SOYBEAN PROCESSING IN INDIA:
A LOCATION STUDY ON AN INDUSTRY TO COME

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TABLE OF CONTENTS

Page

INTRODUCTION

India is short of protein and vegetable oils. Soybeans containing about 20 percent oil and 40 percent high-quality protein can be grown in India and may help to alleviate this shortage. The key issue in implementing a soy economy in India is to develop an efficient system of marketing and processing channels for soybeans. In establishing a processing industry, the necessary plants should be optimally located in relation to the areas of soybean production, both during the period of expanding production and after production stabilizes. The size of each plant should be optimal for each stage.

All decision-makers who participate in shaping the soybean economy--potential growers, investors, processors, industrial consumers (producing goods for final consumption), and policy-makers--need guidelines to help bring their individual decisions and actions in line with the overall requirements of a flourishing soybean industry in India.

A mathematical model simulating a future soybean processing and marketing industry for India is an effective tool to provide these guidelines. The objective of this study, therefore, is to determine optimal size and location of soybean processing plants in India in line with an assumed expansion of soybean production.

The major factors affecting the marketing-processing system for soybeans are: (1) the location of production, as determined by natural requirements and comparative advantages of growing soybeans in different regions of India, (2) the demand for products in which soy oil and soy meal might substitute for traditional ingredients (replacing groundnut oil for vanaspati production and gram flour, for example), (3) the costs of processing soybeans in India, and (4) the comparative costs of shipping soybeans, soy oil, and soy meal by different means of transportation. The available information on these factors--though incomplete on some points--is sufficient to serve as the base for a spatial equilibrium model. The quadratic programming portion of the model reproduces the interregional trade in soybeans and in the joint final products, soy meal and soy oil, among seven regions. The plant location portion of the model at the same time simulates for each region the assembly and processing of soybeans and the distribution of soy meal.

This model yields optima for numbers and average sizes of processing plants for each region at each of the assumed stages of soybean production. In addition, the flow of goods, the quantities demanded, and the related price levels are determined.

As each optimum solution is calculated under two different sets of freight rates for railway transport, the impact of changes in these rates on the marketing-processing system is shown.

A discussion of the problems of implementing these results shows that the key issues are mainly of concern to public policy-makers. Initially, subsidies are necessary (price supports, bank loans, and so on). Certainty about the future rail rates for soybeans and soy meal also is required. In the early stages contractual arrangements between soybean growers and processors should be used to coordinate decisions.

Investors in processing plants should be cautioned to choose appropriate locations and to aim at plant sizes in harmony with considerations that underlie the model results. Arrangements for later expansion of plants should be provided. Industrial consumers of soy meal should be encouraged to generate products and brands and to develop appropriate markets.

SOYBEANS FOR INDIA: POTENTIALS AND CONSTRAINTS

The Deficiency of Edible Oil and Protein in the Indian Diet

India has major deficits in high-quality food protein and in edible oil. In the early 1960s, it was estimated[1] that the average Indian diet included 58 grams of protein daily mainly from plant sources and poorly balanced in terms of essential amino acids, compared to a daily requirement of 70 grams of high-quality protein. Daily intake of food fats and oils was estimated at 29 grams compared to a need for 50 grams. The shortage of protein is reflected in retarded physical and mental development of children, probably greater susceptibility to infection, and other malaise. The deficit in fats and oils shows up in caloric deficiency and reduced energy.

Since the beginning of the 1960s, production of pulses, a major source of protein in the diet, has not increased as rapidly as population. At the same time, the reduced net availability per capita in pulses was not offset by sufficient production in other protein foods.[2]

As with protein, the deficit in food fat has become intensified over the last few years. The production of groundnut oil, which constituted about 70 percent of the total edible oil supply between 1965 and 1969, has been unable to meet the increased demand, especially in the form of vanaspati (a cooking margarine).

The area under groundnut has remained about the same since 1963-64 (see Table 1). Yields and consequently production also remained static. While the area under pulses declined slightly during these seven years, the increase in yield was just enough to keep total production at the former level. Therefore, the net availability per capita of both groundnut oil and pulses has decreased in proportion to the population increase.

The decreased net availability per capita in groundnut oil was partly offset by imports of sunflower oil and soybean oil. The vanaspati industry, the main consumer of imported soy oil, used 67,000 tons in 1968; 110,500 tons in 1969; and 87,700 tons in 1970. These imports indicate the pressure of demand for vegetable oil.

Market forces tend to hide the real shortage of protein as long as adults, who express the demand do not fully realize the protein deficiency of their children. However, it can be shown that the gap between per capita availability of cereals and of pulses--as major sources of protein--is continuously widening. The per capita net availability of pulses expressed in percentage of the per capita net availability of cereals was as follows: 18.2% in 1951-55; 18.9% in 1956-60, 16.2% in 1961-65; 12.5% in 1966-68; 11.9% in 1968-69; and 12.6% in 1969-70.

Despite the oil imports and despite the fact that the real shortage of protein is not fully translated into demand prices, price indexes indicate steep price increases for both gram (the major pulse crop) and groundnut oil. In real terms--

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[1]C. Gopalon and S. C. Balasubramanian, "The Nutritive Value of Indian Foods and the Planning of Satisfactory Diets," Indian Council of Medical Research, Spec. Rept. 42 (1961), pp. 32-35.

[2]I. R. K. Sarma et al., Projections of Demand and Supply of Agricultural Commodities (New Delhi: National Council of Applied Economic Research, 1970), p. 341.

Table 1. Production, Net Availability per Head, and Prices for Groundnuts and Pulses Between 1963-64 and 1969-70[a] and Hypothetical Production of Soybeans and Net Availability per Head of Soy Oil and Soy Meal in India, 1963-1970.

Year	Area (million ha)	Yield (kg/ha)	Production (million tons)	Oil[b] (million tons)	Cake[c] (million tons)	Net availability per capita[d] (kg/year)		Prices[e] Rupees per quintal	Index 1961-62 = 100
		Groundnuts (in shell)				Oil		Oil (Bombay)	
1963-64	6.9	769	5.3	1.48	2.23	2.4		221	116
1964-65	7.4	814	6.0	1.68	2.52	2.6		254	133
1967-68	7.6	759	5.7	1.60	2.41	2.4		300	157
1968-69	7.1	631	4.6	1.30	1.95	2.0		414	217
1969-70	7.2	713	5.1	1.44	2.16	2.2[f]		479	251
		Total Pulses (gram, tur, and others)				Total Pulses		Gram (Hapur)	
1963-64	24.1	418	10.1	--	--	18.5		49	126
1964-65	23.9	520	12.4	--	--	22.3		76	195
1967-68	22.6	534	12.1	--	--	20.2		122	313
1968-69	21.3	490	10.4	--	--	16.9		82	210
1969-70	22.0	531	11.7	--	--	18.0[f]		98	251
		Soybeans (hypothetical)				Oil	Meal		
--	1.5	1,000	1.5	0.27	1.18	0.4	2.0	--	--
--	3.0	1,000	3.0	0.54	2.36	0.9	4.0	--	--
--	4.5	1,000	4.5	0.81	3.56	1.3	6.0	--	--
--	6.0	1,000	6.0	1.08	4.75	1.[illegible]	8.0	--	--

[a]The drought years 1965-66 and 1966-67 are omitted because of abnormally low yields.
[b]Assuming oil yield of 28 percent for groundnuts in shell and of 18 percent for soybeans.
[c]Assuming cake yield of 42 percent for groundnuts in shell and of 79 percent for soybeans.
[d]Sources: for groundnut oil: S. A Shetty, Trends in Prices and Production of Oilseeds in India (Bombay, 1970), p. 56; for total pulses: "Bulletin on Food Statistics," 20th issue, 1970; for soy oil and soy meal availability: computed on the assumption of a population of 600 million, as projected for 1974.
[e]Sources: "Indian Agriculture in Brief": 8th and 10th ed., 1967 and 1970, and "Oilseeds Situation."
[f]Author's extrapolation.

that is, taking into account the price index for all commodities--the prices of these two products for 1969-70 are 45 percent and 50 percent above the 1961-62 prices for groundnut oil and gram, respectively. Considering the more or less static supply, the demand must have increased considerably. At the same time there is no indication of any dramatic change in the supply of traditional pulses or groundnuts over the next years, as would be required for meeting the continuously increasing demand.

Potential of Soybeans for Increasing Edible Oil and Protein Supply

Soybeans contain about 20 percent oil and 40 percent high-quality protein and thus promise to help alleviate India's shortage of edible oil and protein.

There are several ways in which soybeans may enter the present cropping systems in different parts of the country. Because the improved varieties of soybeans are a short-season crop, it appears feasible to produce them on large areas of land that now are fallow during the kharif season.[3]

Soybeans can be interplanted between regularly spaced rows of cotton (two or three rows of soybeans per row of cotton). They may be substituted for any of various low-value kharif-season crops (such as maize, jowar, urd, moong, small millets, bajra, and low-yielding upland paddy) that are traditionally grown. Soybeans may be successfully grown as a spring crop in northern India (after such crops as kharif soybeans, potatoes, and the final harvest of sugar cane).

Soybeans appear unlikely to replace groundnuts in areas well suited to groundnut production, and they are not expected to reduce the production of such pulses as arhar or gram in the foreseeable future.

As will be shown later, there is an estimated total area of 7.7 million hectares in India that, on the basis of present knowledge, could be expected to be brought under soybean cultivation in the long run. If only a fraction of this area--say 1.5 million hectares--were used for soybeans, the 1.5 million tons of soybeans that might be produced would yield approximately 0.4 kg/capita of oil and 2.0 kg/capita of protein-rich meal.

Requirements for Developing a Soybean Processing Industry

It is expected that soybeans will be consumed in India mainly in the form of industrially prepared products. Traditional habits in food preparation, taste, and other factors are likely to limit direct consumption of soybeans for at least a generation. Thus, it is necessary to establish the required industrial processing capacity for soybeans.

The development of a soybean economy in India, if left to itself, would eventually arrive at some kind of processing and marketing system, but it is doubtful that this development would take the quickest and most efficient path. India, with a rapidly growing population and limited capital resources must use its scarce resources efficiently and in the shortest possible time.

There is only limited information in India at this time on such aspects as the technical and economic conditions under which soybeans can best be grown, the costs and problems of processing soybeans, and consumer acceptance of soy products, but there is enough information to combine with other more solid information on related facts into an economic model. This model is designed to simulate possible

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[3]F. Dovring, J. R. Jindia, and R. S. Misra, Economic Production Possibilities of Soybeans in Northern India, Publication Series 1. (Urbana: University of Illinois, Office of International Programs and Studies, 1972).

future flows of soybeans, soy meal, and soy oil in India at optimal quantities. Such a simulation of spatial equilibria in a soybean economy, generated by different assumptions about relevant factors, enables us to predict various patterns of spatial allocation of soybean processing capacity and plant sizes that would evolve under the given assumptions.

This mathematical simulation of spatial equilibria can be done at relatively low cost at one point in time, compared with the cost of a slow, unplanned development based only on insufficient market mechanisms.[4] The results predicted under various assumptions should be useful to all decision-makers whose aggregate action eventually will establish the soybean economy. From these results all participants in the soybean sector--that is, growers, processors, industrial consumers, and, above all, public decision-makers--can, to some extent, read off the probable effects of different actions in the aggregate and on themselves.

Since the model produces long-run equilibria, each individual's short-run views can better be brought in line with the long-run requirements of the Indian economy. In other words, given a free society with relatively liberal economic concepts in India, each individual and the aggregate of the decision-makers will be able to act together more effectively if there is enough information to demonstrate that steps can be taken that will satisfy both the individual (microeconomic) set of conditions and the aggregate (macroeconomic) restraints.

In the effort to extract as much information as possible from the present state of knowledge to enable decision-makers to invest capital most efficiently, the simulation of a spatial soybean economy in India is felt to be an effective tool.

SIMULATION MODEL OF A SOYBEAN PROCESSING INDUSTRY

Spatial economic theory, according to Hoover[5], can be classified into three categories: (1) location theory, (2) theory of interregional trade, and (3) regional analysis.

Location theory compares alternative locations for a specified kind of activity. The theory of interregional trade refers to the economic relationships between specified areas or types of areas. Regional analysis is "concerned with groupings of interrelated economic activities in proximity within certain specified areas."[6]

Our problem of determining optimum size and location of soybean processing plants in India has several theoretical aspects, the most important being the first two of the three categories mentioned above. The determination of optimal location and size of processing plants clearly is a problem in location theory. However, in order to find a basis for solving this problem, the potential flows of soybeans, soy meal, and soy oil among different regions in India must be determined. They are generated in mathematical form, thus involving the theory

[4]Brian Van Arakadie and C. R. Frank, Jr., Economic Accounting and Development Planning, rev. American ed. (New York: Oxford University Press, 1969).

[5]E. M. Hoover, "The Partial Equilibrium Approach," in Spatial Economic Theory, R. D. Dean, W. H. Leahy, and D. L. McKee, eds. (New York: The Free Press, 1970), p. 3.

[6]Ibid.

of interregional trade. With information on potential flows of goods in question, we are able to derive optimal average size and number of plants for each region. On the basis of this conclusion, we then may determine individual plant sizes and locations by taking geographic and geo-economic particularities into account.

Location of Processing Plants Within a Region

The location model forms Part I of the spatial equilibrium model that we apply. This model is based on the following concept:

When the number of plants within a region increases, average processing costs will increase at a linear rate (as plants get smaller), and average assembly cost of the major raw material plus average distribution cost of the major commodity produced will decrease at a decreasing rate. As the number of plants is increased, the sum of the average transportation costs of assembly and distribution at first decreases at a faster rate than average processing costs increase. As numbers continue to increase, the reverse becomes true--that is, average processing costs increase faster than average transportation costs decrease.

The sum of the three cost functions results in a convex (from below) average cost function for the industry. Assuming that in a competitive industry all factors, other than those included in the three cost functions, are negligible for the location of a plant in the given region, the minimum of the sum of these cost functions indicates the optimum number of plants for that region.

Major assumptions. The raw material to be assembled is soybeans. The main commodity produced and distributed is soy meal. Soy oil being shipped in bulk to vanaspati factories for industrial consumption imposes no serious problems of distribution as does the dispersion of soy meal for household consumption. Rates are the same for transporting beans or meal. Transportation costs for soybeans and soy meal are postulated to be a linear function of distance (after some minimum distance). This hypothesis was accepted after testing it on survey data for four trucking companies reporting their freight charges for 43 different transportation relations.

Processing costs per unit of soybeans per unit of time are postulated to be a function of the reciprocal of processing capacity. This hypothesis was accepted after testing it on engineering data provided by three different engineering firms that produce and sell oilseed processing equipment in India.

It is further assumed that the total quantity of soybeans produced in a region (plus the quantity imported into that region minus the quantity exported from that region) moves into processing and thus the ratio of quantity of soybeans available for processing in that region divided by average processing capacity per plant equals the number of plants for the region.

We assume perfect competition and free entry into the industry. And we finally assume that the costs of assembly of soybeans, of distribution of soy meal by a processing plant, and of processing, represent major factors determining the location of soybean processing--other factors being negligible in their locational effect.

Interregional Trade

The quadratic programming model of interregional trade forms Part II of our spatial equilibrium model.

The basic concept of this model is a special case of the general problem of nonlinear programming which is solved for the saddle point.[7] In this case the objective function is a quadratic function constrained by linear inequalities. The solution has been shown to be unique.

Major assumptions and economic environment. A given country, India, is divided into n regions. Each region is represented by one base point at which the supply of soybeans, the demand for the final products, and the processing capacity are assumed to be concentrated. All possible pairs of regions are separated by known transportation costs per physical unit for each product.

The processing capacity in each region is assumed to be unlimited. Processing is performed at costs that are assumed to be fixed. The processing cost is known for each region.

Demand for each of the two final products is assumed to be a logarithmic function of price. This function is represented by an infinite number of its tangents.

The demand function for each final product is known for each region. For each of the n regions a non-negative quantity of one primary product--that is, soybeans--is given.

These "primary" soybeans are mobile and can be processed in regions other than where they originate. After being allocated for processing, these now "intermediate" soybeans are transformed at known conversion rates into two joint final products--meal and oil. The final products are allocated among the regions for consumption.

In this environment it is possible to formulate a model that accounts for the interaction of the spatially separated economic units: it determines the level and location of processing soybeans into meal and oil; it gives volume and direction of all product flows that will minimize the aggregate transportation and processing cost; and finally it determines the pricing system of all products that accompany the optimum allocation system.

Spatial Equilibrium Model of Plant Location

In combining Parts I and II into one spatial equilibrium model, the following concept is applied: Assume there are two systems that are mutually dependent in that the output of one constitutes part of the input of the other. Then, as these systems are optimization models, they form a combined equilibrium model. Their interdependence generates a sequential set of objectives and restrictions, objective of Model I forming a restriction to Model II and objective of Model II forming a restriction to Model I. In other words, for each of the two models the optimum solution is to be found subject to the constraint that the other model be optimized. Since part of the input[8] of one model is generated by the other model, a sequence of alternating applications of both models--one in the objective, the other in the constraint and vice versa--asymptotically approaches an equilibrium solution. We may assume that the solution is unique since each of the two parts of this model has a unique solution.

Additional assumptions. The number of plants in each region may be fractional, while iterations are going on. The final numbers of plants obtained are converted into integers by standard rounding procedures. The error from this procedure is assumed to be negligible.

[7] This section draws heavily from T. Takayama and G. G. Judge, Spatial and Temporal Price and Allocation Models (Amsterdam: North Holland Publishing Company, 1971), Ch. 14.

[8] The other part is held constant.

The overall equilibrium solution is attained at the point where further iterations cease to bring about significant changes.

It is also assumed that assembly of soybeans exported from the distribution of soy meal imported into a region does not affect the location of soybean processing plants.

Connections between the model parts. A flow chart of our spatial equilibrium model, as shown in Appendix, Figure 1, depicts the various connections between the parts of this model. The inputs into the model are partly in functional form (indicated by a thick arrow) and partly in the form of fixed quantities (indicated by a thin arrow). Some of the inputs are determined exogenously and some are endogenously generated. Exogenous inputs in functional form are the constraints on the demands for soy products, the cost of transportation of soy meal and soybeans by truck, and the cost of processing soybeans. Rail transportation rates and supply of soybeans are the only exogenous inputs in the form of fixed quantities.

In running the model, beginning with the quadratic programming portion, certain values for processing costs are first assumed. This yields regional demands and flows of all commodities, as well as the accompanying price levels for all soy commodities.

Those demand and flow activities are selected that allow us to compute for each region the quantities of soybeans assembled locally by processing plants, and the quantities of soy meal distributed locally by processing plants. We insert into the single equation model quantities of these two locally assembled and/or distributed goods, together with the functional relationships of cost of transportation on trucks for soybeans and soy meal, and the cost of processing soybeans. This gives us an optimum number of plants for each region. Their average size is determined by dividing the quantity of regionally processed soybeans by the number of plants per region.

From the average size, with the help of the processing cost function, average processing costs for each region can be computed. These processing costs are fed into the quadratic programming model, in place of the values that were assumed for the first run. Depending upon how far off the mark the assumed processing costs were at the beginning, the second run may or may not bring about considerable changes in the optimum number of plants. A third run in most cases confirms that the values of the second run already are acceptable as an equilibrium solution because no significant changes occur.

At the equilibrium, relevant outputs (see Appendix, Figure 1 marked by heavy circles)--that is, regionally demanded quantities of soy meal and soy oil, regional prices for all three soy commodities, and the optimum numbers and average sizes of plants for the different regions--are read off for further discussion.

Order of iterations. The application of the above spatial equilibrium model involves iterative procedures in two directions:

(1) A spatial equilibrium solution is approached stepwise by alternatively applying the quadratic programming model and the single equation model.

(2) Tangents representing the exponential demand functions are determined stepwise.[9]

[9]Compare section under subhead "Demand Functions for Soy Meal and Soy Oil."

In search of the unique solution to the problem, these steps must be approached in a way that minimizes the number of iterations required to reach the equilibrium. At each stage of the computations, that iteration is taken first which removes most of the arbitrariness from the initial assumptions. The actual sequence of the iterations depends, of course, upon the quality of the first assumptions and more so upon the behavior of the two models--the quadratic programming model and the single equation model.

Our spatial equilibrium model is only partially programmed. The following programs are used: (1) QP for the quadratic programming model (2) SE for the single equation model, (3) DT for the derivation of regional demand functions from a tangent to our exponential function, and (4) TT for testing the tangent on representativeness and, if rejected, finding new tangents. For our special case the most efficient sequence of these programs was found to be the following:

$$\begin{array}{l} SE_1 \searrow \\ \qquad QP_1 \rightarrow SE_2 \rightarrow QP_2 \rightarrow TT_1 \rightarrow QP_3 \rightarrow SE_3 \\ DT_1 \nearrow \end{array}$$

In some cases, especially where very small quantities and the presently applied rail rates were involved, the computations could be halted at TT_1 because the costs of processing as determined in SE_1 did not deviate enough from those in SE_2 to bring about results from QP_2 that would differ significantly from those of QP_1. In addition, TT_1 accepted the tangent determined by DT_1 as representative for the exponential function. In all other cases when TT_1 produced new tangents, QP_3 was run as the last step because its results showed that their impact in SE_3 would yield results not significantly different from those in SE_2.

A FUTURE SOY INDUSTRY IN INDIA: BASIC ASSUMPTIONS AND DATA

In order to solve our problem with the help of the above model, we must provide the necessary data or, if data are unavailable, make appropriate assumptions. Our model requires assumptions concerning the quantities of soybeans supplied over time and the factors included in the demand functions[10]--namely, population and income. These values will be given in the form of a postulated time schedule. Further, we must determine a way to demarcate the regions and provide keys for dividing aggregate supplies and aggregate demands among the regions. Finally, data on costs of processing and transportation must be established.

Development Over Time

As discussed earlier, there are strong forces from the demand side as well as from the production side which would lead to a rapid expansion in soybean production, were it not for other counteracting forces. Serious impediments hampering the development of a soy industry are, for instance, the need for extension and promotion to spread the know-how of growing soybeans among farmers, and the lack of both proper facilities and experience for marketing soy products.

The speed of development of soybean production in India is impossible to predict. The only reason we postulate a certain increase in soybean supplies

[10] For the derivation of the demand functions see "Demand Functions for Soy Meal and Soy Oil as Substitute Products," pp. 13-17.

over time is because the two key variables determining demand--income and population--are changing at relatively stable rates. In order to relate the supply of soybeans to demand situations as they may occur in the future, the development of soy production also must be given a tentative time schedule. Variations from this postulated time schedule will show the effects of deviations in this development.

Projected time schedule. The time schedule that we assume for this study is summarized in Table 2. For the sake of simplicity, the years 1968-69, 1970-71, 1973-74, 1978-79, and 1988-89 are labeled Years 0, A, B, C, and D, respectively. Estimates of the Indian population are taken from official sources. Estimates of income per capita are based on an average annual income between 1964 and 1969, and a compound growth rate of 2 percent annually during the entire period is assumed.

Table 2. Hypothetical Time Schedule for Changes in Soybean Production, Income, and Population, India, Selected Year 1963-1989.

	Model Year				
	0	A	B	C	D
	Crop Year				
	1968-69	1970-71	1973-74	1978-79	1988-89
Soybean production[a] (thousand hectares or tons)	0	20	400	1,200	5,000
Income[b]					
(Rs/capita)	324	337	358	395	481
(percent)	100	104	110	122	148
Population[c]					
(millions)	524	550	592	662	787
(percent)	100	105	113	126	150

[a]The yield is assumed to be 1 ton per hectare. The area under soybeans is assumed to follow the targets set by the Ministry of Food and Agriculture for the last three years of the fourth five-year plan, i.e., 45,000 ha in 1971-72; 130,000 ha in 1972-73; 400,000 ha in 1973-74. For later years our estimates were applied.

[b]The base figure of rupees 313.4 is the average of the years 1964 to 1969, from "India, Pocket Book of Economic Information, 1970," Ministry of Finance, Government of India. The projected annual growth is assumed to be 2 percent.

[c]From "Bulletin of Food Statistics, 1970," Ministry of Food and Agriculture, Government of India. Growth from 1981 to 1988 was estimated, assuming a rate of 1.75 percent per year.

Soybean production for Year A gives the actual number of hectares under soybeans. The entire soybean production is assumed to go into processing and consumption; actually, of course, this is impossible because of large quantities of seed required at this stage of development to expand the area of the next year's production. In Year B it is assumed that the target figure for soy production, as set by the Ministry of Food and Agriculture for this year, will be reached. Again seed production is disregarded and the total supply is assumed to be directed into consumption. Values of Years C and D are chosen so that they lie within the range of what may likely occur.

The arbitrariness of these assumptions reduces the generality in the significance of the price levels computed; however, as long as the price levels computed for all regions remain reasonably feasible, the prices inflict no restrictions upon the flows of the good within India.

Variation in time schedule. To demonstrate the impact of deviations from the time schedule on the pricing of soy products and allocation of processing capacity, some variations in the given time schedule also were calculated. In Variation I it is assumed that the supply of Year B faces the demand of Year C and in Variation II it is assumed that the supply of Year C faces the demand of Year B. Also the conditions of demand considered here for year D assume an export outlet of the world market for soy meal.

Regional Supply of Soybeans

To break down the aggregates of supplies of soybeans for all-India on a regional basis, there must be a demarcation of regions and a key which gives the respective shares of supply from each region. Regional demarcation and determination of each region's contribution in percentage of the total supply was carried out in the following way: Based upon certain assumptions about growing conditions for soybeans in India, the extent to which a selected number of crops might be replaced by soybeans if intensive promotion should take place and the yield, a potential production of soybeans by districts was computed. Conterminous districts of homogeneous potential production densities were grouped into regions and the share of each region in the total potential production was computed.

Assumptions. Experience with the performance of new varieties of soybeans in India in areas that differ in rainfall, soils, or latitudes, in different seasons, and under different economic conditions, leads to the following assumptions concerning soybean production in India:

(1) Soybeans will be grown mainly on rain-fed land. The comparative advantage of soybeans over other crops on rain-fed land is much greater than on irrigated land.

(2) Soybeans will be grown mainly as a kharif crop. We assume that soybean production will be negligible during dry seasons, when irrigation is required.

(3) During the kharif season (June through September) soybeans require an average total rainfall of at least 600 mm, and tolerate a maximal 1,500 mm of rain in that period (see Appendix, Figure 2).

(4) Suitable varieties of soybeans for latitudes below 16° have not yet been developed and it will be several years before they are available.[11] Therefore, in our time frame, soybean production in these areas is assumed to remain negligible.

(5) A minimum potential production density must exist in a district to attract soybean promoting agencies (such as an agricultural extension service, marketing facilities, and the like). Otherwise soybean production does not occur and we assume production in these districts to remain zero for our purposes.

[11] Intensive soybean breeding work is done in Hyderabad, Tirupati, Coimbatore, Bangalore, and elsewhere in southern India, so this assumption may be too rigid. The effects of such a situation are discussed later.

(6) Economic and soil conditions in a district are properly reflected in the official data on area under certain crops or fallow; from these, reliable inferences can be drawn concerning the potential of soybean land in a district.

(7) Soybeans are assumed to occupy the land under the following kharif crops by the following percentages: rice, 5 percent; bajra, 10 percent; and ragi, jowar, maize, small millets, pulses (except tur), cotton, and kharif fallow, each 20 percent.

(8) The yield of soybeans for all districts is assumed to be 1 ton per hectare.

(9) Assumptions (1) through (5) are overruling assumptions (6) and (7).

Demarcation of regions and regional share in supply. On the basis of the above assumptions (6) through (8), the potential production densities for India were determined by districts. C ntiguous districts of similar potential production densities were grouped into a total of seven regions (see Appendix, Figure 3). This procedure, of course, required some compromises, but, in general, distinct regions were easily demarcated.

On the basis of information used in this study, soybean production is expected to occur within only four of these regions. The estimated total area in soybeans in these four supply regions was 7.7 million hectares, giving an ultimate production potential of 7.7 million tons of soybeans (going behond the horizon of the hypothetical time schedules shown in Table 2). The different regions (named for the cities representing the reference points of the regions as shown in Figure 3) contribute to this supply as follows: (1) Calcutta, (2) Bangalore, and (3) Ajmer, each 0 percent; (4) Lucknow, 36 percent; (5) Bhopal, 21 percent; (6) Anand, 13 percent; (7) Akola, 30 percent.

Processing Costs

Soybeans are assumed to be processed by solvent extraction plants. All other modes of processing are assumed to be negligible. The cost of processing soybeans in solvent extraction plants in India with indigenous equipment was computed from synthetic data. Three engineering firms that design and sell oilseed processing equipment provided estimates of investments and operating costs for soybean processing plants of various sizes between 10 and 1,000 tons daily production (see Appendix A). In terms of average costs (rupees per ton of soybeans processed), these costs fit the following function:

$$C = 59.95 + 1,383.5\ S^{-1}$$

where C is average cost in rupees per ton and S is size of the plant in tons per day.

This function shows the economies of scale in processing soybeans. The processing costs are approaching asymptotically the value of about 60 rupees per ton. At capacities larger than about 1,380 tons per day, processing cost can be decreased by amounts of less than 1 rupee per ton (Appendix, Figure 4).

It is assumed that the same function applies for all of the regions. Admittedly in those regions that already have a relatively large number of solvent extraction oil mills (for instance, Gujarat) it may be possible to equip one of those plants to process soybeans into oil and meal of high quality for human consumption. These mills then may be able to operate at lower costs. But first the optimum location of processing capacity should be determined, regardless of what actually exists. Then, only as a second step, we may draw conclusions regarding the design of optimal marketing channels, taking into account special geographical and economic conditions. In our first approach we must assume equal processing cost functions for all the regions. While at the outset equal sizes of processing plants are assumed for all of the regions, the model itself generates regional optimal sizes as described in the section on The Indian Soy Economy: Model Results. Different optimum average sizes for each region imply different regional average processing rates.

Conversion Factors

Conversion factors had to be assumed the same for all regions, because there is not enough evidence to determine in which way they might differ. We assume that soybeans are converted into soy meal and soy oil in the following proportions: soy meal, 79.3%; soy oil, 17.7%; loss, 3.0%.

Demand Functions for Soy Meal and Soy Oil as Substitute Products

There is as yet no open market in India for either of the two major soy products, meal and oil. Soy meal so far has been imported only in minor quanities, mainly for research purposes (for example, in producing baby food). Imported soy oil is sold by the Indian government to the vanaspati industry on a quota basis at prices that probably are below the level an open market would yield. Therefore, to find a basis for estimating the potential demand for the two major soy products in India, closely related commodities were used, on the assumption that soy products are going to be demanded to the same degree. The two products chosen were gram flour and groundnut oil for the vanaspati industry.

Soy meal as a substitute for gram flour. Gram or Bengal gram (Cicer arietinum L.) is "the most important and oldest pulse crop grown in India."[12] Gram contributes about half of the total pulse production of about 10 million tons per year. It is a food product that is generally accepted throughout India, but northern India (north of Gujarat, Maharashtra, and Orissa) accounts for nearly 90 percent of the annual area in gram and about 95 percent of the production. Of the 4.5 million tons produced in 1968-69, 1.1 million tons of gram were moved across state borders by rail and river, compared with only 1.2 million tons of rice out of a production of 40 million tons and 0.5 million tons imported. Out of a wheat production of 18.7 million tons and 3 million tons imported, only 3.9 million tons were moved across state borders by rail and river.

"Dal, besan, flour, crushed or whole gram, boiled or parched, roasted or cooked, salted or sweet preparations...are the important forms in which gram is consumed by the people."[13] Experts in food and nutrition agree that soy meal may well serve as a substitute for gram flour. Since gram in the form of flour is consumed mainly in public eating places (restaurants, hotels, hospitals, and the like), chances are very good that soy meal will be accepted here, if it is available at a somewhat lower price than gram flour.

No data are available of consumption of gram flour as such, but since these gram products to some extent are substituted for one another, total gram consumption can be assumed to represent the demand for gram flour. The demand for gram flour is assumed to run parallel to that for gram, at some constant price

[12] Indian Council of Agricultural Research, Handbook of Agriculture, 3rd ed., (New Delhi, 1969).
[13] Ibid., p. 183.

margin (for grinding gram into flour)[14] above the gram function. Thus the demand for soy meal is assumed to run parallel to that for gram.

The estimate of the demand function for gram is based on time series data. The net availability of gram per capita per year for all-India was taken as quantity consumed. Annual price averages--derived from price index data for gram, published by the Ministry of Food and Agriculture and deflated by the index of wholesale prices for all commodities and goods--were correlated with annual quantities consumed. Seventeen observations for the year 1951 to 1969 were fitted to a function of the following type:

$$P_g = a + Q_g^{\,b},$$

where P_g = price of gram and Q_g = quantity of gram consumed. The parameters of this function are

$$a = 1.5716$$

and

$$b = \underset{(.1812)}{-.84048}$$

The coefficient of multiple correlation is .76; the F-ratio is 21.5. Per capita income was tried as an additional explanatory variable; however, it was found that per capita income does not significantly explain variations in price or in consumption of gram given in the time series data, as indicated above.

<u>Soy oil as a substitute for groundnut oil</u>. Total annual production of edible oil in India since 1960-61 is about 2 million tons; approximately two-thirds of this quantity is groundnut oil. Edible oil in India is consumed either in the form of oil or vanaspati, a cooking margarine. Vanaspati is a relatively new product. Its production has increased as follows: 300 tons in 1930, 30,000 tons in 1937, 300,000 tons in 1957, and 520,000 tons in 1970.[15] The income elasticity of demand for vanaspati, estimated from time series data (annual observations from 1949 to 1969 on per capita net availability of vanaspati and per capita income at 1948-49 prices) is 2.16 while the elasticity of demand for vegetable oil, disregarding oil used in the vanaspati industry, is zero. The general increase in the demand for edible oil in India, as observed earlier, is caused by the increased demand for vanaspati.

Of the total oil consumption in the vanaspati industry, about 60 to 70 percent is groundnut oil. The vanaspati industry is familiar with the use of soy oil in manufacturing its product and almost the entire quantity of soy oil imported during recent years went into vanaspati production. However, because soy oil is more expensive to process than groundnut oil. and because products made from soy oil may have a shorter shelf life than those made from groundnut oil, soy oil sells for a lower price than groundnut oil. The amount of this price difference is not clearly established in Indian markets, because of the quota system and fixed prices of government-distributed imported soy oil, but estimates range between about 200 to 300 rupees per ton.

Given the high demand elasticity for vanaspati on the one hand and the fact that consumers are unfamiliar with the use of soy oil as such for cooking purposes,

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[14]Grinding charges in villages and towns run about 0.05 to 0.07 Rs/kg.

[15]Vanaspati Manufacturers' Association of India, <u>24th Annual Report for 1969</u> (Bombay: 1970).

it seems justified to assume that the demand for groundnut oil by the vanaspati industry may be used to estimate the demand for soy oil in India.

To estimate the demand function for groundnut oil consumed in the vanaspati industry, time-series data were used. Monthly observations for five years (1964 to 1969) on oil consumption (on per capita basis), oil prices (in real terms), and vanaspati consumption (on per capita basis) were applied. After determining the coefficient of autocorrelation (r = .6) and making the appropriate adjustments,[16] the following logarithmic function was fitted:

$$\lg Q_o = -.8590 - .5465 \lg P_o + .653 \lg V_c$$
$$(.4004) \quad (.2213) \qquad (.254)$$

where Q_o = quantity of oil consumed

P_o = price of groundnut oil

V_c = vanaspati consumption

The coefficient of multiple regression is .37 and F-ratio = 5.3. Adding the mean of vanaspati consumption to the intercept and expressing the quantity as a function of price, we arrive at the basic demand function for groundnut oil:

$$P_o = .001955\ Q_o^{-1.8298}$$

Note that the coefficient for vanaspati consumption enables us to consider the effect of income on the demand for groundnut oil consumed in the vanaspati industry.

Demand functions for soy meal and soy oil. The demand functions for both gram flour and groundnut oil were found to be exponential functions of the form

$$P = a\ Q^{-b},$$

where P is the price of the good, Q is the quantity consumed per capita per time unit, and a and b are parameters.

We are assuming that soy meal will be a perfect substitute for gram flour and that soy oil will be a perfect substitute for groundnut oil. However, because of the general shortage of pulses and of vegetable oil in India, we cannot expect that the two soy products will substitute for gram flour and groundnut oil on their present levels of consumption. Instead, we must assume that soy meal will be demanded in addition to the average quantity of gram presently demanded. Likewise, we must assume that soy oil will be demanded in addition to the average quantity of groundnut oil presently consumed by the vanaspati industry.

If this is true, then the demand function for each of the soy products starts from the point of average quantity consumed, QA, on the demand function for the respective product to be substituted (see Appendix, Figure 5). At prices higher than PA, soy products are not expected to find any demand. At prices lower than PA, soy products will be demanded along the demand curves for the respective products for which they substitute.

[16] See J. Johnston, Econometric Methods (New York: McGraw-Hill, 1963), p. 192ff.

Because the model requires linear demand functions, we let the exponential function be represented by an infinite number of its tangents. A tangent is taken as representing the exponential function (written as p = f (q)) for a certain range. This range is bounded by a largest and smallest quantity, so that the price difference between the tangent and the exponential curve for either of these quantities does not exceed a certain tolerance limit. The tolerance limit is 0.5 percent of the price on the exponential function. It is possible that the ranges of two or more tangents are overlapping.

For deriving regional functions this procedure is applied over several steps, thus using an iterative technique to find a set of regional tangents that uniquely represents our exponential function. First an approximation for a linear function of per capita demand for the respective products is determined by taking the total supply of soybeans, the conversion rates, and the total population, and computing the quantity of the respective product available per capita. A tangent of the exponential function at this quantity gives the first approximation for a linear function of per capita demand. From this linear function of per capita demand, the first approximations of regional demand functions are easily derived (by dividing the slope of the per capita demand function by the appropriate regional number of population). Application of these demand functions in the quadratic programming model yields an optimum allocation of quantities among the regions. Not all of the quantities allocated to the regions are within the range for which the tangent linear demand function is defined to represent its exponential function.

Therefore, in a second step on a per capita basis, individual tangents are determined for each of those quantities that do not fall into the defined range. For regions falling out of the defined range at the lower end, the new demand function will be less elastic; for regions falling out of the defined range at the upper end, the new demand function is more elastic. These per capita functions are then converted from per capita into the corresponding regional scale. Another run of the quadratic programming model with these functions, together with those first functions that are still applied, gives a different pattern of allocation in comparison to the first. It shows an increase in average per capita consumption for those regions that were at the lower end and a decrease in per capita consumption for those regions that were at the upper end of the range in average consumption per capita.

If after this run any of the allocated quantities of per capita demand still are placed outside the range for which their tangents are representing the exponential function, then a third step is required, repeating the procedure of the second step.

However, these adjustments in second, third, or further steps do not change the order according to per capita consumption in which all of the regions could be ranked from results of the first run. This order is determined by each region's individual processing costs and its transport relation to the other regions. Therefore, this stepwise technique to find a set of tangents that represent a nonlinear demand function will converge into a unique (within tolerance limits) solution.

Regional demand functions for soy meal. No demand function for gram flour was found to be

$$P_g = 1.5716\ Q_g^{-.84048}$$

As average quantity consumed of gram, QA_m, an average for the years 1964 to 1969 was taken; QA_m = 6.8 kg per capita per year. This same basic function will be used for the different years, since no effect of income or time could be detected on gram consumption.

Per capita demand was converted to regional demand by dividing the slope of per capita demand functions by the corresponding regional population. The proportion of population in the different regions for all of the four Years A, B, C, and D, was assumed to be the same as in 1961, the last year for which census data are available.

The shares of each region in the total population is: (1) Calcutta, 19.7%; (2) Bangalore, 26.3%; (3) Ajmer, 15.2%; (4) Lucknow, 24.5%; (5) Bhopal, 4.1%; (6) Anand, 3.7%; (7) Akola, 6.5%.

Regional demand functions for soy oil. The demand function for groundnut oil was found to be

$$P_o = .001955\ Q_o^{-1.8298}$$

The first parameter of this demand function contains the average value of vanaspati consumption times its coefficient. For the different years under consideration in our study, we must adjust this parameter in accordance with the increase in vanaspati consumption, which will be brought about by the assumed increase in per capita income.

As the average quantity per capita of groundnut oil consumed in the vanaspati industry, QA_o, an average of the years 1964 to 1969 was taken; QA_o = .52 kg per capita per year.

In converting per capita demand functions into regional demand functions, we must take into consideration that consumption of soy oil takes place in the vanaspati factories. The share of each region's capacity in vanaspati production in the all-India production capacity of vanaspati in 1970 was as follows: (1) Calcutta, 11.0%; (2) Bangalore, 24.9%; (3) Ajmer, 42.2%; (4) Lucknow, 8.2%; (5) Bhopal, 0%; (6) Anand, 5.1%; (7) Akola 8.6%.

Initially we assumed that each region's share of India's vanaspati production was equivalent to its share of India's capacity to produce vanaspati. However, if we assume that per capita consumption of vanaspati is equal in all parts of the country, we also must assume that each region's share of the vanaspati production capacity equals its share of India's population. Thus for each region it is this share of the population that must be taken to convert the per capita demand into regional demand.

Interregional Transport by Railroad

The spatial equilibrium model is simulating two types of transport: long-distance transportation between the regions, and short-distance transportation within a region.

Interregional transport is assumed to be carried out by railroads or, if not, freight rates competitive with rail rates are assumed. Rail rates applied to soybeans and soy products on the Indian railways are subject to change.

Presently applied rail rates. The freight rates presently applied on Indian railways[17] were created over the years by the Indian Railway Conference, a regularly convening body of representatives of nine different companies, formerly private, now government owned. All goods that may be transported are grouped into classes and different freight rates are determined for each class. In the long history of this system, different items were classified at different times under different circumstances.

For instance, soybeans were classified at their first repeated appearance on Indian railways in 1936. At that time the debate among members of the railway conference about how to classify soybeans (some argued that soybeans should be treated as "grain or pulses") ended with soybeans being grouped into the same class then assigned to groundnuts in the shell (class 67.5).

Oilcakes in the 1960s were appreciated by the Indian government as a valuable source of foreign exchange. In order to stimulate the export of oilcakes, they were assigned to the lowest class available (class 25).

Table 3 compares the classification and the corresponding rates for soybeans and related commodities as applied by Indian railways. These freight rates--class 67.5 for soybeans, class 25 for oilcakes, and class 65 for vegetable oils--will be used first in running the interregional trade model.

Anticipated changes in rail rates. When the freight rate of a commodity is determined, two crucial economic factors must be taken into consideration: (1) the specific weight and (2) the value per weight unit of the commodity.

Freight rates should be relatively high for a product with a low weight per wagon load, because comparatively more wagons are needed to carry a given number of tons of the product. Likewise, for a commodity of high weight per wagon load, lower freight rates should be charged because it requires less transportation space.

For a commodity with a relatively low price per quintal, a relatively low freight rate should be applied, in order to make it transportable. High-value products, on the other hand, will tolerate higher freight rates;[18] also, there is generally more risk involved, requiring more care, in shipping a valuable good than in shipping a lower-priced commodity.

The weight per wagon load, as given in "Goods Tariff, No. 32," and the price ranges reported by the Indian government for several different products are listed in Table 3, together with the classification and corresponding freight rates of these products.

Soybeans have an accepted weight of 170 quintals per wagon load, which is the same as for some products of the group "grain and pulses" (for example, barley) and which is close to the weight per wagon of oilseeds (185 to 200 quintals). However, soybeans are classified considerably higher than oilseeds. If priced at 80 to 90 rupees per quintal, soybeans have about one-half the value of oilseeds and one-third to one-fourth the value of vegetable oils. This price, however, is

[17] Indian Railway Conference Association, Goods Tariff, No. 32, parts I and II and correction slips, (Calcutta: Eastern Railway Press, 1970).

[18] The vital role that rail transport can play in the economy of a country justifies to some extent the use of railrates for indirect taxation or subsidy. However, it would be useful to have at least a theoretical framework of the economic costs of transporting different goods by rail, against which the freight rate should be determined--and, if necessary, changed--so that an overall most efficient transport system may be maintained.

Table 3. Value and Weight of Different Commodities and Their Classification and Freight Rates for Rail Shipments, India, 1 April 1970.

Commodity	Value (average price range Rs/100 kg)[a]	Weight (100 kg/ wagon)[b]	Classification (if in wagon loads)	Freight Rates (Rs/100 kg) 100 km	500 km
Deoiled Cake Incl. Soy Meal (e.g., groundnut cake, solvent extracted)	50-70[c]	205	25	0.77	1.90
Grain and Pulses (e.g., wheat, gram)	78-121 76-102	170-220	30	0.88	2.23
Oilseeds (e.g., rape and mustard seed and groundnut minus shell)	131-176 142-208	185-220	40	1.23	3.25
Vegetable Oils, Incl. Soy Oil (e.g., groundnut oil)	287-409	110[d]	65	1.68	4.61
Soybeans	90	170	67.5	1.74	4.78
Groundnuts in Shell	138-151[e]	110	75	1.91	5.29

[a]Annual averages of month-end wholesale prices, 1968 and 1969; lowest and highest price reported at any of the two years and at any of the markets given. Source: "Bulletin of Food Statistics, 1970," p. 204ff.
[b]On broad gauge.
[c]Estimated.
[d]Not in tank wagon.
[e]Rajkot, weekly wholesale prices between 12 Dec. 1970 to 29 Jan. 1971.

within the range of annual averages of month-end wholesale prices for rice, wheat, gram, arhar, and other grains and pulses.

Prices, as well as weight per wagon, for soybeans suggest that the freight rate of class 30 as applied to grain and pulses also should be extended to soybeans. This change in the freight rate for soybeans becomes the more urgent as a reclassification for oilcakes (into class 30 or 40) is under consideration. An increase in cost of transporting soy meal combined with high costs of shipping soybeans would impose a serious handicap on the development of a soybean industry in India.

The relation between the freight rates for raw material and final commodities has, of course, serious impacts upon the location of the processing capacity. In order to show these impacts, the model will be run applying changed rates--that is, class 30 for soybeans and oilcakes and class 65 for vegetable oils.

Intraregional Transport by Truck

Short-distance transportation for assembly of soybeans and distribution of soy meal within a region is assumed to be carried out by truck. Over long distances trucks compete with railroads and over very short distances bullock carts compete with trucks for the transport of goods.

One way to measure the costs of transportation of grain on bullock carts is to evaluate the rates at which bullock carts can be rented. From some 40 interviews, the rates reported yield a transportation cost function of

$$T_b = 5.5 + .825 D_b,$$

where T_b is transportation cost in rupees per ton and D_b is distance in kilometers.

Truck transportation rates, which are the same for grain and oilcakes, as reported by four trucking companies for a total of 31 different transportation relations, yielded a cost function of

$$T_t = 2.7 + .106 D_t, \text{ and } T_t \geq 5.0,$$

where T_t is transportation cost in rupees per ton and D_t is distance in kilometers.

The transportation rates for the three different modes of transportation of soybeans--bullock cart, truck, and railway--are depicted in the Appendix, Figure 6.

In India, bullock carts often are used instead of trucks to transport goods. Regardless of the costs of transportation on bullock carts, this mode of transport is necessary wherever adequate roads are lacking. However, in many instances bullock carts may be competing successfully against trucks even on very good roads that are well suited for truck transport; this is explained by the relatively low opportunity costs for the bullock cart plus animals and driver, and the relatively high fixed costs for food and feed.

However, as a general fact, in comparison with bullock carts, trucks must be considered the more efficient mode of transport. For distances between about 20 and 300 kilometers, in most cases trucks are the only economic mode of transportation for soy products. It is expected that the radius of the market area of an individual processing plant will lie within this range. Thus it is appropriate to assume truck transportation for intraregional transport.

THE INDIAN SOY ECONOMY: MODEL RESULTS

The numerical results of our calculations are presented in four parts of this section. First the regional distribution of supplies among consumers is shown. Second, the flows of goods that create these distributional patterns are presented. Each system of supplies, flows, and demands requires certain regional processing capacities. In the third part, the processing capacities required for each region are presented as optimal numbers and average sizes in terms of capacity and marketing area of plants. Also, regional average processing costs are presented. Regional prices for soybeans, soy oil, and soy meal as determined under these various conditions are shown in Appendix B.

Quantities Demanded per Region

Year A. Table 4 is a summary of the regional distribution of soybeans in the form of soy meal and soy oil, under conditions of Year A. The quantity of soybeans supplied is so small that the distributional pattern remains the same, regardless of which of the two sets of rail transportation rates might be applied. Essentially it shows that, given our assumed demands, the soy meal will be entirely absorbed locally, improving the diet of consumers only in the soybean production areas by adding about 100 grams of soy meal per person. Computed for the all-India population, a statistical average consumption of 30 grams per capita is achieved. The soy oil, even at quantities as small as these, turns out to be transportable enough to be partly exported into all of the regions lacking in soybean production. However, consumption of soy oil per capita in the soybean producing regions is about two to four times as high as the consumption in the regions lacking in soybean production.

Table 4. Supply of Soybean and Consumption of Soy Meal and Soy Oil, Year A.

Region	Supply of Soybeans	Total Consumption		Consumption per capita	
		Soy Meal	Soy Oil	Soy Meal	Soy Oil
	(tons)	(tons)		(kg)	
1	--	--	160	--	0.003
2	--	--	410	--	0.003
3	--	--	1,360	--	0.006
4	7,280	5,770	620	0.058	0.014
5	4,190	3,330	--	0.148	--
6	2,610	2,070	350	0.102	0.013
7	5,920	4,690	640	0.131	0.013
India	20,000	15,860	3,540	0.0288	0.006

Year B. The conditions for supply and demand, as postulated for Year B, lead to the consumption pattern presented in Table 5. Given these supplies, under presently applicable rail rates, soy meal is consumed in all of the zero-soybean-production regions. The anticipated rates generate a pattern that eliminates consumption of soy meal in Region 1, but in comparison to the pattern generated by the present rates, the anticipated rates result in higher consumption in Regions 2 and 3 and relatively lower consumption in the soybean production Regions 5, 6, and 7. The consumption of soy meal per capita in the soybean production regions is greater than the all-India average consumption of about 500 grams per person for that year, while Regions 1 and 2, without soybean production, show per capita consumptions below the average. Region 3, located relatively close to the major soybean production regions, and Region 4, which combines large production and large demand, both show about average consumption of soy meal per capita.

The oil consumption of about 130 grams per capita for Year B in the soybean supply Regions 4, 5, and 7 is only slightly above the per capita consumption in Regions 1 through 3, which grow no soybeans.

Table 5. Supply of Soybeans and Consumption of Soy Meal and Soy Oil, Year B, Under Present and Anticipated Rail Transportation Rates.

Region	Supply of Soybeans	Total Consumption				Consumption per capita	
		Present Rates		Anticipated Rates		Present Rates	
		Soy Meal	Soy Oil	Soy Meal	Soy Oil	Soy Meal	Soy Oil
	(tons)	(tons)		(tons)		(kg)	
1	--	3,650	7,570	--	7,580	0.03	0.12
2	--	44,110	16,130	51,460	16,110	0.28	0.11
3	--	52,620	30,290	57,860	30,310	0.58	0.12
4	145,600	115,460	6,460	115,460	6,460	0.79	0.13
5	83,800	29,260	--	25,380	--	1.20	--
6	52,300	26,050	3,970	24,690	3,970	1.19	0.13
7	118,300	46,060	6,380	42,350	6,370	1.20	0.13
India	400,000	7,210	70,800	317,200	70,800	0.54	0.12

Year C. In Table 6 the consumption pattern under conditions of Year C is presented. The larger quantity supplied leads to a more even distribution of soy meal and soy oil among regions. Per capita consumption of soy meal in Region 1 has risen to about half the average consumption of soy meal for all-India for this year, which is about 1.4 kg. However, the regions of soybean supply still show a per capita consumption of about 50 percent above this average. The per capita consumption of soy oil in all the regions has become almost the same--that is, a little more than 300 grams per person.

Table 6. Supply of Soybeans and Consumption of Soy Meal and Soy Oil, Year C, Under Present and Anticipated Rail Transportation Rates.

Region	Supply of Soybeans	Total Consumption				Consumption per capita	
		Present Rates		Anticipated Rates		Present Rates	
		Soy Meal	Soy Oil	Soy Meal	Soy Oil	Soy Meal	Soy Oil
	(tons)	(tons)		(tons)		(kg)	
1	--	95,700	22,930	91,810	23,030	0.73	0.32
2	--	182,230	49,920	194,630	49,600	1.05	0.30
3	--	151,040	90,440	167,320	90,780	1.50	0.32
4	436,800	312,490	18,720	287,010	18,780	1.93	0.34
5	251,400	61,460	--	63,740	--	2.27	--
6	156,900	55,120	11,560	60,290	11,490	2.25	0.34
7	354,900	93,560	18,830	86,800	18,270	2.18	0.33
India	1,200,000	951,600	212,400	951,600	212,400	1.44	0.32

Year D. For Year D, as shown in Table 7, a perfectly elastic demand for soy meal in Region 6 (Anand) was postulated, simulating exports of soy meal to the world market. The world market price was assumed to be 532 rupees per ton.[19] The resulting export of almost 1.7 million tons of soy meal results in a domestic consumption of soy meal in India of 2.9 kg per capita in that year.

Table 7. Supply of Soybeans and Consumption of Soy Meal and Soy Oil, Year D, with Export Outlet in Region 6, Under Present and Anticipated Rail Transportation Rates.

		Total Consumption				Consumption per capita	
		Present Rates		Anticipated Rates		Present Rates	
Region	Supply of Soybeans	Soy Meal	Soy Oil	Soy Meal	Soy Oil	Soy Meal	Soy Oil
	(tons)	(tons)		(tons)		(kg)	
1	--	370,760	94,850	380,830	94,850	2.39	1.10
2	--	429,840	204,960	471,460	204,960	2.08	1.05
3	--	325,070	376,830	329,360	376,830	2.72	1.14
4	1,820,000	747,420	80,100	733,070	80,100	3.88	1.24
5	1,047,000	116,830	--	111,740	--	3.62	--
6	653,000	1,787,110[a]	49,180	1,737,200[a]	49,180	3.60[b]	1.23
7	1,480,000	187,970	79,080	201,340	79,080	3.67	1.17
India	5,000,000	3,965,000	885,000	3,965,000	885,000	2.90	1.12

[a]Includes 104,760 tons for local consumption (assuming 3.6 kg per capita).
[b]Assumed.

Variations. In Table 8 are the results of conditions in which the supply of soybeans of Year B stands against the demand for Year C. Under these conditions, per capita consumption is depressed in comparison with that shown in Table 5 because a given quantity is now divided among an increased number of people.

Table 8. Supply of Soybeans, Year B, and Consumption of Soy Meal and Soy Oil Under Conditions of Year C at Present and Anticipated Rail Transportation Rates.

		Total Consumption				Consumption per capita	
		Present Rates		Anticipated Rates		Present Rates	
Region	Supply of Soybeans	Soy Meal	Soy Oil	Soy Meal	Soy Oil	Soy Meal	Soy Oil
	(tons)	(tons)		(tons)		(kg)	
1	--	--	7,590	--	7,590		0.10
2	--	43,750	16,260	48,700	16,260	0.25	0.10
3	--	50,450	30,260	56,400	30,260	0.50	0.11
4	145,600	115,460	6,400	115,450	6,400	0.71	0.12
5	83,300	30,380	--	26,100	--	1.12	
6	52,300	27,100	3,940	25,430	3,940	1.11	0.12
7	118,300	50,060	6,350	45,120	6,350	1.16	0.11
India	400,000	317,200	70,800	317,200	70,800	0.48	0.11

[19]Average price for soy meal in 1969-71 was, c.i.f. Rotterdam: $100/ton. Freight costs are about $30/ton. The conversion rate was taken as $1 = 7.6 rupees.

Table 9 shows the results of conditions opposite to those underlying Table 8. In this case the supply of soybeans of Year C faces the demand of the earlier Year B.

Table 9. Supply of Soybeans, Year C, and Consumption of Soy Meal and Soy Oil Under Conditions of Year B at Present and Anticipated Rates of Rail Transportation.

		Total Consumption				Consumption per capita	
	Supply of	Present Rates		Anticipated Rates		Present Rates	
Region	Soybeans	Soy Meal	Soy Oil	Soy Meal	Soy Oil	Soy Meal	Soy Oil
	(tons)	(tons)		(tons)		(kg)	
1	--	105,370	22,890	100,050	22,990	0.90	0.35
2	--	189,350	49,630	192,810	49,270	1.22	0.34
3	--	150,380	90,530	164,310	90,920	1.67	0.36
4	436,800	303,940	18,830	286,810	18,900	2.10	0.39
5	251,400	59,240	--	61,950	--	2.44	--
6	156,900	52,990	11,620	57,040	11,550	2.42	0.38
7	354,900	90,330	18,900	88,630	18,780	2.45	0.37
India	1,200,000	951,600	212,400	951,600	212,400	1.61	0.36

Summary. The four different conditions of supply of soybeans and consumption of soy meal and soy oil as postulated for four different points in time consistently generate different patterns of consumption. With an increase in the aggregate quantity of soybeans supplied and an increase in consumption per capita, the movements of soybeans among regions increase in such a way that the distribution of soy products on a per capita basis among regions becomes more and more even. Similarly, if the supply is held constant and the demand is allowed to increase, consumption per capita decreases and the differences among regional consumptions of soy products become greater.

Flows Among Regions

Table 10 summarizes the flows of soybeans, soy meal, and soy oil among regions under the two sets of rail rates for the different model years.

Year A. The supply of soybeans in Year A is so small that all soy meal supplies are absorbed in their regions of production and only the relatively more mobile soy oil is shipped over long distances. Region 1 (Calcutta) is supplied from Region 4 (Lucknow); Region 2 (Bangalore) receives its soy oil from Region 7 (Akola), and Region 3 (Ajmer) finds its suppliers in nearby Regions 4 (Lucknow), 5 (Bhopal) and 6 (Anand). The total quantity of soy oil moved in this year amounts to 54 percent of the total supply of soy oil. Both present and anticipated rail rates generate the same flow pattern.

Year B. In Year B the potential effect of a change in rail rates for soy meal and soybeans becomes obvious. Under the present rates soy meal and soy oil are shipped; under the anticipated rates, soybeans and soy oil are transported.

Table 10. Flows of Soybeans, Soy Meal, and Soy Oil Among Regions, at Supplies and Consumption Rates of Different Years, Under Present and Anticipated Rail Transportation Rates.

	Regional Flow		Year A		Year B		Year C		Year D[a]	
Product	From	To	Present Rates	Anticipated Rates	Present Rates	Anticipated Rates	Present Rates	Anticipated Rates	Present Rates	Anticipated Rates
						(tons)				
Soybeans	4	1						74,882		430,242
	4	3								415,333
	5	1						40,897		
	5	3				51,799		130,120		
	5	6								906,087
	6	3				21,168		80,873		
	7	2				64,894		245,436		594,532
Soy Meal	4	1					33,879		370,760	
	4	3							325,074	
	5	1					56,173			
	5	3			37,192		81,730			
	5	6							713,434	
	6	3			15,424		69,305			
	7	1			3,645		5,644			
	7	2			44,110		182,227		429,837	
	7	6							555,821	500,830
Soy Oil	4	1	159	159	7,571	7,576	22,935	2,532	94,849	9,846
	4	3	507	507	11,742	11,732	35,662	42,744	147,194	73,680
	5	3	742	742	14,833	5,664	44,498	10,693	185,319	24,942
	5	7						3,525		
	6	2			1,568	1,540	5,939	1,968	22,075	22,075
	6	3	109	109	3,718	3,079	10,277		44,324	204,701
	7	2	406	406	14,558		43,985	4,189	182,880	77,648

[a]Assumes export of soy meal from Region 6 to the world market.

Under present rail rates the flow pattern for oil is the same as in Year A, except for additional small shipments from Region 6 (Anand) to Region 2 (Bangalore). Seventy-six percent of the total oil production for Year B is moved among regions. Soy meal is imported into Region 3 (Ajmer) from Regions 5 (Bhopal) and 6 (Anand), while Regions 1 (Calcutta) and 2 (Bangalore) are receiving their soy meal imports from Region 7 (Akola). Thirty-two percent of the total soy meal produced in Year B is moved in interregional trade.

Under anticipated rates in Year B we find Regions 5 (Bhopal) and 6 (Anand) supplying Region 3 (Ajmer) with soybeans and Region 7 (Akola) shipping soybeans to Region 2 (Bangalore). These shipments amount to 35 percent of the total soybean production for Year B. The oil shipments in Year B follow a pattern similar to that found for the present rates, except that the oil imports from Region 7 (Akola) into Region 2 (Bangalore) are now entirely carried out in the form of soybeans. The quantity of soy oil moved under anticipated rates for Year B is 42 percent of the aggregate quantity of soy oil produced.

Year C. Essentially the same flow patterns of soybeans and soy oil under the anticipated rates, and of soy meal and soy oil under the present rates, as for Year B are generated for Year C. The only differences are that now Region 1 (Calcutta) is receiving soy meal under the present rates, and soybeans under the anticipated rates from Regions 4 (Lucknow) and 5 (Bhopal).

Under present rates for Year C 45 percent of the total soy meal production and 77 percent of the total soy oil production are moved across regional borders. Under anticipated rates these interregional movements constitute 48 percent of the soybeans and 31 percent of the soy oil of Year C.

Year D. Flow patterns for Year D are influenced by the assumption that there is an elastic demand for soy meal in Region 6 (Anand) for export to world markets. With that exception, a continuation of the trends recognizable from the three earlier years is observed. At the present rail rates, the proportion of the soy meal moving from region to region increases to 60 percent, with approximately half of that movement to Region 6. The proportion of the soy oil moving from region to region--76 percent--is essentially the same as in Year C.

Under the anticipated rail rates, the same proportion of the soybeans as in Year C--48 percent--but only a small proportion of the soy meal--13 percent--moves among regions. As would be expected, both of these flow patterns included increased volumes to Region 6. As the result of the processing of large quantities of soybeans in Region 6, the proportion of the soy oil moving between regions increases to 47 percent, with a little more than half of this volume originating in Region 6.

Summary. The flow patterns that are generated under the different conditions of supply and demand as postulated for the Years A, B, C, and D are changing from one point in time to the next.

Under the present rail rates no soybeans are transported. Over time we observe an increase at a decreasing rate in the quantity of soy meal transported, relative to the total quantity of soy meal produced in each year. Under the present rail rates, the proportion of the soy oil moving among regions increases quite sharply from Year A to Year B, but remains unchanged after Year B.

Under the anticipated rates, movements of soybeans largely replace movements of soy meal, and follow the same general pattern, increasing over time. With extensive interregional movement of soybeans, it is to be expected that the transportation of soy oil across regional borders will lessen. Data confirm this expectation.

There are two major policy implications arising from these different flow patterns, generated by the different sets of rail rates. As will be shown later in more detail, freight rates have considerable impact upon the location of processing plants. Also, the relation between freight rates for the different goods determines the proportions in which different types of wagons (for example, tank wagons versus box wagons) or of containers (for instance, cans versus burlap bags) may be required to allocate the soybeans or their final products, or both.

Number and Average Size of Plants and Average Processing Costs per Region

The main results of this study are summarized in Table 11. It shows number and average size of plants in terms of capacity and market area and average processing costs per region. The numbers are given in fractions in order to be consistent with the other parts of this table, as the figures on capacity, radius of market area, and costs all are based on these fractional numbers.

In this case, the decimal point should not mislead the reader, as it does not pretend an accuracy of calculations which the data cannot provide. On the contrary, placing the decimal point in a figure which can be correct only as an integer may caution the reader and encourage him to use his own judgment in rounding to find a solution that takes into consideration the many irregularities of the real world which had to be assumed away before computations could be carried out.

Year A. For Year A there are only about two processing plants in India. The computed large radius of the market areas of these plants in reality would be reduced considerably because production of soybeans would reasonably be promoted first in the vicinity of the processing plant, increasing production density there, reducing hauling costs, and creating viable conditions for two solvent extraction plants of perhaps 40 to 50 tons per day each.

Year B. In order to process and economically distribute the supply of Year B for all-India, about 10 to 13 processing plants of capacities between 90 and 160 tons per day each are needed. If the present rates are applicable, fewer (about 10) and relatively larger (about 130 to 160 tons per day) mills will prevail, since all processing takes place in the soybean production regions and the excess soy meal and soy oil are exported. Although large amounts of soy meal are exported instead of being distributed locally, this does not result in fewer and larger plants in the producing regions.

If the anticipated rail rates are in force, more plants (about 12 or 13) of relatively smaller size (about 90 to 140 tons per day) will be necessary, the larger plants in this set being located in regions into which soybeans are imported. Regions 2 (Bangalore) and 3 (Ajmer) would require about two plants each. However, these plants are not really expected to distribute soy meal over the entire region as the large radius of the market areas might indicate. Rather, the plants probably would be located in larger cities where the density of consumption is higher. This reduces the actual radius of the market area considerably.

Table 11. Number, Average Capacity, and Radius of Market Area of Soybean Processing Plants, and Average Processing Costs by Regions for Different Years at Present (P) and Anticipated (A) Rates of Rail Transportation

Region	Year A	Year B		Year C		Year D[a]	
	(P) (A)	(P)	(A)	(P)	(A)	(P)	(A)
			Number of Processing Plants				
1	--	--	--	--	2.3	--	5.8
2	--	--	1.5	--	3.8	--	7.0
3	--	--	1.7	--	3.5	--	5.7
4	0.5	3.8	3.8	7.7	7.1	17.7	13.2
5	0.3	1.9	1.3	3.7	2.2	8.9	3.3
6	0.2	1.2	1.0	2.3	1.7	5.4	5.4
7	0.4	2.4	1.8	4.7	2.8	11.3	8.4
India	1.4	9.3	11.1	18.4	23.4	42.3	48.8
			Average Capacity (tons/day)				
1	--	--	--	--	163	--	259
2	--	--	133	--	209	--	284
3	--	--	137	--	199	--	254
4	47	127	127	189	174	343	237
5	45	147	92	224	120	391	146
6	47	145	104	224	145	400	956
7	51	163	108	250	137	437	336
India	48	143	120	217	171	385	342
			Average Radius of Market Area (km)				
1	--	--	--	--	331	--	208
2	--	--	406	--	258	--	190
3	--	--	394	--	271	--	212
4	507	187	187	132	137	87	100
5	531	215	259	153	198	99	162
6	504	197	218	141	165	93	93
7	471	189	221	135	174	87	101
			Average Processing Costs (Rs/ton)				
1	--	--	--	--	68.5	--	65.3
2	--	--	70.4	--	66.6	--	64.8
3	--	--	70.1	--	66.9	--	65.4
4	89.4	70.8	70.8	67.3	67.9	64.0	65.8
5	90.8	69.4	75.0	66.1	71.4	63.5	69.4
6	89.2	69.5	72.6	66.1	69.5	63.4	61.4
7	87.3	68.4	72.8	65.5	70.1	63.1	64.1

[a]Assume export of soy meal from Region 6 to the world market.

Year C. Given a further increase in the soybean supply in Year C and given the demand restrictions of that year, the number of plants should be about twice that of the earlier Year B; about 20 to 28 plants with capacities of about 120 to 250 tons per day should be available. Under the anticipated rail rates in this year also Region 1 (Calcutta) should have about two to three plants while the requirements for Regions 2 (Bangalore) and 3 (Ajmer) would be around four plants in each. As in Year B, under the anticipated rail rates there are more soybean mills in soybean input regions and fewer and smaller plants in soybean export regions.

Year D. The conditions of supply and demand in Year D require further increases in number and capacity of processing plants. This leads to relatively smaller market areas per plant and also to relatively lower processing costs. For Year D, under the present rail rates it would be economically justifiable to establish soybean mills of capacities of 300 to 500 tons per day or larger in the regions of soybean production. Under the anticipated rail rates, processing plants of similar sizes would be economical only for soybean import regions, which would include Region 6 because of its large exports of soy meal. Under these rates, processing plants in the other soybean production regions would remain fewer and smaller.

Summary. A comparison of the results for the four different years shows the implications of a change in rail rates- and gives a basic idea about optimum capacities per plant and processing costs.

1. Only under the anticipated rail rates (which require the same freight charges for soybeans and for soy meal) and if relatively large quantities of soybeans are supplied can processing capacity be expected to be established in areas without soybean production.

2. There always will be processing plants in the soybean production areas, although these will be relatively smaller and fewer under the anticipated rail rates and larger and more numerous under the present rail rates.

3. Number and size of plants in an area with relatively small soy exports--for example, Region 4 (Lucknow)--are relatively less affected by the type of rail rates than they are in an area with heavy soy exports--for example, Region 7 (Akola).

4. If techniques and costs of processing soybeans remain constant, optimal sizes of soybean processing plants in India for the next 20 years seldom will exceed 400 tons per day. For the next 10 years, sizes of not more than 250 tons per day can be recommended.

5. As the capacity and number of soybean processing plants increase, the market area of the individual plants decreases. The radius of individual market areas on the average lies between 100 to 300 kilometers.

6. Given the cost function corresponding to the given price level and industry as designed by our model, soybean processing may be expected to cost--in rupees per ton--about 80 to 100 in Year A, 70 to 80 in Year B, 65 to 70 in Year C, and 60 to 65 in Year D.

All of these quantitative statements are based upon the assumptions which were necessary to simulate a soybean economy in India. To add a greater flavor of reality to these somewhat "tasteless" isolates from the real world, more practical impacts and implications will be discussed in the next sections.

SENSITIVITY OF THE SYSTEM TO CHANGES IN THE CONSTRAINTS

The choice of each one of the constraining inputs entering into the model, be it a functional relationship or a constant, is based upon some type of assumption. Those inputs were chosen that seemed more likely to occur. In cases where no probabilities of occurrence could be attached to a coefficient, alternative assumptions were made and the results for these observed.

In this section, only the general theory and assumptions behind the spatial equilibrium model are accepted. We then examine the effects of major variables and assumptions (see Appendix, Figure 1; and Table 2) by considering how a change in each of those items would affect the system if other conditions remained the same.

Effects of Changes in Regional Supplies

In the early years, the development of soybean production is likely to depend heavily upon promotional efforts in agricultural extension and marketing, and probably will not occur at similar rates in all regions. If, as a result, one region at a given point in time produces more soybeans than was projected in the model, that region would require additional processing plants, and plants of somewhat larger average size, than shown in the preceding section. The opposite would be true of a region in which production lagged behind schedule. Likewise, if a region that was expected to produce soybeans did not do so, but (under anticipated rail rates) imported soybeans, it--like other importing regions--would require relatively few and large plants. And, if a region of supposedly zero production developed some supplies, under both sets of rail rates it would need more and smaller plants than shown.

Effects of Changes in Rail and Truck Rates

The model compared the effects of the present rail rate system (soybeans in class 67.5, soy meal in class 25, and soy oil in class 65) with the effects of an anticipated system of rail rates (soybeans and soy meal both in class 30 and soy oil in class 65). It was noted that change to anticipated rates would result in shipment of whole soybeans from producing regions to consuming regions with zero production, for processing in plants of above-average size. It also would result in fewer and smaller plants in producing regions.

If, instead of the anticipated rates, the rate on soy meal were increased to a higher level--for example, class 40--while other rates were as specified, the effect upon optimum location and size of processing plants would be similar to that of the change to anticipated rates. On the other hand, if soy meal continued in class 25 and the rate on soybeans were reduced to class 30, soybeans would be shipped into regions of heavy demand for processing only if those regions were close to production areas--for example, Region 3 (Ajmer).

The estimated cost of transportation on trucks used in all regions is 0.106 rupee per ton per kilometer. This rate, determined from interviews, is practically identical to the minimum freight rate "notified by the State Government" of Madhya Pradesh as of March 31, 1967.[20] However, truck transportation rates are not uniform under all conditions. They vary with topography, road conditions, season, and the direction of shipment--and possibly with the number of stops required to pay and to obtain reimbursements of octroi (a duty levied on goods brought into town).

Table 12 shows the effects of three different rates (0.09, 0.106 and 0.2 rupee per ton per kilometer) on optimum number and average capacity of plants in Region 5 for Year D under anticipated rail rates for given values of "marginal" processing costs. If, in the long run, truck rates decline, it will lead to optimal solutions with fewer and larger plants.

Table 12. Examples of Optimum Number, Average Size, and Average Processing Cost of Soybean Processing Plants in Region 5 Under Conditions of Year D and Anticipated Rail Rates Given Different Marginal Rates of Truck Transport and Different "Marginal" Processing Capacities.

"Marginal" Processing Capacity (tons/day)	Item	Marginal Truck Transportation Rates 0.09 (Rs/ton/km)	0.106	0.2
1,200	Optimum number	3.3	3.7	5.6
	Average size (tons/day)	149.0	133.0	87.0
	Average processing cost (Rs/ton)	69.3	70.3	75.8
1,384	Optimum number	3.0	3.3	5.1
	Average size (tons/day)	163.0	146.0	96.0
	Average processing cost (Rs/ton)	68.4	69.4	74.4
1,500	Optimum number	2.8	3.2	4.8
	Average size (tons/day)	172.0	155.0	101.0
	Average processing cost (Rs/ton)	68.0	68.9	73.6

Effects of Changes in Modes and Volume of Consumption

In India, as in other parts of the world outside the Orient, it seems likely that soybeans will be processed mainly by solvent extraction for consumption as soy oil and soy meal (or products thereof). However, in the early stages of the industry's development, investors and public decision-makers may be reluctant to

[20] India, Ministry of Shipping and Transport, Transport Research Division, Basic Road Statistics of India, 1968 (New Delhi: Government of India Press, 1971), p. 206.

risk investing large amounts of scarce capital in solvent extraction plants designed specifically for processing soybeans, when there is only limited experience in large-scale soybean cultivation and in marketing soy products (especially soy meal). Therefore at the initial stage considerable quantities of soybeans may be processed by screw press expellers,[21] by extrusion cookers,[22] into beverage, into flour at the village level,[23] or consumed as whole beans.[24] To the extent that soybeans are processed by these alternative methods, there will be less development of the solvent extraction processing industry at any given point in time.

In somewhat similar manner, differences from assumed conditions in demand for soybean products in different areas or regions affect the allocation of processing plants and the volumes and directions of trade. Under anticipated rail rates, for example, a smaller local demand in either an exporting or an importing region would lead to an optimal solution that calls for fewer and smaller plants than when local demand is larger. Also, concentration of population and demand for soy products in urban areas would favor somewhat fewer and larger plants than is suggested by our findings, which assume uniform distribution of population throughout the region. However, this effect probably would be more than offset by the fact that, in reality, market areas would overlap (rather than each processor having a monopoly, as was assumed) and that would lead to relatively more and smaller plants.

Effects of Changes in Export Demand

It may be too much to expect that in the time-span being considered in this study the costs of producing and processing soybeans in India would become competitive with costs in countries supplying the world market. Also, it may be questionable whether, within the time-span under consideration, the value of foreign exchange earned from soy exports, if subsidized, would be worth the loss of these goods for domestic consumption.

Nevertheless, to illustrate the effects of exports on size and location of plants, in Year D we allowed for export of soy meal. The price level for the exported commodity is determined by the world market price f.o.b. at port of export (or f.o.b. world market price plus export subsidy, if any is given as such). The higher the world market price (plus export subsidy), the higher the inland price level and, consequently, the lower the quantity domestically demanded. With respect to location and size of processing plants this implies that the quantity for local distribution and domestic trade of the product diminishes, with the general effect that fewer and larger plants are needed.

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21 Expeller units are widely used for processing groundnuts and other oilseeds.

22 A method of converting soybeans under pressure and high temperature into a full-fat soy product, which can be blended with all kinds of flavorings.

23 C. C. Mustakas, "Alternative Processes for Full-Fat Soy Flours for Use in Developing Countries," in Proceedings of International Conference on Soybean Protein Foods. A.R.S., USDA. (Peoria, Ill., ARS-71-35, 1967.) pp. 156-162.

24 Recipes for use of soybeans in home cooking in India are available in: S. Kanthamani, Tasty Recipes from Soybeans (Jabalpur, M. P., India: Directorate of Extension and USDA, JNKVV, 1970), 100 pp., and R. Singh, compiler, Soyahar Indian Recipes of Soybeans (Pantnagar, U. P., India: Uttar Pradesh Agricultural University, 1970), 216 pp.

A special case occurs if world market exports are carried out under anticipated rail rates. In this case, soybeans are transported and assembled interregionally at the export site to be processed and exported, and neither costs of local assembly nor costs of local distribution of soy meal are given. Since the plant location model assumes a processing cost function that shows indefinitely decreasing costs of processing,[25] those economies of scale associated with increasingly larger plants theoretically are not offset by any diseconomies connected with scale. This then would imply that the entire capacity needed for processing those soybeans, the products of which are exported--that is, soy meal and soy oil--should economically be located in a single plant adjacent to the port, where ocean-going ships are loaded directly. When only soy oil is being exported, this effect would be less constraining than when both soy meal and soy oil or soy meal alone are exported.

Effects of Changes in Conversion Rates

Conversion rates will probably differ within and among regions and over time. In some areas, soybean varieties may be grown that produce relatively more oil than others; in some areas, processing techniques may be applied that cause relatively greater loss than in other areas. In the early stages of soybean processing, the rates of oil extraction may be lower and the losses higher than in later years after more experience is gathered. Smaller plants may have higher losses than larger plants. The general effects of these--not very substantial--changes on location and size of processing plants can be neglected; generally, they are not expected to amount to more than 10 percent deviation from each of the rates.

Effects of Changes in Processing Costs

In our location model we are assuming processing costs Y to be a function of capacity X in the following form:[26]

$$Y = a + b\,X^{-1}$$

This function implies that processing costs are decreasing at a decreasing rate and gradually are approaching a constant value of a. The assumption of ever-decreasing processing costs as capacity increases may become unrealistic for values of X larger than our observed values for X (largest observed value was X = 1,000 tons/day). However, as long as only that portion of the function based upon observed values is used, the criticism of applying an unrealistic function may not hold.

In the case discussed above, where for one region the majority of soybeans processed are imported from other regions and most of the soy meal is exported to the world market, and therefore only small local assembly and distribution costs occur, our processing cost function may not be the proper tool to determine optimum size of a processing plant. Here the small costs of assembly and distribution are offsetting the ever-growing (at a decreasing rate) economies of scale at an average capacity for the region, which may imply a unrealistic solution.

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25 The processing cost function is considered in the later section on "Effects of Changes in Processing Costs."

26 For estimation of the function, see p. 12.

For a special case such as this, the optimum capacity of a processing plant, which would operate at the relatively high risks underlying the world market, is probably almost impossible to determine from economic theory alone. On this level, political facts overrule economic arguments.

The processing cost function was estimated from engineering data which, in comparison to reality, may be biased in one or the other direction. A change in the constant parameter a has no impact upon the optimum locational pattern; it would have an effect upon farm prices for soy beans. Parameter b, the "marginal" processing capacity, would turn out to be larger than our estimated value if the fixed costs (mainly for investment capital) were higher than assumed, and/or if the variable costs (especially for labor and operational capital) were lower than assumed. A smaller value for b would be caused by the opposite of these forces. In Table 12 for given truck transportation rates, we have illustrated the effects of different values of b (1,200, 1,384 and 1,500) on optimum number and average capacity of plants in Region 5 for Year D under anticipated rail rates.

In the long run, an increase in the value for b in our processing cost function must be anticipated, leading to optimal solutions of slightly fewer and larger plants.

ASPECTS IN DESIGNING AN OPTIMUM MARKETING SYSTEM

Optimal solutions have been found to allocate soybean processing plants in India in terms of regional averages for different points in time and under different assumptions. In determining these solutions the macroeconomic viewpoint was strictly maintained with the objective of minimizing aggregate costs.

Our competence ends at the point where these optimal average solutions are to be translated into real world terms. There are two major reasons why the actual location and size of individual processing plants cannot be determined.

1. The regional average solutions leave a variety of individual solutions for each region, which, taken together, total the average solution for the region, but some of which may not be in line with the overall objective of maximizing the welfare (that is, minimizing costs) of the aggregate. The choice of the best solution cannot be made because of the next reason.

2. We are not familiar enough with geographic and local political particularities of all the regions to be able to make the best decision regarding the location of individual plants. Our choice necessarily would be arbitrary and subjective.

Therefore, no particular individual location for a processing plant is suggested. However, despite the lack of knowledge about risk aversions, competitive strengths and preferences of all the potential individual investors, and the geographical and political particularities within the region, an effort is made to illustrate a solution in terms of actual plants in one region. The object is to: (1) visualize the abstract solution in more concrete terms; (2) show the general aspects important for implementing such systems; (3) provide an example for later comments on implications; (4) stimulate the discussion (and action) on an urgent problem; and (5) point to problems for future research.

Example of a Development According to Model Results

Assuming that the average solutions for the Years A, B, and C are correct, and that present rail rates will prevail throughout the period, then for Region 5 (Bhopal) the following reasoning could be applied:

1. For Year C four processing plants in Region 5 are expected. These should, economically, be located in the four largest cities, if there is a potential production density of soybeans in the vicinity of each of these cities high enough to support a processing plant. The map (Appendix, Figure 7) shows Bhopal, Jabalpur, Sagar, and Kota to be the four largest cities. Production densities in the districts surrounding these cities are among the highest for the region (see Appendix, Figure 2).

2. From these four final plant sites for Year C, the appropriate sequence is chosen in which, during the earlier years, these sites are occupied.

3. In Year A for all-India about two plants for processing soy beans are required. One of these should preferably be established in Region 4 (Lucknow), as this region has the highest requirement. The second highest requirement in terms of number of plants and processing capacity is for Region 7 (Akola). However, let us assume that despite this fact, Region 5 is setting up the second plant.

4. In this Region 5 the two largest cities are Jabalpur and Bhopal. The latter is assumed to be chosen because the high potential production density in the neighboring district Vidisha promises investors that promotional efforts will be more successful around Bhopal than around Jabalpur.

5. This plant, it is assumed, begins with a capacity of about 50 tons per day and it is designed so that an expansion of the capacity may be carried out.

6. For Year B it is assumed that the 10 plants required for all-India are being installed--one plant in Region 6 and two plants in Region 7, with both of these regions preparing for a second and third plant, respectively. In Region 4 at this time four plants have been installed and in Region 5 a second plant is being set up.

7. This second plant, we assume, is built in Jabalpur, as the second largest consumer center for the region. The plant's capacity for the beginning is assumed to be perhaps 50 to 100 tons per day with provision for later expansion.

8. Meanwhile, the operation in Bhopal may have developed a strong local market for its products, and farmers have expanded production, so that the size of the Bhopal plant may have increased from initially 50 tons per day to about 200 tons per day.

9. The exports of Year B from Region 5 into Region 3 (see Appendix, Table 2) of about 40,000 tons of soy meal and of about 15,000 tons of soy oil, may be assumed to be shipped from the Bhopal plant by rail into the consumption center of New Delhi.

10. It is assumed that further developments in the other regions go according to schedule. Then in Year C for Region 5 a third and a fourth processing plant are required.

11. The third plant is assumed to be placed at Kota (Rajasthan) where the potential density of soybean production seems to be sufficiently high. From here the northwestern corner of this region could be provided with soy meal; also the increasing quantities of soy meal and soy oil exported from Region 5 into Region 3 could best be supplied from here on the direct rail connection to New Delhi.

12. The capacity of the Kota plant may be started with 100 tons per day with possible later expansion.

13. The fourth plant to be set up in this time horizon through Year C could be located at Sagar.

14. At this point in time it is assumed that the Kota plant has grown to 100 tons per day or more, the Jabalpur plant has expanded to perhaps 300 tons per day, the Bhopal plant is operating at 350 tons per day, and the plant in Sagar is beginning operation with a capacity of 100 tons per day or more. Thus the total requirement for processing capacity of about 250,000 tons a year would be fulfilled.

15. Exports from Region 5 into Calcutta in Region 1 of about 60,000 tons of soy meal should be shipped from Jabalpur, while Kota and Bhopal would share the export requirements to New Delhi and elsewhere in Region 3 of about 80,000 tons of soy meal and of about 45,000 tons of soy oil.

It should be emphasized that this sketch of a possible development of the soybean industry in Region 5 does not in the least claim to be prescriptive, nor even necessarily desirable. All that can be said is that it would be feasible and in agreement with the average solutions of our spatial equilibrium model, given the basic assumptions for Years A, B, and C.

A number of questions may be raised considering such a development:

1. What is the optimal rate of expansion of an individual plant under the technical restrictions of certain unit sizes of different pieces of equipment, microeconomic constraints of profit maximization, risk aversion and capital restriction, and with the restriction that this plant also must develop the new market?

2. Will the capital be available that is required to achieve this development in a period that corresponds to our time schedule?

3. If the capital were available, would not per capita income in India have to be growing at a faster rate than has been assumed?

4. How should the initial spark be ignited that breaks the vicious circle of farmers not wanting to produce unless a market outlet is guaranteed and processors being reluctant to invest unless soybean supplies are large enough to feed a plant of reasonably large size?

5. How should the market between soybean growers and processors be organized, to reduce risks and to coordinate actions?

It is impossible to deal with all of these questions in detail. The first three are left for further investigation and only the last two will be discussed here because they more directly pertain to the problem of organizing an optimal marketing system.

The Problem of the Initial Start

Suppose a development similar to the one just described for Region 5 is to be implemented. What would ensure that the first processing plant to be built finds a sufficiently large quantity of soybeans in the first year? A capacity of 50 tons per day would require ideally 15,000 tons of soybeans, which would require about 15,000 hectares to be brought under soybeans in that first year.

Even with the most ambitious development program it is impossible to achieve this task in one year's time. Farmers will remain reluctant to grow soybeans until they are sure of a market outlet at remunerative prices, and the investor will not establish the processing plant unless he is sure to have sufficient raw material.

There seem to be three alternative solutions to overcome this problem.

1. Allow for soybean imports for the initial years, while domestic production is promoted to gradually replace the imports.

2. Promote production and start processing with existing solvent extraction or expeller plants; for faster development subsidize farm prices. Then shift processing to a solvent extraction plant especially designed for soybeans.

3. Promote soybean production and store those quantities that are not suitable for seed; subsidize farm prices. Begin processing in a solvent extraction plant when a sufficiently large amount of soybeans has accumulated.

These measures could be taken separately or in some combination with one another. Each of these ways to solve the initial starting problem is costly.

The first solution would favor processing in the vicinity of port facilities--that is, in Regions 6 and 7. It probably would require domestic soybean producers from the beginning to compete against world market prices, unless some type of subsidy is given. Under this condition, rapid expansion of local production of soybeans seems unlikely.

The second method of starting the soybean industry is more difficult to arrange than the first. Managers of the expeller units would have to be convinced of the need to process soybeans under hygienically acceptable conditions and with careful regulation of the heat treatment of the cake, to produce with expellers a partial-fat soy flour that would sell at a premium above the price of cake used for animal feed.[27]

[27] S. W. Williams and K. L. Rathod, A Case Study of Expeller Production of Soybean Flour in India (Urbana-Champaign: University of Illinois College of Agriculture, International Agriculture Publications, INTSOY Series No. 3, 1974).

The already existing solvent extraction operations complain of the under-utilization of capacity, but unfortunately only about 15 percent of the capacity (about 10 plants) is located within our presumed soybean production regions. Soybean processing, which requires additional investment for preparation of the soybeans before processing and for conditioning of the cake for human consumption, could provide these 10 plants with additional business and lower unit costs. As with expellers, management must realize that the value of soy meal lies in its worth as a human food. At this stage of development in India it is not an animal feed.

While the second method may not require subsidies, depending upon how imaginative processors are, the third method of starting a soybean processing industry depends entirely upon public support. Implementation of this method requires a well-coordinated effort of different parties--that is, the government must guarantee and provide funds (directly or via some cooperative organization), a warehouse institution must provide storage, an extension service must provide promotion and inputs, and an investor or a cooperative body of investors must set up the processing plant.

The timing of these efforts is important so that a processing plant of appropriate size goes into operation when a sufficiently large quantity of raw material has accumulated and production in subsequent years can fully supply the plant with soybeans. Under the roof of an enterprising cooperating management which combines these different agencies in one firm, this method could have good chances to succeed.

For all three methods or combinations thereof, an additional device to coordinate the activities of the parties involved are contractual arrangements between soybean growers and soybean processors.

Contractual Arrangements Between Growers and Processors of Soybeans

A necessary condition for a rapidly developing market for soybeans in India is that contractual arrangements between growers and processors be made during the expansion stages of the soy industry. Such arrangements serve to coordinate the actions of both sides and reduce some of the risks faced by both sides from exogenous sources, and by each side separately, from decisions that may be made by the other. The contract should specify the base price to be paid, and the quantity to be delivered (tentatively estimated from the number of hectares to be planted and an anticipated yield). It should also determine time and manner of delivery, manner of pricing for different specified quality standards, time and manner of payment, and penalties for not fulfilling the contract. In addition, the arrangement might possibly include agreements for technical assistance to the grower, and seed and fertilizer to be supplied on credit.

The contract should be designed so that the risks and burdens are shared in fair proportions by both sides.[28] The processor who takes advantage of the growers from his local monopoly position in one year causes his own difficulties the next year, since farmers do not have to grow soybeans.

Contracts to market soybeans may not always be necessary. Certain characteristics have proved to be deterministic in deciding whether, for any agricultural product, contracting in more or less rigid form between the market partners can

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[28]M. Harris and D. Massey, Vertical Coordination via Contract Farming, Misc. Publication No. 1073 (Washington: U.S. Department of Agriculture, Economic Research Service, 1968).

provide an improvement over the open market system.[29] These characteristics indicate that, while for the early stages of marketing soybeans very firm contracts with precise quantity and price agreements are almost indispensable, at later stages, and wherever the crop has become more common, the market probably will function better with less rigid agreements or even without contracts.

Some of the more important of these characteristics for soybean production in India and their effect upon contract marketing are:

The natural risk in producing soybeans. For the Indian farmer, during the first years of growing this new crop the natural risk is rather high, considering the various new cultivation techniques he must learn. In later years the opposite may become true, since soybeans, properly cultivated, have proved to be more tolerant to drought as well as to excessive rainfall than most of the competing crops, such as maize, jowar, moong, rice, and so on.

Capital requirements for producing soybeans. Surveys in Madhya Pradesh of production costs for soybeans on 235 farms in 1970 and 183 farms in 1971 showed that cash expenses for fertilizer, seed, inoculum, and insecticides amounted to approximately 380 rupees per hectare in 1970 and 310 rupees per hectare in 1971. These cash outlays were roughly twice the cash expenditures for purchased fertilizer, seed, and insecticides in producing maize, groundnuts, and paddy (rice), and much in excess of those on jowar, urid, moong, niger, and kodo.[30] With these heavier cash outlays on soybeans, particularly for those who must purchase seed, many farmers will need credit to finance soybean production. A production and marketing contract with the processor could satisfy that need.

The transportability of soybeans. Technically, the transportability of soybeans is in no way different from that of other grains and pulses--although present freight rates on Indian Railways reduce the mobility of soybeans and thus their access to distant markets. This reduces the choice of the individual producer among market outlets and binds him to closer arrangements with the local monopsonistic processor. However, over the long run it is expected that rail rates for soybeans will be changed.

The storability of soybeans. For commercial processing, properly conditioned soybeans are as storable or perishable as are other grains and pulses. It is the storage of quality seed that requires relatively more care and better facilities in order to obtain good germination. Since during the first years of expansion of soybean cultivation the quantity needed for seed makes up a larger proportion of total production than later, there will be a tendency for the grower to depend more on outside storage in the early phases than later, when he will have developed his own storage facilities and gained enough experience to store quality seed.

The general acceptance of quality standards for soybeans. Soybeans are presently unknown in Indian mandi-markets and therefore quality standards have not yet been established. In the long run, however, it is to be expected that

[29] M. von Oppen, "Moglichkeitin und Grenzen der Anwendung vertraglicher Regelungen beim Absatz landwirtschaftlicher Produkte," unpublished dissertation, D. 83 (Berlin: Technische Universität Berlin, 1968).

[30] R. C. Kashive and S. W. Williams, Economics of Soybean Production in Madhya Pradesh (Jabalpur, M.P., India: Jawaharlal Nehru Krishi Vishwa Vidyalaya and University of Illinois/USAID, 1972) pp. 32, 33, 51-62, 100.

merchants will become familiar with the characteristics of soybeans, thus improving acceptance on the open market.

The number of market outlets for soybeans open to the individual producer. At present, as soybeans are a new crop in India, market outlets for individual growers are very limited. Consumption of whole soybeans is not yet accepted and cannot be expected to develop at the same speed as production of soybeans is expected and desired to increase. The desired increase in soybean production and consumption at the greatest speed possible, given the scarcity of time for development in India, will for the near future leave only the alternative of industrial processing of soybeans into meal and oil, and consumption of soy oil in vanaspati and soy meal as such, or in the form of any edible soy product. Therefore, to the majority of soybean growers, under present rail rates the only market outlet is the local processing plant. If rail rates for soybeans are changed, one alternative will be to sell the beans to merchants who are organizing exports into the soybean consuming regions.

The capital requirements for investment and operation of a soybean processing plant. The investment and operation costs for processing soybeans are given in Appendix A. They represent a considerable risk to the investor--especially during the stage when markets for the soy meal have yet to be found and developed--the investor is forced to reduce other risks, such as the risk of uncertain supplies of his raw material.

Government regulation of the market for soybeans. Market regulations enforced by government authorities, and government-guaranteed minimum prices for agricultural products do, theoretically, to some extent replace contracts in marketing the product. The price guarantees for soybeans given by the central government in 1970-71 of 850 rupees per ton and by the state government of Madhya Pradesh for 1970-71 of 1,000 rupees per ton, and the conditions under which the soybeans were actually accepted so far do not seem to attract many producers who, instead, are speculating on using or selling their soybeans as seed for next year's crop. In the future, it is expected that these price guarantees will be lowered so that local processing plants will remain the major market outlet for soybean producers.

To summarize, we expect contractual agreements between soybean growers and processors to be a *conditio sine qua non* for the early phases of developing soybean markets. At later stages a free market system is expected to be the more efficient way of marketing the crop.

CONCLUSIONS FOR DIFFERENT DECISION-MAKERS

At the outset of the study the point was made that the results of the study should provide a guideline to harmonize the individuals' decisions and actions with the requirements of the aggregate economy in developing a soybean industry for India. The results are based upon long-run equilibria. Each set of results for a given set of assumptions represents a maximum welfare solution for the aggregate economy.

If the demand for soybean products develops along the lines that are assumed, for soy meal preferably at a somewhat faster rate,

<u>if</u> the supply of soybeans grows to the extent that it is satisfying this increasing demand at reasonable prices, and

<u>if</u> soybean processing capacity is expanding in accordance with the presumptive locations and average sizes of the results,

<u>then</u> a soybean industry is growing along an expansion path optimal from the aggregate point of view. The general implications for the different groups of individuals involved in carrying out this development are, of course, to make the individual decision such that the resulting action will be based on economic considerations as offered by the study. Some more specific implications are listed below.

<u>Implications for Growers</u>

Contractual arrangements with processors are recommended in the beginning. However, farmers should not try to eliminate middlemen entirely, because later an open market system, involving grain merchants, probably will be more efficient than contract marketing.

As the farmer learns the techniques of growing soybeans he also should acquire experience in storage of soybeans and should provide such storage facilities on his farm or, better, in a cooperatively owned and run godown in a nearby market town.[31] Private storage of soybeans will give the farmer whose market outlets are limited in number some option of when to sell.

<u>Implications for Processors</u>

The processing industry is the key factor in soybean development. It must encourage farmers to expand production; it also must develop markets for soy products that are acceptable for human consumption. An early investment in soybean processing involves many risks and costs which later investors may save. However, the demand situation may be such that quite remunerative prices will prevail during the early stages. Real prices for soy products are expected to decrease gradually over the years.

For most efficient operation, plants should be about the average sizes suggested for the different conditions.

Since results show that for any region over time both the number of plants and their individual size increase, each new plant should be established so that a later expansion in capacity is possible.

Fair contracts with soybean growers should divide the risk in fair proportions between grower and processor. This year's degree of satisfaction among soybean producers determines next year's supplies. In the stage of expanding production and processing, this reality should considerably restrict the conduct of the monopsonistic processor and he should be aware of it.

Market research should be designed to explore the local demand potential first. Where the production potential is estimated to grow relatively slowly (because of restrictions in plant size, capital, and so on), emphasis should be placed upon development of high-value products. Conversely, where a rapid increase

[31]For more on the complex problem of storage and other points concerning regional development, see E. A. J. Johnson, <u>Market Towns and Spatial Development in India</u> (New Delhi: National Council of Applied Economic Research, 1965).

in supplies and in processing is possible, production and marketing of relatively unrefined soy flour is preferable, building up a general demand for the product in low-income classes.

Implications for Consumers

Soybeans are a rich source of vegetable oil and of high-quality protein.

Consumers of the intermediary soy oil are the vanaspati factories. They should be prepared to use a larger proportion of soy oil in the production of vanaspati, and any government regulation of their operations should facilitate their doing these.

Consumers of the intermediary soy meal are the various bread, sweets, baby and child-food industries, and public eating places such as restaurants, hotels, hospitals, and the like. These should be encouraged to use soy meal as a cheap raw material of high nutritional value.

Consumption of soy meal as a final product in households should be encouraged. Defatted soy meal has been shown to be fully acceptable to consumers if used in a 20 percent fortification mix added to wheat flour in chapatis.[32]

Implications for Public Decision-Makers

The general objective of public decision-makers should be to support the establishment of a soybean industry in India as a desirable development wherever and whenever support is needed.

Potential or actual processors of soybeans should be allowed to obtain credit under preferred conditions.

Public feeding programs, such as school lunch programs, should utilize soy products to improve nutrition and to familiarize consumers with the new product.

Minimum prices should be guaranteed, market regulations established, high-quality seed, inoculum and extension service made available. Rail rates on soybeans should be lowered to a level corresponding to rates on grains and pulses. If rates for oilcakes are to be raised, that change should not be made until rates on soybeans are reduced to the indicated level.

The decision about rail rates for soy meal and soybeans should be made soon, as the uncertainty about it impedes investment planning.

Implementation of extensive further research is necessary for a rapid and organized development.

Summary

There are good reasons to expect that soybeans could develop into a major food crop in India. On the one hand, the potential for growing soybeans is very great in North Central India. On the other hand, the demand for products for which soy products (that is, soy meal and soy oil) are expected to be substitutes is increasing with population increase and growth in income per capita. Soy oil, as a substitute for groundnut oil will immediately find a market outlet in the

[32]K. L. Rathod and S. W. Williams, "Acceptance of Soybean-Enriched Wheat Flour for Use in Chapatis," Indian Journal of Nutrition and Dietetics, Vol. 10, pp. 18-26 (1973).

vanaspati industry; soy meal, as a product similar to the widely used gram flour, promises a strong demand, first in the form of flour as such, and later, after some promotional effort, in the form of more sophisticated higher valued products. On these grounds we expect that soybeans can contribute substantially to an urgently needed improvement of the average Indian diet, by adding calories and high-quality protein.

However, potential production of soybeans and potential consumption of soy products are most likely to be realized if proper marketing channels develop in a careful and organized way. India is short of investment capital. The problem is to develop optimal marketing channels for soybeans in India in a manner that will encourage a judicious expansion in production. The main objective of this study has been to determine optima for location and size of processing plants for soybeans.

To solve this problem a spatial equilibrium simulation model was developed consisting of two parts: (1) a quadratic programming model of interregional trade (to determine optimal flows of soybeans, soy meal and soy oil among seven regions, accompanying price levels and processing capacities required per region on the basis of regional processing costs and other input data) and (2) a single equation location model (to determine optimal number and size of plants and processing costs per region on the basis of regional quantities of soybeans assembled and processed and of soy meal distributed). Each model part is dependent upon the other as the optimum solution of the other. By means of iterative, alternative applications of both models their simultaneous optima are approached asymptotically.

The inputs into this model are in the form of fixed coefficients and functional relationships. Regional supplies of soybeans, based on a set of assumptions on location of soybean production, are taken as given quantities. Regional demands for soy meal and soy oil follow tangents to exponential functions from estimated damand functions for their two substitute products, the demand for gram flour being a function of price and the demand for groundnut oil being a function of price and income per capita. Transportation costs for interregional trade are in terms of given freight rates between all possible pairs of reference points of the regions. Transportation of soy meal and soybeans within the regions is mainly carried out by truck, and truck rates are assumed to be a linear function of distance. Processing costs were found to be a nonlinear function of size of the processing plant.

By setting four model years (Year A = 1970-71, Year B = 1973-74, Year C = 1978-79, and Year D = 1988-89), by assuming certain increases in population and income per capita over time, and by postulating an increase in soybean production over time, optimal solutions were found for two sets of rail rates: (1) the presently applied rates, soybeans being transported at rates (100 percent) which are higher than for soy oil (96 percent) or soy meal (44 percent) and (2) an anticipated set of rates, with rates for soy oil unchanged (100 percent) and the rates of soybeans and soy meal being equal (48 percent). In addition, variations to these input sets were run, assuming soybean production to increase faster/slower than the growth of population and income, and also assuming exports of soy meal to the world market.

The model is sensitive to changes in the constraints and yields feasible results. Under present freight rates of rail transport, processing plants should be located in the vicinity of soybean production only. All-India average capacities would grow from about 50 tons per day in Year A (two plants for all-India) to about 150 tons per day in Year B (10 plants), to about 220 tons per day in Year C (20 plants) and to about 360 tons per day in Year D (47 plants) (see Table 11).

Under the anticipated rates, after soybean production has increased sufficiently, additional plants should be located also in the consumption regions. All-India average capacities under the anticipated rates of rail transport would be optimal at about 50 tons per day in Year A (two plants), 120 tons per day in Year B (12 plants), 180 tons per day in Year C (25 plants) and 300 tons per day in Year D (60 plants) (see Table 11).

An example is given of how such a development for a particular soybean production region could be visualized in terms of setting up specific sizes of individual plants and their location. The problems of the initial start and of the coordination of activities require major attention. Other problems--such as storage, the growth of the individual firm, and the relation between plans for a soy economy in India and the Five-Year Plans of the country--require further research, as will some theoretical problems arising from this study.

APPENDIX A

Appendix Table 1. Estimates by Three Bombay, India, Engineering Firms of Costs of Investment and Variable Costs of Soybean Processing Plants of Various Capacities.

Plant Capacity	Investment Cost[a]			Variable Cost[b]		
	IAEC	DeSmet	Servotech	IAEC	DeSmet[c]	Servotech
(tons/day)	(million rupees)			(rupees per day)		
10	1.2	1.45		1,150	430	
20	1.8	1.8		2,119	800	
50	3.0	2.5	3.2	3,800	1,204	1,720
60		3.5			1,796	
100	4.0	4.4	5.0	6,525	2,740	2,750
150		5.9			4,080	
200	6.0			12,425		
250		9.1	10.0		6,375	5,625
500		16,5	18.0		12,670	9,800
750			25.0			13,280
1,000			33.0			16,550

[a]Includes plant, machinery, auxiliaries, and buildings.
[b]Includes consumption of solvent, steam, electricity, and costs of operating, handling, and sundries; 300 work days per year.
[c]Does not include costs of handling and sundries.

APPENDIX B

Estimated Prices

Appendix Table 2 presents the prices of the three soy products which accompany the various systems of processing and interregional trade. These prices are in terms of actual prices based on the all-India General Price Index (working class) for 1970 of 218.[1] The appropriate quality adjustment for differences in quality characteristics between the soy products and the respective products for which these are substituting were made by adding a grinding margin of 60 rupees per ton to the price of gram and by subtracting from the price of groundnut oil a margin of 268.8 rupees per ton for higher costs of processing soy oil into vanaspati (compared with groundnut oil). These two adjustments just offset each other in their effect upon the price of soybeans.[2] To the extent that these adjustment values may change over time, different margins may be assumed without contradicting the optimal locational pattern. Adjustments of this kind amount to adding or subtracting relatively small constants to the intercepts of the demand functions, and have little or no effect upon the spatial equilibria of interregional trade systems.

The reader should be cautioned not to take these prices as predictions of the future. The estimates of quantities of soybeans supplied and the two demand factors, population and income, are based upon more or less arbitrary assumptions for the model years and variations thereof. Consequently, the estimated regional levels of prices for soybeans, soy meal, and soy oil also are arbitrary.

The prices are generated automatically as by-products of the calculations of the various spatial equilibria. They are presented here for the more methodologically interested reader who may want to check the implication of one or another assumption upon the behavior of the prices relative to each other.

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[1]Government of India, Ministry of Finance, Department of Economic Affairs, Pocket Book of Economic Information (New Delhi: Government of India Press, 1970).

[2]The conversion rates of soybeans are 17.7 percent for soy oil and 79.3 percent for soy meal.

Appendix Table 2. Regional Price Levels for Soybeans, Soy Meal, and Soy Oil for Different Years and Variations Under Present (P) and Anticipated (A) Rates of Rail Transportation in India.

Product	Region No.	Year A P = A	Year B P	Year B A	Year C P	Year C A	Year D[a] P	Year D[a] A	Variation I S:[b] Year B D:[c] Year C P	Variation I S:[b] Year B D:[c] Year C A	Variation II S:Year C D:Year B P	Variation II S:Year C D:Year B A
		(rupees per ton)										
Soybeans	1	(1,121)[d]	(977)	(968)	(844)	841	(497)	495	(1,232)	(1,214)	(804)	706
	2	(1,121)	(974)	970	(841)	839	(517)	508	(1,230)	1,221	(706)	706
	3	(1,112)	(935)	931	(798)	787	(471)	471	(1,192)	1,182	(663)	652
	4	1,088	900	898	754	759	412	410	1,158	1,151	621	623
	5	1,083	878	876	741	732	434	427	1,138	1,129	606	597
	6	1,086	881	878	743	735	471	475	1,138	1,131	608	599
	7	1,081	892	892	761	759	438	429	1,147	1,142	623	628
Soy Meal	1	(745)	738	(740)	683	690	536	532	(742)	740	675	677
	2	(745)	721	716	666	662	543	532	723	721	655	653
	3	(745)	699	694	638	629	514	514	705	701	629	616
	4	740	683	683	614	622	464	407	688	688	603	609
	5	731	653	664	592	598	488	495	660	670	583	585
	6	736	653	657	594	590	532	532	660	664	583	577
	7	734	653	660	598	607	477	467	655	654	588	598
Soy Oil	1	4,370	3,437	3,435	2,513	2,506	945	945	4,462	4,462	1,807	1,800
	2	4,364	3,520	3,511	2,585	2,598	1,017	1,017	4,534	4,534	1,881	1,892
	3	4,318	3,385	3,385	2,461	2,454	893	893	4,409	4,409	1,756	1,748
	4	4,191	3,261	3,258	2,336	2,328	769	769	4,285	4,285	1,630	1,623
	5	(4,207)	(3,274)	(3,274)	(2,349)	(2,343)	(782)	(782)	(4,298)	(4,298)	(1,643)	(1,637)
	6	4,209	3,276	3,278	2,352	2,365	784	784	4,303	4,303	1,647	1,658
	7	4,196	3,341	3,343	2,417	2,430	850	850	4,366	4,366	1,713	1,724

[a]Assumes export of soy meal from Region 6 to the world market.
[b]Supply.
[c]Demand.
[d]Prices in parentheses are for regions and situations in which the solution did not show the product.

APPENDIX C

Suggestions for Further Research

Practical Problems

1. Specify more exactly the potential location of production.

2. Determine the production function for soybeans at different locations, taking into account risk aversion and regional weather factors.

3. Investigate market demand for soy meal and prod cts made of soy meal, by means of acceptance studies at various levels of consumption--for example, households, roadside restaurants, hospitals, schools, and so on.

4. Determine improved demand functions for soy products.

5. Determine the optimum path of growth of an individual processing plant, assuming different restrictions in supply, demand, credit, risk aversion, technical requirements of unit sizes, and so on.

6. Evaluate capacities and determine costs of alternatives for storage of soybeans (farm, market town, processing site) in relation to storage of other grains over the seasons. Develop a system of storage of foodgrains.

7. On the basis of research in points (1) through (6) and (8), improve the results of this study and compare them with actual development.

Theoretical Problems

8. Program the entire spatial equilibrium model into one routine and apply with improved input data.

9. Develop a dynamic model of a spatial equilibrium.

Figure 1: Flow Chart of a Spatial Equilibrium Model to Allocate Soybean Processing Plants.

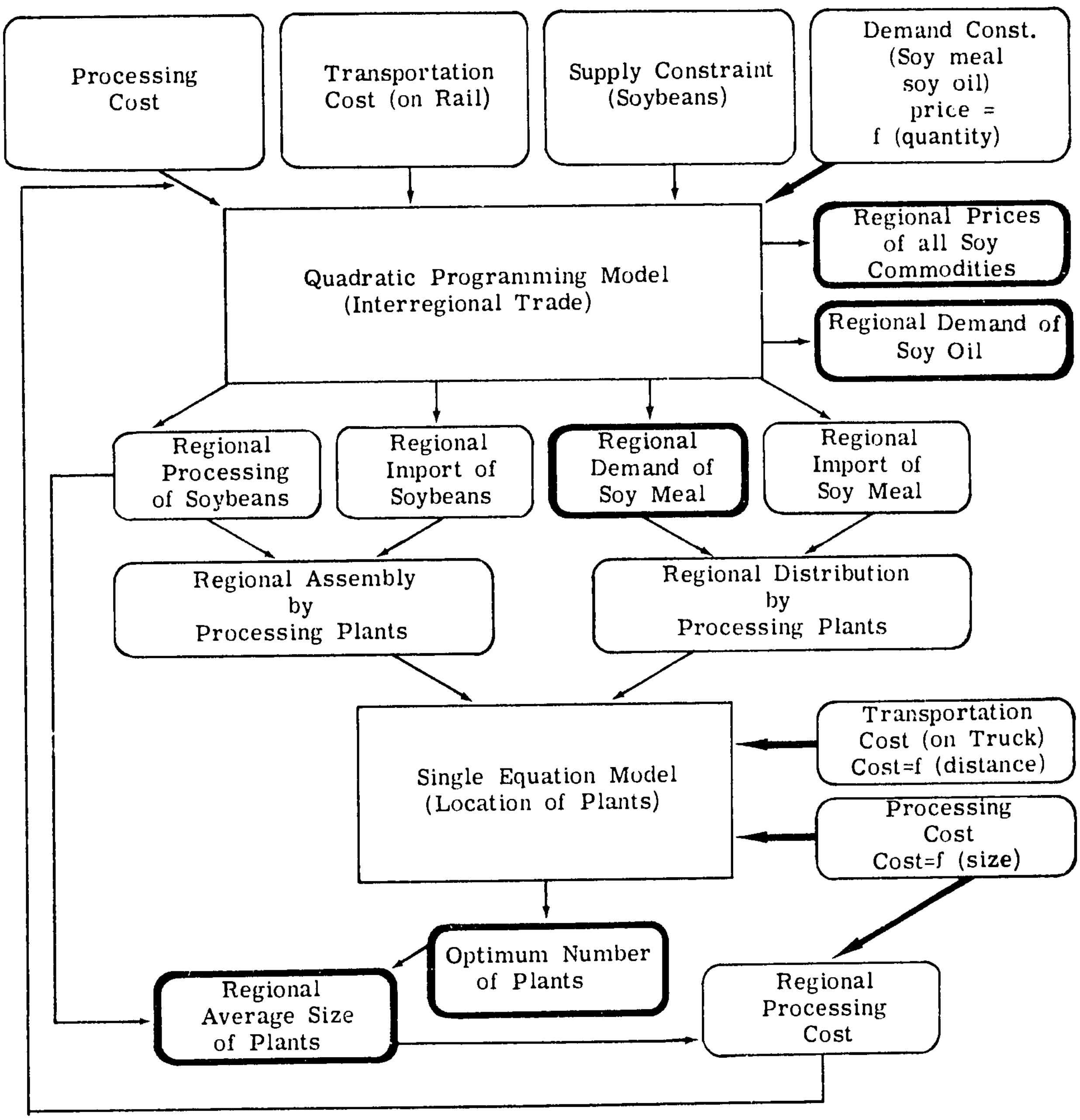
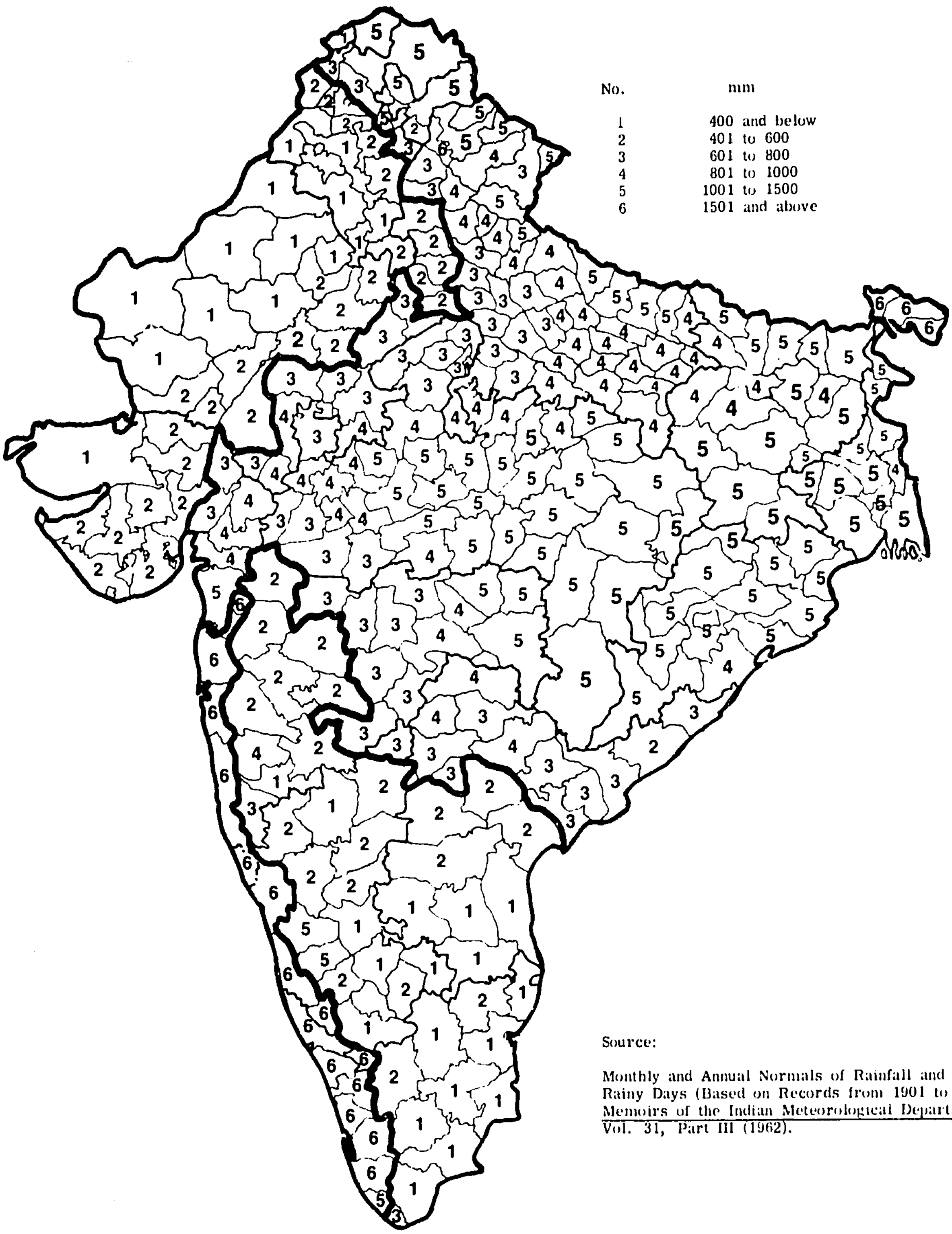


Figure 2. Average Rainfall (June-September)



Source:

Monthly and Annual Normals of Rainfall and of Rainy Days (Based on Records from 1901 to 1950). Memoirs of the Indian Meteorological Department, Vol. 31, Part III (1962).

Figure 3. Potential Soybean Production Density (tons per square kilometer), Demarcation of Regions, and Reference Points

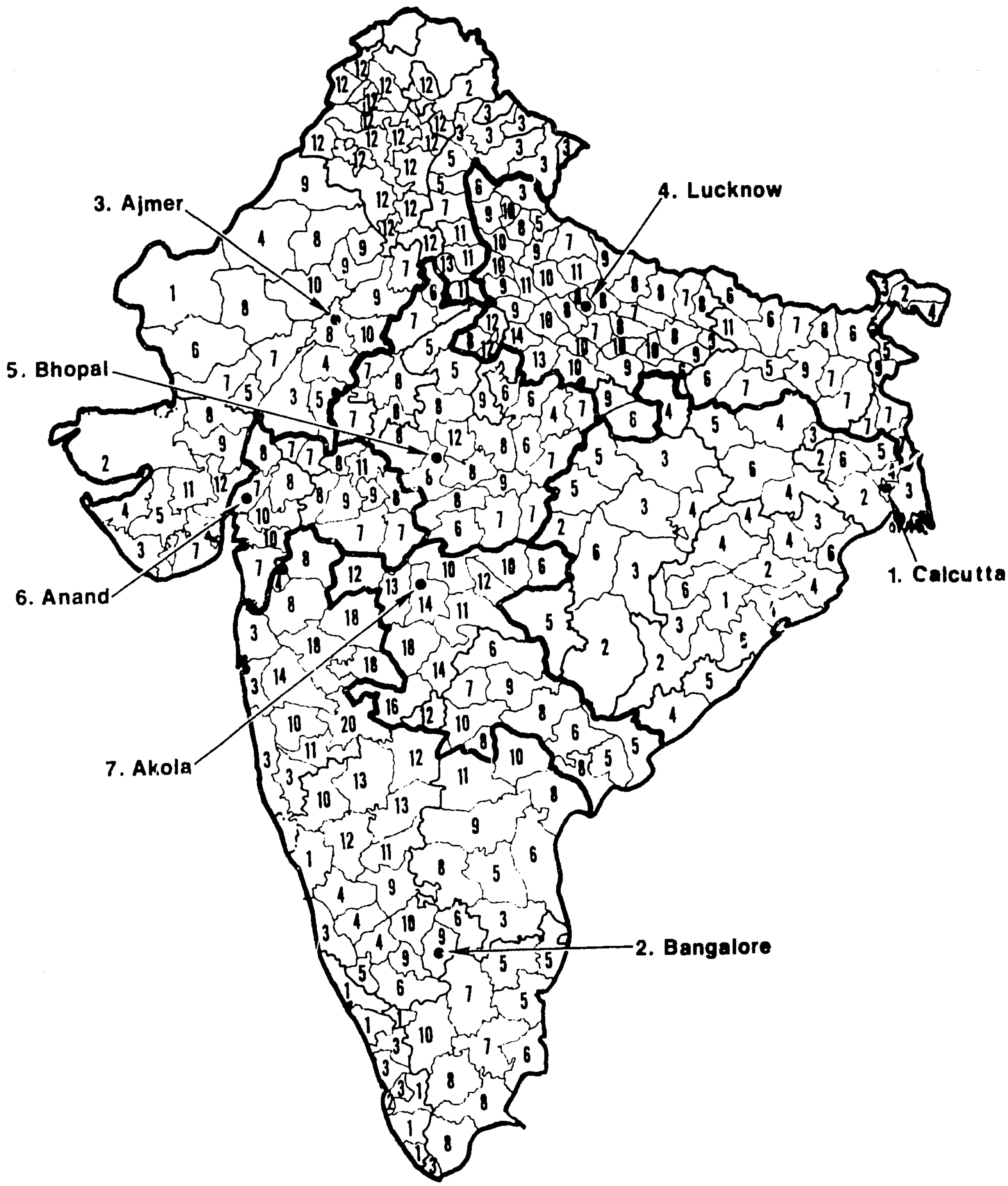


Figure 6. Freight Rates for Different Modes of Transport in India

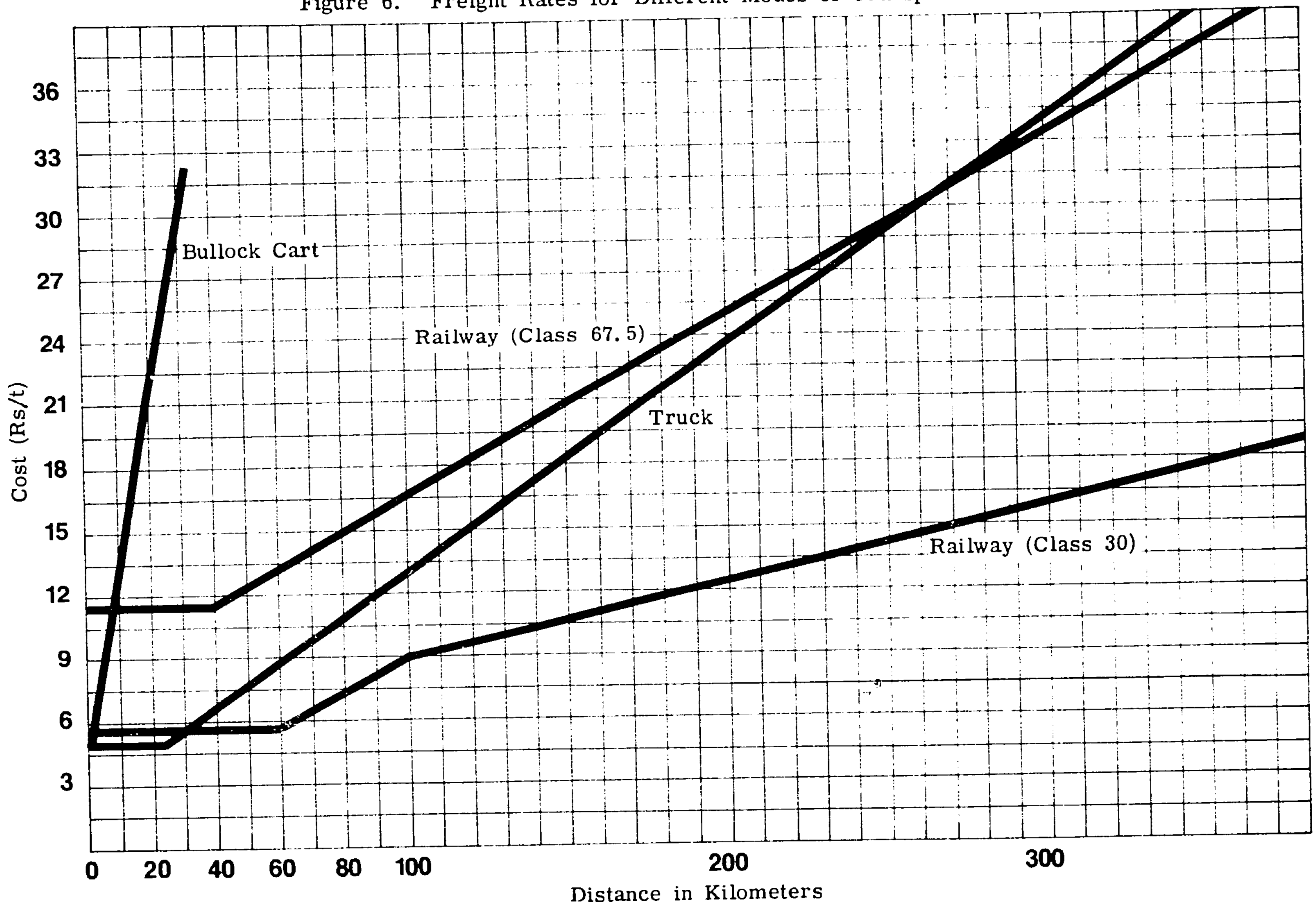


Figure 5: Demand Functions of (a) an Original Product and (b) a Substitute for the Original Product.

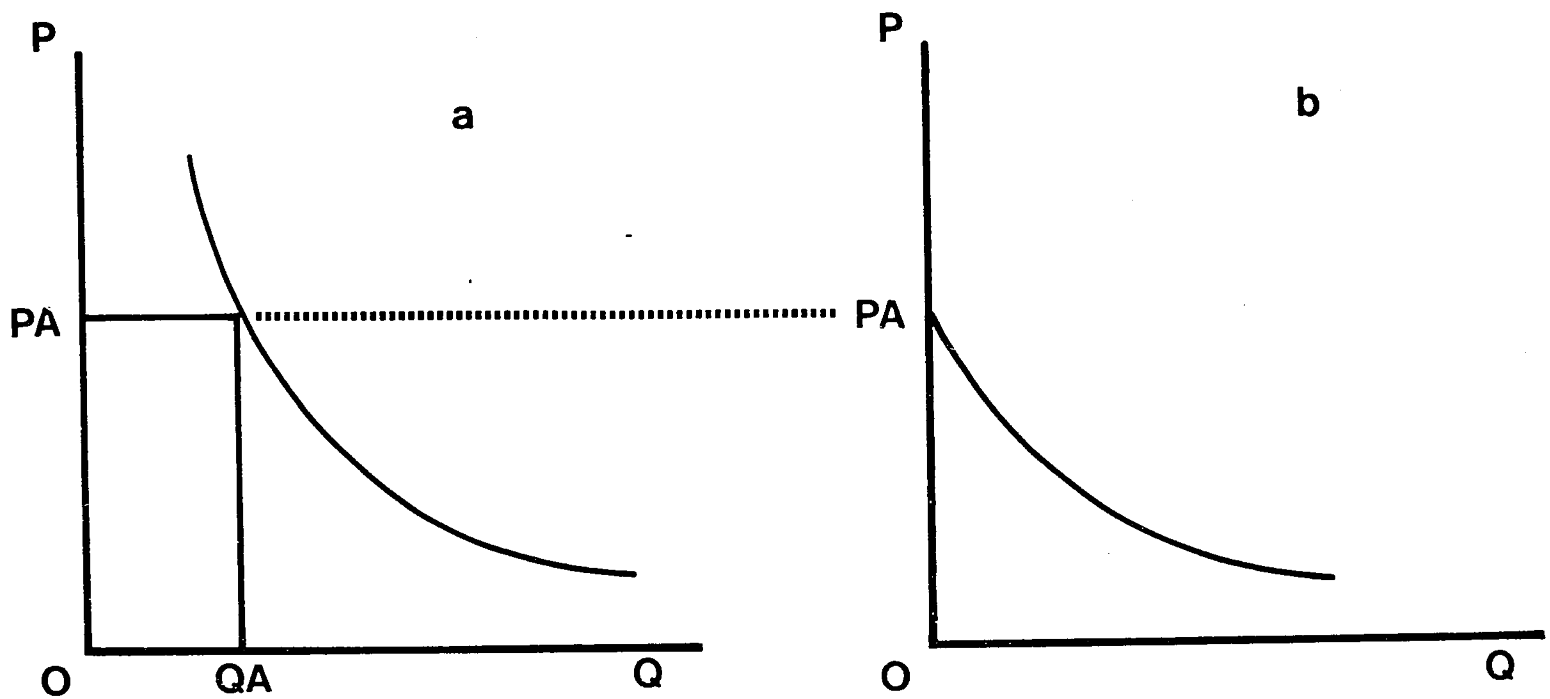
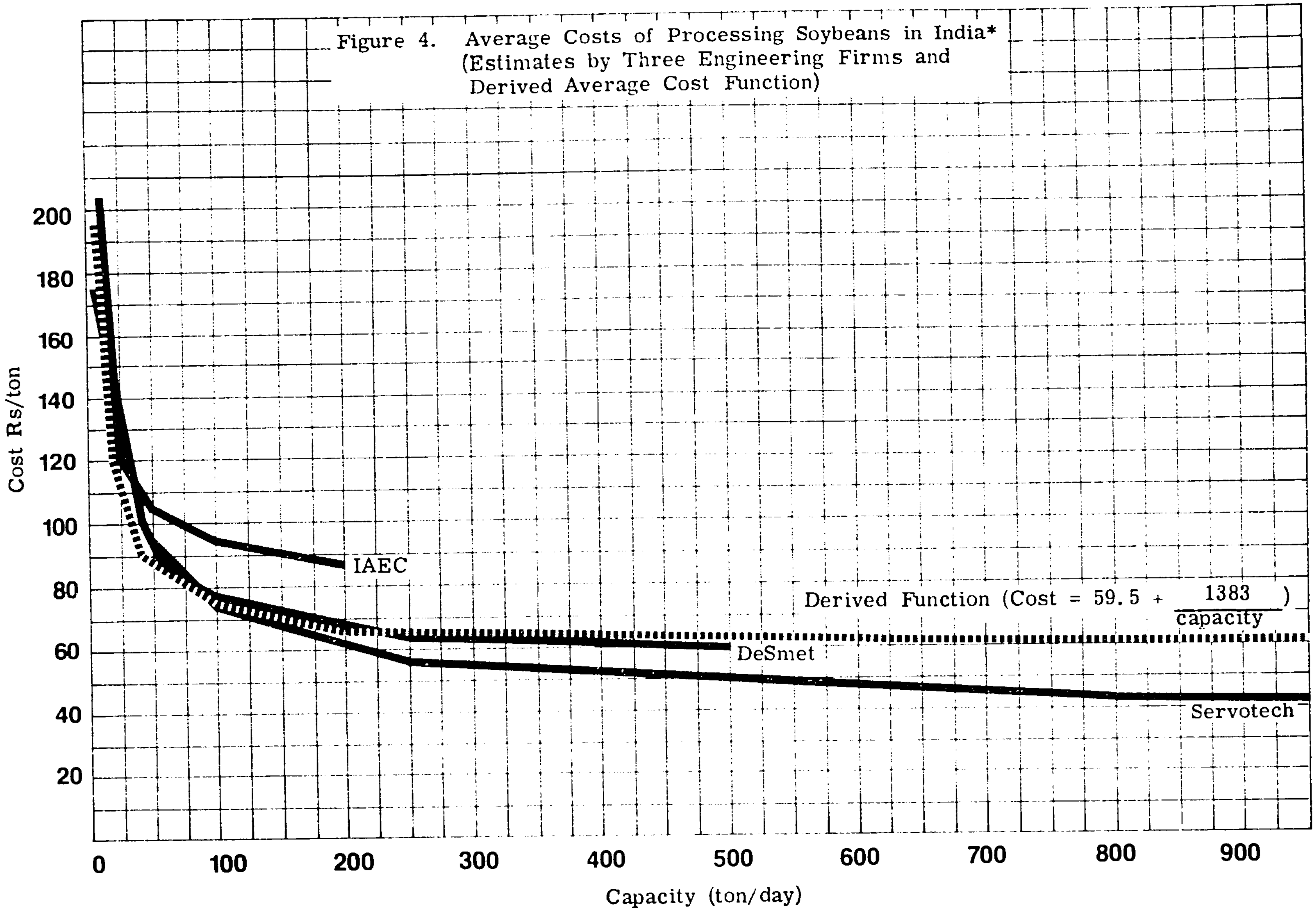


Figure 4. Average Costs of Processing Soybeans in India* (Estimates by Three Engineering Firms and Derived Average Cost Function)



*Assuming 300 Workdays/Year

Figure 7. Map Region 5 (Bhopal)