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SOME CONSIDERATIONS ON THE RELATION OF INDUSTRIAL PROJECTS WITH TRANSPORTATION SERVICES

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I. Scope and Limitations of the Study

1. This study analyzes some of the relations that link an industrial project to transportation services. Its purpose is to consider in particular the areas in the process of development and economic integration, as exemplified by the Central American countries.

General considerations are formulated with respect to the degree to which industrial development depends on transport facilities and, more specifically, with respect to the factors that must be taken into account in the evaluation of industrial projects.

The influence of the availability and cost of transportation are taken into account as one of the dominant factors in the location of industrial projects. At the same time, the relations of the various means of transportation with different types of industries and levels of production, will also be analyzed.

2. The concept of underdevelopment always implies deficiencies in transportation means. These deficiencies originate in the transportation infrastructure itself as well as in the specific services. It is quite common to find large regions, some of them rich in economic potential, isolated for lack of a network of routes. However, the available infrastructure facilities are generally under-utilized, due to the present poverty of the regions, and the consequent limitations of the markets' economic potential.

Another common element to all under-developed countries is the strong pressure that exists in them to attain rapidly effective economic development. The accelerated progress of communication means reveals to the peoples of these poor countries the possibility of a better way of life, which constitutes an aspiration that cannot be delayed.

3. The scope of the study covers only those areas in the process of integration. It considers countries whose development is limited by their relatively small area, with borders arbitrarily separating regions that are naturally complementary. The study refers to a region that is creating, through its own integration, a larger market, and initiating the process of import substitution of manufactured products, as well as a base for larger exports of products outside of the area.

4. Such is the case of the Central American region, in which, during the last ten years, a Common Market has been formed, involving the progressive integration of five countries in the process of development.

The countries of this region have naturally tended to unite, not only for common economic interests, but also because they are conscious of constituting de facto, a common nationality, racially homogeneous, with similar culture and customs.

One of the premises of Central American economic integration requires that attainement of a balanced regional development, avoiding artificial concentration of industry in certain countries. This political decision constitutes a basic orientation of the pursued model of industrial development.

II - Measurement of the External Economies Created by Transportation

1. It is impossible to isolate the effect caused by transportation in the formation and development of industrial enterprises, due to the fact that the variety of factors that affect industry are intimately related among

themselves. Consequently, it should be noted that thefact of limiting the present study to the specific impact of transportation does not imply lack of acknowledgement of the whole series of factors that must also be considered and which must be conjugated in order to obtain a more accurate evaluation of any industrial project.

The measurement of the external economies - positive or negative - generated by transportation systems to an industrial enterprise, involves many difficulties and uncertainties. Nevertheless, the qualitative appraisal, and when possible the quantification of these relations, is indispensable to the project analyst.

It is always hard to gauge influences such as those that may result from the establishment of heavy industries on future transportation costs. More so in under-developed countries, where it is difficult even to obtain basic cost statistics for different transportation means.

In areas of rapid growth, the availability and cost of transportation frequently varies. For this reason it is of less importance, for example, to introduce technical refinements in methods for analyzing the optimum location of a particular industry, than to delve deeply into everything that is essential in the present and future situation of transportation means in general, as well as their global effect on a specific industry.

When considering the influence that transportation costs may have on an industrial project, the analyst must employ real values. Frequently, however, the rates are not derived from real costs. For example, in - under-developed countries, the lack of legislation with respect to cargo transportation, or its insufficient enforcement, in practice, foment the establishment of numerous transport enterprises of minimum size, whose rates are fixed in a rather arbitrary manner. In some cases, these rates do not cover total outlays, as they do not permit amortization of the depreciated vehicles. Such rates contribute to artificially distort the structural forces of industrial development that are originated by the transportation system. Therefore, if the rates cause losses to the transportation enterprise, or excessive profits, industrial projects must be evaluated with basis on real transportation costs. This practice is indispensable in the analysis of the advisability of establishing an industry, from the point of view of the national economy as a whole.

III - Effects of the Availability of Transportation Services

1. Under-developed countries in the process of integration are characterized by their lack of efficient interconnected transport systems, since, in general, their route structures have been directly and independently oriented towards the great export and import markets. It is interesting to note that more than 90% of the goods exchanged among South American countries, are carried by sea because of the lack of adequate internal services.

The deficiency in transportation means limits the mobility of production factors and, consequently, the size of the economic area.

The scarce labor force with a certain degree of technical qualification, travels very little because of the lack of adequate communication among regions that are not yet integrated. Obtaining ordinary labor, however, presents no real problem, even for the larger industrial projects, because of the abundance of human resources in poor countries and, also, because industries are generally established in sites with economic access to large population concentrations.

2. When considering the possible location of an industry, the analyst first examines the transportation means available, at present or in the near future, in a given region, as well as the existence of alternative means and of rapid, regular and reliable transportation systems. Transportation cost in itself, often difficult to determine, may have less influence on location, particularly if it represents only a small percentage of the total cost of the product.

In order to insure input and product transfer, large industries prefer some times, to include transportation services in their industrial projects. Often, it is also justifiable for an industrial enterprise to provide - transportation for its labor force in order to assure and facilitate its access to the factory.

IV - Considerations on Transportation Costs

1. Optimum location of an industry, from the transport cost point of view, presupposes minimum total costs of the acquisition of raw materials and of the distribution of the finished product. The greater percentage of these transportation costs in relation to the total sales price, the greater must be the care observed in their evaluation. Such is the case, for example, of petroleum derived fuels, whose transportation cost represents, in some countries, more than 40% of their total cost. On the - other hand, transportation costs that turn out to be very small in relation to manufacturing costs, may be immaterial and sometimes, even be absorbed by the manufacturer.

The integration of under-developed countries is always hampered by the lack of modern transportation means and by the inevitably high transportation costs. Even when, for example, good highways are available, excessive distances and the long trips cannot be avoided. The scarce economic potential of a region and a low density network of routes, tend to reduce the utilization of transportation means. Participation of the transportation sector in the total gross domestic product, in under-developed countries, usually varies between one and five percent, while in countries with higher incomes, it reaches values between 7 and 10 percent.

2. The various transportation means offer different unit rates according to the transportability of the cargo, the type of route, the distance and the traffic's intensity.

It is common knowledge that different types of materials are subject to different unit rates. Factors such as weight, volume, perishability, value, fragility, etc., substantially affect the cost of unit transported. Transportation without transhipment of large quantities of the same material, organized so that vehicles may be fully loaded, lowers costs substantially.

However, variations in costs are usually less in under-developed countries, since expenditures corresponding to labor are also lower and, therefore, savings or additional requirements of this input, represent more limited expenses. The additional cost of transshipment is generally lower in a country that has an abundant labor force, as the supplementary outlays of hiring an extra laborer, or the time factor costs, may very well turn out to be insignificant within the total transportation costs.

In countries where labor is expensive, the differences in highway transport costs increase significantly according to the different types of roads.

Rates charged for cargo on a first class highway may very well be less than half of the costs corresponding to a secondary, unpaved road. On the other hand, in countries where the price of labor is small in relation to total cost of transportation, differences in costs resulting from the various types of roads are much less. For example, in Mexico only a 25% increase in rates for cargo transported on unpaved roads has been authorized.

Attention should be called to the fact that abrupt topography lengthens the distance of the routes, particularly in the case of railway transportation, and at the same time involves higher maintenance costs. All this bears direct effect on transportation costs.

Unit costs of transportation tend to decrease in inverse proportion to an increase in the distance travelled. This effect may well be more pronounced in under-developed countries, where the proportion of fixed expenses is usually greater, and these, by their very nature, remain practically constant for any distance. Consequently, short runs tend to be much more expensive per unit transported, than long ones.

Often rates change according to the direction in which the cargo is being transported, the variation corresponding to the traffic's intensity. Rates towards a port may, for an equal distance, be different than those applied to merchandise coming from the same port. Other factors that can also produce periodical variations in rates, are the seasonal peaks in traffic, which may be very pronounced and of short duration in one-crop countries, coinciding with the most active period of agricultural harvest.

Finally, it should be pointed out that in countries where transportation has not developed sufficiently, it is normal for rates to be regulated, not so much on the basis of a real costs analysis, as on negotiations between transportation users and suppliers, with rather arbitrary variations determined by the influx of competition.

V - Industrial Projects and Transportation

A. Optimum Location of Industry

1. The systematic and rational analysis of the optimum location of an industrial project begins with the quantification of the following variables: raw materials, fuel, energy, water, labor and, particularly, transportation means. These factors are combined in concordance with the different location possibilities for the establishment of a factory, as well as according to the different production and profit levels that are obtainable - all in relation to the perspectives offered by the market. The ideal location will be that which minimizes total production and transportation costs.

The analysis of the combinations of these locational forces must be made keeping in mind - especially when countries in the process of rapid development are being considered - the variability and uncertainty of projections and the effects that the future establishment of related industrial complexes or competitive industries, may have on the area. At the same time, environment factors that provide well-being and comfort to the labor force, - such as personal services, climate, etc., must not be overlooked.

2. The effects of transportation development on the process of industrial expansion vary within the various zones of a region. The central areas, where the transportation network is denser, are decidedly favored. To the availability of all types of services and labor, are added in these areas, the effects of the formation of industrial complexes, the greater capacity to save required for investment in new industries or for replacement of equip-

ment, the concentration of incomes and salaries, and the expansion and greater density of markets; all of which creates a "virtuous circle" of concentration of advantages that contribute to accelerate the industrial development of the favored region.

On the other hand, those zones with a lesser availability of transportation services, may suffer adverse effects of arrested growth, or even a retrocession in industrial development. Such is the case in the majority of secondary cities in underdeveloped countries, not able to accumulate enough potential advantages in comparison with these offered by the capital city. Often, the physical linkage of a medium size - town with a country's principal city, cuts short the smaller town's industrial growth, draining towards the greater urban center, its capital, labor and, what is even more important, its enterpreneurial capacity. Once the protective barrier provided by high transportation costs is lost, many small industries that exist in the smaller center find themselves unable to face the strong competition of large enterprises.

3. High transportation costs, characteristic of under-developed countries, reduce the economic radius of accessibility to the markets, and at the same time, limit the possible supply sources. Thus, there results less concentration of industries near the sources of raw materials, or in the large markets.

If difficulties caused by frontier barriers come into play, they contribute to increase, even more, transportation costs, and therefore, create an additonal parameter in industrial location. Even in cases when merchandise transported from one country to another is not subject to tariffs, the delays and inconveniences created by customs inspections, contribute to increase, substantially, transportation costs. This is one of the reasons why states tend towards self-sufficiency, limiting their markets and areas of supply of raw materials, to the region confined within their own national borders. This situation, in addition to restricting the size of industries, influences their location within a region.

4. In the previous chapter we have seen the great diversity and variability present in transportation costs. When the scope of alternatives that transportation may offer to an industry are analyzed, pariicular importance must be given to the rapid changes that may occur in a country in the process of development and the additonal effects that industrial development itself may cause. It should be pointed out that past experience has shown that in under-developed countries, industries usually adapt to the existing transportation facilities, and not vice versa: the transportation arteries constructed by the state determine possible location and define the boundaries for the development of the majority of industries.

5. An enterprise always tries to locate itself so as to take optimum advantage of the transportation means available.

It is obvious that an industry must be established in a site with immediate access to transportation routes. In under-developed countries, this greatly reduces location alternatives, in view of the limited extension of transportation network.

The junctions where several supply lines coincide for various markets, or towards which raw materials may flow, are favorite sites for establishing certain types of industries, particularly in those cases where this type of location makes possible the elimination of costly transhipments.

Frequently, ports offer, to industries that import raw materials, the double advantage of being transportation junction centers and, at the same time, permit those industries to take advantage, in some cases, of the low rates assigned to traffic moving towards the consumption centers, which are the result of an unbalance in the traffic flow.

6. The locational theories which show that transportation is a determining factor for the establishment of an industry, favoring sites close to markets, or to sources of raw materials, are well known.

The differences, in weights or volumes, of the materials that enter a factory, in relation to its products, represent proportional differences in transportation expenditures, which tend to orient industries towards the markets, or towards the sources of raw materials. In this manner, great decreases in weight and volume during the manufacturing process, as in the case of extractive industries, tend towards their establishment near the sources of raw materials. On the other hand, when the weight or volume of the finished product is greater than the weight of the raw materials transported, it is obvious that location near the markets is more favorable. This is the case of industries when the manufacturing process requires the addition of water, such as soft-drink bottling plants.

The differences in rates per unit transported, corresponding to inputs and outputs of a factory, also create locational tendencies. For example, when the transportation of finished products is cheaper than the needed supplies, as in the canning of food products, it is more advantageous to - locate the industry close to the source of raw materials.

The opposite case, that is, favorable location near the markets, often occurs in manufactures that require a high degree of elaboration, the final product of which, causes transportation expenses much greater than those of its raw materials, for example, the manufacturing of furniture, shoes, clothing, etc.

7. Competitive industries distribute among themselves a region in marketing areas of variable sizes and shapes, resulting from the different

combinations of production and transportation costs.

Uniform cost lines, in relation to transportation, do not expand uniformly and concentrically around a site, but rather broaden like tentacles along transportation routes. Often, an industry near a good - road, attains access to marketing areas quite distant from its site.

High transportation costs permit small producers, with disadvantages in their manufacturing costs, to establish their own limited distribution areas. A lowering of transportation costs tends to expand market areas and allow, many types of industries to obtain the consequent economies of scale. These expansions of markets often stimulate, through competition, greater production efficiency.

8. Any improvement in transportation services, as well as any change in cost-structure, tends to alter the process of industrial development. In under-developed countries, the changes are usually of greater importance. Large inaccessible regions may be incorporated into markets through the construction of a highway or railway. By the same token, the opening of territorial borders and the possibility of transporting merchandise between countries, modify the locational structure of industries in a region.

In general, the development in transportation means has followed a certain sequence parallel to the technical evolution achieved in this field. First, ports were developed a round maritime transportation, then followed the era of the railways, recently, automotive transport has achieved a major role, and finally, also air transportation. At the same time technological innovations have been improving and lowering costs of each of the transportation means. The under-developed countries have the advantage of being able to utilize the latest advances attained in the richer countries without incurring the high costs of scientific research. In this manner, they some times pass, directly "from oxcart to jet", in a very short period. In view of the social efforts that these changes may involve, it is up to the technicians in poor countries to study carefully the proper way to gain profit from, and adapt to the new medium, the available developments, without incurring in inconveniences that may well be greater than the advantages themselves.

B. Different Types of Industries

1. For certain types of industries, transport means are a decisive factor. Under this classification fall the industries that require the movement of large volumes of materials, of low value in relation to their weight, for example, fertilizer plants, pulp and paper industries, steel mills, petroleum refineries, etc.

Unfortunately, these industries are, in many cases, the same ones that favor large scale operations. In countries where transportation is expensive, and have markets of low density, the manufacture of this type of products is nearly always accomplished at less than optimum scale. The tendency to obtain greater efficiency through large installations is not attained in markets limited by high transportation costs. This has contributed, among other non-economic causes, to the establishment of five petroleum refineries in Central America, for a present market of approximately 45,000 barrels per day, which, under more favorable conditions, could have been supplied by one plant alone. In this industrial process, the sum of all transport costs involved in the production and distribution of refined products, reaches 40% of the total cost. Therefore, this factor becomes dominant in determining a favorable location for the largest possible production scale of a plant.

Something similar occurs in the manufacture of fertilizers in the Central American countries. The sum of transportation costs for the supply of raw materials and for the distribution of products represents a high proportion of the total cost of the fertilizers. This is one of the factors that has contributed to the establishment, in Central America, of two separate manufacturing plants by the same enterprise. It should be noted that the fertilizer factories have been installed in ports, so as to receive directly by sea, the imported raw materials (ammonia, phosphoric rock). The finished products are then transported from the manufacturing sites to the most important internal markets. Thus a costly transhipment of raw materials is avoided.

It is interesting to note that in the case of Central America, the high incidence of the transportation factor in the total cost of fertilizers, has made preferable, the import of highly concentrated fertilizers, with - greater value per weight unit. This has allowed, even within highly industrialized countries, the establishment of small factories that produce low-density fertilizers, to supply the markets near the plant.

2. It is useful to enumerate some of the industries that are more greatly affected by transportation costs and which, consequently, require the most advantageous location of their manufacturing bases.

The metal foundry industry is oriented towards the sources of raw materials, since it discards, during the production process, a large proportion of the mineral rock. For similar reasons, sugar mills, pulp and paper factories and the ones that manufacture henequen, are closely located near the agricultural sources of supplies. The finished products of these industries are less heavy and of less volume than the raw materials of which they are made. For example, in order to produce one unit of -

weight of henequen fiber, more than thirty unit weights of the basic material are required.

When the value of a product is low in relation to its weight, and transportation costs of raw materials and product are similar, and when transshipments are costly, locations at route junctions offer advantages. Such is the case of flour and wheat mills, and some types of fertilizers.

Industries that manufacture finished products ready for the consumer's acquisition, are oriented towards the markets. In countries with little mineral resources, nearly all industries are included in this category. Among these, the following should be mentioned: traditional industries such as beverages, textiles, shoes, clothing, furniture, leather goods manufacture, etc.; some intermediate industries such as the majority of basic chemicals and metal products; and also, some consumers' goods factories such as electric appliances, etc.

C. Large Scale Operation and Industrial Specialization

1. It is well known that in many fields of industrial manufacture, large scale operation may be very advantageous. This is due to the fact that investments in plant installation and in manufacturing outlays, corresponding to each additional unit produced, usually grow less rapidly than the size of the factory. However, it should be noted that savings resulting from decreases in the utilization of labor, are less significant in regions where this factor is abundant, as is generally the case in under-developed countries.

For example, a small paper plant may require double the initial investment per production capacity unit than a large installation. At the same time, it is possible to reduce manufacturing costs by two thirds with an optimum size plant.

Studies made for the Central American region show that the economies that would be obtained by the instalment of optimum size nitrogen fertilizer factories, instead of small inefficient plants, would amount to savings of around 50% in production costs. Similar results have been obtained from studies made in connection with bottle manufacturing plants.

However, the savings offered by highly efficient large-scale production, are limited in under-developed regions. Costly and inefficient transportation, customs barriers, and the large distances to be covered in order to supply markets with a low density of purchasing power, tend to nullify the possible advantages that would permit large scale operation.

Frequently, under-developed countries must resign themselves to produce at higher costs than those prevalent in the large industrial countries. It is usually considered acceptable that the competitive price for the domestic market is that for which merchandise may be imported. This price included transportation costs of the goods from the country of origin.

Another difficulty that confronts small countries, is the impossibility of satisfying the rapidly growing demand with plants of proportional capacity, due to the indivisibility of the size of available production units. It is for this reason that increases in the capacity of plants take place through investments spaced in the form of pronounced "leaps", that always cause idle capacity during the initial period of operation of new equipment. As examples of this are metal foundries, manufacture of nitrogen fertilizers, etc.

2. The reduction of transportation costs expands markets, stimulates competition and industrial specialization. Small enterprises are forced to limit the variety of their products in order to compete with large-scale production.

High transport costs and long distances create small markets which do not favour specialization. On the contrary, the demand of a small market that tends towards self-supply, requires a great variety of small quantities of manufactured goods.

D. Different Transportation Means

1. For the industrial development of a region, all transportation means are indispensable - automotive, rail, maritime and air. However, each of the above-mentioned media has a different influence on the development of different industries. At the same time, even though to a lesser degree, transportation means follow, in their development, the requirements of industry.

The availability and cost of a region's internal transport facilities as well as those that link it with the rest of the world, are determining factors of industrial development. Internal transportation tends to affect, more directly, the location and scale of an industry. On the other hand, transportation costs of imports and exports, added to production costs, are no less important to an industry.

It must be noted that industrial development stimulated by air and maritime transportation is almost exclusively concentrated in the port zones; on the other hand, railways and even more so, highways, come to be real channels of economic benefits to the interior of a country.

Land transport routes become, in fact, axes of location for industrial complexes. This tendency is particularly determinative in the case of railways, since it is essential for factories to receive their raw materials and ship their products directly from and on the railroad's wagons. In the same manner, industrial plants are favoured by the immediate proximity of a good highway, due to the fact that the high cost of any transportation infrastructure makes the construction of a branch highway prohibitive for a private enterprise, thus practically eliminating any location in sites distant from the already existing route.

The importance to the industry of a country, of each one of the transportation means, cannot be based exclusively on the volume of cargo transported. It must be kept in mind that some transportation mediums have adequate vehicles to move heavy units or that specialize in the transportation of large volumes; others, offer greater guarantees in the transportation of fragile or highly perishable merchandise. Speed and the possibility of direct delivery to many different places, are factors also with decisive importance for certain industries.

An enterprise must also take into account the fact that the lack of development in one or another transportation system, is frequently due to causes of a non-technical nature. For example, in many countries the railway system has not known how to profit from, and publicize all its potentially exploitable advantages. It is possible that the relatively small number of technical personnel required for running a railway has contributed, unfavorably, by limiting the system's capacity to react positively to the changing requirements of transportation, particularly the ones arising from industrial demands. Therefore, in many cases, it has not been able to resist the pressing competition of automotive transport. On the other hand, the monopolistic advantage enjoyed in the past by the railroad, made it unnecessary to employ promotional techniques and to offer the clients maximum flexibility of operation, factors which are today indispensable to compete on equal terms with other transportation services.

2.. Road transportation has the advantage of being accessible to a large number of industrial enterprises, small as well as large. When the highway network is extensive, the automotive medium is very flexible, and particularly appropriate for the transference of merchandise distributed along short distances and to a large number of purchasers, whether they be direct consumers, or distributors. Industries oriented towards their market, and many of those located at transport junctions, prefer the automotive medium for the distribution of their products. This is also the case of industries that must provide themselves with a large variety of raw materials, as for example, food processing plants.

3. Because of the incidence of high fixed costs in transportation, the use of railroads for very short hauls is prohibitive. However, even for distances of 100 kilometers, the low traction cost of moving cargo by rail makes it advantageous and efficient to transport large volumes or heavy cargo that fill entire wagons, particularly in the case of materials with a low value in relation to their weight. Railway transportation often turns out to be the ideal medium for the exchange of many types of industrial products between neighboring countries.

Heavy industry, which gives rise to routes of intensive traffic, depends fundamentally on railway transportation. Some times very large extractive industries may even find it necessary to construct their own raillines, in order to move their products from their plants near the mines.

The meat packing industry uses railways intensively for the shipment of live cattle, because of the convenience and efficiency provided by this medium of transportation.

4. Maritime transportation may be divided into two categories: over-

seas and cabotage between ports of the same country or neighboring ones. Even more than in the case of railways, the high cost of loading and unloading, as well as of the port installations, required for transportation by ship, make it practically impossible to take advantage of this medium when distances are short. However, its very low haulage cost becomes evident in long distances, which is why maritime transportation prevails advantageously among all media of international cargo movement.

5. The development of industries that produce goods of high value in relation to their weight, and of those for which rapid transportation is a decisive factor, is greatly benefited by the availability of an efficient system of air transportation. However, the most in portant contribution that this medium provides to industry consists, perhaps, in the possibility of great mobility that it offers to industrial entrepeneurs and to promoters and sellers of merchandise. It would be difficult to conceive a process of economic integration such as the ALALC without the possibility of - swift transfer of the technical and promotional personnel of industrial enterprises, from one country to the other.

The transportation of all types of cargo by air can be advantageous for the service of remote areas, in the case that the low density of traffic would not justify the construction of land routes.

VI - Some Significant Factors in Central America

1. Among the factors that have contributed to industrial under-development of the Central American countries, the following may be mentioned:

Low availability of capital;

Poor operational organization of input and product mobilization;

Institutional and legal deficiencies

that hinder technological change and improvements within private enterprise;

Scarcity of entrepeneurs, technicians and trained labor;

Market defects, such as monopolies, etc.;

Insufficient technical knowledge and poor mobility of information.

Not withstanding these obstacles, industrial growth in Central America has been satisfactory in recent years, reaching increases of 10% annually in some countries. At the same time, the Common Market has developed rapidly on sound institutional bases - with inter-area trade increases of more than 30% during each one of the last five years.

Economic integration has become the accepted means to promote the accelerated economic growth of the Central American Region. As the differences in economic potential among the countries are not excessive, a balanced growth model for the Region is possible.

2. The remarkable progress achieved by the Common Market is due, to a great extent, to the development in recent years of a regional highway network. In contrast with the South American countries, where international traffic takes place almost totally via maritime transportation, in Central America, 80% of transportation between countries , is effected by road. Maritime coastal trade is very limited, not withstanding the fact that the Central American isthmus has oceans that border it, and in spite of being the construction of land routes costly due to mountainous topography.

On the other hand, transportation by railway is very deficient, because of the lack of attention that this system has received.

In the face of the present period of industrial development in the Region, as the establishment of new industries that require the transportation of large cargo volumes increases, the coordination and the adequate and rational exploitation of each and every one of the transportation media, represents one of the most pressing problems of the integral development of the countries.

Whenever cargo volumes do not justify the construction of first-class infrastructures, transportation costs inevitably become high. The abundance and low cost of labor represents saving in service costs. On the other hand, it is certainly a disadvantage to have to import at high prices, the necessary equipment and fuel. The efficiency of operation within - transport enterprises is indispensable factor in achieving a reduction of the total cost of the services.

It should be noted that second-class roads can furnish adequate access to many potential markets. Consequently, a significant part of investment in transportation infrastructure of a country with large areas of low-density traffic should be assigned for such type of projects.

3. For internal traffic between small neighboring countries, in the process of integration, the emphasis should fall on land transportation, complemented by coastal navigation and air transportation. Of course, the infrastructure should be expanded as much as possible, even with the specific purpose of accelerating the integration of the region, but care must be taken not to incur in expenditures that may be - in any way - a luxury. The coordination and efficient operation of transportation media should be strived for, as well as the maximum reduction of specific costs

in accordance to the needs and the existing possibilities. For the industrial development of a region, it is often enough to have one first-class main route that will reduce transportation costs, if it is adequately fed by secondary and tertiary roads.

4. Central American industrial development is at present - completing a stage in its process of substitution of imports of - traditional products. The following stage should be oriented, on the one hand, towards the strengthening of existing industry in order to enable it to compete advantageously in the international market and, on the other, towards the substitution of imports of intermediate products as well as of some capital goods.

In view of the fact that the resource endowment in each of the five countries is somewhat similar, there arises the problem of - optimum location of intermediate industries. If the possibility of - installing a maximum of one or two plants is contemplated for those products with a demand that does not justify the establishment of - numerous small industries, the evaluation of the various projects proposed by each of the five countries, must take into account transportation costs, which will bear in the determination of the optimum delivery price of the products in each zone of the region.

VII - Interrelation between Transportation Costs and Market Areas in Central America

1. Before the establishment of the Central American economic integration, the industrial sector within the five countries was res-

tricted by the small size of markets and by the limitations of the extent of the supply areas. A good part of the existing industry, made up almost totally of market-oriented manufacturing plants, had to be established in the capital cities, where the five large - markets existed. The perfectioning of the Central American Common Market and the termination of the Regional Highway Network, will make pertinent the careful selection of the optimum location and the adequate scale of each industry called on to supply several countries.

2. The accompanying diagram endeavors to define the potential market areas that an industry located in each one of the capitals of the Central American countries may have, taking into account only the factor of cost of transportation.

The diagram and its analysis are presented as simple outlines for a much more extensive and precise study, that would be necessary in order to arrive at more concrete conclusions. Similar - diagrams could be elaborated as well, in reference to specific - products.

In order to obtain lines of equal cost of transportation, average rates for merchandise transported by different types of highways - and by railway, have been considered. For greater precision, it - must be established the difference between the costs of transportation in mountainous, rolling and plain terrains. The participation of the maritime coastal transportation system could be included as well. The consideration of other influential factors such as -

speed, comfort, etc., areomitted for the sake of simplicity.

Around each one of the Central American capitals, lines of equal transportation cost have been traced, for values of $5.00/Ton and $20.00/Ton. The approximate population of the areas that may be supplied from each one of the capitals, with products capable of "bearing" these transportation costs, are then obtained.

If incomes of the total population of each separate area in the diagram are estimated, preferably differentiating the *per capita* incomes in the various zones of the countries and deducting subsistence incomes, total income values are obtained which constitute indexes of each area's purchasing power.

3. From this simple preliminary analysis, some general conclusions may be derived.

Those industries with a very high transportation cost, must limit themselves to supplying only one of the larger markets.

In relation to those products for which only an additional - cost of $5.00/Ton is acceptable, in so far as transportation is concerned, those markets that offer the greatest purchasing power are Guatemala's, El Salvador's and Costa Rica's.

However, for those manufactured items that are able to bear additional costs of $20.00/Ton in transportation costs, the centrally located cities such as Tegucigalpa and San Salvador, as well as Guatemala, become the most favored as distribution centers.

For merchandise of high value in relation to its weight, for which transportation cost is less important, the optimum location of the plant will be influenced by allocation factors other than transportation; therefore, the most advantageous site for the plant may be in any region within Central America.

This analysis also evidences that, as the Central American region is fully integrated, the transportation factor may favor the establishment of factories in boundary zones between countries. Even though some of these zones have favorable locational conditions for industry, they have been ignored up to date, due to the obstacles encountered by transport vehicles in crossing borders.

CENTRAL AMERICA: MARKET AREAS LIMITED BY LINES OF EQUAL TRANSPORTATION COST

City	Area for Transport Cost of: $ 5.00/Ton		Area for Transport Cost of: $20.00/Ton	
	Population (Millions)	Total Income (Millions $)	Population (Millions)	Total Income (Million $)
Guatemala	2.1	610	7.1	2040
San Salvador	2.1	610	6.9	1910
Tegucigalpa	0.9	190	5.1	1350
Managua	1.0	297	2.8	820
San José	1.4	511	2.0	690

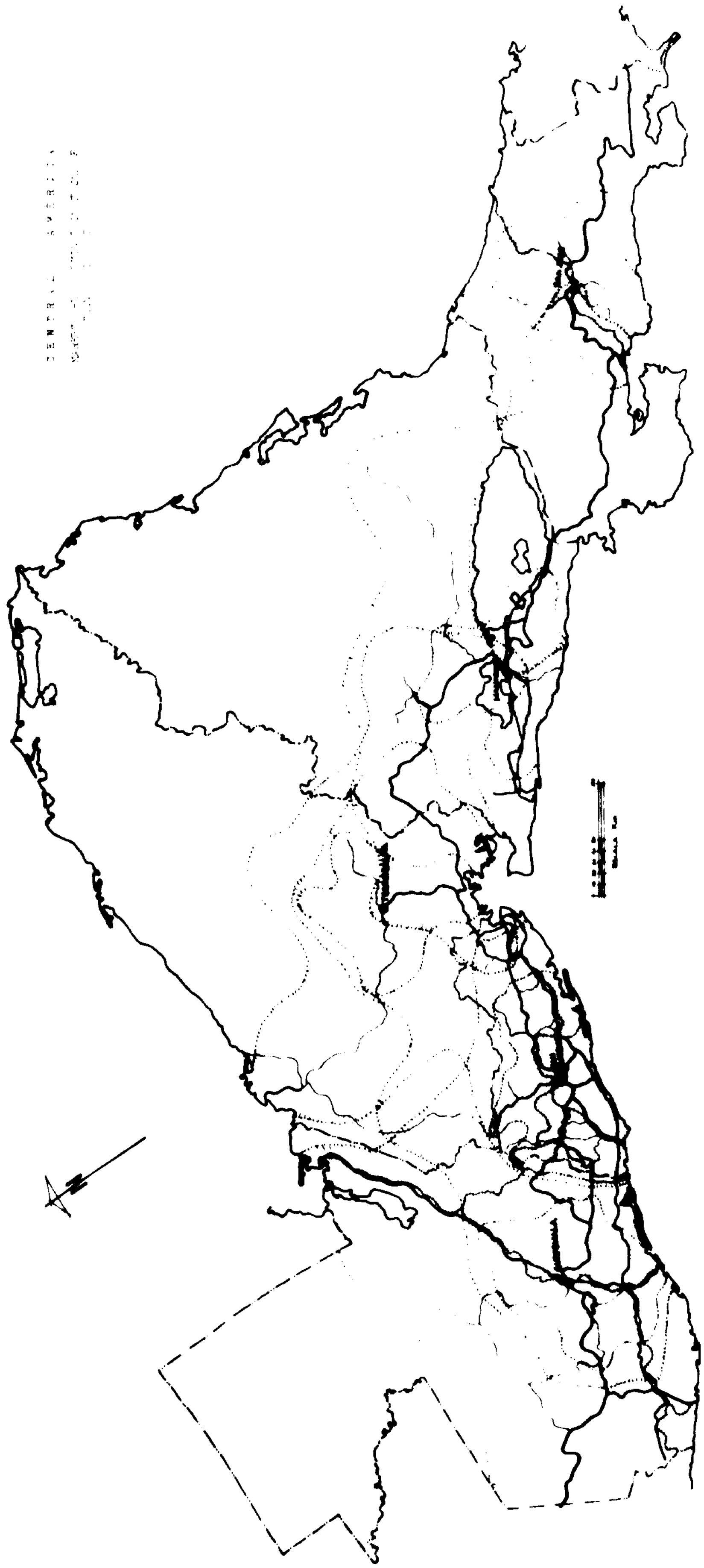
REFERENCE STATISTICS

Average Costs of Land Transportation

Paved highways	$ 0.044/ton
Secondary highways	$ 0.053/ton
Dirt Roads	$0 .85/ton
Trails	$ 0.15/ton
Railway	$ 0.45/ton

Per capita Product (estimated for 1965)

Guatemala	$ 290/capita
El Salvador	$ 291/capita
Honduras	$ 211/capita
Nicaragua	$ 297/capita
Costa Rica	$365/capita



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CAPITAL BUDGETING AND PRICING TECHNIQUES

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INTRODUCTION

Identifying appropriate pricing policies which lead to the "correct" amount of capital investment in physical capacity and its efficient utilization, while recognizing opportunity costs of resources used, is a difficult and perplexing problem. The capital budgeting and pricing scheme we describe below is designed to assist in solving such problems. It differs in several significant aspects from more conventional capital budgeting procedures. Pricing policies are recognized herein as planning instruments to be used in achieving certain specified objectives for a particular physical system or facility within realistic social and political contexts. Indeed, we shall go further and assert that capital budgeting is not rationally executed in abstraction or isolation from pricing problems. In particular, the really difficult pricing decisions confronted by modern managements usually involve the question of how to "recapture" capital, research, development, administrative and similar costs not easily or directly related to variations in output. In large measure, these less directly related or traceable costs derive from commitments of an investment character so that the problems of evaluating these investments and their "recapture" (either actual or potential) through price assessments become closely intertwined. The fact that these capital charges or prices may not be assessed directly to consumers in all cases, say as a matter of public policy, does not eliminate, moreover, the necessity to evaluate these market possibilities so long as efficient allocation of investment resources is an objective.

This is not to say that attention should be focused only on narrow microfactors affecting the particular system under consideration; pertinent broader issues can and do influence capital budgeting and pricing decisions. Accordingly, other and broader qualitative variables are brought explicitly into the decision process herein outlined at specified "decision points." Thus important qualitative aspects interact upon the planning decision, and upon the strictly economic optimizing process,in a more clearly specified manner than in most conventional practice. Our approach necessitates greater emphasis upon demand and supply curve estimation procedures and assumptions, but these estimation problems are not our major concern here. We begin our procedure assuming that the requisite supply and demand functions are given or known in addition to an estimate of the present cost of the facility under consideration. We then proceed to find pricing schemes which are optimal with reference to specified objectives for the system in question.

II

It is well to digress for a moment, though, on just what information supply and demand functions convey and, explicity, whether the usual demand curves of economic analysis measure benefits in a meaningful way. Indeed, a rather extensive literature and controversy exists on this point. One problem is that demand curves measure monetary sums while, in a strict sense, what should really be measured is the satisfaction or utility people derive from money. Of course, if every unit of money were like every other unit in terms of the extra satisfactions it would buy, this would not be a problem. It is, however, difficult to imagine real circumstances in which every unit of expenditure indicated by a demand curve would be of constant benefit value--or, more technically, of constant marginal utility.

This proposition can be illustrated by considering the basic character of consumer decisions. A rational consumer might be expected to rank all the possible ways he could spend his money income according to the satisfaction they yielded and would spend his money by proceeding down this hierarchial ordering until all his funds were exhausted.[1/] Assuming that every product can be consumed in exactly the desired amounts (i.e. that there is perfect product divisibility), the rational consumer would spend on every product until the marginal satisfaction from the last unit of money spent on each product is equal to the marginal satisfaction derived from the last unit spent on every other product--otherwise he could make himself better off by transferring funds from a product yielding low satisfaction to one supplying large satisfaction. Furthermore, if money income were increased, the consumer would proceed down the list further than before and the last dollar expended probably would yield less utility than before.

1/ Savings should be treated as one form of expenditures.

Contrarily, with a reduction in income, the last unit of money spent would supply more satisfaction than before.

It is worth noting the possible consequences if a price increase or decrease occurs on one of the products consumed. Say the price increases. If the consumer does not want to reduce by much the quantity of the product consumed, the result might be that his total money outlay on the product increases. However, to increase outlay on this product, the consumer must decrease expenditures on other products--assuming that money income remains the same. A decrease in expenditure on the other products means, though, that the last dollar spent on each of these products probably yields more utility and the marginal utility of money therefore has increased to the consumer because of the price change.

On the other hand, the consumer might curtail his consumption so that he spent less in toto on the product after the price increase. This, in turn, would free funds for making increased expenditures on other products, with the marginal utility of the last dollar spent thereby being reduced.

When most consumers are in the former situation--that is, when more is spent on a product after a price increase--demand for that product is said to be inelastic. The demand elasticity is defined to be less than unity when demand is inelastic and greater than unity when it is elastic. A unitary demand elasticity is the case for which total expenditure on a product remains unchanged in the face of a price change.

The demand elasticity, as a rule, will be different at different points on most demand functions. The usual assumption is that the demand elasticity is greater than unity at high prices, and less than unity at low prices. The concept of "demand elasticity" is very useful in analyzing the meaning of the suggestion that benefits should be measured in dollar units of constant marginal utility. In essence, this proposition implies that a demand function relating quantity to dollars of constant marginal utility should be used to measure benefits rather than a normal demand function. It is well, therefore, to consider the relationship between a constant marginal utility demand function and regular demand function.

In the elastic portion of the conventional demand curve any increase in price decreases total expenditures on the product or service under analysis and frees money for expenditure on other products. This forces the marginal utility of the last dollar spent downward. To restore the marginal utility of the last dollar to its original position would require taking money away from the consumer. This in turn would depress consumption of the product being analyzed below its original level and make the depressive effect of the price increase even greater than it would otherwise have been. In the inelastic portion of the curve the situation would just be reversed. In short, only when demand is unit elastic will there be no induced income effects on demand which would require compensatory action to restore the marginal utility of money to its original position.

Thus, for measuring benefits in dollars of constant marginal utility, the usual demand curve will provide an improper estimate unless demand happens to be just unit elastic. The degree of the overestimate depends on the extent to which the two demand functions diverge; this, in turn, is largely a function of how important an item of consumption the product under analysis happens to be. For goods that absorb a big proportion of income, the divergence will be large; for goods that account for only a small percentage of total consumer expenditures, the bias should not be great.

Because of these difficulties, it has sometimes been suggested that the proper approach to benefit valuation is not to attempt measuring benefits in dollars of constant marginal utility but rather to determine what would be the maximum number of dollars, regardless of utility value, that people would pay rather than do without a product or service. The reasoning behind this approach is that if this sum is larger than the total costs of providing the good or service, production is economically justified.

Again, the area under the demand curve usually is accepted as a reasonably valid first approximation to the amount to be estimated. Remembering that a demand curve indicates the price that must be charged to bring a certain number of customers into the market, this sum would be identical to that realized by a monopolist practicing perfect price discrimination. Such a monopolist would arrange his customers according to the maximum each was willing to pay rather than do without his product and would extract from each this maximum.

A regular demand curve, however, actually would overestimate the maximum amount that customers would pay because extracting every penny available to be spent on a product changes the basic assumptions under which demand curves are usually constructed. Specifically, perfect price discrimination means that more income will be spent on the product under analysis at every level of output than would otherwise be the case. Thus, under a system of perfect price discrimination, less money income might be expected to be available at every level of consumption than would be available without price discrimination. Assuming that the product under analysis is not an inferior good, 1/ less of the product being subjected to price discrimination (and less of other non-inferior products as well) would be demanded for a given price than would otherwise be the case because of the reduction in income.

1/ An inferior good is defined to be one whose consumption rises when income declines because it is substituted for other goods of higher price. Hamburger (in place of steaks and roasts) and rye flour (in place of wheat flour) are usually thought to be illustrative examples of inferior goods.

The preceding is, however, strictly a partial analysis. It overlooks the fact that one man's purchase is another's sale. Consequently, if in a system with price discrimination those who gained income had the same marginal propensity to consume and exactly the same marginal product preferences, on balance, as those who lost income, the effect would be to restore demand to the initial state. It is doubtful, of course, that these assumptions would be met in reality. But it is also not clear what the net effect would be of permitting price discrimination. Depending on preference and consumption patterns, the ultimate effect on the sales of a particular product at a given price could be an increase, a decrease, or no change. If an increase occurred, the area under demand curves would tend to underestimate benefits; if a decrease was the result, the tendency would be to overestimate benefits.

Still another objection might be leveled against either the price-discriminating-monopolist or constant-marginal-utility of money concepts of benefit measurement. As compared with the usual competitive criterion, both essentially establish a second or double standard for determining whether or not production of a good is economically justified. The competitive test for determining whether a good should be produced is that at some level of output, the price that consumers are willing to pay is greater than the supply price at that output. By contrast, the full areas under the

the constant-marginal-utility of money or price-discriminating-monopolist demand curves normally will result in higher estimates of benefits. These criteria therefore could suggest production of goods that would be excluded on the single-price competitive standard. But to obtain this production, either legalized monopoly and price discrimination or government subsidization would have to be instituted for those goods which, though justified by a "full-area" criterion, do not have demand curves that ever lie above their supply functions.

It seems very doubtful that acceptance could ever be obtained for the rather major change in the economic institutions of most countries that complete adoption of any "full-area criterion " would imply. There are few signs at least that most Western societies would want to undertake a large scale subsidization program or abandon competitive pricing in favor of monopolistic price discrimination on any extensive scale.

Of course, under certain circumstances a double standard might be defensible. For example, a "full area" count of benefit might be sanctioned for voluntary non-profit and public service activities. In a sense, even Western economies already use such a mixed system since many educational and cultural activities (e.g. symphony orchestras and art museums) as well as certain public utilities are financed in this way. Still, adoption of a "full-area" concept of benefits is clearly a policy decision.

There is still another, simply pragmatic difficulty with any "full area" measure of benefits. This is the need to know the shape of demand functions much beyond the normal range of available data or experience. As a rule, the investigator trying to estimate a demand function has only a limited number of price and quantity observations, perhaps as illustrated in Figure 1, where each dot represents one observation. The usual procedure in estimating a demand function is to fit a line or curve, depending on the circumstance, to these data according to some criterion of best fit (as a rule, least squares). Where there are data, this procedure should yield reasonably good results. But it is obvious that not much of substance is known about the shape of the demand function out beyond the limited range of the available price and quantity data. For "full area" measures of benefits, this is a serious handicap.

No one of the previously stated objections may be overriding when taken by itself. But the cumulative effect of these many criticisms could be of substantial magnitude. Furthermore, potentially difficult policy decisions often must be made at certain stages in the evaluation.

From the technical standpoint this suggests that the best capital budgeting procedure would be one that minimizes the number of applicable criticisms and difficult decisions.

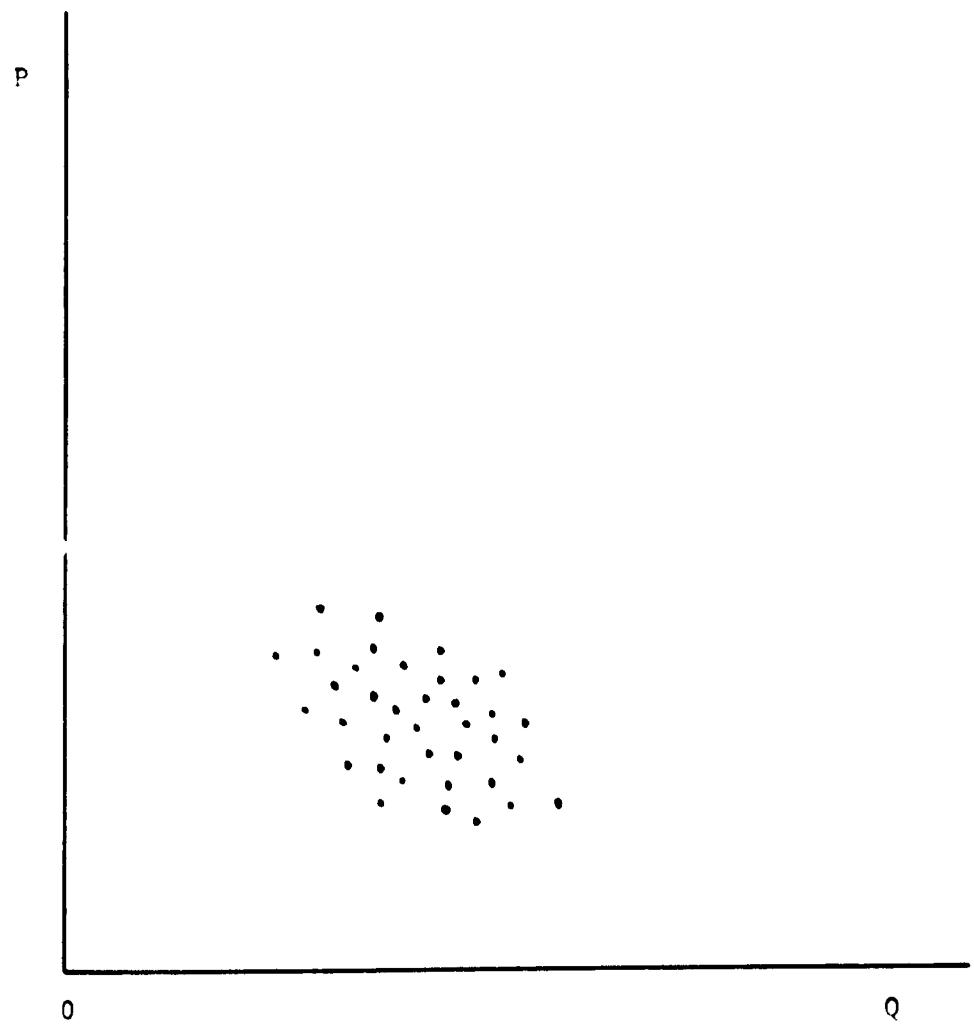

FIGURE 1: Observed demand data points.

The objective sould be to arrive at a correct decision with a minimum of assumption and information gathering. One obvious way to do this is to proceed sequentially. Projects initially should be tested for feasibility with a minimum of assumptions and avoiding a maximum of difficulties. If proven infeasible under these conditions, additional assumptions and decisions should be introduced in approximate order of "defensibility," testing for feasibility at each stage. The process should continue until conditional feasibility or total infeasibility was clearly established. It is this that we refer to when seeking explicit identification of qualitative decision points. In the absence of a better name this alternative approach, as outlined in succeeding paragraphs, could be called "sequential capital budgeting."

III

In addition to the characteristics of closer integration of pricing and capital budgeting, explicit identification of qualitative decision points, and conscious use of pricing schemes as planning instruments, we endeavor to keep the needed series of computations as simple and straight-forward as possible. Indeed, although our model was programmed for an electronic digital computer, our assumptions of strict linearity of demand and supply functions enable an ordinary desk calculator to suffice for most applications. The linearity constraint on the demand and especially on the supply functions can be relaxed without too great an increase in computational labor, but departure from linearity for what we shall term the "composite net outlay curve" creates considerable difficulties with doubtful improvement in approximation of reality. The form of the derived composite net outlay curve is discussed in more detail below. Even with the linearity constraints relaxed for the composite curve, however, the conceptual procedure remains essentially as described.

Suppose we are given the present discounted cost of a productive facility, and we want to determine if construction of the facility or system is economically rational, and to ascertain the best type of pricing schedule to assign to the system. Exogenous information needed as inputs to our model are estimates of the demand and supply functions for each time interval of the total planning period. 1/ The supply functions, furthermore, pertain only to all factors other than the fixed or capital facility whose rationality is under investigation. Depending upon the circumstances, the functions could shift but retain constant slope over time, or else the slopes could change over time also. The demand functions can be expressed in symbols as:

$$D = f(P, T, K, Y, \Delta N, \ldots)$$

where P = price of transport services

T = time

K = cost of system capacity

Y = consumer income

ΔN = growth in population

1/ We specify a time interval as one year, and the length of the planning period, about the same as the economic life of the system, is taken to be 20 years, though this time horizon can

Similarly, the supply functions for all factors other than the fixed facility are:

$$S = g(P, T, K, Y, \Delta N, \ldots)$$

for any one time interval. These supply functions, it should be noted, pertain to the offering of all labor, administrative and other skills needed to "complete" the system's productivity when joined with the fixed capital facility under investigation.

What we shall call "net outlay curves" can be obtained for every time interval by subtracting the supply from the demand functions in each interval. These represent derived demand curves for the facility itself after supply and operating costs and costs other than charges for system use have been subtracted, and are thus net effective demands for the facility's capacity. Assumption of linear supply and demand curves greatly facilitates derivation of the net outlay curves, as show in Figure 2. As Figure 3 illustrates, however, assumption of a curved or even a kinked supply curve does little to increase mathematical complexity if only the two axes' intercepts are used to locate the net outlay curve. As shown in Figure 3, the resulting linear approximation is conservative over the length of the function. The net outlay curves thus determined for each time interval are then

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easily be modified to reflect different estimates of economic life. Each demand curve is a monotonically decreasing function of capacity in each time interval. Supply functions are positive linear functions of capacity.

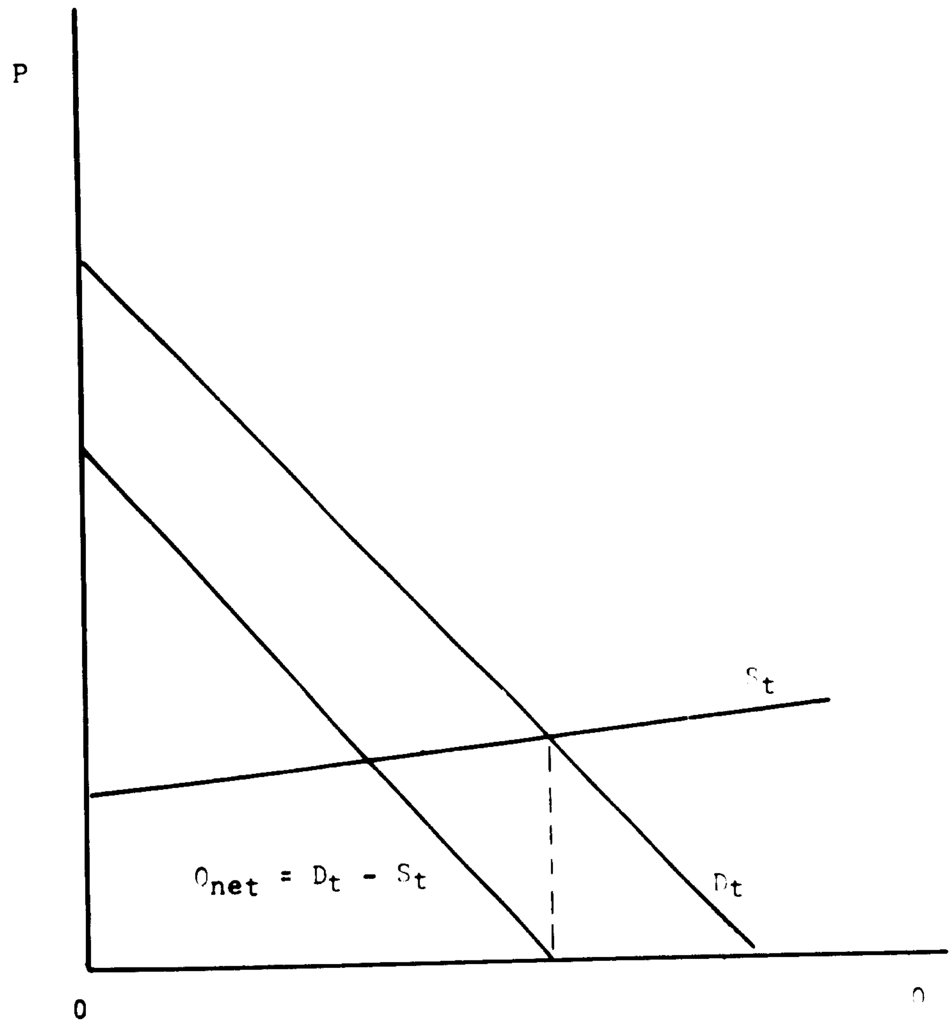

FIGURE 2: Net outlay curve (O_{net}) derived from linear demand and supply curves in time interval t.

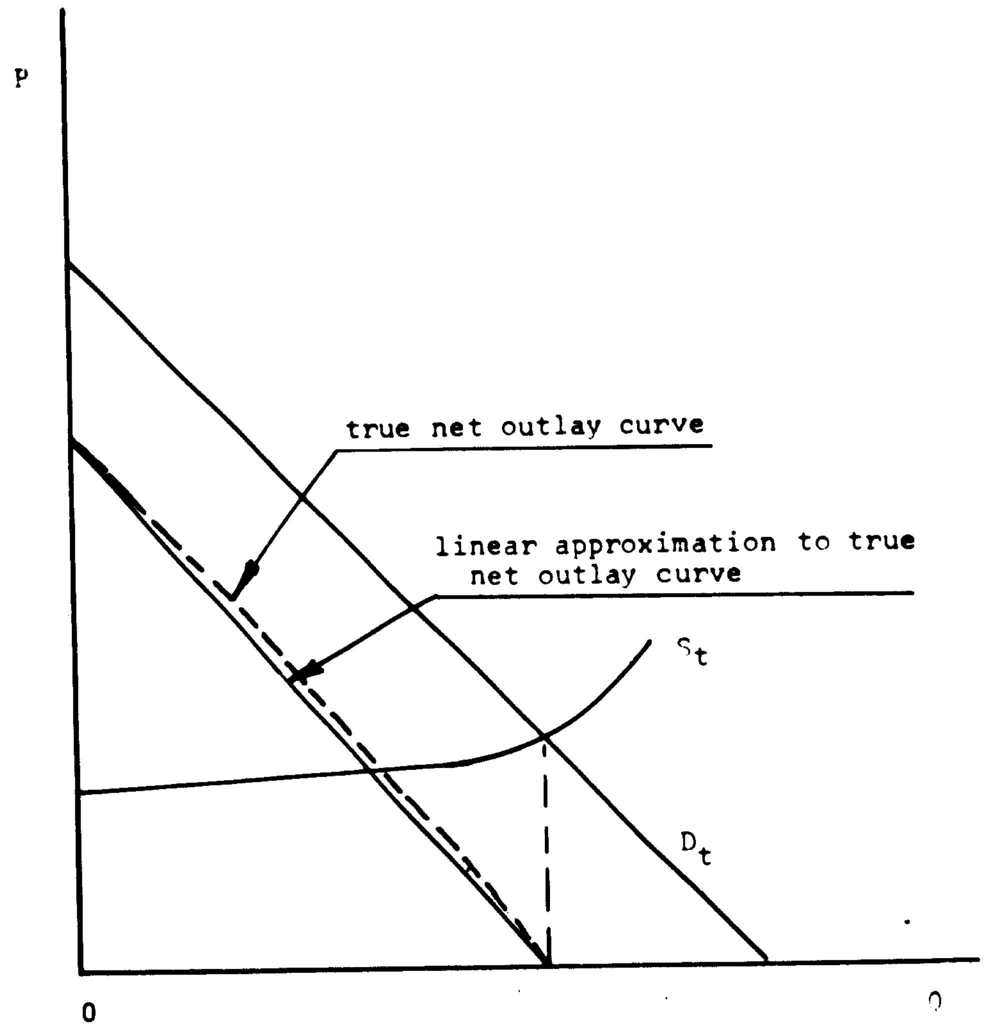

FIGURE 3: Linear net outlay curve as an approximation to the true net outlay curve, derived from a linear demand curve and a curvilinear supply curve.

discounted to the present using the appropriate present value factor 1/ according to its relevant time interval and the discount rate selected. Since the discounted net outlay curves are to be aggregated horizontally along the quantity axis, they are expressed for convenience mathematically with relation to the axis. 2/ That is, the intercept A in the linear equation

$$Q_{net} = A - BP$$

is the quantity (Q) axis intercept and B is the slope with reference to the vertical price (P) axis. A composite discounted net outlay curve for the total planning period is shown in Figure 3, and is a piecewise linear function. A strictly linear proxy for the piecewise linear composite curve is found by taking the price axis intercept to be the arithmetic mean of all the individual net outlay curve price intercepts weighted by their relevant present value factors.

1/ Discount rates from 2 to 20 per cent were used in the model testing for comparative purposes.

2/ Peter O. Steiner, in "Peak Loads and Efficient Pricing," The Quarterly Journal of Economies Vol. LXXI, No. 4, (Nov., 1957), pp. 588ff, used similar net outlay curves in handling peak load pricing problems in utilities and added his different period demand functions vertically. Here, however, we are involved with trends over considerable periods of time, not short-run cycles as in the Steiner case. Our demand curves exist at one point in time only and do not necessarily reappear cyclically. We are interested here in aggregate figures over an entire planning period, not with possible cyclical combinations of different net outlay curves in any peak period.

Once the weighted mean price intercept is found (P_m in Figure 4) the slope of the proxy curve follows easily and the function is completely described. The area under the linear approximation is equal to that under the piecewise linear curve. How much accuracy is sacrificed by using such a linear approximation? Only if the price axis intercept of the individual net outlay curves vary over a wide range, or else if there are very few time intervals being considered--say less than five--will the approximation affect the price levels subsequently determined, and then only prices in the higher portion of the pricing schedule. If the length of the price axis intercept is small relative to the quantity axis intercept, loss of accuracy with respect to price levels determined is negligible.

IV

Having obtained our linear composite discounted net outlay curve, we can now experiment with different pricing schemes and identify pertinent qualitative decision points. Following the flow diagram shown in Figure 5a, we first make a contigency check to see if the system proposed is economically feasible even with total discounted consumers' surplus (the entire area under the composite net outlay curve) counted as benefits. If present benefits less present costs prove to be negative after this check, it is time to stop and reconsider the need for the system or at least its design and construction costs.

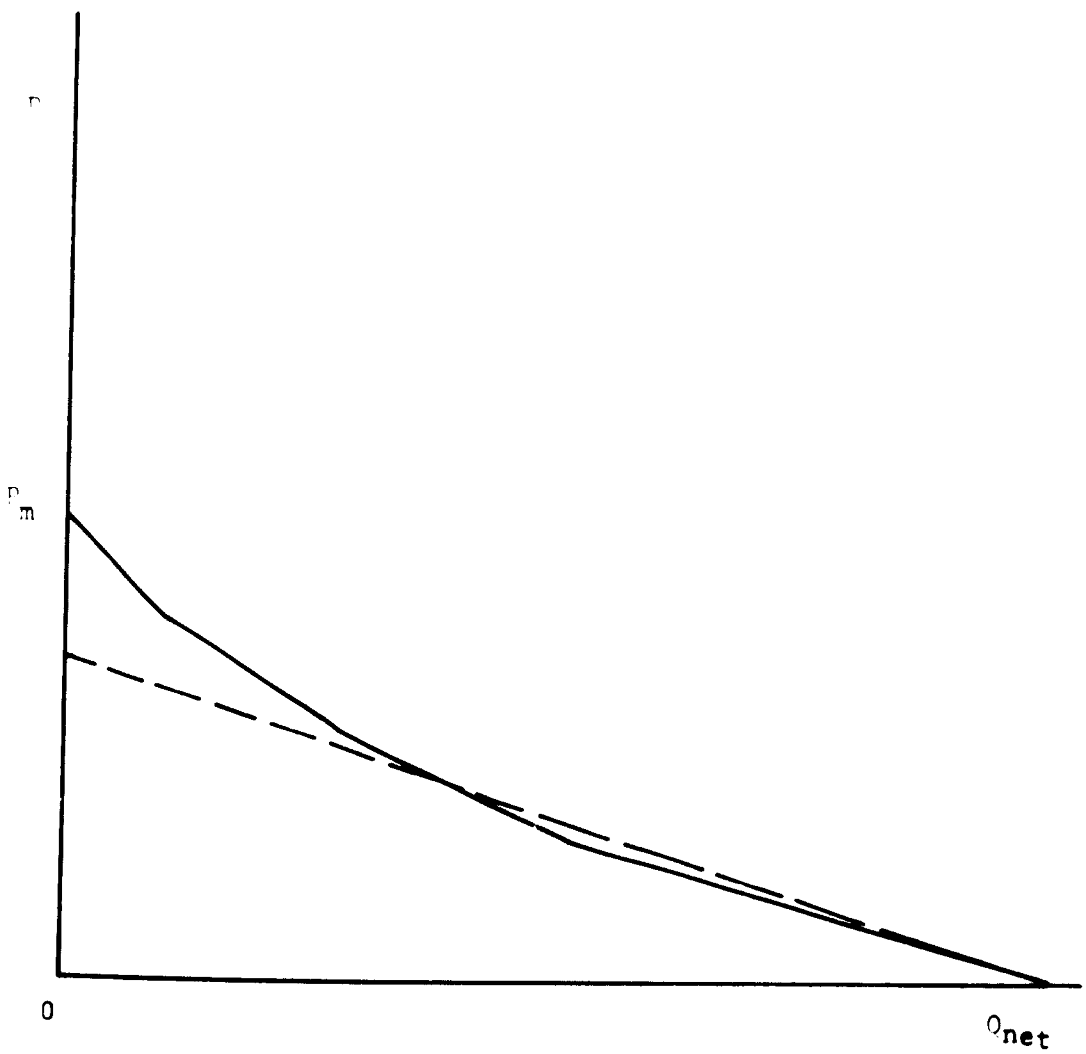

FIGURE 4: Composite net outlay curve with a linear approximation.

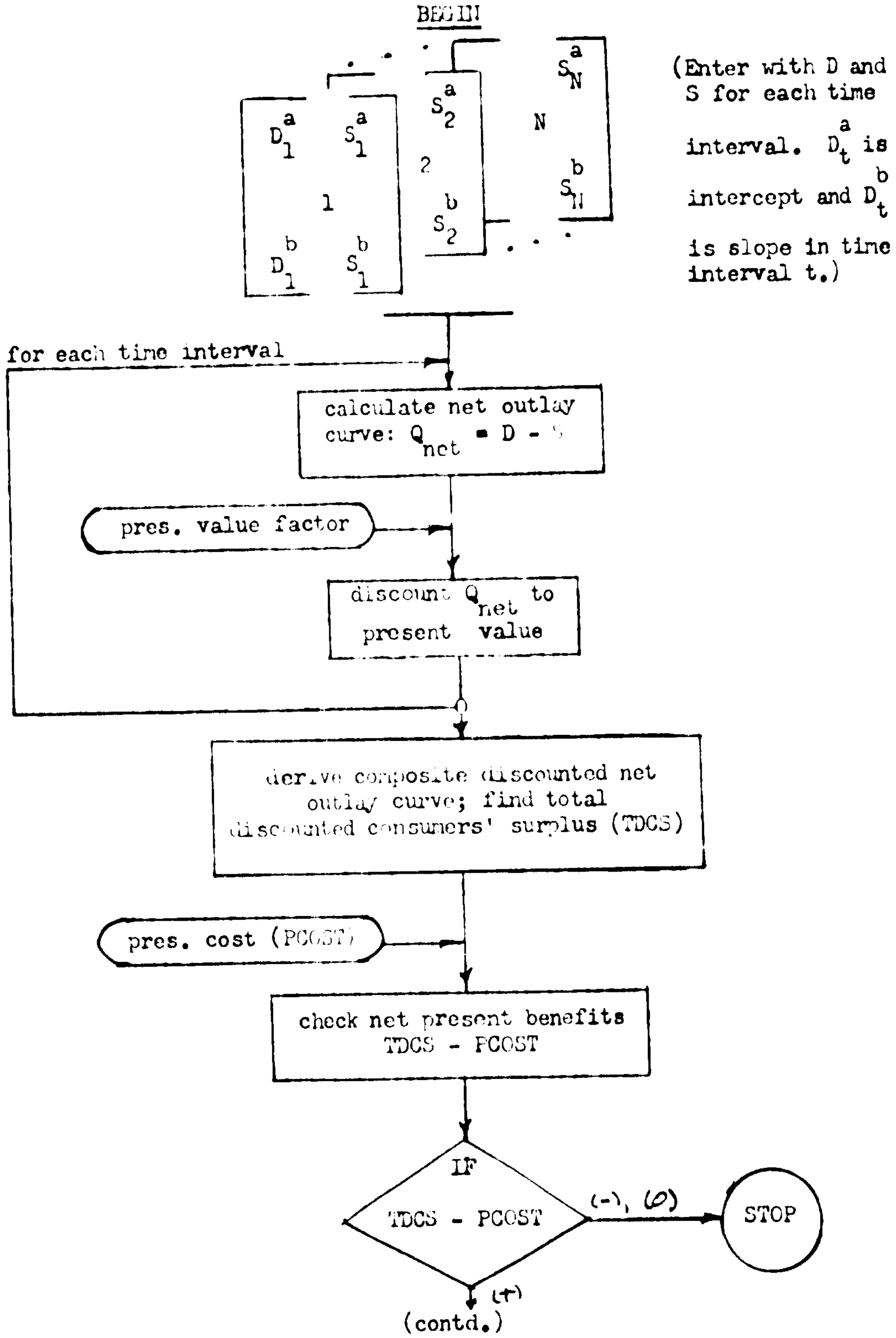

FIGURE 5a: Flow diagram of computer calculations.

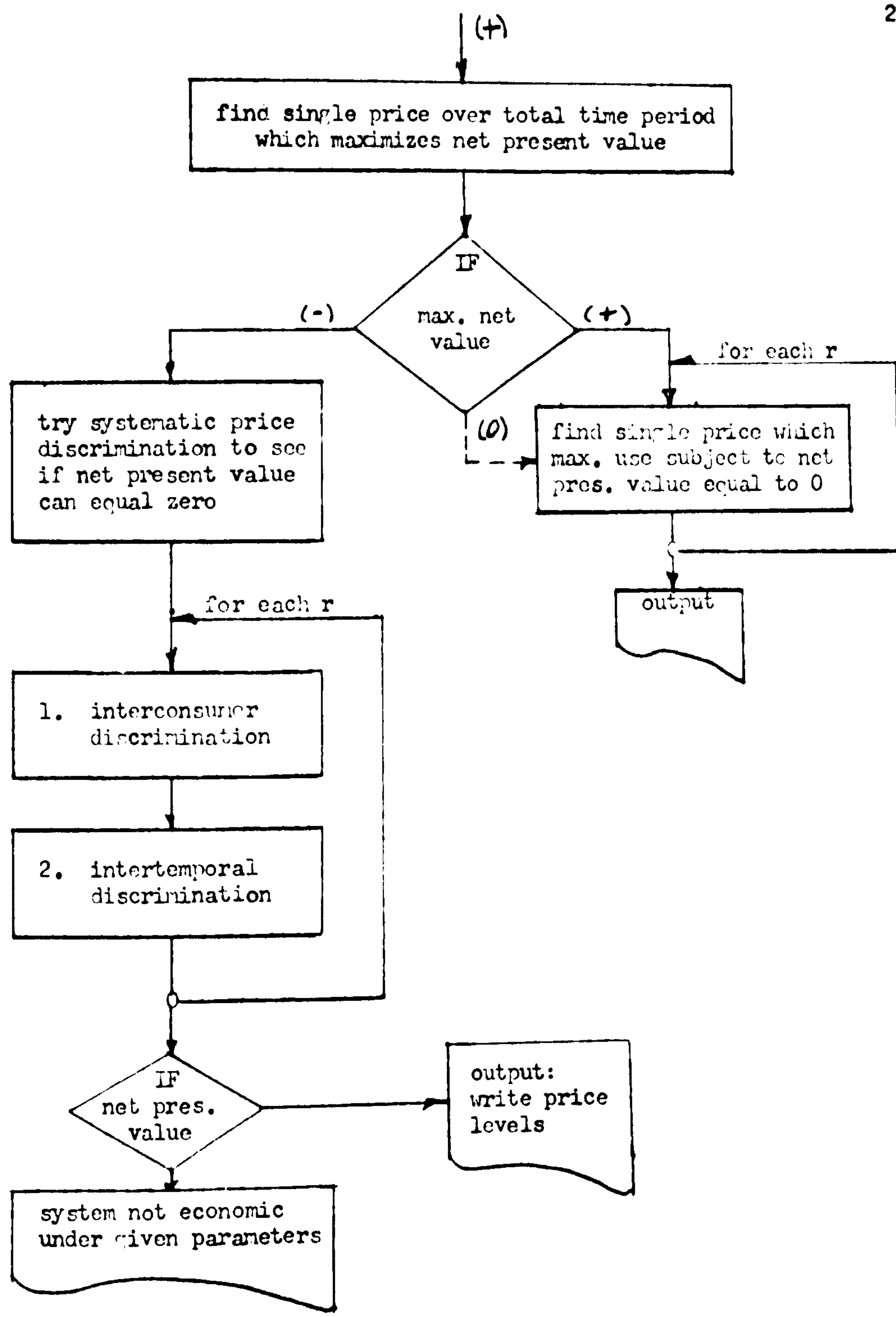

FIGURE 5b: Flow diagram of computer calculations (contd.).

Or perhaps there are prevailing, non-economic arguments favoring construction of the system. Here they should be specified and considered, and their importance weighed against the economic deficit resulting from construction of the facility.

If the facility passes this first contingency check, possible pricing schemes and specified pricing objectives should be examined. Desirable attributes of any pricing policy include simplicity both in administration and in comprehension by the consumer, social and political feasibility, and efficacy in achieving the desired objectives. Given these considerations, one price over the entire planning period has much to recommend it if financial or other objectives are thereby or also met.

With a single price or any other kind of pricing scheme, two general kinds of objectives are of interest and lie at essentially opposite ends of a spectrum of objectives: (1) maximize revenue realized from the system or project, which normally implies high opportunity costs of capital in alternative uses, or (2) maximize consumer use of the facility subject to some constraint of a minimal net return, say net present revenue equal to zero. Of course many combinations of these two extremes are possible. The main interest is to discover the set of alternative pricing schemes which will encourage use yet still enable the facility to pay for itself.

Returning to the diagram in Figure 5b, the single price over the entire planning period which maximizes net present value (discounted revenue less present cost) is the unit elastic price of the composite discounted net outlay curve. (See Figure 6.) If the net present value so determined proves to be non-negative, then the single price over the total planning period which maximizes use subject to a constraint of zero net present value can be found by finding the vertical dimension O E of the rectangle O D E F under the net outlay curve in Figure 6, O D E F being the rectangle whose area is exactly equal to the cost stream discounted to the present.

Computations may indicate, however, that the best single price fails to generate enough revenue over the planning period to provide a total greater than the present cost. We have a branching decision point where three general types of pricing schemes are available in an attempt to retrieve more revenue, all involving forms of price discrimination:

(1) Cyclical price discrimination applicable to situations in which very sharp seasonal, daily or other variations occur in the rate at which the service or product is consumed, such discrimination often being a means of ameliorating the high costs and other problems associated with very intensive peak use or demands;

(2) Interconsumer price discrimination, wherein different price levels for different categories of customers are establsihed within any single time interval, but the various levels remain constant for these different consumer groups over and between time intervals thoughout the planning perid; and

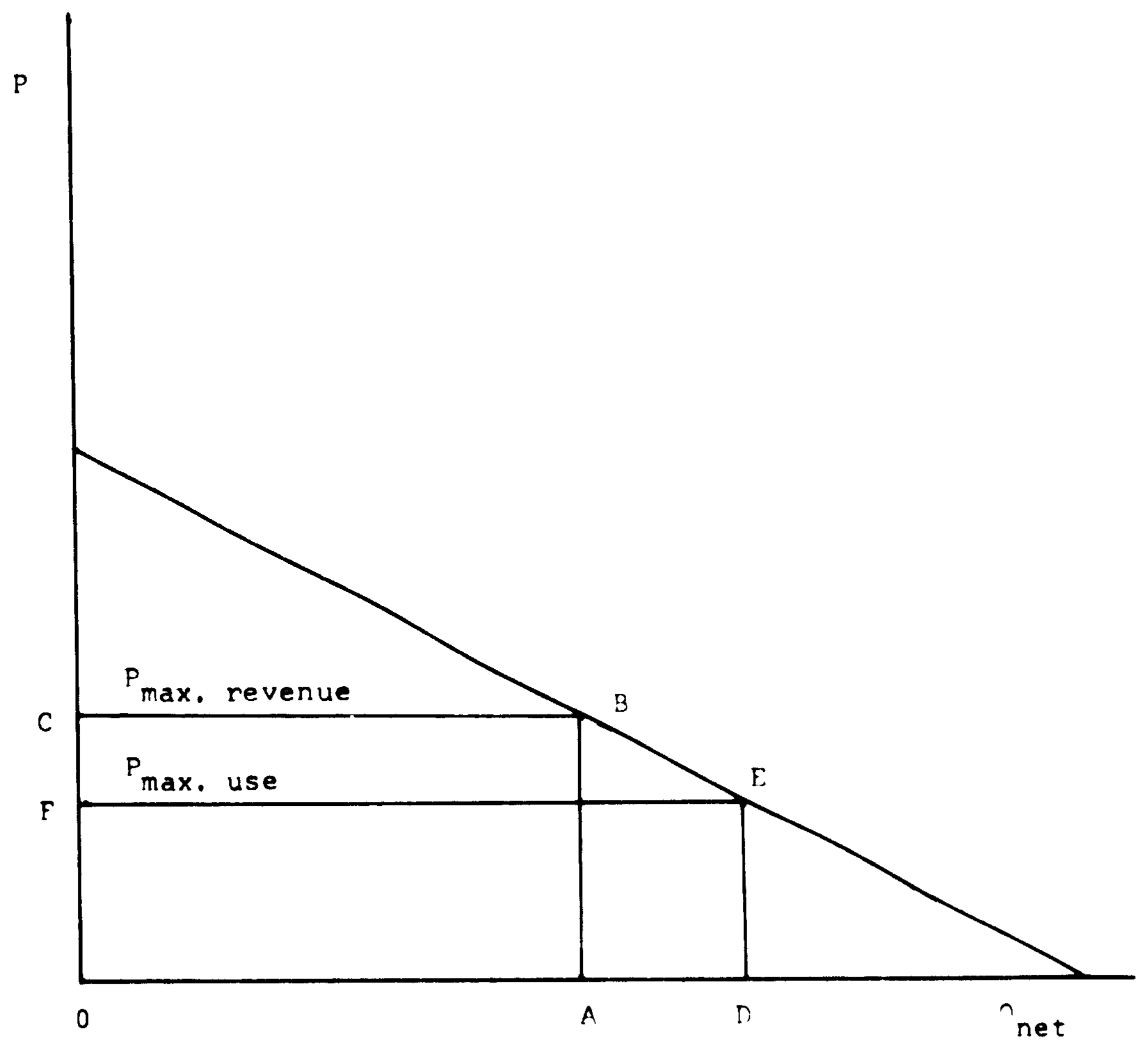

FIGURE 6: Maximum revenue and use price levels.

(3) Intertemporal discrimination, in which there is only one price charged in any time interval, but that price may change over time within the total planing period.

Only the last two of these alternatives will be investigated here, though it should be noted that all three types of price discrimination not only interact with one another, but also influence and are influenced by capital budgeting decisions.

The upper extreme of the second alternative by itself is of course a separate price for each consumer until the total area under the composite net outlay curve is approximately recovered as revenue. The upper limit on intertemporal price discrimination by itself (i.e. without interconsumer or cyclical discrimination) would be the unit elastic price for the net outlay curve of each time interval.

The interconsumer price levels can be found by straightforward trigonometric manipulation of the area under the composite net outlay curve. As soon as enough gross present revenue is obtained to fulfill the stated objective, the number of discriminatory levels is fixed. In keeping with the goals of administrative simplicity and consumer acceptance, the implicity assumption within the model is that the fewest number of price levels necessary to reach the objective is desired.

Determination of the optimal intertemporal pricing scheme relative to some objective is somewhat more involved than for the interconsumer case. Suppose we want to determine the optimal intertemporal pricing scheme with a maximum of two price levels over the total planning period. One other assumption is needed here in order to keep the number of possible permutations in the model within reasonable bounds. A constraint could be stated that prices must decline, or rise, over time. For example, in a two level intertemporal pricing scheme, the second price changed might be constrained to some fraction of the initial price. Such a constraint seems quite realistic, particularly when considering the introduction of new products or services. The opposite assumption is also permissiable within the model, but it often seems less plausible. If the second type of constraint is assumed, then the model helps to identify the minimum increment of increase in price, of all the feasible increments, which meets the objective.

Given a planning period composed of twenty time intervals, the extremum conditions for the two-level intertemporal scheme are: (1) initial price in the first time interval and secondary price in the remaining nineteen, or (2) initial price changed over the first nineteen periods and the secondary price in the last period only. For any subperiod of more than one time interval, the best single price for that subperiod is found in a manner analogous to finding the single best price for the total period described above. It is more convenient within the algorithm, however, particularly with computers, to obtain optimal prices in a somewhat different manner from that described above. We can find the single best price in a sub-period to be the arithmetic mean of the unit elastic prices of each of the component time intervals of the subperiod, weighted by their associated output quantities suitably discounted to the present. The single price found by this method is exactly the same as that of the method described above and illustrated in Figure 6, but the mathematical format is more amenable to making subsequent iterations as necessary. The weighting factor for any time interval unit elastic price is

$$W_t = \frac{Qt}{(1+r)^t}$$

and the single optimal price within a subperiod of the total planning period composed of, say, intervals one to five, is then

$$_1P^*_5 = \frac{P_t \; W_t}{W_t}$$

where P_t is the unit elastic price for time interval t.

The computer algorithm proceeds iteratively to determine the optimal price levels for each possible combination of subperiods within the total planning period until the net present revenue generated is non-negative and the constraint of decreasing or increasing price levels is met. The number of intertemporal price levels can be increased beyond two at a substantial increase in computer time required for the calculation. A sample listing of the requisite values obtained by hand methods for a five-interval subperiod is given in Table I.

Appendix A contains a tabular guide for hand calculation of a single optimal price using hypothetical data, and Appendix B is printout of the preliminary computer routines in FORTRAN II language. 1/ Results from preliminary testing of the model indicate that at interest rates of around ten percent and below intertemporal price schemes seem to be more easily implemented in meeting desired objectives than the intertemporal alternatives.

With continuously increasing demand, efficient intertemporal price discrimination with a secondary price lower than the initial one may not be a feasible alternative. When parameters exist which require some price discrimination to meet the given constraint of non-negative net present benefits, more than two intertemporal price levels are likely to be required, whereas less than seven intertemporal price level are likely to suffice. The question arises, obviously, of which type of price discrimination is likely to be most acceptable politically and administratively - - questions almost certainly better answered by legislators, administrators, and others than by economists alone.

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1. We stress that the program listing contained in Appendix B is only preliminary and is under continual revision and development. At the time of writing, the computer algorithms are being translated into FORTRAN IV, for further testing with real data.

TABLE I

INTERTEMPORAL PRICING SCHEME CALCULATIONS
FOR THE BEST SINGLE PRICE, WITH AN INTEREST
RATE OF TWO PERCENT AND A FIVE YEAR PLANNING
PERIOD (t = 1, . . . , 5)

t	P_t	Q_t	W_t	W_tP_t
1	5.00	4.54	4.46	22.28
2	6.00	5.54	5.33	31.98
3	7.00	6.36	6.00	41.98
4	8.00	7.27	6.72	53.75
5	9.00	8.18	7.41	66.70
			Σ = 29.92	Σ = 216.69

$$ {}_1P_5^* = \frac{\sum_1^5 W_t P_t}{\sum_1^5 W_t} = \frac{216.69}{29.92} \; ; \quad {}_1P_5^* = 7.24 \text{ units} $$

NOTES:

1. t is time interval in years.
2. P_t is unit elastic price level in time interval t.
3. Q_t is associated quantity at price P_t, obtained from Q_{net} curve in time interval t.
4. $W_t = Q_t / (1 + r)^t$.
5. See Appendix A for input data.

APPENDIX A

SAMPLE CALCULATIONS TO IDENTIFY THE BEST SINGLE PRICE TO OBTAIN MAXIMUM REVENUE, WITH AN INTEREST RATE OF TWO PERCENT AND A PLANNING PERIOD OF FIVE YEARS ASSUMED.

INPUT DATA ARRAYS

TIME INTERVAL (YEARS)	D_t^a	D_t^b	S_t^a	S_t^b
1	20*	1.0	10*	.1
2	22	1.0	10	.1
3	24	1.0	10	.1
4	26	1.0	10	.1
5	28	1.0	10	.1

* In demand and supply units

NOTES:

1. Assume constant demand and supply slopes; right-shifting (increasing) demand over time.
2. Present value factor (PRVF) is $1 / (1 + r)^t$
3. D_t^a is price axis intercept of demand curve at time t.
4. S_t^a is price axis intercept of supply curve at time t.
5. D_t^b is slope of demand curve in time interval t.
6. S_t^b is slope of supply curve in time interval t.

TABULAR CALCULATIONS FOR BEST SINGLE PRICE

t	PRVF	PI_t	A_t	B_t	$DISA_t$	CS_t	DCS_t
1	.98039	10.00	9.09	.909	8.91	45.45	44.56
2	.96117	12.00	10.91	.909	10.48	65.45	62.91
3	.94232	14.00	12.73	.909	11.99	89.09	83.95
4	.92385	16.00	14.55	.909	13.44	116.36	107.50
5	.90573	18.00	16.36	.909	14.82	147.27	133.39
					59.65	463.63	432.32

NOTES:

1. PI_t is the price axis intercept of the net outlay curve in time interval t: $PI_t = D^a_t - S^a_t$
2. A_t is the quantity axis intercept of the net outlay curve in time interval t: $A_t = PI_t \;/\; D^b_t + S^b_t$
3. B_t is the slope of the net outlay curve with reference to the price axis in time interval t: $B_t = A_t \;/\; PI_t$
4. $DISA_t$ is the A_t intercept discounted to the present.
5. CS_t is the consumers' surplus in time interval t.
6. DCS_t is CS_t discounted to the present.
7. DAC is the quantity axis (Q) intercept of the composite net outlay curve discounted to the present:

$$DAC = \sum_{1}^{5} DISA_t \quad , \quad DAC = 59.65$$

8. PIC is the composite net outlay curve price axis intercept.
9. BC is the slope of the composite net outlay curve:

$$BC = DAC \;/\; PIC$$

10. P^* is the single best price for maximum revenue:

$$PIC = 2 \times DCS \;/\; DAC$$

$$P^* = PIC \;/\; 2$$

$$P^* = 7.25 \text{ units}$$

APPENDIX B

FORTRAN II SOURCE PROGRAM LISTING OF
PRELIMINARY TESTING ROUTINES

```
C     J.R. MEYER AND L.M. COLE
C     PROGRAM FOR CAPITAL BUDGETING WITH INTERCONSUMER AND
C     INTERTEMPORAL PRICE DISCRIMINATION AT DIFFERENT DISCOUNT
C     RATES AND DIFFERENT LENGTHS OF PLANNING PERIODS
C     ASSUMPTIONS -- GIVEN ESTIMATED DEMAND AND SUPPLY FUNCTIONS
C     IN EACH TIME INTERVAL OVER THE TOTAL PLANNING PERIOD,(ASSUME
C     THEM TO BE LINEAR),GIVEN THE PRESENT COST OF THE FACILITY.
      DIMENSION DA(50),SA(50),DB(50),SB(50)
      COMMON PCOST,TDGRM,PIC,DAC,BC,PSTAR,PB1,PB2,PB3,PB4,PB5,PB6,
     1PB7,JR,PVNRRA,DA,SA,DB,SB,N,PVNRER,JSTAR,PBEST1,PBEST2,TDCS
      PRVF(JR,IT) = 1. / ((1. + FLOATF(JR) / 100.) ** IT)
C     ARRAYS OF DEMAND AND SUPPLY PRICE AXIS INTERCEPTS AND SLOPES
      READ INPUT TAPE 5,702,(DA(IT),DB(IT),SA(IT),SB(IT), IT = 1,20)
      WRITE OUTPUT TAPE 6,703
      WRITE OUTPUT TAPE 6,704,(IT,DA(IT),DB(IT),SA(IT),SB(IT),IT,
     1IT = 1,20
C     * * * BEGIN MAIN PROGRAM XEQ HERE * * *
      I = 1
      N = 20
C     PCOST = GIVEN AMOUNT
      WRITE OUTPUT TAPE 6,701,I,N,PCOST
      DO 100 JR = 2,20,2
C     CHECK TOTAL DISCOUNTED CONSUMERS SURPLUS GREATER THAN PCOST
      TDCS = 0.
      DAC = 0.
      DO 10 IT = 1,N
      PI = DA(IT) - SA(IT)
      A = PI / (DB(IT) + SB(IT))
      B = A / PI
      CS = (A/2.) * PI
      DCS = CS * PRVF(JR,IT)
      TDCS = TDCS + DCS
      DISA = A * PRVF(JR,IT)
      DAC = DAC + DISA
      WRITE OUTPUT TAPE 6,666,JR,IT,PI,A,B,CS,DCS,TDCS,DISA,DAC
  666 FORMAT(1H ,2I5,8F15.5 //)
   10 CONTINUE
      WRITE OUTPUT TAPE 6,800,TDCS,JR,PCOST
      WRITE OUTPUT TAPE 6,807,DAC
      IF(TDCS - PCOST) 11,11,12
   11 WRITE OUTPUT TAPE 6,801, JR
      GO TO 100
C     FIND SINGLE PRICE (PSTAR) OVER TIME WHICH MAX. NET PRESENT
C     REVENUE
   12 WRITE OUTPUT TAPE 6,803
      PIC = (2. * TDCS) / DAC
      BC = DAC / PIC
      SP = (DAC / 2.) / BC
C     (CONTINUED NEXT PAGE)
```

```
      TDGR = SP * (DAC / 2.)
      PSTAR = SP
      TDGRM = TDGR
C     TDGRM = TOTAL MAX. DISCOUNTED GROSS REVENUE
      DIFF = TDGRM - PCOST
      WRITE OUTPUT TAPE 6,699,TDGRM,DIFE
      IF(DIFE - 0.00005) 13,15,13
   13 IF(DIFE) 14,15,16
   14 CALL TRA
C     INTERCONSUMER (INTRATEMPORAL) PRICE DISCRIMINATION ROUTINE
      WRITE OUTPUT TAPE 6,804,TDGRM,PSTAR,PMUSE,PB1,PB2,PB3,PB4,
     1PB5,PB6,PB7,JR
      WRITE OUTPUT TAPE 6,802,JR,PVNRRA
      CALL TER2
C     INTERTEMPORAL PRICE DISCRIMINATION SUBROUTINE
C     (TWO LEVELS MAXIMUM)
      WRITE OUTPUT TAPE 6,310,TDGRM,JSTAR,PBEST1,PBEST2,JR
      WRITE OUTPUT TAPE 6,311,JR,PVNRER
      GO TO 100
   15 PMUSE = SP
      WRITE OUTPUT TAPE 6,805,TDGRM,PMUSE,JR
      GO TO 100
C     FIND SINGLE PRICE (PMUSE) WHICH MAX. USE WITH PRESENT
C     VALUE = 0.
   16 PSTAR = SP
      WRITE OUTPUT TAPE 6,804,TDGRM,PSTAR
      ROOT = SQRTF((DAC ** 2) - 4. * BC * PCOST)
      PONE = (DAC + ROOT) / (2. * BC)
      PTWO = (DAC - ROOT) / (2. * BC)
      IF(PONE - SP) 17,18,18
   17 PMUSE = PONE
      GO TO 19
   18 PMUSE = PTWO
   19 WRITE OUTPUT TAPE 6,806,TDGRM,PMUSE,JR
  100 CONTINUE
  699 FORMAT(1H ,4X,7HTDGRM =F15.5,5X,6HDIFE =F15.5 //)
  700 FORMAT(1H ,2I4,F15.9 //)
  701 FORMAT(1H ,3HI =I3,5X,3HN =I4,5X,7HPCOST =F15.5 ///)
  702 FORMAT(5X,2F15.5,5X,2F15.5)
  703 FORMAT(1X,2HIT,9X,6HDA(IT),19X,6HDB(IT),19X,6HSA(IT),19X,
     16HSB(IT),9X,2HIT //)
  704 FORMAT(1H ,I2,2X,F15.5,10X,F15.5,10X,F15.5,10X,F15.5,8X,I2)
  800 FORMAT(1H0,4X,6HTDCS =F15.5,2X,4HJR =I3,2X,7HPCOST =F15.5)
  801 FORMAT(1H0,4HJR =I3,3X,63HSYSTEM CANNOT BE ECONOMICALLY
     1EFFICIENT UNDER GIVEN PARAMETERS. ///)
  802 FORMAT(10X,4HJR =I3,5X,8HPVNRRA =F15.5 //)
  803 FORMAT(5X,5HTDGRM,8X,5HPSTAR,5X,5HPMUSE,6X,3HPB1,7X,3HPB2,
     17X,3HPB3, 7X,3HPB4,7X,3HPB5,7X,3HPB6,7X,3HPB7,5X,2HJR //)
  804 FORMAT(1H ,F12.5,3X,9F10.5,2X,I3)
  805 FORMAT(1H ,F15.5,10X,F10.5,72X,I3)
  806 FORMAT(1H ,F15.5,10X,F10.5,72X,I3)
  807 FORMAT(1H ,5X,5HDAC =F10.5 //)
  310 FORMAT(1H ,F15.5,I5,2F10.5,I5)
  311 FORMAT(10X,4HJR =I3,5X,8HPVNRER =F15.5 //)
      END
```

```
      SUBROUTINE TRA
      DIMENSION DA(50),SA(50),DB(50),SB(50)
      COMMON PCOST,TDGRM,PIC,DAC,BC,PSTAR,PB1,PB2,PB3,PB4,PB5,PB6,
     1PB7,JR,PVNRRA,DA,SA,DB,SB,N,PVNRER,JSTAR,PBEST1,PBEST2,TDCS
      P2 = PIC / 3.
      Q2 = DAC / 3.
      TDGR2 = (2. * TDCS) / 3.
      IF(TDGR2 - PCOST) 20,21,21
   21 TDGRM = TDGR2
      PB1 = P2
      PB2 = 2. * P2
      PVNRRA = TDGRM - PCOST
      GO TO 200
   20 P3 = PIC / 4.
      Q3 = DAC / 4.
      TDGR3 = (3. * TDCS) / 4.
      IF(TDGR3 - PCOST) 22,23,23
   23 TDGRM = TDGR3
      PB1 = P3
      PB2 = 2. * P3
      PB3 = 3. * P3
      PVNRRA = TDGRM - PCOST
      GO TO 200
   22 P4 = PIC / 5.
      Q4 = DAC / 5.
      TDGR4 = (4. * TDCS) / 5.
      IF(TDGR4 - PCOST) 24,25,25
   25 TDGRM = TDGR4
      PB1 = P4
      PB2 = 2. * P4
      PB3 = 3. * P4
      PB4 = 4. * P4
      PVNRRA = TDGRM - PCOST
      GO TO 200
   24 P5 = PIC / 6.
      Q5 = DAC / 6.
      TDGR5 = (5. * TDCS) / 6.
C     (CONTINUED NEXT PAGE)
```

```
      IF(TDGR5 - PCOST) 26,27,27
   27 TDGRM = TDGR5
      PB1 = P5
      PB2 = 2. * P5
      PB3 = 3. * P5
      PB4 = 4. * P5
      PB5 = 5. * P5
      PVNRRA = TDGRM - PCOST
      GO TO 200
   26 P6 = PIC / 7.
      Q6 = DAC / 7.
      TDGR6 = (6. * TDCS) / 7.
      IF(TDGR6 - PCOST) 28,29,29
   29 TDGRM = TDGR6
      PB1 = P6
      PB2 = 2. * P6
      PB3 = 3. * P6
      PB4 = 4. * P6
      PB5 = 5. * P6
      PB6 = 6. * P6
      PVNRRA = TDGRM - PCOST
      GO TO 200
   28 P7 = PIC / 8.
      Q7 = DAC / 8.
      TDGR7 = (7. * TDCS) / 8.
  500 IF(TDGR7 - PCOST) 30,31,31
   30 WRITE OUTPUT TAPE 6,807
  807 FORMAT(10X,44HNEED MORE THAN 7 INTRATEMPORAL PRICE LEVELS.)
   31 TDGRM = TDGR7
      PB1 = P7
      PB2 = 2. * P7
      PB3 = 3. * P7
      PB4 = 4. * P7
      PB5 = 5. * P7
      PB6 = 6. * P7
      PB7 = 7. * P7
      PVNRRA = TDGRM - PCOST
  200 RETURN
      END
```

```
      SUBROUTINE TER2
      DIMENSION DA(50),SA(50),DB(50),SB(50)
      COMMON PCOST,TDGRM,PIC,DAC,BC,PSTAR,PB1,PB2,PB3,PB4,PB5,PB6,
     1PB7,JR,PVNRRA,DA,SA,DB,SB,N,PVNRER,JSTAR,PBEST1,PBEST2,TDCS
      PRVF(JR,IT) = 1. / ((1. + FLOATF(JR) / 100.) ** IT)
      JSTAR = 0
      NN = N - 1
      DO 300 J = 1,NN
      W1 = 0.
      WP1 = 0.
      DO 301 IT = 1,J
      PI = DA(IT) - SA(IT)
      A = PI / (DB(IT) + SB(IT) )
      B = A / PI
      ELQ = A / 2.
      TW1 = ELQ * PRVF(JR,IT)
      PEL = ELQ / B
      TWXP1 = PEL * TW1
      WP1 = WP1 + TWXP1
      W1 = W1 + TW1
  301 CONTINUE
      PMN1 = WP1 / W1
      K = J+1
      W2 = 0.
      WP2 = 0.
      DO 302 IT = K,N
      PI = DA(IT) - SA(IT)
      A = PI / (DB(IT) + SB(IT))
      B = A / PI
      ELQ = A / 2.
      TW2 = ELQ * PRVF(JR,IT)
      PEL = ELQ / B
      TWXP2 = PEL * TW2
      WP2 = WP2 + TWXP2
      W2 = W2 + TW2
  302 CONTINUE
      PMN2 = WP2 / W2
      WRITE OUTPUT TAPE 6,334,PMN1,PMN2,J
  334 FORMAT(1H ,54X,6HPMN1 =F15.5,5X,6HPMN2 =F15.5,3HJ =I5 //)
   31 DGR1 = 0.
      DO 303 IT = 1,J
      QNET = A - (B * PMN1)
      GR = QNET * PMN1
      GRD = GR * PRVF(JR,IT)
      DGR1 = DGR1 + GRD
  303 CONTINUE
C     (CONTINUED NEXT PAGE)
```

```
      DGR2 = 0.
      DO 304 IT = K,N
      QNET = A - (B * PMN2)
      GR = QNET * PMN2
      GRD = GR * PRVF(JR,IT)
      DGR2 = DGR2 + GRD
  304 CONTINUE
      TDGR = DGR1 + DGR2
      IF(J - 1) 32,32,33
   32 TDGRM = TDGR
      WRITE OUTPUT TAPE 6,333,TDGR,TDGRM,J
      GO TO 300
   33 IF(TDGR - TDGRM) 34,35,35
   34 WRITE OUTPUT TAPE 6,333,TDGR,TDGRM,J
  333 FORMAT(1H ,54X,6HTDGR =F15.5,5X,7HTDGRM =F15.5,5X,3HJ =I5 //)
      GO TO 300
   35 TDGRM = TDGR
      JSTAR = J
      PBEST1 = PMN1
      PBEST2 = PMN2
      PVNRER = TDGRM - PCOST
  300 CONTINUE
      WRITE OUTPUT TAPE 6,333,TDGR,TDGRM,J
      WRITE OUTPUT TAPE 6,311,JR,PVNRER
  311 FORMAT(10X,4HJR =I3,5X,8HPVNRER =F15.5 //)
      IF(JSTAR) 36,36,305
   36 JSTAR = J * 100
      TDGRM = TDGR
      PBEST1 = PMN1
      PBEST2 = PMN2
      PVNRER = TDGRM - PCOST
  305 RETURN
      END

*     DATA
```

LISTING OF KEY VARIABLE NAMES

A	QUANTITY AXIS INTERCEPT OF NET OUTLAY CURVE
B	SLOPE OF NET OUTLAY CURVE
DA(IT)	DEMAND CURVE INTERCEPT IN TIME INTERVAL IT
DB(IT)	DEMAND CURVE SLOPE IN TIME INTERVAL IT
DAC	DISCOUNTED A INTERCEPT OF COMPOSITE NET OUTLAY CURVE
DISA	DISCOUNTED A INTERCEPT,NET OUTLAY CURVE
PCOST	PRESENT COST
PI	PRICE AXIS INTERCEPT OF NET OUTLAY CURVE
PMUSE	BEST SINGLE PRICE TO MAXIMIZE USE
PRVF	PRESENT VALUE FACTOR
PSTAR	BEST SINGLE PRICE TO MAXIMIZE REVENUE
PVNRER	PRESENT VALUE OF NET REVENUE WITH SUBROUTINE TER2
PVNRRA	PRESENT VALUE OF NET REVENUE WITH SUBROUTINE TRA
SA(IT)	SUPPLY CURVE INTERCEPT IN TIME INTERVAL IT
SB(IT)	SUPPLY CURVE SLOPE IN TIME INTERVAL IT
TDCS	TOTAL DISCOUNTED CONSUMERS SURPLUS
TDGR	TOTAL DISCOUNTED GROSS REVENUE
TDGRM	MAX. OF ALL TOTALS OF DISCOUNTED GROSS REVENUE

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