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Modeling and Cost Analysis of Global Logistics and Manufacturing System

by

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ABSTRACT

Three major transportation modes, sea shipping, railroad shipping, and trucking, are explored in terms of the factors that affect pricing policy. This thesis explores the factors and the pricing policy for each transportation mode, develops the cost model of each mode, and uses their cost models to examine the accuracy of an approximate total cost model. These cost models are also applied in estimating total distribution and operational costs in automobile industries. The effects of number of plants and their locations on total operational costs in global markets are inspected.

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Chapter 1 Introduction

Transportation and information technology have developed rapidly in past years. It is now easier for companies to respond to demands for their products and to distribute their products to their clients. In addition, competitive pressures are requiring more companies to go global. In the past several years, many corporations have substantially increased the magnitude of global operations, including both manufacturing and distribution.

When a company plans to set up a global manufacturing and distribution network, it must consider two major alternative systems: (1) a centralized production system - building a big plant to finish the production process, and then using its distribution and logistics channels to ship its products to its clients; (2) a decentralized production system - building several plants in different places, and using the products of these plants to meet the demand in the local market or nearby markets. For example, if the company chooses the decentralized system, it may build one plant in the U.S. to meet the demands in the U.S. market, and another plant in Western Europe to meet the demands in Western Europe, Eastern Europe, and Africa. Both of these systems have their own advantages and disadvantages. According to its situation, a company will carefully choose between these two alternatives in order to reduce total operational costs and increase profits.

In these two systems, the number and the locations of factories are the key factors in determining total operational costs. There are many factors that will affect decisions about the number of plants and their locations: transportation costs, manufacturing costs, taxes and duties, local issues and local restrictions, exchange-rate uncertainty, etc. These factors make a global system more complex and difficult to be analyzed.

Global operations have become more important in recent years. For this reason, several authors have explored this area. Arntzen, Brown, Harrison, and Trafton (1995) used global supply chain model to analyze the manufacturing and distribution strategy of Digital Equipment Corporation[1]. They modeled the important issues in global system, such as, demand, production, inventory, shipping, duty drawback and duty relief. Huchzermeier and Cohen (1996) discussed the issues of valuing operational flexibility under exchange rate risk in global system[2]. Rosenfield (1996) analyzed multi-regional operations and used stochastics models to simulate exchange rate uncertainty[3].

Rosenfield used three major costs to compose the majority of total operational costs: production costs, distribution and handling costs, and taxes. For most products, these costs consist more than 80% of operational costs. They used a geographic distance model to model distribution and handling costs in local system[4]. This model states that the average distance over which the products are shipped is proportional to the square root of the area served by the plant. Total transportation costs are also proportional to demand. The total transportation costs can be expressed as:

$$\text{Total Transportation Costs} = A * D * r^{1/2}$$

Here, A is a constant coefficient, D is the total demand in the whole market, and r is the average area served by each facility. Because

$$r = R / M$$

Therefore,

$$\text{Total Transportation Costs} = A * D * r^{1/2} = A * D * (R / M)^{1/2}$$
$$= C * D * M^{(-1/2)}$$

R is the total market area served. M is number of total plants in the whole market. C is a constant and equal to $A * R^{1/2}$.

[1] Arntzen, Bruce C., Brown, Gerald G., Harrison, Terry P., and Trafton, Linda L. (1995), *Global Supply Chain management at Digital Equipment Corporation*, Interfaces 25, Jan.-Feb., 1995

[2] Huchzermeier, Arnd, and Cohen, Morris A. (1996), *Valuing Operational Flexibility Under Exchange Rate Risk, Operations Research*, Vol. 44, No. 1, Jan. Feb., 1996

[3] Donald B. Rosenfield (1996), *Global and Variable Cost Manufacturing Systems*, European Journal of Operational Research, 1996

[4] Magee, John F., Copacino, William C., and Rosenfield, Donald B. (1985), *Modern Logistics Management*, Chapter 10, John Wiley & Sons, N.Y

One of the purposes of this thesis is to test such simple approaches in estimating transportation costs.

In global systems, there are four major transportation modes: sea shipping, railroad shipping, trucking and air shipping. The costs of these four models constitute total transportation costs. Every shipping mode has its specific characteristics and supply-and-demand relationship. Carriers of different shipping modes will have their specific considerations and procedures to determine their freight rates. Even though there are common factors needed to be considered in all shipping modes, these factors will have different weights in different modes. For example, distance is a critical factor in determining the freight rate of trucking. However, because facility, capacity and accessibility of seaports are very important in determining sea shipping costs, compared to these factors, distance becomes less important for sea shipping. Therefore, each shipping mode should have its unique model for freight rates.

On the other hand, for different products, transportation costs are responsible for different portion of total costs. In some cases, transportation costs account for just 10% or less of total costs. However, in some other cases, the portion may be more than half of the total costs, for instance, raw material transportation. Therefore, applying oversimplified models to estimate total transportation will induce a different scale of errors in total operational costs.

In the automobile industry, because many components are required to assemble a car, and it is difficult to produce all components at a same plant, automobile companies have to ship some components from other plants or component suppliers. Transportation and shipping costs become more important in the automobile industry than those in other industries. We thus explore the automobile industry because first, it is one of the largest industries in the world, and second, transportation costs are critical in the automobile industry.

The objectives of this thesis are:

1. To realize the characteristics and important factors of different transportation modes, with a major product of the automobile industry.
2. To develop cost models for different transportation modes.
3. To check the accuracy of simplified models such as the Geographic Distance Model by using the freight rate models of these transportation modes.
4. To analyze and estimate global operational costs in the automobile industry.

Aircraft cannot carry very heavy cargoes, because of its characteristics. For this reason, automobile companies rarely use this mode to ship their products. Therefore, the mode of air shipping is not discussed in this thesis.

In Chapter Two, the general pricing theory in shipping industries is introduced. Total transportation costs are divided into three parts: sea shipping cost, railroad shipping cost and trucking cost. For each mode cost, I will analyze its specific characteristics, find the important factors in determining its freight rate, and develop its individual pricing model.

Chapter Three includes two major parts. In the first part, the cost models of the three modes are combined together as the total transportation cost model. This model and the Geographic Distance Model are used to analyze the U.S. automobile market. By comparing their results, the accuracy of the Geographic Distance Model is examined. In the second part, the total transportation cost model is associated into total operational cost model. The case of a global automobile market is analyzed by using the total operational cost model. Chapter Four concludes the thesis.

Chapter 2 Transportation Costs and Models

2.1 Introduction and Basic Theory for Pricing

Because of the deregulation in most major modes of transportation, it is difficult to realize the pricing behavior of them by a regulated formula. The reasons are: first, there are too many factors involving in determining freight rates. Some of the factors are related to shippers, such as shipped commodity characteristics and total shipped amount. Some factors are related to carriers, such as total capacity of the individual carrier and all carriers. There are also some other factors that are unrelated to both of them, such as shipping season. Second, for different transportation modes, there are different factors resulting in total operation cost for carriers. Even when different modes have common determinants, these determinants have different weights in determining freight rates. For example, fixed cost or equipment cost is not so important for trucking, but it covers a big part for sea-shipping. Therefore, economists spent a lot of time and energy to determine a proper policy to determine freight rates.

The theoretical way to approach pricing strategies for different modes of transportation is through a well-known theorem in economics. It states that a competitive equilibrium is Pareto optimal and therefore efficient in the sense that no industry can increase its output without decreasing that of another, and no individual's welfare can increase without decreasing that of another. Economists analyzing the efficiency of the surface freight industry have generally focused on competitive equilibrium as the norm.[1] Economists also suggest that it is a reasonable pricing policy for carriers to charge shippers the marginal shipping cost in order to get maximum profit for the whole commodity.

[1] See Meyer et al. (1959) and Moore (1975)

In following two examples, one in the competitive market and the other one in joint profit maximizing market, we can see what this economic theorem means, how it works, and why it is reasonable for carriers to charge marginal cost.

In a competitive market, if price is less than marginal cost, price should be required to increase and then be equal to marginal cost, because of over-utilization of resources and increasing demand in that sector. If price is greater than marginal cost, then through the function of supply-and-demand in economic market, then the normative price should be forced to decrease to attract demand and then be equal to marginal cost. Here, demand is estimated on an industry level and is postulated to be a function of rates, trip attributes, non-transportation output, etc., and cost is estimated on a firm level and is postulated to be a function of output, factor prices, and trip characteristics.

On the other hand, in joint profit maximizing market, if one firm, through ownership, or a group of firms, through collusion, were to gain monopoly power in an industry, it has enough power to affect market price. Neoclassical economic theory states that the industry will produce where marginal cost equals marginal revenue in order to maximize profits for the whole community. It is obvious that the firm will not allow a market price less than marginal cost, otherwise it will lose money. Moreover, the firm will tend to set the price as high as it can in order to get more profit. However, when the market price is greater than marginal cost, even though the firm can get more profit, there is a "deadweight loss" in the whole community. "Deadweight loss" is not characteristics of customers or the firm, but lost in the whole system. From the viewpoint of resource efficiency for the whole system, because a resource is used and no benefit is produced, this is not an efficiently economic system. Therefore, in an industry that produces many outputs, profit will be maximized where marginal cost equals marginal revenue for each commodity.

From the previous two examples, apparently, charging marginal cost is reasonable and efficient for carriers, shippers and the whole system. Therefore, the policy of charging marginal shipping cost is generally accepted and used as the basic rule in current freight rate structure for most transportation modes. I also use a marginal cost model to approach freight rate in this thesis.

In addition to economic forces, federal transportation policy is another important determinant of transportation activity. This includes not only the equilibrium quantity of service, but also its quality and cost. It is fairly easy to visualize how transportation regulation, through restrictions on entry, rates and routes, can affect the equilibrium service and costs of a particular mode. What should be realized is that because the various modes are in competition, the relative service levels of all modes have been affected.

It should be noted that there are many modes competing for freight, for instance, railroad, trucking, barge, pipeline and air freight. However, tractability calls for the problem to be segmented. Pipelines mainly carry natural gas and petroleum products in large volumes. Barge competes mainly with rail for bulk commodities. Air freight makes up a very small share of the transportation market. Trucking is both a substitute and complement for railroad transportation. Full truckload truck transportation competes directly with rail, and less than truckload lot truck transportation offers a service complementary to that of rail.

In this thesis, my focused commodity is motor vehicle. Because of the high freight rate and the capacity constraint of air shipping, most of these commodities are not shipped through air. So I will not discuss the freight structure of air shipping.

In this chapter, I focus on the pricing behavior of three shipping modes: sea shipping (Section II), railroad shipping (Section III), and trucking (Section IV). In each section, I will generally discuss the important factors in determining marginal cost and freight rate of this mode, and the effect of these factors on the pricing behavior. Finally, I will use the existing data to develop an individual mathematical model for this mode.

2.2 Sea Shipping

The most conspicuous feature of the sea-shipping tariff has been its size: practically every one of hundreds or more different articles are separately identified so that each can, in principle, carry an individual freight rate. When, as is common, a separate rate is quoted for each specific commodity, one speaks about 'commodity rates'. A single tariff may include several thousands of commodity rates. In some tariffs, freight rates are divided into ten to twenty classes, and the commodities are assigned to different classes. These quotations also apply to containerized cargo. For a less-than-full container load, commodity rates as published for conventional cargo normally apply. For a full container load, a simplified tariff which may include twenty or thirty commodity classes normally used.

Based on the principle of economic theory described in Section 2.1, the freight rate structure can be approached by marginal costs.

There are many factors that participate in shaping the level and structure of freight rates, and which makes it very difficult to compare individual freight rates. For example, the following rather exhaustive list (Table 2.2.1) of twenty-seven factors was suggested by the US delegates in the Inter-American Maritime Conference in 1941.

Table 2.2.1 Factors of Determining Freight Structure

(Source: Inter-American Maritime Conference, *Report of Delegates of the United States*, Washington, Government printing Office, 1941)

1. Character of cargo
2. Volume of cargo
3. Availability of cargo
4. Susceptibility to damage
5. Susceptibility to pilferage
6. Value of goods
7. Packing
8. Direct cost of operation
9. Distance
10. Cost of handling
11. Lighterage
12. Special deliveries or devices
13. Fixed charges
14. Insurance
15. Package
16. Stowage
17. Heavy lifts
18. Extra length
19. Goods from other sources of supply
20. Goods via competitive gateways
21. Competition from other carriers
22. Port facilities
23. Port regulations
24. Port charges and dues
25. Canal tolls
26. Port location
27. Possibility of securing return cargo

For costing purposes, the marginal cost of the *k*th cargo can conveniently be divided into three parts: (1) Fixed cost component, (2) Direct cargo cost component, (3) Indirect cost component. We can see more detailed components in these three groups and their percentage of total cost in Table 2.2.2

Table 2.2.2 Detailed Cost Per 20 Feet Container (Per TEU) of 2,800 container ships

(Source: Container Market Profitability to 1997)

1. Fixed Costs	**$ Per Teu**	**%**
Bunkers	61	3.5
Ports	62	3.6
Capital	168	9.7
Operating	133	7.7
Administration	281	16.2
Subtotal	**707**	**40.8**
2. Direct costs		
Terminals	286	16.5
Transport	470	27.1
Depots	7	0.4
Refrigeration	7	0.4
Subtotal	**769**	**44.4**
3. Indirect Costs		
Empty Containers	85	4.9
Equipment Provision	88	5.1
Maintain & Repair	68	3.9
Cargo Insurance	16	0.9
Subtotal	**256**	**14.8**
Total Costs	**1733**	**100**

Explanation:

Fixed costs: the cost irrelative to shipping quantity

- Bunkers - Fuel for the ship's engines.
- Ports - Pilotage, towage, dockage fees, port dues, etc.
- Capital - Payments toward equity in the vessel, including interest charges.
- Operating - Stores and lubes, ship repairs and maintenance, insurance and managing the ship
- Administration - Managing the movement of cargo through the service network

Direct Costs: the cost relative to shipping quantity and induced in the shipping process directly

- Terminals - Moving containers on and off the vessel, including terminal gate charges, crane usage, transfers, removal of hatch covers and all other interminal cargo expenses
- Transport - Cargo movement by rail, truck or barge from the port to an inland destination
- Depots - Costs for consolidating cargo into full container loads (stuffing/stripping) at container freight stations
- Refrigeration - Cost for provision of refrigeration facilities and monitoring the temperature of frozen cargo

Indirect Costs: the cost relative to shipping quantity and induced indirectly

- Empty Containers - Cost for restowage, transportation and loading of empties. Does not include opportunity cost of not carrying full containers
- Equipment Provision - Cost for containers and trailers, includes both leasing and purchasing costs
- Maintenance & Repair - Costs for maintaining containers and trailers
- Cargo Insurance - Covers the cargo on both the land and sea portions of the trip

The investigation of the structure of break-bulk cargo handling costs [2] indicates that a very substantial proportion of the variations in both the direct and indirect handling costs are explained by the package type, the package weight, and the "stowage factor". Here, the definition of "stowage factor" is the ratio of package measurement (including broken stowage) to package weight. Alternatively, we can use package measurement as a substitute for the stowage factor to describe characteristics of cargo and this does not reduce the explanatory power by much[3].

By the suggestion of Jansson and Shneerson [4], the marginal costs of different cargoes and the cargo characteristics can be describe by:

$$MC_{ijk} = (a_{ijk} * m)+(b_{ijk} * w)+ c_{ijk}$$

Where MC_{ijk} : the marginal cost of shipping from the ith port to the jth port an article of the kth package type

m : package measurement

w : package weight

$a_{ijk} * m$: measurement-proportional cost component

$b_{ijk} * w$: weight-proportional cost component

c_{ijk} : fixed cost per package unit (independent of package size)

In the common case where more than one port is called in each service range, the tariff construction will be somewhat involved, in view of the likely possibility that some of the coefficients, a_{ijk}, b_{ijk}, and c_{ijk} take different values for different ports for each given package type.

[2] Jansson J. O., and Shneerson D. (1982), *Port Economics*

[3] Jansson J. O., and Shneerson D. (1986), *Liner Shipping Economics, Chapter 11*

[4] Jansson J. O., and Shneerson D. (1986), *Liner Shipping Economics, Chapter 11*

The technically most suitable tariff format would be a number of "article matrices" of the kind shown by Fig. 2.2.3 with three entries for each pair of ports. One entry gives the charge per m^3, a second entry gives the charge per ton (1000kg), and a third entry gives the fixed charge per package unit, which consequently is independent of the package size.

Table 2.2.3 Layout of 'Article Matrix' of a Cost-Based Tariff of Freight Rates

Port of loading Port of unloading	First port	Second port	....
First port	×	a_{21} per m^3 b_{21} per ton c_{21}	....
Second port	a_{12} per m^3 b_{12} per ton c_{12}	×	....
....	....	....	....

There have to be as many article matrices as there are package types. The most insignificant package types could perhaps be grouped together under a heading like 'general cargo, not otherwise specified'. The previous example suggests that a range of package weights be specified. An additional charge could be levied on exceptional units, both on unusually small and unusually big units, if there are good cost reasons for this.

More important is a peak and off-peak differential. The basic freight rates should be specified to apply to a period of time, i.e. the slack season. Outside this period, one or more extra peak charges should be levied on top of the basic freight rates. However, Table 2.2.3 does not show this kind of modification for this issue. Finally, a quantity rebate may be justified. If this is the case, a simple way of making the freight rate of a given article taper off with increases in the size of shipments is to levy a fixed charge per shipment. This may also be justified on account of clerical work required in connection with the documentation, etc. which is largely independent of the size of the shipment.

The logical extension of the pricing principles to containers is immediate. Containers represent one class of package type. Only one 'article matrix' of the kind described in the previous paragraph may be required. Freight rates for modules other than 20-foot containers should either be a multiple of the basic freight rates for 20 footers, or the other modules could be defined as separate articles.

In fact, for container shipping, the tariff might be further simplified, without great loss in efficiency. The fixed charge, c_{ij}, and even the charge per ton, b_{ij}, could be superfluous; the former because it would practically be identical to all containers, and the latter because for containerizable cargo, the effect of weight will be nil in most cases. The tariff would then have a single charge per cubic meter that will vary according to the ports of loading and unloading. For example, company A is an automobile company and plans to use containers to ship its cars from Yokohama, Japan to Long Beach, California. Company B is a lumber company and also plans to use containers to ship its lumber from the same origin to same destination. Because of the volume constraint of containers and because of safety reasons, company A just can use a 20-feet container to hold one car and nothing else. Company B also uses 20-feet containers to ship its lumber. Because both of them use the same size of containers, even though the size, the weight and the value of their cargoes are different, the fixed cost for one container of these two kinds of cargoes will be similar. On the other hand, compared to the total shipping tonnage of a ship, the difference between the weights of a container of these two kinds of cargoes is still very small. The weight factor of cargoes can be neglected. Therefore, the critical determinant factor is the volume of containers.

The distance between loading and unloading ports is the most important factor in determining coefficient a_{ij}. When the distance is longer, a_{ij} will become larger. The other factors which will affect coefficient a_{ij} are the conditions of the ports. These conditions include geographical conditions, facility conditions, etc.

However, cost-based tariffs outlined above will look very different from the present liner conference tariffs. The radical difference is the type of commodity. Commodity type is chief determinant in the current freight rate system, but is not so important in the proposed tariff system. It is mainly in cases where commodities are handled in loose form that the commodity type is a principal cost factor. Packaged cargo is very dominating so far as liner shipping is concerned. Indirectly the type of commodity will play a role for the freight rates, in so far that the measurement and weight of packages are influenced by the content. There may be some other intrinsic commodity qualities affecting the freight-rate structure.

In fact, it is difficult to construct the proposed tariff tables. The reason is that some factors discussed before are difficult to quantify, such as conditions of ports. On the other hand, the data of the these factors fluctuate frequently and is difficult to collect. Therefore, it is really difficult to include these factors and obtain a precise mathematical model, even for the cost matrix mentioned before, for marginal cost or freight rate of all commodities.

In this thesis, because the focused commodity is containerized motor vehicles as noted previously, the model can be simplified and just related to shipping distance and number of containers. That is

Total cost = Unit container shipping cost (20-foot or 40-foot)
* Total number of containers (20-foot or 40-foot)
* Shipping distance

The unit container shipping cost is calculated by Drewry Shipping Consultants. Drewry derived this coefficient by analyzing annual cost of a ship in Pacific trade and Atlantic trade. The results of these two cases are listed in Exhibit 2.2.4 and 2.2.5

Table 2.2.4 Costs per Ship (2,800 TEU) on Annual Basis in Cross-Pacific Trade

(Derived by Drewry Shipping Consultants, 1992)

teu per round trip	round trips per year	cost per round trip	yearly cost per ship	miles per crossing
4094	8.57	$7,114,000	$60,469,000	8275

tons per teu	cost per teu-mile ($)	cost per ton-mile ($)
5	0.208	0.042
6	0.208	0.035
7	0.208	0.030
8	0.208	0.026
9	0.208	0.023
10	0.208	0.021
11	0.208	0.019
12	0.208	0.017
13	0.208	0.016
14	0.208	0.015
15	0.208	0.014

In Pacific trade case shown in Exhibit 2.2.4, the data are based on a six ship service, traveling a 42-day route and calling once per week at each port. The exhibit shows the expenses for one ship traveling a complete cycle, stopping at a total of 8 ports between Singapore and Los Angeles. The port rotation is as follows: Singapore, Hong Kong, Kaohsiung, Busan, Kobe, Tokyo, Los Angeles, Oakland, Tokyo, Kobe, Busan, Kaohsiung, Hong Kong, Singapore. The ship moves eastbound with 2288 teu and westbound with 1806 teu. Therefore, the average of shipped containers per round trip is 4094. The total mile per Pacific crossing is 8275. Drewry uses the following equation to get cost per teu-mile and cost per ton-mile in Exhibit 2.2.4:

$$\$0.208 \text{ /teu-mile} = \frac{\$60{,}469{,}000 \text{ /year}}{(4094 \text{ teu /round trip})*(8.57 \text{ round trips /year})*(8275 \text{ miles})}$$

Here, 1 teu-mile represents that one 20-foot container is shipped in one nautical mile.

For Atlantic trade, Drewry uses an example with four vessels of 1600 teu, sailing on a 28 round-trip cycle and calling once a week at each port in the service. The port rotation for each individual ship is Antwerp, Felixstowe, Bremerhaven, Rotterdam, Le Havre, New York, Baltimore, Norfolk, Charleston, New York and Antwerp. Each ship moves westbound with 780 teu and eastbound with 1200 teu. With the same methodology, Drewry can calculate cost per teu-mile in Atlantic trade.

From Exhibit 2.2.4 and 2.2.5, given the total weight of cargoes or total amount of containers, origin and destination, we can get total cost for sea shipping. For example, a car company wants to ship 1,000 cars from Yokohama to Los Angeles. One container can hold just one car. The distance between these two ports is 4,385 nautical miles. From the Exhibit 2.2.4, the shipping cost per teu-mile is $0.208. The total shipping cost will be $912,080. (= 1,000*4,385*0.208)

Table 2.2.5 Costs per ship (1,600 TEU) on annual basis in Cross-Atlantic Trade

(Derived by Drewry Shipping Consultants, 1992)

teu per round trip	round trips per year	cost per round trip	yearly cost per ship	miles per crossing
1980	12.9	$3,023,000	$38,867,143	4625

tons per teu	cost per teu-mile ($)	cost per ton-mile ($)
5	0.330	0.066
6	0.330	0.055
7	0.330	0.047
8	0.330	0.041
9	0.330	0.037
10	0.330	0.033
11	0.330	0.030
12	0.330	0.028
13	0.330	0.025
14	0.330	0.024
15	0.330	0.022

2.3 Railroad Shipping

In rail shipping industry, because (1) different commodities require different shipping equipment and cars, (2) the operation costs for different equipment and cars are different, and (3) the demand elasticity of different commodities is different, there is price-discrimination among shippers of different commodities. In fact, such discrimination was officially sanctioned under the value-of-service pricing philosophy that the Interstate Commerce Commission (ICC) adopted shortly after its founding in 1887. Every year, ICC collects data of pricing policy and performance of railroad shipping. The objectives of ICC are: (1) prohibit personal price discrimination (2) guarantee value-of-service pricing (3) maintain carriers' profitability. Though there was a deregulation in rail shipping industry in 1980, the phenomenon of discrimination continued. We can see this pattern by Table 2.3.1.

Table 2.3.1 U.S. Railroad Revenue Per Carload (in 1982 dollars)

(Source: AAR, Analysis of Class 1 Railroads, 1980-1990.)

Year	1980	1982	1984	1986	1988	1990
Grain	1821	1531	1353	1120	1088	1101
Coal	1039	1143	1106	1023	967	900
Stone gravel	809	889	722	596	516	503
Food Products	2358	2280	2033	1797	1596	1454
Primary Forest	545	579	571	526	530	547
Lumber wood	3086	3215	3040	2553	2465	2187
Pulp paper	2101	2326	2289	2133	2015	1863
Chemicals	2572	2722	2465	2370	2157	1955
Metal Products	2114	2196	1858	1816	1759	1539
Motor vehicles	2587	2711	2518	2445	2409	2243
All carloads	1470	1477	1372	1266	1156	1064

The table reports real revenue per carload by commodity type for Class 1 railroads during the period 1980-1990. These are proxies for real rates, since they do not reflect distance traveled that does vary among commodities. Nevertheless, the revenue per carload data do provide a broad indicator of relative rates, because they are based on gross industry revenue by category and total carloads by category.

The data show that while real rates on most commodities have been falling since deregulation, the structure of rates has remained fairly constant. Shippers of high-value products such as automobiles and lumber continue to pay premium prices for freight service, while bulk shippers pay lower rates. Grain and coal shippers are in the middle.

To calculate these railroad rates more precisely, we begin with revenue observations from the ICC Waybill Sample. Each year, railroads are required to submit to the ICC a stratified sampling of the documents which accompany rail freight movements. (The stratification controls for multi-car movements.) This Waybill Sample, used by officials at the ICC, provides details on about 400,000 movements including commodity shipped, distance, equipment, and rate.

The focus of the STL is car-type miles, specifically, the miles of seven car-types which where aggregated from the detailed information in the AAR Analysis. The Waybill reports nominal revenue per movement along with equipment in the AAR Analysis. The Waybill reports nominal revenue per movement along with equipment identification, commodity identification and mileage. These are translated into real rates (in 1982 dollars) per car-type-mile using the Producer Price Index; these are reported in the first row of table 2.3.2 as RRATE. The distribution of these per-mile rates conforms to the distribution of carload rates reported in table 2.3.1. Chemical and automotive shipments command the highest rates. Coal and grain are in the middle range. Stone and gravel are lowest.

The rates recorded here are for loaded car-miles. In fact, the railroad must absorb the costs of the loaded and empty portions of each movement. Methodologically, too, the marginal cost estimated to which these rates will be compared are calculated on an over-all mileage basis, because the expenditure data (the left hand side in the cost regression) cannot be segregated to reflect empty and loaded movements. To reflect these facts, we calculate for each car-type an "effective rate", i.e., an estimate of the distributed rate the railroad typically receives for moving a particular car-type one mile.

Table 2.3.2 Railroad Freight Rate Data for 1988 ($/car-miles)

	Base Rate *RRATE*	Load/Empty Ratio *L/E*	Adjustment Coefficient *FACTOR*	Efficient Rate *FRATE*
Closed hopper	2.3110	1.0310	0.5080	1.1730
Open hopper	2.2738	1.1040	0.5250	1.1930
TOFC/COFC flat cars	1.1302	15.940	0.9410	1.0630
Multilevel flat cars	2.4014	1.3350	0.5720	1.3730
Tank cars	3.0349	0.9420	0.4850	1.4720
Equipped gondola	1.5988	1.0180	0.5040	0.8057
Box cars	1.9489	1.112	0.527	1.026

We begin by calculating the ratio of loaded to empty miles by car-type and year based on data in the Analysis. These ratios are reported in the second line of table 2.3.2. The very high utilization for TOFC/COFC flat cars reflects two facts: (1) railroads often receive payments for moving empty containers, and (2) there is a national fleet of intermodal cars that is jointly utilized. Utilization of multi-level flat cars also is relatively high because of national pooling arrangements. Tank cars have low utilization, because they are highly specialized and frequently owned by individual chemical manufacturers.

We use the L/E ratio to form a "payment factor" (FACTOR) which converts the loaded car-mile rate into an effective (i.e., distributed) car-mile rate. The formula for the payment factor is simply:

FACTOR = L/(L+E)

The payment factors are reported in line 3 of table 2.3.2, and effective rates (FRATE), the product of FACTOR times RRATE, are given in line 4.

The adjustment from RRATE to FRATE causes some rate compression (rates of tank cars move closer to rate of multilevel flat cars) and a change in ordering (closed hopper drops below open hopper), but the basic rate structure is the same. The structure is such that auto and chemical shippers, on average, pay 20-25 percent more per car-mile than coal or grain shippers, while box-car and intermodal shippers pay 20 percent less. The question, of course, is whether the cost of providing service differs in the same way and to the same extent.

2.4 Trucking

The regulated trucking market can be segmented into two distinct groups: common carriers of general commodities and common carriers of specialized commodities. General commodity carriers tend to specialize in relatively small shipments and hence are characterized by less-than-truck-load (LTL) carriage and terminal consolidation. As LTL carriers of general commodities, their traffic encompasses the spectrum of manufactured and related goods that are suitable for truck transport, and their customers tend to be relatively small shippers who do not generate a sufficient volume to support rail or full-truckload operations. In contrast, the carriers of specialized commodities utilize full-truckload (TL) operations and perform few, if any, consolidation functions. While their traffic also includes the spectrum of manufactured goods, these carriers tend to compete directly with the railroads and hence concentrate on large-load, long-haul traffic.

The difference in technologies between the two sectors results primarily from differences in operating authorities. While operating authorities for specialized carriers are more restrictive in specifying commodities for transport than are common general freight operating authorities, specialized carrier authorities are less restrictive in routing entitlements. Carriers of specialized commodities have authorities to carry products from one region to another region. Thus, if a specialized product is manufactured, processed, or distributed at one plant, an operating authority for a specialized carrier might enable the carrier to distribute the product to all major consumers in a given region. This type of operating authority does not require the capital-intensive consolidated terminal distribution systems that are necessitated by operating authorities for carriers of general freight, because operating authorities of special commodity carriers allow for direct delivery to large consumers. At the same time, without consolidated terminal distribution systems, small shipments of less-than-truckload freight become quite costly. In contrast, carriers of general freight have operating authorities that allow service to a mapping of specific points, but not to entire regions. Pointwise authorities encourage consolidated pickup and distribution centers at each point of operating authority. Consolidation terminals permit carriers of general freight inasmuch as more than one shipment can be made per haul. The expenses of terminal usage, both in overhead and delay of delivery, make general freight carriers more expensive than specialized freight carriers for large truckload shipments. For large shipments, particularly for medium or long distances, rail carriers and trucking carriers of specialized commodities compete for the same market.

Because regulated trucking firms are typically limited in the commodities which they can carry or the routes they can cover, by acquiring firms with different operating rights, regulated trucking firms can obtain longer hauls, higher load factors, fewer empty backhauls, and thus lower operating costs. Consequently, larger firms may be more profitable not because their costs are inherently lower, but because they can obtain higher utilization of equipment through diversified operating rights. Since many of the recent mergers have been characterized by the extension of operating rights and authorities, this indicates that if economies of scale do in fact exist, they may be of a regulatory rather than a technological nature. This implies, of course, that economies of scale would not exist if any carrier were free to carry any commodity to any place along any route.

According to Friedlander and Spady[5], the general specification used to describe trucking costs and technology is

$$C = C(\Psi, w, t)$$

where w : factor prices (labor, fuel, capital and purchased transportation)

t : operating characteristics

Ψ : transportation output

The assumptions of the general model are:

[5] Friedlaender, Ann F. and Spady, Richard H. (1980), *Freight Transport Regulation, Appendix C, E.*

1. Firms are able to make optimal adjustments in capacity.
2. The general cost function is the linear combination of logarithm of its factor prices.

The cost function for specialized commodity carriers can be described in more specific form:

$$\ln TC(\Psi, w, t) = \alpha_0 + \Sigma \alpha_i \ln w_i + \Sigma \beta_j \ln t_j + \gamma \ln \Psi$$
$$+ ½ * \Sigma\Sigma A_{ij} \ln w_i \ln w_j + \Sigma\Sigma B_{ij} \ln w_i \ln t_j$$
$$+ \Sigma C_i \ln w_i \ln \Psi + ½ \Sigma\Sigma D_{ij} \ln t_i \ln t_j$$
$$+ \Sigma E_i \ln t_i \ln \Psi + ½ F \ln \Psi \ln \Psi$$

where:

TC : total cost for the firm

w_1 : the price of labor

w_2 : the price of fuel

w_3 : the price of capital

w_4 : the price of purchased transportation

t_1 : average load (tons/truck)

t_2 : average length of haul

t_3 : insurance per ton-mile

Ψ : output in ton-miles

$\alpha_i, \beta_j, \gamma, A_{ij}, B_{ij}, C_i, D_{ij}, E_i, F$: coefficients ($i = 1, 2, 3, 4,\quad j = 1, 2, 3$)

From total cost function, the functions of marginal cost and average cost can be derived:

$$MC = \partial TC / \partial \Psi = TC * w_4 / \Psi * [\gamma + \Sigma C_i \ln w_i + \Sigma E_j \ln t_j + F \ln \Psi]$$

and

$$AC = TC * w_4 / \Psi$$

From this point, it would be simple to calculate the total, average and marginal costs for any firm in the sample. All one need to do is to substitute that firm's output, factor prices, and technology variables into the above equations. The values of all the factors and coefficients are shown in Table 2.4.1 and 2.4.2[6].

Friedlander and Spady segmented trucking market as fully as possible on a regional basis and thus analyze geographic differences in trucking technology on a relatively desegregate scale. Because of limitations in the number of observations, all the factors and coefficients were settled on a somewhat more aggregate breakdown for econometric analysis: regional carriers in the Official Territory, which comprises the New England, Middle Atlantic, and Central Regions; all other regional carriers, which comprise carriers in the Southern, South-Western, and Western Regions, and which we refer to as carriers in the South-West Region for notational simplicity. Although it was recognized that this lever of aggregation may introduce some bias, this bias is minimal.

According to Table 2.4.3, the result of marginal cost is equal to $ 1.1654 per ton-mile in official region, and $ 1.1358 per ton-mile in south-west region.

[6] Data Source: Friedlaender, Ann F. and Spady, Richard H. (1980), *Freight Transport Regulation, Appendix C, E.*

Table 2.4.1 Weighted Average Used in the Trucking Cost Function

Variable	Units	Official Region	South-West Region
w_1	\$(000)/man-year	31.868068	30.956642
w_2	\$/standardized vehicle-mile	0.064234	0.116276
w_3	Index	6.229777	5.753408
w_4	\$/standardized vehicle-mile	0.357404	0.345916
Ψ	ton-miles (000)	48,632.005	79,118.917
Manufactures Output			
t_1	tons/vehicle	14.3419	14.773176
t_2	miles	329.4268	457.31263
t_3	\$(000)/ton-mile	0.000539	0.000417
Bulk Output			
t_1	tons/vehicle	20.795576	21.996293
t_2	miles	146.75698	218.21319
t_3	\$(000)/ton-mile	0.000539	0.000417

Table 2.4.2 Coefficient Estimates for Cost Functions of Official, South-West and Interregional Carriers

Coefficient	Variable	Official	South-West
α_0	Constant	8.8839	9.5417
α_1	$\ln w_1$	0.3485	0.2675
α_2	$\ln w_2$	0.0423	0.0498
α_3	$\ln w_3$	0.2925	0.3003
α_4	$\ln w_4$	0.3167	0.3841
β_1	$\ln t_1$	-0.8441	-0.5346
β_2	$\ln t_2$	-0.1767	-0.1769
β_3	$\ln t_3$	0.0319	0.2679

γ_y	$\ln \Psi$	0.7873	0.9362
A_{11}	$½*(\ln w_1)^2$	0.1223	0.0781
A_{12}	$\ln w_1 \ln w_2$	-0.0099	0.0136
A_{13}	$\ln w_1 \ln w_3$	-0.0136	-0.0035
A_{14}	$\ln w_1 \ln w_4$	-0.099	-0.0882
A_{22}	$½*(\ln w_2)^2$	-0.0178	-0.0122
A_{23}	$\ln w_2 \ln w_3$	-0.0258	-0.0192
A_{24}	$\ln w_2 \ln w_4$	0.0535	0.0178
A_{33}	$½*(\ln w_3)^2$	-0.0343	-0.0386
A_{34}	$\ln w_3 \ln w_4$	0.0737	0.0613
A_{44}	$½*(\ln w_4)^2$	-0.0282	0.009
B_{11}	$\ln w_1 \ln t_1$	-0.0059	-0.0311
B_{12}	$\ln w_1 \ln t_2$	-0.0046	-0.0244
B_{13}	$\ln w_1 \ln t_3$	0.0055	-0.0103
B_{21}	$\ln w_2 \ln t_1$	-0.0054	-0.0046
B_{22}	$\ln w_2 \ln t_2$	0.0096	0.0073
B_{23}	$\ln w_2 \ln t_3$	-0.0086	-0.0067
B_{31}	$\ln w_3 \ln t_1$	0.0184	-0.0199
B_{32}	$\ln w_3 \ln t_2$	0.0079	-0.0123
B_{33}	$\ln w_3 \ln t_3$	-0.0016	0.0036
B_{41}	$\ln w_4 \ln t_1$	-0.0071	0.0158
B_{42}	$\ln w_4 \ln t_2$	-0.0129	0.0293
B_{43}	$\ln w_4 \ln t_3$	0.0046	0.0134
C_{1y}	$\ln w_1 \ln \Psi$	-0.0238	-0.0316
C_{2y}	$\ln w_2 \ln \Psi$	-0.0081	-0.0091
C_{3y}	$\ln w_3 \ln \Psi$	-0.0396	-0.0336
C_{4y}	$\ln w_4 \ln \Psi$	0.0715	0.0743
D_{11}	$½*(\ln t_1)^2$	0.3563	-0.1427
D_{12}	$\ln t_1 \ln t_2$	-0.1116	-0.0423

D_{13}	$\ln t_1 \ln t_3$	-0.053	0.0562
D_{22}	$½*(\ln t_2)^2$	0.0646	0.133
D_{23}	$\ln t_2 \ln t_3$	-0.0203	-0.0559
D_{33}	$½*(\ln t_3)^2$	0.0088	0.0793
E_1	$\ln t_1 \ln \Psi$	-0.2007	-0.0457
E_2	$\ln t_2 \ln \Psi$	-0.0135	-0.0144
E_3	$\ln t_3 \ln \Psi$	-0.0635	0.0155
F_{yy}	$½*(\ln \Psi)^2$	0.0273	0.0874

Table 2.4.3 Elasticity of Costs with Respect to Output and Operating Characteristics at the Point of Approximation, Carrier of Specialized Commodities

Elasticity of cost with respect to	Official	South-West
Output ($\partial \ln C / \partial \ln \Psi$)	1.1654	1.3858
Average load ($\partial \ln C / \partial \ln t_1$)	-0.8841	-0.5346
Average length of haul ($\partial \ln C / \partial \ln t_2$)	-0.1767	-0.1769
Insurance ($\partial \ln C / \partial \ln t_3$)	0.0319	0.2679

Chapter 3 Total Cost Model of Global System and Case Analysis

In total cost model in global system, there are three major parts: (1) manufacturing costs (2) shipping and handling costs (3) taxes and duties. According to Rosenfield[1] (1995), a simple model for total cost function can be written as:

$$TotalCost = \sum_{j=1}^{M} F(Y_j) + C_1 * D + (C_2 - C_1) * (D - \sum_{i=1}^{N} \min(\sum_{j \in market\,i} Y_j, D_i)) \qquad (3.1)$$

where:

Y_j	: production at plant j
$F(\ )$	: production function
D	: total demand
D_i	: size of market i, $i = 1$, N
M	: number of plants
C_1	: unit cost for distribution, handling, taxes, and duties within the same market
C_2	: unit cost for distribution, handling, taxes, and duties to other markets

In Equation 3.1, the first term is the term for total production costs. The second term is the term for minimum possible costs of transportation, handling, taxes and duties that are incurred by the demands located in the same market as plant's location. The final term is the term for extra costs of transportation, handling, taxes and duties that are incurred by the demands located outside the market where plants locate. If we assume that taxes are constant for all the countries in the world and that there are no duties for delivering to a different country, then this term basically is constituted by the extra

[1] Donald B. Rosenfield (1996), *Global and Variable Cost Manufacturing Systems*, European Journal of Operational Research, 1996

transportation and handling costs for shipping the products out of the region where plants locate.

This model is a very simplified model, particularly in the approach for transportation costs. This chapter explores building up the total costs from the various components and thus expands section 3.1.

If the assumptions[2] of a more general model, which is referred to as the Geographic Distance Model, are accepted, transportation and distribution costs are assumed to decrease with an increasing number of plants as markets that are closer to their nearest plants. Therefore, for a geographic area with distance proportional transportation costs, the total costs are proportional to $M^{(-1/2)}$. These costs can be separated from the second term in Equation 3.1. Then, Equation 3.1 can be written as:

$$TotalCost = \sum_{j=1}^{M} F(Y_j) + [C_3 + C_4 * M^{-1/2}] * D + (C_2 - C_1) * (D - \sum_{i=1}^{N} \min(\sum_{j \in market..i} Y_j, D_i)) \tag{3.2}$$

C_3 : unit costs for taxes and duties

C_4 : unit costs for distribution and handling with the market which has only one plant

However, the assumptions of the Geographic Distance Model are not always valid in most markets. In order to check how accurate this model is and to gain some insight for global models, two cases are discussed. In these cases, I use Ford Taurus as the target product. In Case One, according to demand in the continental U.S., I will compare the results of the Geographic Distance Model and the real pricing policy of shipping industry from chapter two, and check the estimation accuracy of this model. Because the target market is in continental U.S., trucking is the only shipping mode used in this case

[2] Magee, John F., Copacino, William C., and Rosenfield, Donald B. (1985), *Modern Logistics Management*, Chapter 10, John Wiley & Sons, N.Y

analysis. The reasons for the errors of this model are discussed. In Case Two, a global automobile market is analyzed according to the data of demand in all countries worldwide. The models of sea-shipping, trucking and railroad shipping in chapter 2 are used to estimate total distribution costs and total operational costs. Thus we expand the model implicit in equation 3.2. These costs in the global systems with one, two, and three plants are estimated. The effects of number of plants on total distribution costs and total operational costs are shown and discussed. In the last section, the limitations of the Geographic Distance Model are discussed.

3.1 Case I: Comparison of the Results of the Geographic Distance Model and the U.S. Automobile Market

There are three major assumptions of the Geographic Distance Model: (1) Demand density should be constant in the whole area. That is, demand in unit geographic area should be equal. (2) Transportation costs are proportional to distance. (3) Plants should be located in the geographic center of their response area in order to minimize total transportation costs. Therefore, total transportation costs can be expressed as

$$\text{Total Transportation Costs} = C_4 * D * M^{(-1/2)}$$

Here, C_4 is the total transportation costs for the system which has only one plant in the center of the area.

Table A.1.1 shows Ford Taurus 1995 annual sales in each state of the U.S. Its total sales for U.S. market are 642,997 cars. If the company ships all of its cars by trucking, its total shipping costs are about $1,356 millions dollars. If we regard the U.S. as a big system that has one big plant in Kansas City, the geographic center of the U.S., we can get value of C_4 equal to $2109 dollars*(no. of plants)$^{1/2}$ /car. Then, by using the Geographic Distance Model, total shipping costs for two-plant system and three-plant system can be evaluated. Table 3.1.1 shows the results. More detailed assumptions and calculations are shown in Appendix I.

In Table 3.1.1, plant locations are chosen according to the rule that each plant has nearly equally large response area. Total distribution costs for 1-plant system in the Geographic Distance Model are equal to that calculated directly from the practical shipping pricing policy.

Table 3.1.1 The Results of Geographic Distance Model and Direct Calculation

No. of Plants	Location	Costs by Model Calculation ($)	Costs by Direct Calculation ($)	Difference ($)	(%)
1	Kansas City	1,355,928,187	1,355,928,187	-	-
2	Denver Cincinnati	958,786,016	882,859,618	75,926,398	8.6
3	Kansas City Salt Lake City Charleston, WV	782,845,504	706,230,614	76,614,890	10.8

According to Table 3.1.1, the difference between the results of the Geographic Distance Model and direct calculation is quite large. That is, there are errors which cannot be neglected when we use the Geographic Distance Model to analyze the cases in the real world.

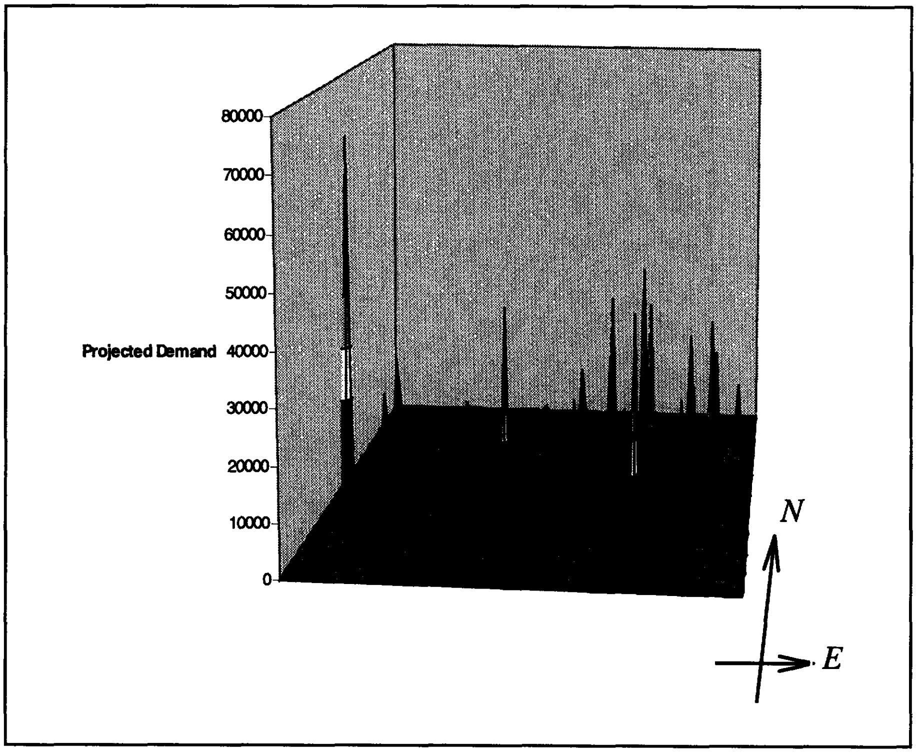
We can understand the reasons for the errors of the Geographic Distance Model from the following two analyses:

a. The assumptions of even distributed demands throughout the whole region are not satisfied in the U.S. market.

We observe this in Figure 3.1.1 and Table A.1.1.

In Figure 3.1.1, most of the demands are located on the east part of the U.S. In fact, more than 55% of demands are located in East Coast and Great Lake areas. However, the area of this region just consists about 25% of total area in the U.S. It means that the demand densities of these regions are about four times higher than the rest regions in the U.S.

Figure 3.1.1 Geographical Distribution of Projected Demand for Ford Taurus in the U.S.



We can also see the errors in a different way. In Table 3.1.2, we can see the total shipping costs for one plant system which has some alternative plant locations. More detailed calculations are shown in Table A.1.1 & Table A.1.4.

Table 3.1.2 Total Shipping Costs for One Plant System with Different Plant Locations

Plant Location	Kansas City	St. Louis	Cincinnati	Detroit
Total Shipping Cost ($)	1,355,928,187	1,250,205,890	1,217,690,711	1,342,549,260

From Table 3.1.2, we can observe that the plant location for minimum shipping costs among these four alternatives is Cincinnati, not Kansas City, even though Kansas City is close to the U.S. geographical center. Cincinnati is located around the midpoint between the U.S. geographical center and the East Coast. This result conflicts with the assumptions of the Geographic Distance Model. In the model, the supplier location for minimum shipping costs is in the geographical center of the system area.

The conflicts are also caused by unevenly distributed demand. The movement of plant location in one direction will decrease the shipping costs for the demand in the same direction, and increase the costs in the opposite direction. Because most of the demands are in the east side of the U.S., if the plant location moves from the geographical center to east side, the reduced costs on the east side are greater than increased costs on the west side. Therefore, total shipping costs for the whole system will decrease.

Demand is not equally distributed even in each state. For each state, most of the demands are found in the metropolitan area or the region closer to big cities or its capital. This also induces the errors about the model estimation.

b. Shipping rates are different in different regions.

From Chapter 2, trucking rates are not constant throughout the U.S., and are the functions of factor prices (fuel, labor, etc.). Different factor prices induce different freight rates. On average, the freight rates in New England, Middle Atlantic, and Central Regions, are lower than other regions in the U.S.[3]

On the other hand, the freight rates between big cities are lower than those in rural regions. The reasons are, (1) the freight suppliers serving metropolitan regions are more numerous than those in rural regions, and (2) it is easier for trucking companies between big cities to cooperate with other trucking companies in order to increase equipment utilization and reduce operation costs.

[3] In New England, Middle Atlantic, and Central Regions, the freight rate for trucking is 1.1654 ton-mile. In the rest regions, Southern, South-Western, and Western Regions, the rate is 1.3858 ton-mile.

3.2 Case II: Analysis for the projected demand in the world from 1997 to 2002

This case analyzes the global car market by using the following equation:

Total Costs = Production Costs + Distribution Costs + Tax

Appendix II[4] shows Ford Automobile 1995 annual sales in the U.S. and other countries. Because a global system is complex and some data are inaccessible, the following assumptions are made to simplify this system:

a. Assumptions of annual projected demands:

1. The lifetime of target type of automobile is 5 years. Other new type of automobiles will totally take over the market. The demand of target automobile is zero after 5 years.
2. The annual demand in every region will not change during 5 years.
3. Ford's market shares are identical in geographically close countries. Therefore, for some countries which only have data of annual sale of all brands of cars, the specified annul sales for Ford can be calculated according to the market share in a nearby country which has available information of market share.
4. For the countries where the geographic distribution of demand is unknown, all the demands in this country are located close to its capital, especially in undeveloped countries. Therefore, Ford needs to be responsible for the costs of shipping its cars only to the capital. However, because the demands in all the U.S. states are known, the demands are located in the geographical center of each state.
5. The sale of the target type of automobile accounts for a fixed percentage of total sales in all regions. For example, the sale of Taurus is 30% of Ford total sales in all states in the U.S. and all countries.

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[4] *World Road Statistics, 97' Edition*, International Road Federation
Ward's automotive Yearbook, 1993, Ward's Communications
International Motor Business, 1995, The Economist Intelligence Unit, U. K.

According to the previous assumptions for sales, sales for all regions in the world are estimated as shown in Table 3.2.1. More detailed information about sales in each country is shown in Appendix II.

Table 3.2.1 Annual sales of Ford Taurus in major regions in the world

Region	Sales (cars)	% of total sales
Africa	13,405	1.16
Caribbean America	3,175	0.27
Central & South America	54,108	4.67
North America	545,335	47.10
Far East	68,321	5.90
Middle East	11,555	1
East Europe	17,100	1.48
West Europe	406,150	35.08
Pacific	38,569	3.33
Total	**1,157,718**	**100**

b. Assumptions of production model: The production model is

Production Costs = Fixed Costs Per Plant * Number of Plants
+ Variable Costs Per Unit * Total Demand

According to the data[5], the setup cost for a plant with annual capacity of 250,000 cars is about $ 150 million dollars. I assume that the setup cost is constant and unrelated to the production capacity of the plant. On the other hand, I assume that yearly

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1993-1994 World Automotive Market Report, Auto & Truck International
[5] Ashoka Mody & David Wheeler, *Automation and World Competition*

depreciation is 15%. After 5 years, the surplus value of the plant is only 25% (=100% - 5*15%) of the setup cost. Therefore, fixed cost for one plant to operate 5 years is $112,500,000 dollars. Variable cost is equal to $5,500 dollars per car. These costs are constant during these 5 years. The other assumption is that the capacity of each plant is infinite.

c. Assumptions of shipping:

1. Containers can be shipped only to some certain seaports. For each region, a certain seaport is chosen according to its annual container traffic.
2. All the countries choose the closest seaport which is already determined according to previous condition to import or export their cars.
3. For the country which has its own seaport, it will use the feeder system to transfer the products from the regional seaport to its own seaport with no additional costs.
4. The distance between the country's capital and seaport is straight line distance.
5. All factors' prices are fixed during production period. Therefore, the coefficients in the models will not change.
6. The models, factor prices, and coefficients of sea-shipping, railroad shipping and trucking for all countries are same as those for the U.S. That is,

Trucking : (1.1654+1.3858)/2 = $1.2756 dollars/ton-mile

Railroad : $1.373 dollars/ton-mile

Sea Shipping: Cross-Pacific : $0.208 dollars/teu[6]-mile

Cross-Atlantic : $0.33 dollars/teu-mile

[6] Teu is the unit for one 20-feet container. 1 teu = 1 20-feet container.

d. Assumptions of taxes: The tax rate is a constant and equal to 35%, the current U.S. corporate tax rate, in all countries. Net profit of a car is close to its variable production cost. Therefore,

Unit Tax Costs = 35% * Unit Variable Production Costs

= 0.35 * $5,500 dollars/car = $1,925 dollars/car

- **Analysis for plant locations:**

1. From Table 3.2.1, about half of the total demands of the target cars in the world are located in North America, and about 35% are located in Western Europe. According to the total cost model, in order to avoid additional costs for shipping and handling, if the company just wants to set up one plant, it should be located in North America. If the company wants to set up two plants, the first plant should be in North America, and the second one should be in Western Europe.
2. There are two alternative locations for the third plant: Far East or North America.
3. In case one, if the company just sets up a plant in the U.S., we can see that the plant location for minimum shipping costs in the U.S. is Cincinnati. However, if the defined system is North American, which includes the U.S., Canada, and Mexico, the optimal location will change. The annual sales of target car are 38,269 in Canada and 8,661 in Mexico. Because the annual sales in Canada are more than that in Mexico, the optimal location will move to the region around Detroit in the north..
4. Table 3.2.2 shows the demand distribution in Western Europe. Following the similar analysis in the U.S., if the second plant is located in Western Europe, it should be located in the middle of France.

Table 3.2.2 Demand Distribution in Western Europe

Country	U. K.	Spain	Germany	France	Italy
% of total sales in W. Europe	30.92	9.51	24.12	11.19	11.53

5. Table 3.2.3 shows the demand distribution in Far East. If the third plant is located in the Far East, it should be in Taiwan.

Table 3.2.3 Demand Distribution in the Far East

Country	Hong Kong	China	India	Japan	S. Korea
% of total sales in Far East	1.61	9.24	6.37	34.26	5.01

Pakistan	Philippines	Singapore	Taiwan	Thailand
2.14	3.92	2.29	29.25	3.42

6. If the third plant is located in North America, according to the demand distribution in the U.S., Canada, and Mexico, these two plants should be in Detroit and Salt Lake City.
7. According to the previous conclusions, I used the projected demand of all countries in the world to calculate total costs for the systems with one, two and three plants. Table 3.2.4 summarizes these results..

Table 3.2.4 Plant Locations in the Systems with Different Numbers of Plants

System	**Plant Locations**
1 Plant	Detroit, U.S.
2 Plants	(1) Detroit, U.S. (2) Paris, France
3 Plants - Alternative 1	(1) Detroit, U.S. (2) Paris, France (3) Taiwan
3 Plants - Alternative 2	(1) Detroit, U.S. (2) Salt Lake City, U.S. (3) Paris, France

- **Results of analysis**

The cost components and their percentage ratios are shown in Table 3.2.5 & 3.2.6

Table 3.2.5 Costs for 1-Plant & 2-Plant System (for 5 years)

	One Plant System		**Two Plant System**	
Costs	**$**	**%**	**$**	**%**
Production (fixed)	112,500 K	0.19	225,000 K	0.41
Production (variable)	31,837,245 K	52.93	31,837,245 K	57.35
Distribution	17,052,400 K	28.35	12,310,122 K	22.17
Taxes	11,143,035 K	18.53	11,143,035 K	20.07
Total	**60,145,180 K**	**100**	**55,515,402 K**	**100**

Table 3.2.6 Costs for Two Alternatives in 3-Plant System (for 5 years)

	Location : Taiwan		**Location : U.S.**	
Costs	**$**	**%**	**$**	**%**
Production (fixed)	337,500 K	0.63	337,500 K	0.64
Production (variable)	31,837,245 K	59.72	31,837,245 K	60.41
Distribution	9,990,267 K	18.74	9,388,126 K	17.81
Taxes	11,143,035 K	20.91	11,143,035 K	21.14
Total	**53,308,047 K**	**100**	**52,705,906 K**	**100**

- **Observations**

1. From Table 3.2.5:
    - Under the previous assumptions, because total demands for 5 years are fixed, variable production costs and taxes are unrelated to the numbers of the plants in the systems.
    - Fixed production cost is increased by $112,500,000 dollars from one-plant system to a two-plant system
    - Distribution and Handling costs are decreased by $4,742,278,000 dollars
2. Because variable production costs and taxes are constant, the optimal number of plants depends on the fixed production costs and distribution costs.
3. In a one-plant system, building the second plant reduces distribution costs. The reduced parts are more than the induced extra fixed production costs of the second plant. Therefore, total operational costs in a two-plant system are less than those in a one-plant system.
4. Table 3.2.6 shows that the system with the third plant in Salt Lake City, U.S. has less operational costs than the other alternative with the third plant in Taiwan. The reason is that most of the demands are located in North America. Building an additional plant in Taiwan reduces much distribution costs for unit demand in the Far East and the Middle East; because the demands in these regions consist just 6.9% of total demands in the world, the total distribution costs are not reduced so much as the amount reduced by building an additional plant in Salt Lake City.

3.3 The Limitations of the Application of the Geographic Distance Model

Based on previous analysis, we know that there are limitations of application of the Geographic Distance Model. Any application would have to satisfy the following two conditions to avoid estimation errors:

1. Transportation costs would have to be proportional to shipping distances.
2. Demand would have to be equally distributed throughout the whole geographic regions.

In practice, most global markets do not satisfy these conditions. Only regional markets with small areas might satisfy these assumptions. The reasons are:

1. **Transportation Costs are more likely to be proportional to shipping distances in regional markets**. In regional markets, the choices of transportation modes are limited. For example, for the cargo shipment with a small country, such as Switzerland, trucking and railroad shipping are the only economic choices. In addition, the freight rates are more likely to stay constant, because the factors which determine freight rates are more likely to stay constant in a small region. On the other hand, in global systems, four different transportation modes are available. Each of them has its individual pricing. Also, there are more factors which will affect freight rates. These make the transportation costs in global systems more complex and not proportional to shipping distances.

2. **Demands are more likely to be equally distributed throughout the whole geographic regions.** In regional markets, two conditions are more likely to be satisfied in the whole regions: (1) evenly distributed populations (2) evenly distributed incomes. These two conditions cause equally distributed demand throughout the whole regions.

In section 3.1, although the income of each person is similar in the U.S., because of unequally distributed population in the U.S., the demand distribution is still uneven in the U.S. market. It induces 10.8% error as shown in Table 3.1.1.

The markets outside of the U.S. are even more complex and heterogeneous than those in the U.S.. It is more difficult for them to satisfy the conditions of the Geographic Distance Model. For example, there are big income and population gaps between the countries in Western Europe and Eastern Europe, even though these countries are geographically close. Therefore, applications of the Geographic Distance Model in European market will yield greater errors than those in the U.S. market. In global markets, these gaps of population and income are larger between different locations, and the estimation accuracy of the model will be much lower.

In conclusion, we can use a model such as the Geographic Distance Model only as an approximation to part of a total cost model.

Chapter 4 Summary and Conclusion

The major objective of the thesis has been to understand the characteristics of the pricing behavior in different transportation modes and try to develop cost models for them. Simplified models, such as the Geographic Distance Model, are evaluated by comparing the results of these cost models.

The major results of this research are the pricing models in Chapter Two. Such models are effective tools in tabulating total system costs, as shown by the examples in Chapter Three.

Based on the analysis in Chapter 2 and Chapter 3, we know that there are limits to the Geographic Distance Model. One possible way to mitigate estimation errors is through market segmentation. We need to divide the large markets into several sub-markets in order to create homogenous conditions within the markets. Such market segmentation is an area of future research.

The applications of the cost models showed the following:

1. In the example for the automobile industry, a decentralized system has less operational costs than a centralized system. From Tables 3.2.5 & 3.2.6, we get the following results:

Table 4.1 Change of Plants, Fixed Production Costs, and Distribution Costs

Change of total plants in the system	1 → 2	2 → 3
Increased fixed Production Costs	$ 112.5 M	$112.5 M
Decreased Distribution Costs	$4,727.3 M	$2,922.0 M

Under the assumptions in section 3.2, variable production costs and taxes are unrelated to the total number of plants in the system. From Table 4.1, when the number of total plants increases by one, increased fixed production costs are much less than decreased distribution costs. As such increasing, the total number of plants will decrease total operational costs, and the decreased distribution costs will also decrease. When there are sufficient plants in the system, the decreased distribution costs will be equal to the increased fixed production costs, and the company will get the minimum total operational costs. If the number of plants in the system is more than the optimal number, the decreased distribution costs will be less than the increased fixed production costs, and the total operational costs will increase.

2. Because of the characteristics and freight rates of railroad shipping and trucking are quite similar, these two transportation modes compete with each other. The biggest differences between these two modes are the convenience and reliability. Because trucking has more flexibility than railroad shipping, it is easy for trucking carriers to offer door-to-door service. On the other hand, railroad shipping schedule is less affected by uncontrolled factors, such as, weather, traffic congestion, etc.. Railroad shipping thus has higher reliability than trucking. The shippers choose between these two modes according to the characteristics of their products and their requirements for the shipment.

3. The freight rates for sea shipping are about 1/6 of those for trucking and railroad shipping. A company can have lower distribution costs by avoiding shipment via trucking and railroad. Locating plants close to seaports will, therefore, provide economic advantages.

Any conclusions need to be subject to the following qualifications:

1. Different countries have their specific pricing policy and structures for their shipping modes. Some of them are similar to those in the U.S., but some of them are quite different. Because of unavailable freight rate data in many countries, it is difficult to precisely estimate all the coefficients for the shipping modes in different countries. Using the models in the U.S. for other countries will induce some error.

2. In the production model, I assume that production costs consist of a fixed and a variable component, and the plants have unlimited capacity. However, this assumption is only an approximation. When plant capacity increases, the production costs should vary in a nonlinear manner that is more complex than a fixed and a variable cost.

3. From previous results, we can know that demand locations are very important factors in determining unit distribution costs and total costs. Accurate estimation of costs requires geographical distribution of demands.

4. In railroad shipping and trucking industries, especially in railroad shipping industry, the carriers offer discounts on their freight rates for long distance shippers. Because the calculations of these discounts are complex and different in different cases, I just assume that there is no discount on the freight rats in this thesis. In fact, the long-distance shipping costs for railroad shipping and trucking are lower than the results of Chapter 3.

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6. *1993-1994 World Automotive Market Report*, Auto & Truck International

Appendix I

The following numbers and formulas are used in the calculation procedure.

Weight of 4-door Taurus : 3326 lb. = 1.66 tons

Freight rate for trucking : Official : $1.1654 ton-mile

South-West : $1.3858 ton-mile

Transportation Cost = State Annual Sales (cars/year)

* Weight of Unit Car (tons/car)

* Distance between Plants and Demand (miles)

* Freight Rate by truck ($/ton-mile)

Note:

1. In the calculation of Table A.1.2 & Table A.1.3, each state will get cars from the closest plant.
2. The distance for each state is measured from the geographic center of the state to the supply plant location.
3. There is no limitation on the capacity of the plant production.

Data source:

1. *World Road Statistics*, 1997 Edition, International Road Federation
2. *The Automotive News*, 1996, Crain Communications, Inc.
3. *Ward's automotive Yearbook,* 1993, Ward's Communications
4. Chapter 2

Table A.1.1 Transportation Cost in the U.S. with One Plant

(Plant Location : Kansas City)

State	Sales	% of total Taurus in US	Distance to Kansas City	$ by truck
Alabama	8210	1.277	692	13069468
Arizona	10244	1.593	1250	29455543
Arkansas	4247	0.660	391	3819588
California	70164	10.912	1750	282462653
Colorado	9791	1.523	616	13874470
Connecticut	8576	1.334	1204	19974184
Delaware	2001	0.311	1134	4389785
Dist. of Columbia	610	0.095	1067	1259150
Federal Government	1410	0.219	1067	2909461
Florida	47653	7.411	1231	134945046
Georgia	22145	3.444	792	40346839
Idaho	1612	0.251	1482	5495686
Illinois	33123	5.151	500	32038798
Indiana	11586	1.802	487	10915078
Iowa	4584	0.713	197	1747004
Kansas	4789	0.745	245	2699104
Kentucky	7957	1.237	500	9152253
Louisiana	10659	1.658	842	20646061
Maine	2873	0.447	1600	8892804
Maryland	18736	2.914	1041	37732077
Massachusetts	14197	2.208	1529	41993993
Michigan	37361	5.810	777	56158668
Minnesota	12439	1.934	443	12675946
Mississippi	5259	0.818	637	7705662
Missouri	15961	2.482	100	3671598
Montana	1308	0.203	1117	3361008
Nebraska	2780	0.432	492	3146433
Nevada	3729	0.580	1450	12438529
New Hampshire	3543	0.551	1550	10622449
New Jersey	23805	3.702	1228	56552220
New Mexico	3583	0.557	769	6338431
New York	28118	4.373	1250	67993879
North Carolina	18237	2.836	1036	36550747
North Dakota	909	0.141	965	2016791
Ohio	32801	5.101	663	42071085
Oklahoma	5297	0.824	350	4264878
Oregon	6995	1.088	1852	29799316
Pennsylvania	27151	4.222	1000	52524380
Rhode Island	2045	0.318	1250	4944020
South Carolina	10506	1.634	1221	24815069

South Dakota	1046	0.163	694	1669138
Tennessee	12043	1.873	538	14904162
Texas	44257	6.883	652	66379397
Utah	3868	0.601	1137	10115781
Vermont	1546	0.240	1300	3888087
Virginia	18198	2.830	1086	38231792
Washington	10691	1.663	1906	46873735
W. Virginia	3523	0.548	739	5989157
Wisconsin	10135	1.576	562	11018481
Wyoming	708	0.110	853	1388303
Total	**642997**	**100.000**		**1355928187**

Table A.1.2 Transportation Cost in the U.S. with Two Plant

(Plant Location : Denver & Cincinnati)

State	Sales	Distance to Denver	Distance to Cincinnati	$ by truck
Alabama	8210	1297	455	8593364
Arizona	10244	790	1856	18615903
Arkansas	4247	1006	601	5871029
California	70164	1100	2280	177547953
Colorado	9791	250	1208	5630873
Connecticut	8576	1936	778	12906906
Delaware	2001	1759	581	2249087
Dis of Columbia	610	1681	515	607743
Federal Government	1410	1681	515	1404285
Florida	47653	1848	885	97015732
Georgia	22145	1406	453	23077169
Idaho	1612	831	1930	3081589
Illinois	33123	980	290	18582503
Indiana	11586	987	109	2443005
Iowa	4584	676	591	5241012
Kansas	4789	455	803	5012621
Kentucky	7957	1106	100	1830451
Louisiana	10659	1341	806	19763331
Maine	2873	1460	991	5507980
Maryland	18736	1685	516	18702931
Massachusetts	14197	1990	820	22521304
Michigan	37361	1281	268	19370043
Minnesota	12439	926	697	19943870
Mississippi	5259	1214	687	8310502
Missouri	15961	745	490	17990831

Montana	1308	553	1602	1663955
Nebraska	2780	290	1021	1854605
Nevada	3729	900	2050	7720466
New Hampshire	3543	1990	875	5996544
New Jersey	23805	1785	675	31085300
New Mexico	3583	457	1508	3766792
New York	28118	1700	600	32637062
North Carolina	18237	1685	509	17957848
North Dakota	909	768	1094	1605073
Ohio	32801	1277	109	6916664
Oklahoma	5297	697	843	8493201
Oregon	6995	1249	2370	20096839
Pennsylvania	27151	1600	437	22953154
Rhode Island	2045	2089	853	3373799
South Carolina	10506	1734	618	12559961
South Dakota	1046	554	1096	1332424
Tennessee	12043	1155	277	7673704
Texas	44257	1036	1061	105474012
Utah	3868	537	1727	4777638
Vermont	1546	1900	750	2243127
Virginia	18198	1666	535	18834262
Washington	10691	1313	2395	32290249
W. Virginia	3523	1375	205	1661404
Wisconsin	10135	1050	391	7665883
Wyoming	708	248	1392	403633
Total	**642997**			**882859618**

Table A.1.3 Transportation Cost in the U.S. with Three Plant

(Plant Location : Kansas City, Salt Lake City & Charleston in W. Vagina)

State	**Sales**	**Distance to Kansas City**	**Distance to Salt Lake**	**Distance to Charleston**	**$ by truck**
Alabama	8210	692	1673	535	10104285
Arizona	10244	1250	655	2076	15434704
Arkansas	4247	391	1532	733	3819588
California	70164	1750	720	2420	116213206
Colorado	9791	616	537	1375	12095114
Connecticut	8576	1204	2284	509	8444235
Delaware	2001	1134	2152	476	1842626
Dis of Columbia	610	1067	2205	359	423650
Federal Government	1410	1067	2205	359	978910

Florida	47653	1231	2337	794	87040103
Georgia	22145	792	1920	515	26235634
Idaho	1612	1482	336	2160	1245985
Illinois	33123	500	1380	483	30949479
Indiana	11586	487	1545	307	6880758
Iowa	4584	197	1068	757	1747004
Kansas	4789	245	1062	645	2699104
Kentucky	7957	500	1666	247	4521213
Louisiana	10659	842	1856	870	20646061
Maine	2873	1600	2507	941	5230080
Maryland	18736	1041	2092	363	13157295
Massachusetts	14197	1529	2328	720	19774804
Michigan	37361	777	1649	368	26597670
Minnesota	12439	443	1318	937	12675946
Mississippi	5259	637	1794	852	7705662
Missouri	15961	100	1287	620	3671598
Montana	1308	1117	566	1820	1703071
Nebraska	2780	492	606	1204	3146433
Nevada	3729	1450	470	2200	4031799
New Hampshire	3543	1550	2378	772	5290665
New Jersey	23805	1228	2193	547	25190606
New Mexico	3583	769	623	1527	5135036
New York	28118	1250	2100	470	25565699
North Carolina	18237	1036	2022	299	10548912
North Dakota	909	965	1049	1297	2016791
Ohio	32801	663	1727	153	9708712
Oklahoma	5297	350	1206	999	4264878
Oregon	6995	1852	757	2572	12180390
Pennsylvania	27151	1000	2000	350	18383533
Rhode Island	2045	1250	2358	738	2918949
South Carolina	10506	1221	2222	489	9938222
South Dakota	1046	694	904	1336	1669138
Tennessee	12043	538	1669	395	10942647
Texas	44257	652	1400	1199	66379397
Utah	3868	1137	180	1781	1601443
Vermont	1546	1300	2270	720	2153402
Virginia	18198	1086	2185	310	10913311
Washington	10691	1906	800	2449	19674180
W. Virginia	3523	739	1781	150	1215661
Wisconsin	10135	562	1436	580	11018481
Wyoming	708	853	310	1661	504541
Total	**642997**				**706230614**

Table A.1.4 Transportation Cost for Alternative Plant Locations in the U.S. in One Plant Case

State	Taurus Sales	Plant Location: St. Louis distance (mile)	Plant Location: St. Louis cost ($)	Plant Location: Cincinnati distance (mile)	Plant Location: Cincinnati cost ($)	Plant Location: Detroit distance (mile)	Plant Location: Detroit cost ($)
Alabama	8210	527	9953193	455	8593364	734	13862701
Arizona	10244	1503	35417345	1856	43735590	2041	48095010
Arkansas	4247	405	3956351	601	5871029	896	8752816
California	70164	2000	322814460	2280	368008485	2300	371236629
Colorado	9791	860	19370202	1208	27208377	1282	28875115
Connecticut	8576	1103	18298609	778	12906906	645	10700456
Delaware	2001	904	3499441	581	2249087	597	2311024
Dist. of Columbia	610	830	979470	515	607743	527	621904
Federal Government	1410	830	2263217	515	1404285	527	1437007
Florida	47653	992	108745317	885	97015732	1210	132642978
Georgia	22145	560	28528068	453	23077169	727	37035545
Idaho	1612	1675	6211386	1930	7157000	1965	7286790
Illinois	33123	180	11533967	290	18582503	350	22427159
Indiana	11586	257	5760113	109	2443005	286	6410087
Iowa	4584	372	3298911	591	5241012	614	5444977
Kansas	4789	445	4902454	803	8846450	992	10928616
Kentucky	7957	275	5033739	100	1830451	366	6699449
Louisiana	10659	677	16600217	806	19763331	1071	26261201
Maine	2873	1332	7403259	991	5507980	780	4335242
Maryland	18736	834	30229157	516	18702931	532	19282867
Massachusetts	14197	1100	30211506	820	22521304	650	17852253
Michigan	37361	540	39029190	268	19370043	70	5059339
Minnesota	12439	608	17397235	697	19943870	674	19285751
Mississippi	5259	492	5951626	687	8310502	1000	12096801
Missouri	15961	125	4589498	490	17990831	660	24232548
Montana	1308	1396	4200508	1602	4820354	1573	4733094
Nebraska	2780	723	4623722	1021	6529489	1025	6555070
Nevada	3729	1750	15012018	2050	17585507	2000	17156592

New Hampshire	3543	1100	7538512	875	5996544	716	4906886
New Jersey	23805	999	46006244	675	31085300	649	29887940
New Mexico	3583	1034	8522676	1508	12429590	1564	12891166
New York	28118	1000	54395103	600	32637062	550	29917307
North Carolina	18237	747	26354641	509	17957848	656	23144102
North Dakota	909	975	2037690	1094	2286393	1105	2309382
Ohio	32801	433	27476289	109	6916664	206	13071861
Oklahoma	5297	491	5983015	843	10272264	1036	12624040
Oregon	6995	2095	33709270	2370	38134114	2364	38037572
Pennsylvania	27151	800	42019504	437	22953154	450	23635971
Rhode Island	2045	1153	4560364	853	3373799	694	2744920
South Carolina	10506	889	18067647	618	12559961	830	16868557
South Dakota	1046	775	1863951	1096	2635987	1073	2580670
Tennessee	12043	324	8975741	277	7673704	542	15014974
Texas	44257	845	86028514	1061	108019234	1349	137340195
Utah	3868	1380	12277729	1727	15364955	1649	14670997
Vermont	1546	1060	3170286	750	2243127	600	1794502
Virginia	18198	836	29430735	535	18834262	631	22213868
Washington	10691	2139	52603840	2395	58899578	2230	54841778
W. Virginia	3523	520	4214292	205	1661404	368	2982422
Wisconsin	10135	377	7391401	391	7665883	367	7195343
Wyoming	708	1084	1764267	1392	2265554	1386	2255788
Total	**642997**		**1250205890**		**1217690711**		**1342549260**

Appendix II

The following numbers and formulas are used in the calculation procedure.

Weight of 4-door Taurus : 3326 lb. = 1.66 tons

Freight rate:

trucking in US: Official : $1.1654 ton-mile

South-West : $1.3858 ton-mile

in other countries : (1.1654+1.3858)/2 = $1.2756 dollars/ton-mile

railroad: $1.373 dollars/ton-mile

sea Shipping: Cross-Pacific : $0.208 dollars/teu[1]-mile

Cross-Atlantic : $0.33 dollars/teu-mile

Transportation Cost = State Annual Sales (cars/year)

* Weight of Unit Car (tons/car)

* Distance between Plants and Demand (miles)

* Freight Rate by truck ($/ton-mile)

Note:

1. The distance for each state is measured from the geographic center of the state to the supply plant location.
2. In U.S., Canada, and Mexico, the products are shipped directly by trucking to the location of demand.
3. The demand location in Canada is equally divided into Vancouver, Ottawa, Toronto, and Montreal.
4. The total distribution costs in U.S. is calculated from Appendix I.
5. There is no limitation on the capacity of the plant production.

[1] Teu is the unit for one 20-feet container. 1 teu = 1 20-feet container.

Data source:

1. *World Road Statistics*, 1997 Edition, International Road Federation
2. *The Automotive News*, 1996, Crain Communications, Inc.
3. *Ward's automotive Yearbook,* 1993, Ward's Communications
4. *International Motor Business,* 1995, The Economist Intelligence Unit, U. K.
5. *1993-1994 World Automotive Market Report*, Auto & Truck International
6. Ashoka Mody & David Wheeler (1990), *Automation and World Competition, New Technologies, Industrial Location and Trade*, St. Martin's Press, New York
7. *Distances Between Ports*, 1965, U.S. Naval Oceanographic Office
8. Chapter 2

Table A.2.1 Distribution Cost in Global System with 1 Plant

Plant Location : Detroit, U.S.

Country	Sales for Taurus	Import Port	Unit Cost from Detroit to export Port	Unit Cost from Export to Import Ports	Import Port to Capital		Total Cost
					Distance	Unit Cost	
Africa							
Algeria	428	Casablanca	$1,256	$1,001	560	$1,186	$1,474,847
Angola	121	Durban	$1,256	$2,254	1488	$3,151	$804,284
Benin	176	Abidjan	$1,256	$1,628	352	$745	$639,369
Botswana	55	Durban	$1,256	$2,254	432	$915	$243,445
Burkina Faso	50	Abidjan	$1,256	$1,628	400	$847	$185,589
Burundi	61	Durban	$1,256	$2,254	1472	$3,117	$402,184
Cameroon	134	Abidjan	$1,256	$1,628	848	$1,796	$624,945
Cape Verde	13	Durban	$1,256	$2,254	1120	$2,372	$78,430
Central African Republic	18	Abidjan	$1,256	$1,628	1200	$2,541	$95,688
Chad	2	Abidjan	$1,256	$1,628	1120	$2,372	$12,139
Comoros	12	Durban	$1,256	$2,254	1280	$2,710	$77,723
Congo	17	Durban	$1,256	$2,254	1664	$3,524	$117,423
Djibouti	12	Mombasa	$1,256	$4,564	1040	$2,202	$93,493
Equatorial Guinea	2	Durban	$1,256	$2,254	800	$1,694	$10,491
Eritrea	13	Mombasa	$1,256	$4,564	800	$1,694	$98,615
Ethiopia	13	Mombasa	$1,256	$4,564	688	$1,457	$95,502
Gambia	20	Durban	$1,256	$2,254	1040	$2,202	$113,956
Ghana	127	Abidjan	$1,256	$1,628	192	$407	$418,693
Guinea	8	Abidjan	$1,256	$1,628	800	$1,694	$35,087
Guinea-Bissau	21	Durban	$1,256	$2,254	800	$1,694	$108,735
Ivory Coast	504	Abidjan	$1,256	$1,628	0	$0	$1,453,284
Kenya	129	Mombasa	$1,256	$4,564	0	$0	$751,588
Liberia	5	Abidjan	$1,256	$1,628	352	$745	$16,384
Libya	857	Casablanca	$1,256	$1,001	1104	$2,338	$3,936,658
Madagascar	4	Durban	$1,256	$2,254	0	$0	$14,299
Malawi	43	Durban	$1,256	$2,254	928	$1,965	$235,696

Mali	23	Casablanca	$1,256	$1,001	1232	$2,609	$109,638
Mauritania	40	Casablanca	$1,256	$1,001	1040	$2,202	$176,981
Mauritius	63	Durban	$1,256	$2,254	0	$0	$219,576
Morocco	1991	Casablanca	$1,256	$1,001	0	$0	$4,493,017
Mozambique	40	Durban	$1,256	$2,254	224	$474	$157,715
Namibia	12	Durban	$1,256	$2,254	848	$1,796	$66,293
Niger	110	Abidjan	$1,256	$1,628	576	$1,220	$450,652
Nigeria	953	Abidjan	$1,256	$1,628	352	$745	$3,459,830
Rwanda	23	Durban	$1,256	$2,254	800	$1,694	$120,210
Saint Lucia	16	Durban	$1,256	$2,254	800	$1,694	$81,852
Sao Tome & Principe	5	Durban	$1,256	$2,254	800	$1,694	$25,681
Senegal	47	Abidjan	$1,256	$1,628	832	$1,762	$220,561
Seychelles	15	Durban	$1,256	$2,254	1120	$2,372	$86,458
Sierra Leone	47	Durban	$1,256	$2,254	1120	$2,372	$275,430
Somalia	0	Mombasa	$1,256	$4,564	448	$949	$0
South Africa	4161	Durban	$1,256	$2,254	0	$0	$14,605,747
Sudan	630	Mombasa	$1,256	$4,564	1088	$2,304	$5,117,701
Swaziland	42	Durban	$1,256	$2,254		$0	$148,890
Tanzania	174	Mombasa	$1,256	$4,564	192	$407	$1,082,587
Togo	68	Abidjan	$1,256	$1,628	288	$610	$236,733
Tunisia	67	Casablanca	$1,256	$1,001	896	$1,897	$277,415
Uganda	48	Mombasa	$1,256	$1,628	448	$949	$184,288
Zaire	210	Durban	$1,256	$2,254	1632	$3,456	$1,462,787
Zambia	252	Durban	$1,256	$2,254	912	$1,931	$1,371,146
Zimbabwe	1525	Durban	$1,256	$2,254	640	$1,355	$7,417,328
Subtotal	**13405**						**$53,987,063**

Caribbean America

Bahamas	35	San Juan	$1,256	$455	0	$0	$59,454
Barbados	28	San Juan	$1,256	$455	0	$0	$47,081
Bermuda	30	San Juan	$1,256	$455	0	$0	$50,931
Cuba	10	San Juan	$1,256	$455	0	$0	$16,327
Dominican Republic	216	San Juan	$1,256	$455	0	$0	$369,252
Guadeloupe	252	San Juan	$1,256	$455	0	$0	$431,273
Haiti	7	San Juan	$1,256	$455	0	$0	$12,168

Jamaica	114	San Juan	$1,256	$455	0	$0	$195,100
Martinique	0	San Juan	$1,256	$455	0	$0	$0
Netherlands Antilles	194	San Juan	$1,256	$455	0	$0	$331,156
Puerto Rico	1806	San Juan	$1,256	$455	0	$0	$3,090,326
Trinidad & Tobago	108	San Juan	$1,256	$455	0	$0	$184,164
Virgin Islands	15	San Juan	$1,256	$455	0	$0	$26,492
Other	363	San Juan	$1,256	$455	0	$0	$620,417
Subtotal	**3175**						**$5,434,140**

C. & S. America

Argentina	9371	Buenos Aires	$1,256	$1,400	0	$0	$24,890,438
Belize	0	Cristobal	$1,256	$666	672	$1,423	$1,505
Bolivia	90	Callao	$1,256	$1,111	512	$1,084	$310,644
Brazil	35424	Santo's	$1,256	$1,636	0	$0	$102,438,610
Chile	1910	Valparaso	$1,256	$1,542	0	$0	$5,344,674
Colombia	1212	Cristobal	$1,256	$666	352	$745	$3,233,246
Costa Rica	561	Limon-Moin	$1,256	$666	0	$0	$1,078,208
Ecuador	1140	Callao	$1,256	$1,111	560	$1,186	$4,050,691
El Salvador	142	Cristobal	$1,256	$666	960	$2,033	$562,245
French Guiana	70	Cristobal	$1,256	$666	1424	$3,015	$344,818
Guatemala	261	Limon-Moin	$1,256	$666	480	$1,016	$767,700
Guyana	14	Cristobal	$1,256	$666	1120	$2,372	$61,827
Honduras	27	Limon-Moin	$1,256	$666	320	$678	$70,889
Nicaragua	180	Limon-Moin	$1,256	$666	208	$440	$425,937
Panama	577	Cristobal	$1,256	$666	0	$0	$1,109,574
Paraguay	175	Santo's	$1,256	$1,636	624	$1,321	$736,623
Peru	330	Callao	$1,256	$1,111	0	$0	$781,894
Suriname	315	Cristobal	$1,256	$666	1280	$2,710	$1,459,185
Uruguay	627	Santo's	$1,256	$1,636	832	$1,762	$2,916,809
Venezuela	1680	Cristobal	$1,256	$666	640	$1,355	$5,504,903
Subtotal	**54108**						**$156,090,422**

North America

Canada	38269		$0	$0		$3,356	$128,442,845
Mexico	8661		$0	$0		$6,503	$56,327,119
United States	498405		$0	$0			$1,040,647,567
Subtotal	**545335**						**$1,225,417,530**

Far East

Afghanistan	1	Singapore	$5,222	$1,636	0	$0	$7,973
Bangladesh	19	Singapore	$5,222	$1,636	0	$0	$132,709
Brunei	52	Singapore	$5,222	$1,636	0	$0	$355,433
Burma	0	Singapore	$5,222	$1,636	0	$0	$1,502
Cambodia	134	Singapore	$5,222	$1,636	0	$0	$922,336
China	6314	Shanghai	$5,222	$1,208	592	$1,254	$48,516,841
Hong Kong	1099	Hong Kong	$5,222	$1,327	0	$0	$7,197,526
India	4350	Madras	$5,222	$1,966	560	$1,186	$36,424,280
Indonesia	98	Singapore	$5,222	$1,636	0	$0	$674,786
Japan	23404	Yokohama	$5,222	$1,966	0	$0	$168,218,238
Laos	306	Singapore	$5,222	$1,636	0	$0	$2,097,005
S. Korea	3421	Pusan	$5,222	$1,966	160	$339	$25,749,295
Malaysia	600	Singapore	$5,222	$1,636	0	$0	$4,112,944
Maldives	0	Singapore	$5,222	$1,636	0	$0	$3,210
Mongolia	84	Shanghai	$5,222	$1,208	1344	$2,846	$781,443
Pakistan	1465	Madras	$5,222	$1,966	1280	$2,710	$14,500,167
Philippines	2681	Marila	$5,222	$1,360	0	$0	$17,645,124
Singapore	1565	Singapore	$5,222	$1,636	0	$0	$10,734,447
Sri Lanka	381	Madras	$5,222	$1,966	0	$0	$2,741,279
Taiwan	19986	Kaoshung	$5,222	$1,360	0	$0	$131,543,751
Thailand	2340	Singapore	$5,222	$1,636	80	$169	$16,444,901
Vietnam	19	Singapore	$5,222	$1,636	0	$0	$126,948
Subtotal	**68321**						**$488,932,138**

Mid East

Subtotal	**11555**	Jeddah	$1,256	$3,785	560	$1,186	**$71,948,240**

East Europe

Armenia	318	Piraeus	$1,256	$1,323	1120	$2,372	$1,575,573
Byelarus	631	Hamburg	$1,256	$1,254	928	$1,965	$2,822,965
Bulgaria	411	Piraeus	$1,256	$1,323	320	$678	$1,339,920
Com. of Indep. Sta	176	Piraeus	$1,256	$1,323	0	$0	$453,292
Croatia	4563	Hamburg	$1,256	$1,254	640	$1,355	$17,636,896
Cyprus	188	Limassol	$1,256	$1,523	0	$0	$523,419
Czechoslovakia	741	Hamburg	$1,256	$1,254	384	$813	$2,462,431
Estonia	948	Hamburg	$1,256	$1,254	944	$1,999	$4,272,352
Georgia	40	Piraeus	$1,256	$1,323	1168	$2,473	$202,324
Hungary	1272	Hamburg	$1,256	$1,254	704	$1,491	$5,087,712
Latvia	385	Hamburg	$1,256	$1,254	848	$1,796	$1,656,428
Lithuania	883	Hamburg	$1,256	$1,254	640	$1,355	$3,411,597
Macedonia	71	Piraeus	$1,256	$1,323	0	$0	$184,085
Poland	1454	Hamburg	$1,256	$1,254	608	$1,287	$5,520,715
Romania	3200	Piraeus	$1,256	$1,323	480	$1,016	$11,506,875
Slovenia	972	Hamburg	$1,256	$1,254	512	$1,084	$3,493,522
Yugoslavia	641	Piraeus	$1,256	$1,323	0	$0	$1,653,883
Ukraine	206	Piraeus	$1,256	$1,323	0	$0	$532,499
Subtotal	**17100**						**$64,336,487**

West Europe

Austria	7348	Rotterdam	$1,256	$1,155	736	$1,558	$29,167,128
Belgium	9332	Antwerp	$1,256	$1,096	160	$339	$25,107,883
Denmark	3739	Copenhagen	$1,256	$1,264	0	$0	$9,422,861
Finland	1510	Copenhagen	$1,256	$1,264	816	$1,728	$6,413,173
France	45432	Le Havre	$1,256	$1,040	208	$440	$124,315,002
Germany	97952	Hamburg	$1,256	$1,254	240	$508	$295,638,029

Greece	3374	Piraeus	$1,256	$1,323	0	$0	$8,701,752
Iceland	145	Felixstowe	$1,256	$1,013	1680	$3,557	$843,328
Ireland	3278	Felixstowe	$1,256	$1,013	0	$0	$7,438,004
Italy	46843	La Spezid	$1,256	$1,238	310	$656	$147,551,564
Luxembourg	691	Antwerp	$1,256	$1,096	160	$339	$1,859,910
Malta	218	Algeciras	$1,256	$963	0	$0	$482,574
Netherlands	1344	Rotterdam	$1,256	$1,155	20	$42	$3,296,659
Norway	2452	Copenhagen	$1,256	$1,264	0	$0	$6,179,052
Portugal	7437	Algeciras	$1,256	$963	0	$0	$16,499,448
Spain	38634	Algeciras	$1,256	$963	0	$0	$85,713,113
Sweden	3686	Copenhagen	$1,256	$1,264	544	$1,152	$13,536,462
Switzerland	7139	Rotterdam	$1,256	$1,155	496	$1,050	$24,710,757
UK	125597	Felixstowe	$1,256	$1,013	0	$0	$284,950,933
Subtotal	**406150**						**$1,091,827,630**

Pacific

Australia	31716	Sydney Port	$5,222	$1,354	0	$0	$208,573,550
Fiji	39	Sydney Port	$5,222	$1,354	0	$0	$258,023
French Pacific Ocean	68	Sydney Port	$5,222	$1,354	0	$0	$447,036
Guam	195	Sydney Port	$5,222	$1,354	0	$0	$1,283,819
New Caledonia	124	Sydney Port	$5,222	$1,354	0	$0	$817,903
New Zealand	6341	Auckland	$5,222	$1,177	0	$0	$40,575,261
Papua New Guinea	39	Sydney Port	$5,222	$1,354	0	$0	$259,108
Samoa	6	Auckland	$5,222	$1,177	0	$0	$35,475
Vanuatu	5	Sydney Port	$5,222	$1,354	0	$0	$31,032
W. Samoa	35	Auckland	$5,222	$1,177	0	$0	$225,099
Subtotal	**38569**						**$252,506,307**

Total (for 1 year)	**1157718**	**$3,410,479,956**
Total (for 5 year)	**5788590**	**$17,052,399,781**

Table A.2.2 Distribution Cost in Global System with 2 Plants

Plant Location : Detroit, U.S. & Paris, France

Country	Sales for Taurus	Import Port	Unit Cost from Plant to Export Port	Unit Cost from Export to Import Ports	Import Port to Capital		Total Cost
					Distance	Unit Cost	
Africa			**Supply Plant : Paris**				
			Paris to Le Havre	**Le Havre to Import Ports**			
Algeria	428	Casablanca	$203	$338	560	$1,186	$739,867
Angola	121	Durban	$203	$2,237	1488	$3,151	$675,062
Benin	176	Abidjan	$203	$1,190	352	$745	$376,754
Botswana	55	Durban	$203	$2,237	432	$915	$184,564
Burkina Faso	50	Abidjan	$203	$1,190	400	$847	$111,437
Burundi	61	Durban	$203	$2,237	1472	$3,117	$337,236
Cameroon	134	Abidjan	$203	$1,190	848	$1,796	$425,872
Cape Verde	13	Durban	$203	$2,237	1120	$2,372	$64,159
Central African Republic	18	Abidjan	$203	$1,190	1200	$2,541	$69,395
Chad	2	Abidjan	$203	$1,190	1120	$2,372	$8,696
Comoros	12	Durban	$203	$2,237	1280	$2,710	$64,351
Congo	17	Durban	$203	$2,237	1664	$3,524	$99,557
Djibouti	12	Mombasa	$203	$2,800	1040	$2,202	$60,671
Equatorial Guinea	2	Durban	$203	$2,237	800	$1,694	$8,334
Eritrea	13	Mombasa	$203	$2,800	800	$1,694	$61,653
Ethiopia	13	Mombasa	$203	$2,800	688	$1,457	$58,540
Gambia	20	Durban	$203	$2,237	1040	$2,202	$92,607
Ghana	127	Abidjan	$203	$1,190	192	$407	$229,009
Guinea	8	Abidjan	$203	$1,190	800	$1,694	$23,662
Guinea-Bissau	21	Durban	$203	$2,237	800	$1,694	$86,374
Ivory Coast	504	Abidjan	$203	$1,190	0	$0	$702,062
Kenya	129	Mombasa	$203	$2,800	0	$0	$387,887
Liberia	5	Abidjan	$203	$1,190	352	$745	$9,655
Libya	857	Casablanca	$203	$338	1104	$2,338	$2,466,698
Madagascar	4	Durban	$203	$2,237	0	$0	$9,940
Malawi	43	Durban	$203	$2,237	928	$1,965	$189,626

Mali	23	Casablanca	$203	$338	1232	$2,609	$70,979
Mauritania	40	Casablanca	$203	$338	1040	$2,202	$108,887
Mauritius	63	Durban	$203	$2,237	0	$0	$152,628
Morocco	1991	Casablanca	$203	$338	0	$0	$1,077,521
Mozambique	40	Durban	$203	$2,237	224	$474	$115,353
Namibia	12	Durban	$203	$2,237	848	$1,796	$52,921
Niger	110	Abidjan	$203	$1,190	576	$1,220	$286,948
Nigeria	953	Abidjan	$203	$1,190	352	$745	$2,038,737
Rwanda	23	Durban	$203	$2,237	800	$1,694	$95,489
Saint Lucia	16	Durban	$203	$2,237	800	$1,694	$65,020
Sao Tome & Principe	5	Durban	$203	$2,237	800	$1,694	$20,400
Senegal	47	Abidjan	$203	$1,190	832	$1,762	$149,790
Seychelles	15	Durban	$203	$2,237	1120	$2,372	$70,727
Sierra Leone	47	Durban	$203	$2,237	1120	$2,372	$225,315
Somalia	0	Mombasa	$203	$2,800	448	$949	$0
South Africa	4161	Durban	$203	$2,237	0	$0	$10,152,490
Sudan	630	Mombasa	$203	$2,800	1088	$2,304	$3,343,546
Swaziland	42	Durban	$203	$2,237	0	$0	$103,494
Tanzania	174	Mombasa	$203	$2,800	192	$407	$592,920
Togo	68	Abidjan	$203	$1,190	288	$610	$135,725
Tunisia	67	Casablanca	$203	$338	896	$1,897	$162,845
Uganda	48	Mombasa	$203	$2,800	448	$949	$190,053
Zaire	210	Durban	$203	$2,237	1632	$3,456	$1,238,054
Zambia	252	Durban	$203	$2,237	912	$1,931	$1,101,466
Zimbabwe	1525	Durban	$203	$2,237	640	$1,355	$5,785,762
Subtotal	**13405**						**$34,880,733**

Caribbean America

Supply Plant : Detroit

			Detroit to N.Y.	**N.Y. to San Juan**			
Bahamas	35	San Juan	$1,256	$455	0	$0	$59,454
Barbados	28	San Juan	$1,256	$455	0	$0	$47,081
Bermuda	30	San Juan	$1,256	$455	0	$0	$50,931
Cuba	10	San Juan	$1,256	$455	0	$0	$16,327
Dominican Republic	216	San Juan	$1,256	$455	0	$0	$369,252
Guadeloupe	252	San Juan	$1,256	$455	0	$0	$431,273
Haiti	7	San Juan	$1,256	$455	0	$0	$12,168

Jamaica	114	San Juan	$1,256	$455	0	$0	$195,100
Martinique	0	San Juan	$1,256	$455	0	$0	$0
Netherlands Antilles	194	San Juan	$1,256	$455	0	$0	$331,156
Puerto Rico	1806	San Juan	$1,256	$455	0	$0	$3,090,326
Trinidad & Tobago	108	San Juan	$1,256	$455	0	$0	$184,164
Virgin Islands	15	San Juan	$1,256	$455	0	$0	$26,492
Other	363	San Juan	$1,256	$455	0	$0	$620,417
Subtotal	**3175**						**$5,434,140**

C. & S. America			Supply Plant : Detroit				
			Detroit to N.Y.	N.Y. to Import Ports			
Argentina	9371	Buenos Aires	$1,256	$1,400	0	$0	$24,890,438
Belize	0	Cristobal	$1,256	$666	672	$1,423	$1,505
Bolivia	90	Callao	$1,256	$1,111	512	$1,084	$310,644
Brazil	35424	Santo's	$1,256	$1,636	0	$0	$102,438,610
Chile	1910	Valparaso	$1,256	$1,542	0	$0	$5,344,674
Colombia	1212	Cristobal	$1,256	$666	352	$745	$3,233,246
Costa Rica	561	Limon-Moin	$1,256	$666	0	$0	$1,078,208
Ecuador	1140	Callao	$1,256	$1,111	560	$1,186	$4,050,691
El Salvador	142	Cristobal	$1,256	$666	960	$2,033	$562,245
French Guiana	70	Cristobal	$1,256	$666	1424	$3,015	$344,818
Guatemala	261	Limon-Moin	$1,256	$666	480	$1,016	$767,700
Guyana	14	Cristobal	$1,256	$666	1120	$2,372	$61,827
Honduras	27	Limon-Moin	$1,256	$666	320	$678	$70,889
Nicaragua	180	Limon-Moin	$1,256	$666	208	$440	$425,937
Panama	577	Cristobal	$1,256	$666	0	$0	$1,109,574
Paraguay	175	Santo's	$1,256	$1,636	624	$1,321	$736,623
Peru	330	Callao	$1,256	$1,111	0	$0	$781,894
Suriname	315	Cristobal	$1,256	$666	1280	$2,710	$1,459,185
Uruguay	627	Santo's	$1,256	$1,636	832	$1,762	$2,916,809
Venezuela	1680	Cristobal	$1,256	$666	640	$1,355	$5,504,903
Subtotal	**54108**						**$156,090,422**

North America — **Supply Plant : Detroit**

Canada	38269		$0	$0		$3,356	$128,442,845
Mexico	8661		$0	$0		$6,503	$56,327,119
United States	498405		$0	$0			$1,040,647,567
Subtotal	**545335**						**$1,225,417,530**

Far East — **Supply Plant : Paris**

			Paris to Le Havre	Le Havre to Import Ports			
Afghanistan	1	Singapore	$203	$3,848	0	$0	$4,709
Bangladesh	19	Singapore	$203	$3,848	0	$0	$78,389
Brunei	52	Singapore	$203	$3,848	0	$0	$209,950
Burma	0	Singapore	$203	$3,848	0	$0	$887
Cambodia	134	Singapore	$203	$3,848	0	$0	$544,812
China	6314	Shanghai	$203	$4,576	592	$1,254	$38,092,212
Hong Kong	1099	Hong Kong	$203	$4,328	0	$0	$4,979,605
India	4350	Madras	$203	$3,148	560	$1,186	$19,735,940
Indonesia	98	Singapore	$203	$3,848	0	$0	$398,587
Japan	23404	Yokohama	$203	$4,802	0	$0	$117,125,073
Laos	306	Singapore	$203	$3,848	0	$0	$1,238,674
S. Korea	3421	Pusan	$203	$4,802	160	$339	$18,280,480
Malaysia	600	Singapore	$203	$3,848	0	$0	$2,429,463
Maldives	0	Singapore	$203	$3,848	0	$0	$1,896
Mongolia	84	Shanghai	$203	$4,576	1344	$2,846	$642,360
Pakistan	1465	Madras	$203	$3,148	1280	$2,710	$8,879,994
Philippines	2681	Marila	$203	$4,287	0	$0	$12,037,495
Singapore	1565	Singapore	$203	$3,848	0	$0	$6,340,698
Sri Lanka	381	Madras	$203	$3,148	0	$0	$1,278,114
Taiwan	19986	Kaoshung	$203	$4,287	0	$0	$89,739,087
Thailand	2340	Singapore	$203	$3,848	80	$169	$9,876,039
Vietnam	19	Singapore	$203	$3,848	0	$0	$74,986
Subtotal	**68321**						**$331,989,451**

Mid East

Supply Plant : Paris
Paris to Le Havre

Subtotal	**11555**	Jeddah	$203	$3,603	560	$1,186	**$57,683,543**

East Europe

Supply Plant : Paris **By Land Directly**

Armenia	318		$0	$0	2320	$4,913	$1,563,383
Byelarus	631		$0	$0	1424	$3,015	$1,902,136
Bulgaria	411		$0	$0	1216	$2,575	$1,059,329
Com. of Indep. Sta	176		$0	$0	900	$1,906	$334,920
Croatia	4563		$0	$0	736	$1,558	$7,111,331
Cyprus	188		$0	$0	1920	$4,066	$765,745
Czechoslovakia	741		$0	$0	656	$1,389	$1,029,306
Estonia	948		$0	$0	1520	$3,219	$3,049,727
Georgia	40		$0	$0	2304	$4,879	$195,363
Hungary	1272		$0	$0	880	$1,863	$2,369,681
Latvia	385		$0	$0	1376	$2,914	$1,120,924
Lithuania	883		$0	$0	1328	$2,812	$2,482,028
Macedonia	71		$0	$0	1120	$2,372	$169,261
Poland	1454		$0	$0	1024	$2,168	$3,152,298
Romania	3200		$0	$0	1328	$2,812	$8,999,012
Slovenia	972		$0	$0	832	$1,762	$1,712,427
Yugoslavia	641		$0	$0	1008	$2,134	$1,368,630
Ukraine	206		$0	$0	1488	$3,151	$650,493
Subtotal	**17100**						**$39,035,996**

West Europe

Supply Plant : Paris **By Land Directly**

Austria	7348		$0	$0	752	$1,592	$11,700,403
Belgium	9332		$0	$0	208	$440	$4,110,354
Denmark	3739		$0	$0	768	$1,626	$6,080,320
Finland	1510		$0	$0	1600	$3,388	$5,114,699
France	45432		$0	$0	0	$0	$0
Germany	97952		$0	$0	752	$1,592	$155,974,234

Greece	3374		$0	$0	1376	$2,914	$9,829,827
Iceland	145		$0	$0	1952	$4,133	$598,296
Ireland	3278		$0	$0	624	$1,321	$4,331,847
Italy	46843		$0	$0	752	$1,592	$74,590,619
Luxembourg	691		$0	$0	224	$474	$327,903
Malta	218		$0	$0	1152	$2,439	$530,589
Netherlands	1344		$0	$0	368	$779	$1,047,092
Norway	2452		$0	$0	1120	$2,372	$5,814,633
Portugal	7437		$0	$0	960	$2,033	$15,117,581
Spain	38634		$0	$0	768	$1,626	$62,827,550
Sweden	3686		$0	$0	1280	$2,710	$9,991,198
Switzerland	7139		$0	$0	288	$610	$4,353,762
UK	125597		$0	$0	272	$576	$72,338,769
Subtotal	**406150**						**$444,679,675**

Pacific

Supply Plant : Paris

Paris to Le Havre

Australia	31716	Sydney Port	$203	$4,055	0	$0	$135,037,530
Fiji	39	Sydney Port	$203	$4,055	0	$0	$167,060
French Pacific Ocean	68	Sydney Port	$203	$4,055	0	$0	$289,439
Guam	195	Sydney Port	$203	$4,055	0	$0	$831,224
New Caledonia	124	Sydney Port	$203	$4,055	0	$0	$529,561
New Zealand	6341	Auckland	$203	$4,462	0	$0	$29,580,368
Papua New Guinea	39	Sydney Port	$203	$4,055	0	$0	$167,762
Samoa	6	Auckland	$203	$4,462	0	$0	$25,862
Vanuatu	5	Sydney Port	$203	$4,055	0	$0	$20,092
W. Samoa	35	Auckland	$203	$4,462	0	$0	$164,103
Subtotal	**38569**						**$166,813,002**

Total (for 1 year)	**1157718**	**$2,462,024,493**
Total (for 5 year)	**5788590**	**$12,310,122,465**

Table A.2.3 Distribution Cost in Global System with 3 Plants

Plant Location : Detroit, U.S. & Paris, France

Taiwan

Africa

Supply Plant : Paris

Country	Sales for Taurus	Import Port	Unit Cost from Plant to Export Port (Paris to Le Havre)	Unit Cost from Export to Import Ports (Le Havre to Import Ports)	Import Port to Capital		Total Cost
					Distance	Unit Cost	
Algeria	428	Casablanca	$203	$338	560	$1,186	$739,867
Angola	121	Durban	$203	$2,237	1488	$3,151	$675,062
Benin	176	Abidjan	$203	$1,190	352	$745	$376,754
Botswana	55	Durban	$203	$2,237	432	$915	$184,564
Burkina Faso	50	Abidjan	$203	$1,190	400	$847	$111,437
Burundi	61	Durban	$203	$2,237	1472	$3,117	$337,236
Cameroon	134	Abidjan	$203	$1,190	848	$1,796	$425,872
Cape Verde	13	Durban	$203	$2,237	1120	$2,372	$64,159
Central African Republic	18	Abidjan	$203	$1,190	1200	$2,541	$69,395
Chad	2	Abidjan	$203	$1,190	1120	$2,372	$8,696
Comoros	12	Durban	$203	$2,237	1280	$2,710	$64,351
Congo	17	Durban	$203	$2,237	1664	$3,524	$99,557
Djibouti	12	Mombasa	$203	$2,800	1040	$2,202	$60,671
Equatorial Guinea	2	Durban	$203	$2,237	800	$1,694	$8,334
Eritrea	13	Mombasa	$203	$2,800	800	$1,694	$61,653
Ethiopia	13	Mombasa	$203	$2,800	688	$1,457	$58,540
Gambia	20	Durban	$203	$2,237	1040	$2,202	$92,607
Ghana	127	Abidjan	$203	$1,190	192	$407	$229,009
Guinea	8	Abidjan	$203	$1,190	800	$1,694	$23,662
Guinea-Bissau	21	Durban	$203	$2,237	800	$1,694	$86,374
Ivory Coast	504	Abidjan	$203	$1,190	0	$0	$702,062
Kenya	129	Mombasa	$203	$2,800	0	$0	$387,887
Liberia	5	Abidjan	$203	$1,190	352	$745	$9,655
Libya	857	Casablanca	$203	$338	1104	$2,338	$2,466,698
Madagascar	4	Durban	$203	$2,237	0	$0	$9,940
Malawi	43	Durban	$203	$2,237	928	$1,965	$189,626
Mali	23	Casablanca	$203	$338	1232	$2,609	$70,979

Mauritania	40	Casablanca	$203	$338	1040	$2,202	$108,887
Mauritius	63	Durban	$203	$2,237	0	$0	$152,628
Morocco	1991	Casablanca	$203	$338	0	$0	$1,077,521
Mozambique	40	Durban	$203	$2,237	224	$474	$115,353
Namibia	12	Durban	$203	$2,237	848	$1,796	$52,921
Niger	110	Abidjan	$203	$1,190	576	$1,220	$286,948
Nigeria	953	Abidjan	$203	$1,190	352	$745	$2,038,737
Rwanda	23	Durban	$203	$2,237	800	$1,694	$95,489
Saint Lucia	16	Durban	$203	$2,237	800	$1,694	$65,020
Sao Tome & Principe	5	Durban	$203	$2,237	800	$1,694	$20,400
Senegal	47	Abidjan	$203	$1,190	832	$1,762	$149,790
Seychelles	15	Durban	$203	$2,237	1120	$2,372	$70,727
Sierra Leone	47	Durban	$203	$2,237	1120	$2,372	$225,315
Somalia	0	Mombasa	$203	$2,800	448	$949	$0
South Africa	4161	Durban	$203	$2,237	0	$0	$10,152,490
Sudan	630	Mombasa	$203	$2,800	1088	$2,304	$3,343,546
Swaziland	42	Durban	$203	$2,237	0	$0	$103,494
Tanzania	174	Mombasa	$203	$2,800	192	$407	$592,920
Togo	68	Abidjan	$203	$1,190	288	$610	$135,725
Tunisia	67	Casablanca	$203	$338	896	$1,897	$162,845
Uganda	48	Mombasa	$203	$2,800	448	$949	$190,053
Zaire	210	Durban	$203	$2,237	1632	$3,456	$1,238,054
Zambia	252	Durban	$203	$2,237	912	$1,931	$1,101,466
Zimbabwe	1525	Durban	$203	$2,237	640	$1,355	$5,785,762
Subtotal	**13405**						**$34,880,733**

Caribbean America

			Supply Plant : Detroit				
			Detroit to N.Y.	**N.Y. to San Juan**			
Bahamas	35	San Juan	$1,256	$455	0	$0	$59,454
Barbados	28	San Juan	$1,256	$455	0	$0	$47,081
Bermuda	30	San Juan	$1,256	$455	0	$0	$50,931
Cuba	10	San Juan	$1,256	$455	0	$0	$16,327
Dominican Republic	216	San Juan	$1,256	$455	0	$0	$369,252
Guadeloupe	252	San Juan	$1,256	$455	0	$0	$431,273
Haiti	7	San Juan	$1,256	$455	0	$0	$12,168
Jamaica	114	San Juan	$1,256	$455	0	$0	$195,100

Martinique	0	San Juan	$1,256	$455	0	$0	$0
Netherlands Antilles	194	San Juan	$1,256	$455	0	$0	$331,156
Puerto Rico	1806	San Juan	$1,256	$455	0	$0	$3,090,326
Trinidad & Tobago	108	San Juan	$1,256	$455	0	$0	$184,164
Virgin Islands	15	San Juan	$1,256	$455	0	$0	$26,492
Other	363	San Juan	$1,256	$455	0	$0	$620,417
Subtotal	**3175**						**$5,434,140**

1948.96

C. & S. America

Supply Plant : Taiwan

Taiwan to Import Ports

Argentina	9371	Buenos Aires	$0		0	$0	$0
Belize	0	Cristobal	$0	$1,924	672	$1,423	$1,506
Bolivia	90	Callao	$0	$1,988	512	$1,084	$276,519
Brazil	35424	Santo's	$0	$2,901	0	$0	$102,778,040
Chile	1910	Valparaso	$0	$2,146	0	$0	$4,098,899
Colombia	1212	Cristobal	$0	$1,924	352	$745	$3,235,743
Costa Rica	561	Limon-Moin	$0	$1,893	0	$0	$1,061,861
Ecuador	1140	Callao	$0	$1,988	560	$1,186	$3,618,440
El Salvador	142	Cristobal	$0	$1,924	960	$2,033	$562,538
French Guiana	70	Cristobal	$0	$1,924	1424	$3,015	$344,962
Guatemala	261	Limon-Moin	$0	$1,893	480	$1,016	$760,086
Guyana	14	Cristobal	$0	$1,924	1120	$2,372	$61,857
Honduras	27	Limon-Moin	$0	$1,893	320	$678	$70,095
Nicaragua	180	Limon-Moin	$0	$1,893	208	$440	$420,683
Panama	577	Cristobal	$0	$1,924	0	$0	$1,110,764
Paraguay	175	Santo's	$0	$2,901	624	$1,321	$738,299
Peru	330	Callao	$0	$1,988	0	$0	$656,667
Suriname	315	Cristobal	$0	$1,924	1280	$2,710	$1,459,834
Uruguay	627	Santo's	$0	$2,901	832	$1,762	$2,922,815
Venezuela	1680	Cristobal	$0	$1,924	640	$1,355	$5,508,363
Subtotal	**54108**						**$129,687,968**

North America | **Supply Plant : Detroit**

Canada	38269		$0	$0		$3,356	$128,442,845
Mexico	8661		$0	$0		$6,503	$56,327,119
United States	498405		$0	$0			$1,040,647,567
Subtotal	**545335**						**$1,225,417,530**

Far East | **Supply Plant : Taiwan**

				Taiwan to Import Ports			
Afghanistan	1	Singapore	$0	$374	0	$0	$435
Bangladesh	19	Singapore	$0	$374	0	$0	$7,245
Brunei	52	Singapore	$0	$374	0	$0	$19,403
Burma	0	Singapore	$0	$374	0	$0	$82
Cambodia	134	Singapore	$0	$374	0	$0	$50,351
China	6314	Shanghai	$0	$127	592	$1,254	$8,718,679
Hong Kong	1099	Hong Kong	$0	$92	0	$0	$100,582
India	4350	Madras	$0	$704	560	$1,186	$8,219,159
Indonesia	98	Singapore	$0	$374	0	$0	$36,837
Japan	23404	Yokohama	$0	$325	0	$0	$7,608,718
Laos	306	Singapore	$0	$374	0	$0	$114,477
S. Korea	3421	Pusan	$0	$325	160	$339	$2,271,344
Malaysia	600	Singapore	$0	$374	0	$0	$224,528
Maldives	0	Singapore	$0	$374	0	$0	$175
Mongolia	84	Shanghai	$0	$127	1344	$2,846	$250,463
Pakistan	1465	Madras	$0	$704	1280	$2,710	$5,001,460
Philippines	2681	Marila	$0	$19	0	$0	$50,187
Singapore	1565	Singapore	$0	$374	0	$0	$585,999
Sri Lanka	381	Madras	$0	$704	0	$0	$268,370
Taiwan	19986	Kaoshung	$0	$0	0	$0	$0
Thailand	2340	Singapore	$0	$374	80	$169	$1,272,491
Vietnam	19	Singapore	$0	$374	0	$0	$6,930
Subtotal	**68321**						**$34,807,915**

Mid East

Supply Plant : Taiwan

Taiwan to Import Ports

Subtotal	**11555**	Jeddah		$0	$1,310	560	$1,186	**$28,843,665**

East Europe

Supply Plant : Paris **By Land Directly**

Armenia	318			$0	$0	2320	$4,913	$1,563,383
Byelarus	631			$0	$0	1424	$3,015	$1,902,136
Bulgaria	411			$0	$0	1216	$2,575	$1,059,329
Com. of Indep. Sta	176			$0	$0	900	$1,906	$334,920
Croatia	4563			$0	$0	736	$1,558	$7,111,331
Cyprus	188			$0	$0	1920	$4,066	$765,745
Czechoslovakia	741			$0	$0	656	$1,389	$1,029,306
Estonia	948			$0	$0	1520	$3,219	$3,049,727
Georgia	40			$0	$0	2304	$4,879	$195,363
Hungary	1272			$0	$0	880	$1,863	$2,369,681
Latvia	385			$0	$0	1376	$2,914	$1,120,924
Lithuania	883			$0	$0	1328	$2,812	$2,482,028
Macedonia	71			$0	$0	1120	$2,372	$169,261
Poland	1454			$0	$0	1024	$2,168	$3,152,298
Romania	3200			$0	$0	1328	$2,812	$8,999,012
Slovenia	972			$0	$0	832	$1,762	$1,712,427
Yugoslavia	641			$0	$0	1008	$2,134	$1,368,630
Ukraine	206			$0	$0	1488	$3,151	$650,493
Subtotal	**17100**							**$39,035,996**

West Europe

Supply Plant : Paris **By Land Directly**

Austria	7348			$0	$0	752	$1,592	$11,700,403
Belgium	9332			$0	$0	208	$440	$4,110,354
Denmark	3739			$0	$0	768	$1,626	$6,080,320
Finland	1510			$0	$0	1600	$3,388	$5,114,699
France	45432			$0	$0	0	$0	$0
Germany	97952			$0	$0	752	$1,592	$155,974,234

Greece	3374		$0	$0	1376	$2,914	$9,829,827
Iceland	145		$0	$0	1952	$4,133	$598,296
Ireland	3278		$0	$0	624	$1,321	$4,331,847
Italy	46843		$0	$0	752	$1,592	$74,590,619
Luxembourg	691		$0	$0	224	$474	$327,903
Malta	218		$0	$0	1152	$2,439	$530,589
Netherlands	1344		$0	$0	368	$779	$1,047,092
Norway	2452		$0	$0	1120	$2,372	$5,814,633
Portugal	7437		$0	$0	960	$2,033	$15,117,581
Spain	38634		$0	$0	768	$1,626	$62,827,550
Sweden	3686		$0	$0	1280	$2,710	$9,991,198
Switzerland	7139		$0	$0	288	$610	$4,353,762
UK	125597		$0	$0	272	$576	$72,338,769
Subtotal	**406150**						**$444,679,675**

Pacific

Supply Plant : Taiwan

Taiwan to Import Ports

Australia	31716	Sydney Port	$0	$1,366	0	$0	$43,309,467
Fiji	39	Sydney Port	$0	$1,366	0	$0	$53,580
French Pacific Ocean	68	Sydney Port	$0	$1,366	0	$0	$92,829
Guam	195	Sydney Port	$0	$1,366	0	$0	$266,592
New Caledonia	124	Sydney Port	$0	$1,366	0	$0	$169,842
New Zealand	6341	Auckland	$0	$1,773	0	$0	$11,241,089
Papua New Guinea	39	Sydney Port	$0	$1,366	0	$0	$53,805
Samoa	6	Auckland	$0	$1,773	0	$0	$9,828
Vanuatu	5	Sydney Port	$0	$1,366	0	$0	$6,444
W. Samoa	35	Auckland	$0	$1,773	0	$0	$62,362
Subtotal	**38569**						**$55,265,837**
Total (for 1 year)	**1157718**						**$1,998,053,461**
Total (for 5 year)	**5788590**						**$9,990,267,306**

Table A.2.4 Distribution Cost in Global System with 3 Plants

Plant Location : Detroit, & Salt Lake City, U.S.
Paris, France

Country	Sales for Taurus	Import Port	Unit Cost from Plant to Export Port	Unit Cost from Export to Import Ports	Import Port to Capital		Total Cost
					Distance	Unit Cost	
Africa			**Supply Plant : Paris**				
			Paris to Le Havre	**Le Havre to Import Ports**			
Algeria	428	Casablanca	$203	$338	560	$1,186	$739,867
Angola	121	Durban	$203	$2,237	1488	$3,151	$675,062
Benin	176	Abidjan	$203	$1,190	352	$745	$376,754
Botswana	55	Durban	$203	$2,237	432	$915	$184,564
Burkina Faso	50	Abidjan	$203	$1,190	400	$847	$111,437
Burundi	61	Durban	$203	$2,237	1472	$3,117	$337,236
Cameroon	134	Abidjan	$203	$1,190	848	$1,796	$425,872
Cape Verde	13	Durban	$203	$2,237	1120	$2,372	$64,159
Central African Republic	18	Abidjan	$203	$1,190	1200	$2,541	$69,395
Chad	2	Abidjan	$203	$1,190	1120	$2,372	$8,696
Comoros	12	Durban	$203	$2,237	1280	$2,710	$64,351
Congo	17	Durban	$203	$2,237	1664	$3,524	$99,557
Djibouti	12	Mombasa	$203	$2,800	1040	$2,202	$60,671
Equatorial Guinea	2	Durban	$203	$2,237	800	$1,694	$8,334
Eritrea	13	Mombasa	$203	$2,800	800	$1,694	$61,653
Ethiopia	13	Mombasa	$203	$2,800	688	$1,457	$58,540
Gambia	20	Durban	$203	$2,237	1040	$2,202	$92,607
Ghana	127	Abidjan	$203	$1,190	192	$407	$229,009
Guinea	8	Abidjan	$203	$1,190	800	$1,694	$23,662
Guinea-Bissau	21	Durban	$203	$2,237	800	$1,694	$86,374
Ivory Coast	504	Abidjan	$203	$1,190	0	$0	$702,062
Kenya	129	Mombasa	$203	$2,800	0	$0	$387,887
Liberia	5	Abidjan	$203	$1,190	352	$745	$9,655
Libya	857	Casablanca	$203	$338	1104	$2,338	$2,466,698
Madagascar	4	Durban	$203	$2,237	0	$0	$9,940
Malawi	43	Durban	$203	$2,237	928	$1,965	$189,626

Mali	23	Casablanca	$203	$338	1232	$2,609	$70,979
Mauritania	40	Casablanca	$203	$338	1040	$2,202	$108,887
Mauritius	63	Durban	$203	$2,237	0	$0	$152,628
Morocco	1991	Casablanca	$203	$338	0	$0	$1,077,521
Mozambique	40	Durban	$203	$2,237	224	$474	$115,353
Namibia	12	Durban	$203	$2,237	848	$1,796	$52,921
Niger	110	Abidjan	$203	$1,190	576	$1,220	$286,948
Nigeria	953	Abidjan	$203	$1,190	352	$745	$2,038,737
Rwanda	23	Durban	$203	$2,237	800	$1,694	$95,489
Saint Lucia	16	Durban	$203	$2,237	800	$1,694	$65,020
Sao Tome & Principe	5	Durban	$203	$2,237	800	$1,694	$20,400
Senegal	47	Abidjan	$203	$1,190	832	$1,762	$149,790
Seychelles	15	Durban	$203	$2,237	1120	$2,372	$70,727
Sierra Leone	47	Durban	$203	$2,237	1120	$2,372	$225,315
Somalia	0	Mombasa	$203	$2,800	448	$949	$0
South Africa	4161	Durban	$203	$2,237	0	$0	$10,152,490
Sudan	630	Mombasa	$203	$2,800	1088	$2,304	$3,343,546
Swaziland	42	Durban	$203	$2,237	0	$0	$103,494
Tanzania	174	Mombasa	$203	$2,800	192	$407	$592,920
Togo	68	Abidjan	$203	$1,190	288	$610	$135,725
Tunisia	67	Casablanca	$203	$338	896	$1,897	$162,845
Uganda	48	Mombasa	$203	$2,800	448	$949	$190,053
Zaire	210	Durban	$203	$2,237	1632	$3,456	$1,238,054
Zambia	252	Durban	$203	$2,237	912	$1,931	$1,101,466
Zimbabwe	1525	Durban	$203	$2,237	640	$1,355	$5,785,762
Subtotal	**13405**						**$34,880,733**

Caribbean America

Supply Plant : Detroit

			Detroit to N.Y.	**N.Y. to San Juan**			
Bahamas	35	San Juan	$1,256	$455	0	$0	$59,454
Barbados	28	San Juan	$1,256	$455	0	$0	$47,081
Bermuda	30	San Juan	$1,256	$455	0	$0	$50,931
Cuba	10	San Juan	$1,256	$455	0	$0	$16,327
Dominican Republic	216	San Juan	$1,256	$455	0	$0	$369,252
Guadeloupe	252	San Juan	$1,256	$455	0	$0	$431,273
Haiti	7	San Juan	$1,256	$455	0	$0	$12,168

Jamaica	114	San Juan	$1,256	$455	0	$0	$195,100
Martinique	0	San Juan	$1,256	$455	0	$0	$0
Netherlands Antilles	194	San Juan	$1,256	$455	0	$0	$331,156
Puerto Rico	1806	San Juan	$1,256	$455	0	$0	$3,090,326
Trinidad & Tobago	108	San Juan	$1,256	$455	0	$0	$184,164
Virgin Islands	15	San Juan	$1,256	$455	0	$0	$26,492
Other	363	San Juan	$1,256	$455	0	$0	$620,417
Subtotal	**3175**						**$5,434,140**

C. & S. America

Supply Plant : Detroit

			Detroit to N.Y.	**N.Y. to Import Ports**			
Argentina	9371	Buenos Aires	$1,256	$1,400	0	$0	$24,890,438
Belize	0	Cristobal	$1,256	$666	672	$1,423	$1,505
Bolivia	90	Callao	$1,256	$1,111	512	$1,084	$310,644
Brazil	35424	Santo's	$1,256	$1,636	0	$0	$102,438,610
Chile	1910	Valparaso	$1,256	$1,542	0	$0	$5,344,674
Colombia	1212	Cristobal	$1,256	$666	352	$745	$3,233,246
Costa Rica	561	Limon-Moin	$1,256	$666	0	$0	$1,078,208
Ecuador	1140	Callao	$1,256	$1,111	560	$1,186	$4,050,691
El Salvador	142	Cristobal	$1,256	$666	960	$2,033	$562,245
French Guiana	70	Cristobal	$1,256	$666	1424	$3,015	$344,818
Guatemala	261	Limon-Moin	$1,256	$666	480	$1,016	$767,700
Guyana	14	Cristobal	$1,256	$666	1120	$2,372	$61,827
Honduras	27	Limon-Moin	$1,256	$666	320	$678	$70,889
Nicaragua	180	Limon-Moin	$1,256	$666	208	$440	$425,937
Panama	577	Cristobal	$1,256	$666	0	$0	$1,109,574
Paraguay	175	Santo's	$1,256	$1,636	624	$1,321	$736,623
Peru	330	Callao	$1,256	$1,111	0	$0	$781,894
Suriname	315	Cristobal	$1,256	$666	1280	$2,710	$1,459,185
Uruguay	627	Santo's	$1,256	$1,636	832	$1,762	$2,916,809
Venezuela	1680	Cristobal	$1,256	$666	640	$1,355	$5,504,903
Subtotal	**54108**						**$156,090,422**

North America

Supply Plant : Detroit and Salt Lake City
by land directly

Canada	38269		$0	$0		$1,804	$69,019,322
Mexico	8661		$0	$0		$6,503	$56,324,434
United States	498405		$0	$0			$684,329,239
Subtotal	**545335**						**$809,672,995**

Far East

Supply Plant : Salt Lake City

			Salt Lake City to L.A.	L.A. to Import Ports			
Afghanistan	1	Singapore	$1,613	$1,636	0	$0	$3,777
Bangladesh	19	Singapore	$1,613	$1,636	0	$0	$62,867
Brunei	52	Singapore	$1,613	$1,636	0	$0	$168,376
Burma	0	Singapore	$1,613	$1,636	0	$0	$712
Cambodia	134	Singapore	$1,613	$1,636	0	$0	$436,930
China	6314	Shanghai	$1,613	$1,208	592	$1,254	$25,727,171
Hong Kong	1099	Hong Kong	$1,613	$1,327	0	$0	$3,230,723
India	4350	Madras	$1,613	$1,966	560	$1,186	$20,723,390
Indonesia	98	Singapore	$1,613	$1,636	0	$0	$319,660
Japan	23404	Yokohama	$1,613	$1,007	0	$0	$61,297,570
Laos	306	Singapore	$1,613	$1,636	0	$0	$993,395
S. Korea	3421	Pusan	$1,613	$1,088	160	$339	$10,397,125
Malaysia	600	Singapore	$1,613	$1,636	0	$0	$1,948,387
Maldives	0	Singapore	$1,613	$1,636	0	$0	$1,521
Mongolia	84	Shanghai	$1,613	$1,208	1344	$2,846	$477,388
Pakistan	1465	Madras	$1,613	$1,966	1280	$2,710	$9,212,540
Philippines	2681	Marila	$1,613	$1,358	0	$0	$7,964,640
Singapore	1565	Singapore	$1,613	$1,636	0	$0	$5,085,130
Sri Lanka	381	Madras	$1,613	$1,966	0	$0	$1,364,690
Taiwan	19986	Kaoshung	$1,613	$1,358	0	$0	$59,376,100
Thailand	2340	Singapore	$1,613	$1,636	80	$169	$7,998,906
Vietnam	19	Singapore	$1,613	$1,636	0	$0	$60,138
Subtotal	**68321**						**$216,851,134**

Mid East

Supply Plant : Paris
Paris to Le Havre

Subtotal	**11555**	Jeddah	$203	$3,603	560	$1,186	**$57,683,543**

East Europe

Supply Plant : Paris **By Land Directly**

Armenia	318		$0	$0	2320	$4,913	$1,563,383
Byelarus	631		$0	$0	1424	$3,015	$1,902,136
Bulgaria	411		$0	$0	1216	$2,575	$1,059,329
Com. of Indep. Sta	176		$0	$0	900	$1,906	$334,920
Croatia	4563		$0	$0	736	$1,558	$7,111,331
Cyprus	188		$0	$0	1920	$4,066	$765,745
Czechoslovakia	741		$0	$0	656	$1,389	$1,029,306
Estonia	948		$0	$0	1520	$3,219	$3,049,727
Georgia	40		$0	$0	2304	$4,879	$195,363
Hungary	1272		$0	$0	880	$1,863	$2,369,681
Latvia	385		$0	$0	1376	$2,914	$1,120,924
Lithuania	883		$0	$0	1328	$2,812	$2,482,028
Macedonia	71		$0	$0	1120	$2,372	$169,261
Poland	1454		$0	$0	1024	$2,168	$3,152,298
Romania	3200		$0	$0	1328	$2,812	$8,999,012
Slovenia	972		$0	$0	832	$1,762	$1,712,427
Yugoslavia	641		$0	$0	1008	$2,134	$1,368,630
Ukraine	206		$0	$0	1488	$3,151	$650,493
Subtotal	**17100**						**$39,035,996**

West Europe

Supply Plant : Paris **By Land Directly**

Austria	7348		$0	$0	752	$1,592	$11,700,403
Belgium	9332		$0	$0	208	$440	$4,110,354
Denmark	3739		$0	$0	768	$1,626	$6,080,320
Finland	1510		$0	$0	1600	$3,388	$5,114,699
France	45432		$0	$0	0	$0	$0
Germany	97952		$0	$0	752	$1,592	$155,974,234

Greece	3374		$0	$0	1376	$2,914	$9,829,827
Iceland	145		$0	$0	1952	$4,133	$598,296
Ireland	3278		$0	$0	624	$1,321	$4,331,847
Italy	46843		$0	$0	752	$1,592	$74,590,619
Luxembourg	691		$0	$0	224	$474	$327,903
Malta	218		$0	$0	1152	$2,439	$530,589
Netherlands	1344		$0	$0	368	$779	$1,047,092
Norway	2452		$0	$0	1120	$2,372	$5,814,633
Portugal	7437		$0	$0	960	$2,033	$15,117,581
Spain	38634		$0	$0	768	$1,626	$62,827,550
Sweden	3686		$0	$0	1280	$2,710	$9,991,198
Switzerland	7139		$0	$0	288	$610	$4,353,762
UK	125597		$0	$0	272	$576	$72,338,769
Subtotal	**406150**						**$444,679,675**

Pacific

Supply Plant : Salt Lake City

			Salt Lake City to L.A.	**L.A. to Import Ports**			
Australia	31716	Sydney Port	$1,613	$1,354	0	$0	$94,097,821
Fiji	39	Sydney Port	$1,613	$1,354	0	$0	$116,412
French Pacific Ocean	68	Sydney Port	$1,613	$1,354	0	$0	$201,689
Guam	195	Sydney Port	$1,613	$1,354	0	$0	$579,220
New Caledonia	124	Sydney Port	$1,613	$1,354	0	$0	$369,013
New Zealand	6341	Auckland	$1,613	$1,177	0	$0	$17,688,019
Papua New Guinea	39	Sydney Port	$1,613	$1,354	0	$0	$116,901
Samoa	6	Auckland	$1,613	$1,177	0	$0	$15,465
Vanuatu	5	Sydney Port	$1,613	$1,354	0	$0	$14,001
W. Samoa	35	Auckland	$1,613	$1,177	0	$0	$98,128
Subtotal	**38569**						**$113,296,668**
Total (for 1 year)	**1157718**						**$1,877,625,306**
Total (for 5 year)	**5788590**						**$9,388,126,528**