapet the cost will be the highest (Rs. 0.738 million) where each unit will process 24 tonnes of raw mangoes. The transportation cost of the raw material to these five plants works out to Rs. 0.14 million, being the highest.

Table 2. Optimum plant location, plant size and assembling costs in relation to number of plants.

Sl. No.	Capacity (Mangoes tonnes/season)	Transportation cost (TC) Rs (million)	Processing cost (PC) Rs (million)	Total of location cost (TC + PC) Rs (million)
1	9860	0.131	0.369	0.5 S
2	4930	0.129	0.450	0.579 S, C, K
3	3286	0.105	0.511	0.616 S, C, K
4	2465	0.117	0.559	0.676 S, C K, M
5	1972	0.140	0.598	0.738 S, C, K, M, B

S - Srinivasapur C - Chintamani K - Kolar
M - Mulbagal B - Bangarapet

By considering the geographical production spread of mangoes and also the seasonal nature of processing (80 days), three plant locations are considered ideal. Even though the cost of locating three plants (SCK) works out to be relatively higher yet there is a reduction in transportation cost.

If we examine the other best alternatives, the total cost increases as indicated in Table 3 and Table 4. After scanning the transport cost matrix through linear programming method, the output for different capacities with minimum costs were obtained.

Table 3. Details of location costs in alternative model - I.

Sl. No.	Capacity (Mangoes tonnes/season)	Transportation cost (TC) Rs (million)	Processing cost (PC) Rs (million)	Total of location cost (TC + PC) Rs (million)
1	9860	0.168	0.369	0.537 C
2	4930	0.131	0.450	0.581 S, C
3	3286	0.129	0.511	0.640 S, C, M
4	2465	0.138	0.559	0.697 S, M, C, B
5	1972	0.140	0.598	0.738 S, C, K, M, B

S - Srinivasapur C - Chintamani K - Kolar
M - Mulbagal B - Bangarapet

Investment required to set up the processing plants, their capacities, numbers and locations

Locating a processing plant is a crucial policy decision which has to take into account various factors so as to enhance the competitiveness of a firm particularly in a market economy. The prime concern has been to economize the transportation cost. Other considerations such as regular supply of raw material, infrastructural facilities and incentives are also crucial in determining the economic viability of locating of such units. Large scale production is imperative since small scale production is often vulnerable to fluctuations in demand and price. Hence, the appropriate strategy is to aim at large output, so as to establish a market for processed mango pulp.

For setting up of 1000 tonnes capacity fruit processing plant, the total project investment is estimated at 7.5 million (Table 1). To set up this kind of plant there are many institutions which provide financial assistance. For instance, Karnataka State Finance Corporation provides assistance up to 75% of fixed capital, towards land, building and machinery. If the project cost is less than Rs. 2 million, KSFC also provides the working capital requirement. If the project cost exceeds Rs. 2 million, the working capital should be raised from other sources such as Commercial Banks, Khadi and Village Industries Corporation (KVIC).

Table 4. Details of location costs in alternative model - II.

Sl. No.	Capacity (Mangoes tonnes/season)	Transportation cost (TC) Rs (million)	Processing cost (PC) Rs (million)	Total of location cost (TC + PC) Rs (million)
1	9860	0.188	0.369	0.557 K
2	4930	0.134	0.450	0.584 C, K
3	3286	0.138	0.511	0.649 S, C, B
4	2465	0.140	0.559	0.699 S, C, K, B
5	1972	0.140	0.598	0.738 S, C, K, M, B

S - Srinivasapur C - Chintamani K - Kolar
M - Mulbagal B - Bangarapet

It is interesting to note that in Chittoor area the processing firms would not sell the mango pulp directly either to the domestic or international markets. There are many agencies who get into contract agreement with the processors. The raw materials, chemicals, tins, cartons etc., are supplied by these exporters. The processors job is only to prepare the pulp to the specifications of the exporter. This is because of high costs involved for tins (Rs. 24.00) and cartons (Rs. 16.00). Hence it requires a very heavy investment which the processing firms cannot make. This type of arrangement would be feasible and can be encouraged in Srinivasapur region also.

CONCLUSIONS

Processing is an important value addition activity that enables converting surplus mangoes into pulp and thereby eliminating the wastage. Establishment of the processing units is being encouraged by the Government by providing subsidies and concessions.

At present, five processing units are located in and around Kolar with a capacity of one tonne per day. This capacity is negligible in view of the existing total production of mangoes at 98,600 tonnes in the district. It is assumed that about 10% of the mango produced in that area is available

for processing. An attempt has been made in this study to consider the establishment of more fruit processing plants at reasonable low costs in different areas of the Kolar district using the linear programming approach. If we consider the establishment of processing plants at five different locations of the district, the total of transportation and processing cost would be very high.

The total cost would be minimum if only one plant is located at Srinivasapur. When we consider 2 plants, one at Srinivasapur and the other at Chintamani the total cost would be higher at Rs. 0.616 million per plant. For four plants at four locations, the total cost would be higher at Rs. 0.676 million per plant.

The ideal situation keeping in view the geographical spread of production are three plants at Srinivasapur, Chintamani and Kolar. Though the processing cost is slightly higher in this case, the transportation cost is the least. Moreover it is easy to access the plant for the mango growers.

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Appendix I. Quantity of mangoes available for processing in different taluks are as follows:

Taluk	Quantity (tonnes)
Srinivasapur	5235
Chintamani	2289
Kolar	804
Mulbagal	902
Bangarapet	630

The total quantity of mangoes available for processing in the above places would be 9860 tonnes.

Structure of the model

Transportation cost matrix

Minimize $7.5 X_{11} + 13.5 X_{12} + 19.5 X_{13} + 26.25 X_{14} + 34.5 X_{15} + 13.5 X_{21} + 7.5 X_{22} + 24 X_{23} + 39.75 X_{24} + 39 X_{25} + 19.5 X_{31} + 24 X_{32} + 7.5 X_{33} + 22.5 X_{34} + 15 X_{35} + 26.25 X_{41} + 39.75 X_{42} + 22.5 X_{43} + 7.5 X_{44} + 37 X_{45} + 34.3 X_{51} + 39 X_{52} + 7.5 X_{53} + 37.5 X_{54} + 7.5 X_{55}$

Subject to

$X_{11} + X_{12} + X_{13} + X_{14} + X_{15} = 5235$

$X_{21} + X_{22} + X_{23} + X_{24} + X_{25} = 2289$

$X_{31} + X_{32} + X_{33} + X_{34} + X_{35} = 804$

$X_{41} + X_{42} + X_{43} + X_{44} + X_{45} = 902$

$X_{51} + X_{52} + X_{53} + X_{54} + X_{55} = 630$

$X_{11} + X_{21} + X_{31} + X_{41} + X_{51} = 1972$

$X_{12} + X_{22} + X_{32} + X_{42} + X_{52} = 1972$

$X_{13} + X_{23} + X_{33} + X_{43} + X_{53} = 1972$

$X_{14} + X_{24} + X_{34} + X_{44} + X_{54} = 1972$

$X_{15} + X_{25} + X_{35} + X_{45} + X_{55} = 1972$