Locating Industry Along the Shores of Osaka Bay

By

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(Received January 29, 1962)

1. Introduction

With World War II as a turning point, the relative economic position of the Kinki area has been sinking conspicuosly. Although the economic activity of the nation as a whole exceeds the pre-war level, it is regretted that the Kinki economy fails to show recovery of its position as yet. This phenomenon is notably observed in secondary industries. That the Kinki area has allowed the Kanto and Chubu areas to get a head start in the development of secondary industries may be due to the fact that light industry which mainly produces consumer goods has had a greater weight in those regions.

While Japan's economy in general is switching over from light industry to heavy industry, it is considered that the Kinki economy has failed to adapt itself to the requirements of heavy industry, which demands high efficiency as well as the application of modern technology, because of the basic lack of industrial water supply, a deadlock in land transportation, undue competition to secure industrial water, which in turn makes land an object of speculation, all these resulting from the over concentration of industrial plants.

In order to cope with the economic "ground-subsidence" of the Kinki economy, efforts are to be exerted to secure ample and cheap industrial land and water supply, to replenish and improve transportation facilities, and thus, to consolidate the condition for good location of industries, and to enhance the industrial structure.

In this study we have followed up an inquiry into how to pevent the economic "ground-subsidence" of the Kinki area and, further, in order to enhance its industrial structure, how to achieve adequate locations for what industries, on what scales, by formulating simplified models for the location of industries.

Here, by the "appropriate" location of industries and the "appropriate" scales on which those industrial enterprises should be run are meant the most suitable

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locations and scales, from the view point of a wider industrial region for the purpose of achieving the enhancement of the level of mining and manufacturing production, based on regional economic planning.

2. Selection of Appropriate Industries for Various Industrial Location Conditions

It will be necessary, in the first place, to select appropriate industries in order to blueprint new industrial location along the shores of Osaka Bay.

Standards for this selection are laid down as follows:

(a) Growing industries centering around the heavy chemical industry to promote the industrial structure as well as to prevent the economic "ground-subsidence" of the Kinki area.

(b) For the same purpose as above, those industries which will bring about larger earnings and make additional economic values.

(c) Industries most suitable for promoting the activities of enterprises in the districts along the shores of Osaka Bay, which possess the most suitable conditions for the location of industries with which the coastal districts of Osaka Bay are endowed.

Japan's economy after the termination of World War II, as well as that of West Germany, in the field of secondary industry, especially the manufacturing industry, has made a remarkable development without parallel in the world.

This field of industry in Japan is charged with a great mission and much is expected from it in the hope that it will accomplish the task of maintaining the present high rate of Japan's economic growth into the future, to satisfy the demands of expanding exports as well as mounting domestic consumption, and, further to absorb the increased labor force.

In the past, the production of the manufacturing industries has swung upward rapidly and its internal composition is changing at a good clip toward a higher percentage of the heavy chemical industry.

In addition, the industries as well as enterprises have been transformed in a great measure, because of the modernization of production equipment, the adoption of new production methods, introduction of new products and the sudden rise of new industries.

In order to promote the production and accelerate the development in the field of the manufacturing industry, it will be necessary to advance continuously the reorganization of the industrial composition, centering on the heavy chemical industry, and to expedite the expansion of the structure of industries by their sound development on one hand, and by their diversification on the other.

For this purpose, it is important to establish an efficient structure of export enterprises to comply with structural changes in world trade.

In order to accomplish this purpose, it is indispensable to devise a plan for the rapid and great expansion of the machinery as well as the chemical industries, both of which are high level processing industries, and also to give priority to these industries.

Naturally they will expand the market for consumer goods through the round-about method of production and act as an important factor to sustain economic growth at a high rate.

Further, to promote the continuous development of the manufacturing industries, it will be necessary to advance technology, to develop industries and to create new products. Among other things, the high polymer chemical industry, which is based on the electronic and petro-chemical industry, should be developed.

Also, such key industries as the metal industry, including iron and steel, and the ceramic industry, including cement, should be reinforced, in parallel with the intensification and diversification of the structure of production on one hand and the replenishment of public facilities, on the other.

Such light industries as textiles and foodstuffs are the industries where a characteristic intensification of employment is observed. Their sound development in the future is most desirable from the view point of their role in Japan's export and labor absorption.

However, it will be necessary for them to change their production to more highly processed goods and to more diversified lines of goods of the secondary and tertiary industries.

In accordance with the analysis discussed above, growing industries with great additional values have been selected.

The stage has now been reached where the industries are to be selected that have most suitable conditions for locating within the region along the shores of Osaka Bay.

It goes without saying that the location of a new industry must be decided on after a thorough study of all conditions necessary for the best location, taking the features of that industry into consideration.

In other words, the selection of the site should satisfy those locating conditions and further the requirements of the industry itself for its most advantageous operation of business.

It is usual with an industrial plant that once it has been constructed it continues to operate there semi-permanently.

Therefore, once a plant has been badly located, giving inconvenience to its

business operation, improvements will cost so much that the enterprise is placed at a disadvantage in competing with other enterprises.

For the manufacturing industry, the selection of an appropriate plant site is more important than the way the business is conducted.

In the following, location of industries are considered from the standpoint of economic geography, which is necessary when selecting suitable industries.

(1) Relation between Land and Location of Industries

When constructing a plant, land presents basic condition as to area and value.

Speaking of location, land site will include all conditions pertaining to the location of industries, and it will be included in the major factors for location of industries such as traffic facilities and others.

Here, the scale of the enterprise comes to the fore. It is now past the date when land is available anywhere desired, and the acquisition of land has become extremely difficult on the one hand, and on the other, as a plant comes to be run on a larger scale than ever before, the enterprise now requires a larger site e.g., 3~6 millon square meters. Consequently, at present, for the construction of a plant, a vast area of land is required as well as a great deal of expense.

(2) Relation between Water and Location of Industries

Main industries in Japan are said to be characterized by their great requirement of land and water. This fact explains that water supply is one of the basic conditions for the location of industry.

A great quantity of water is required for the industries in many ways and for various purpose, e.g. as in the pulp or chemical fiber industries where much cleaning water is used in their process, or such an industry as is equipped with large coolers, or conversely, with large boilers, or as in the synthetic chemical industry, where water itself is used as a raw material.

When locating an industrial plant, it will be necessary to make a detailed research on water supply as well as the land locality.

(3) Relation between Transportation Facilities and the Location of Industries

It is natural that transportation facilities like roads, railroads, ports, etc. have a far-reaching influence on the location of industries.

From the fact that a great number of Japan's main industries, in a country poor in resources, are concentrated in coastal districts, it may be gathered that port facilities produce a powerful effect on the location of industries.

Further, the importance of transportation facilities in relation to the location of industries is verified by the development of inland industrial districts in places where a good accomodation of land transportation facilities is available.

In this connection, among basic factors in the facility of transportation for the location of industries may be counted the volume of raw materials and products to be transported, the transportation time, and the transportation cost.

(4) Relation between Coal & Petroleum and Location of Industries

Up to this date, existence of a coal field has been as important a factor in the location of industries as electric power. However, coal has been and is giving ground to petroleum of late.

In this country, coal reserves are confined to those in Kyushu, Hokkaido, Joban and Ube, and the location of industries chiefly dependent on coal is restricted to these districts. That is, all soda chemical industries (Solvey process) are concentrated in the neighborhood of the Yamaguchi and Fukuoka coal fields, and ammonium sulphate plants using the gas process are located in Omuta, Yawata, Onahama, Sunagawa and Ube.

Furthermore, the geographical distribution of steam electric power plants is seen more often than not in the coal field zones.

In this way, coal has formed the foundation of industry and a coal field has more or less attracted industrial plants to its neighborhood.

The recent petroleum industry in Japan is getting rapidly more and more prosperous, because of the advantage it enjoys of refining at the place of consumption. Further, new petro-chemical products which appear one after another on the market, its convenience for transportation and handling and its reasonable price, etc. are now qualifying petroleum to replace coal eventually.

(5) Relation between Electric Power and the Location of Industries

Surveying the present condition of electric power supply, we see that approximately 76% of all hydro-electric plants are concentrated in the Chubu District and northward (northern half of Japan), and nearly 74% of steam electric plants are located in the Kansai District and westward (western half of Japan).

In Western Japan, therefore, steam and water power plants came to stand in a supplementary position in the power supply picture. Consequently, power supply in the Hokuriku, Tohoku, Kanto and Chubu Districts is rather abundant and the price is reasonable.

Almost all calcium carbide plants, calcium cyanamide plants, and electrolytic pig iron plants are located north of the Chubu District.

Ammonium sulphate plants (electrolytic process), aluminum, sodium hydroxide (electrolytic process), and synthetic fiber plants are no exception and they are located where power is abundant and cheap.

In this respect, districts along the shores of Osaka Bay are somewhat at a disadvantage. But the remarkable development of efficient steam power plants

makes their weight greater in power supply, making the price difference with water power less and less.

(6) Relation between Raw Materials and the Location of Industries

when considering the construction and location of a new plant, the most advantageous place is, as a matter of course, one where raw materials for production can be obtained most cheaply, steadily and quickly.

Main domestic and imported raw materials used in Japan are outlined in the following:

(i) Industries where calcium is used as principal material are the cement, calcium carbide, calcium cyanamide, soda chemicals, and vinyl industries, etc. They are located near lime pits.

In practice, however, limestone is distributed throughout the country, and the location of these plants is subjected to the influence of such factors as power supply, transportation facilities, etc. besides the lime supply.

(ii) Pyrite is used in the ammonium sulphate industry. In the location of a plant, the availability of pyrites, that is, its nearness to a pyrites mine is one of important factors, though power supply, coal-producing district, petroleium base, and transportation facilities, etc. are mentioned herewith.

(iii) Sulphur is widely used for the production of sulphuric acid, for the vinyl and pulp industries, for the carbon bisulphide, rayon filament, staple fiber industries and other chemical industries. The location of these industries, however, is influenced by other factors than the availability of sulphur, because it is not as weighty as lime, and it does not carry such an importance in their production as lime in the case of cement manufacturing.

(iv) Among other main basic raw materials which are domestic products, there are copper, lead, zinc, silicate, lumber, agricultural and marine products, etc. Smelteries of copper, lead and zinc ores are usually situated at their mines, or in the coastal districts, convenient for transportation.

Pulp plants are apt to be located in the port district or the mouths of rivers, and near a producing center of pulpwood, where water supply is abundant. The glass industry is located at the consumer locality.

(v) As for imported raw materials, coking coal, iron ores, bauxite, phosphate ores, rock-salt, crude petroleum, wool, cotton, rubber, etc. are to be mentioned.

Since importation is a sine qua non for the industries which make use of these materials, it is natural that they are invariably concentrated in port districts.

From the standpoint of domestic factors, they are attracted to the place

where watersupply, electric power, and land are easily obtainable, and moreover, transportation is convenient. A marked tendency is seen lately for them to converge in a consumer district.

(vi) Among the industries where by-product materials are processed and other manufacturing is carried out, we find the manufacturing of petro-chemicals, rayon, staple fiber, alminum, calcium cyanamide, crude steel and rolled steel, machines and tools, shipbuilding, metal products, etc.

The tendency is that they are located at places convenient for transportation in relation to the carry-in of materials, or at the consumer area; or they are attached to the plants where materials are produced, or near them. Plants involved with steel and iron, and petroleum, tend to grow into a combinate, where integration takes place with the plant producing the materials.

(7) Relation between Market for Products and the Location of Industries

For the industries which depend to a great extent on foreign raw materials, it is becoming important to bring the goods to the consumer market most rapidly at the least expense.

Meanwhile, the consumption of raw materials per production unit has been on the decrease, due to recent technological innovations. Therefore, raw materials as a factor are becoming less important for an enterprise than they have in the past, except for those which are specifically dependent on domestic raw materials in a great measure.

When the plant is located in a district close to the consumer area, it will enjoy the advantage of being able to manufacture goods according to the requirements of the market. Further, the utility value of by-products will still be enhanced by the establishment of a combinate.

Yet, the consumer area is almost always an existing big industrial zone or a large city, and it will be impossible for a new enterprise to locate, because conditions for the location of industries are tight in regard to land purchase, water supply, transportation, etc., however attractive the location may be in respect to the marketability of the products.

In the actual location of a new plant, other supplementary factors than the above mentioned must be taken into consideration, such as meteorological and geographical features of the place, labor market condions, etc.

Table 1 is prepared on the basis of the above analysis. Main terms of location, classified by trade, are numbered 1, 2, 3,··· and incidental factors are numbered a, b, c, etc. in the order of necessity.

Table 1.

Type of Industry	Location Factors
Canning of Marine Products	1. Easy access to raw and other materials 2. Abundant supply of other materials 3. Convenient sea transportation a. Near to the consuming district b. Convenient railways c. Convenient highways
Dairy Farming	1. Near to the dairy farming zone 2. Abundant supply of milk a. Cheap milk b. Near to the consuming district c. Convenient highways
Flour	1. Near to the wheat-producing districts or convenient for importation a. Near to the consuming district
Wool Spinning	1. Abundant supply of water 2. Water of fine quality 3. Related subcontractors are not far off a. Cheap water b. Convenient highways c. Consuming district is not far off d. Cheap land
Cotton Spinning	1. Abundant supply of electricity 2. Cheap water 3. Abundant supply of water a. Water of fine quality b. Favorable temperature of water c. Convenient railways d. Convenient highways e. Abundant supply of land f. Cheap land
Staple Fiber and Rayon	1. Abundant supply of water 2. Water of fine quality a. Cheap water b. Cheap power c. Abundant supply of power d. Convenient sea transportation e. Easy disposal of public nuisances f. Abundant supply of land
Dyeing	1. Water of fine quality 2. Abundant supply of water 3. Cheap water a. Favorable climate not to affect the operation

Hard Fiber Board	1. Abundant supply of raw and other materials 2. District producing raw and other materials is not far 3. Cheap raw and other materials a. Cheap power b. Abundant available land c. Consuming district is near
Furniture	1. Consuming district is not far off a. Wood producing district is not far off b. Dry climate
Saccharification of Wood	1. Near to wood producing district 2. Abundant supply of wood 3. Abundant supply of water 4. Water of fine quality a. Cheap wood materials b. Cheap fuel c. Abundant supply of fuel d. Cheap water
Paper	1. Pulp mill is not far off 2. Cheap raw and other materials 3. Abundant supply of raw and other materials 4. Cheap water 5. Abundant supply of water 6. Water of fine quality 7. Convenient railways a. Cheap power b. Abundant supply of power c. Abundant available land d. Easy disposal of public nuisances
Pulp	1. Wood producing district is not far off 2. Cheap wood 3. Abundant supply of wood 4. Abundant supply of water 5. Cheap water a. Water of fine quality b. Convenient railways c. Abundant available land d. Easy disposal of public nuisances
Electrolytic Soda	1. Cheap power 2. Abundant supply of power a. Easy acquisition of raw materials, e.g. industrial salt, soda ash, etc. b. Cheap raw materials c. Abundant supply of water d. Convenient railways e. Convenient sea transportation f. Consuming district is not far off g. Easy disposal of public nuisances

Ammonia Soda Process	1. Abundant supply of raw materials, i.e. lime stone, industrial salt, etc. 2. Abundant supply of fuel 3. Convenient sea transportation 4. Extensive land a. Proximity to raw materials b. Cheap raw materials c. Cheap fuel d. Cheap power e. Abundant supply of water f. Convenient railway transportation
Ammonium Sulphate	1. Cheap raw materials, such as, sulfide ores, crude oil, etc. 2. Abundant supply of raw materials 3. Cheap power 4. Abundant supply of power 5. Cheap water 6. Abundant supply of water 7. Convenient railway transportation 8. Convenient sea transportation a. Cheap fuel b. Abundant supply of fuel c. Near to the consuming district d. Easy disposal of public nuisances
Calcium Cyanamide	1. Near to raw materials, such as, lime stone, cokes, etc. 2. Cheap raw materials 3. Abundant supply of raw materials 4. Cheap power 5. Abundant supply of power 6. Convenient railway transportation a. Abundant supply of fuel b. Abundant suply of water c. Water of fine quality d. Easily obtainable labor e. Extensive land f. Cheap land
Superphosphate	1. Convenient land transportation 2. Convenient railway transportation a. Cheap raw materials, such as, phosphate ores, sulfide ores, etc. b. Abundant supply of raw materials c. Cheap water d. Abundant supply of water e. Good access to highways f. Near to the consuming district g. Easy disposal of public nuisances h. Extensive land i. Cheap land

Petroleum Refinery	1. Convenient sea transportation 2. Cheap water 3. Abundant supply of water 4. Cheap land a. Convenient railways and highways b. Easy disposal of public nuisances c. Extensive land d. Solid ground
Petro-chemistry and Gas	1. Adjacent to an oil refinery plant or iron works 2. Abundant supply of naphtha, top gas, etc. 3. Abundant supply of water 4. Extensive land a. Cheap raw materials, i.e. naphtha, top gas, etc. b. Convenient railways c. Convenient highways d. Cheap land e. Solid Ground
Cement	1. Cheap raw materials, such as, lime stone, etc. 2. Abundant supply of raw materials, such as, lime stone, etc. 3. Cheap fuel 4. Convenient railways a. Near to the consuming district b. Proximity to raw materials c. Proximity to fuel d. Adundant supply of fuel e. Abundant supply of water f. Convenient sea transportation
Ready Mixed Concrete	1. Near to the consuming district 2. Convenient highways 3. Convenient sea transportation a. Cheap raw materials (cement & others) b. Abundant supply of raw materials (cement & others)
Plate Glass	1. Convenient railways 2. Convenient highways 3. Convenient sea transportation a. Cheap fuel b. Abundant supply of water c. Near to the consuming district
Plate Glass Products	1. Convenient railways 2. Convenient highways 3. Near to the consuming district a. Easy acquisition of raw materials b. Cheap raw materials c. Abundant supply of raw materials d. Cheap fuel e. Extensive land

Fire-brick	1. Raw materials are available in near-by districts 2. Cheap raw materials 3. Abundant supply of raw materials 4. Cheap fuel a. Abundant supply of fuel b. Cheap power c. Convenient railways d. Convenient highways e. Convenient sea transportation f. Near to the consuming district
Pottery	1. Near to a clay-producing district 2. Abundant supply of clay a. Cheap fuel b. Abundant supply of fuel c. Convenient railways d. Convenient highways
Blast Furnace	1. Extensive land 2. Convenient sea transportation 3. Easy access to iron ores, scrap iron, etc. 4. Cheap water 5. Abundant supply of water 6. Convenient railways 7. Convenient highways 8. Cheap land 9. Solid land a. Cheap iron ore, scrap iron, etc. b. Abundant supply of iron ore, scrap iron, etc. c. Easy access to fuel d. Cheap fuel e. Abundant supply of fuel f. Abundant supply of power g. Cheap power h. Near to the consuming district
Open Hearth	1. Cheap power 2. Abundant supply of power 3. Convenient sea transportation a. Cheap raw materials, such as, pig iron, etc. b. Abundant supply of raw materials, such as, pig iron, etc. c. Cheap water d. Abundant supply of water e. Convenient railways f. Convenient highways

Special Steel	1. Cheap power 2. Abundant supply of power 3. Easy access to raw materials, such as, sand iron, molybden ores, etc. a. Cheap raw materials, such as, sand iron, molybden ores, etc. b. Abundant supply of raw materials, such as, sand iron, molybden ores, etc. c. Convenient railways d. Extensive land
Magnesia Clinker	1. Convenient coastal transportation 2. Near to the consuming district a. Cheap raw materials b. Abundant supply of raw materials c. Cheap fuel d. Abundant supply of fuel e. Convenient railways f. Convenient highways
Aluminum	1. Cheap power 2. Abundant supply of power a. Convenient sea transportation b. Convenient railways c. Convenient highways
Industrial Machines	1. Convenient railways 2. Convenient highways a. Easy access to raw materials, such as steel materials, etc. b. Cheap raw materials, such as steel materials, etc. c. Abundant supply of raw materials, such as steel materials, etc. d. Cheap power e. Abundant supply of power f. Convenient sea transportation g. Extensive land h. Cheap land i. Easy access to related subcontractors
Electric Machines and Apparatus	1. Abundant supply of power 2. Convenient railways 3. Convenient highways a. Cheap supply of raw materials b. Abundant supply of raw materials c. Cheap power d. Extensive land e. Cheap land f. Clear air

Communication Machines	1. Easy access to related subcontractors 2. Near to the consuming district 3. Easily obtainable labor 4. Good temper of the workers a. Easy access to raw materials b. Cheap power c. Abundant supply of power d. Convenient railways e. Convenient highways f. Extensive land g. Cheap land
Automobile	1. Easy access to related subcontractors 2. Abundant supply of power 3. Convenient railways 4. Convenient highways a. Cheap raw materials, such as, steel materials, etc. b. Cheap power c. Easily obtainable labor d. Extensive land e. Cheap land
Shipbuilding	1. Convenient sea transportation 2. Extensive land a. Cheap steel materials, etc. b. Abundant supply of steel materials, etc. c. Cheap power d. Abundant supply of power e. Cheap land f. Easily obtainable labor g. Solid land
Rolling Stock	1. Convenient railways a. Convenient highways b. Convenient sea transportation c. Extensive land
Watches and Cameras	1. Easy access to related subcontractors 2. Clear air a. Easily obtainable labor
Steam Power Generating Plants	1. Near to the consuming district 2. Abundant supply of fuel 3. Cheap water 4. Abundant supply of water 5. Superior quality of water 6. Cheap land a. Easy access to fuel b. Cheap fuel c. Convenient sea transportation d. Easy disposal of public nuisance e. Extensive land f. Solid land

Selection has been made as follows of the trades which are considered to be appropriate for the location of industries in the coastal districts along the shores of Osaka Bay:

Flour: dairy products: canning and bottling: beer brewery: petroleum refinery (include chemicals): pig ore process: industrial machinery: electric machinery & equipment: electrical apparatus: electric communication and related equipment: rolling stock: automobiles: pulp: paper: rubber products: rayon and staple fiber: ammonium sulphate: cement: plate glass.

3. Target Figures for Industrial Production in the Coastal Districts of Osaka Bay

In order to lay down the target figures for industrial production in the districts along the shores of Osaka Bay, it is neeessary in the first place to decide on the target year.

As it is usual with the economic planning in Japan to set forth the target year as 1970, as in the case of the "income doubling plan" here the target year is fixed likewise at 1970.

Now the problem we are confronted with is to seek for target figures for industrial production in 1970, in connection with 19 prospective industries, selected for this region, in the previous article. For this purpose, estimation is to be made of the total output in 1970, under the assumption that the demand and the supply are always well balanced.

The Input-Output Analysis is employed for this purpose. Its general expression is as follows:

$$\sum_{j} \alpha^*_{ij'} Z^*_{j'} + Y^*_j = Z^*_j \qquad (1)$$

hence

$\alpha^*_{ij'}$: Input coefficient in the target year

Y^*_j : Final demand subtotal of (j)th industry in the target year

Z^*_j : Total output of (j)th industry in the target year

(1) By determining $\alpha^*_{ij'}$, taking the effect of technological innovation and others into consideration, by formulating an econometric model, and by estimating Y^*_j in the target year, we obtain Z^*_j, the total output in the target year in the equation (1), employing vector and matrix.

(2) The value of Z^*_j can easily be obtained by equation (2), corresponding to the final demand, if the inverse matrix has been first calculated.

$$Z = [I - A]^{-1} Y \qquad (2)$$

hence

I : Identity matrix
Z: Vector of Z_j^*
Y: Vector of Y_j^*
A: Matrix of α_{ij}^*

The target figures for the production of the prospective industries in 1970 should be calculated theoretically in this way. However, for convenience' sake, data of the target output of this region, presented by the Ministry of International Trade & Industry, are utilized here. These data are shown in Table 2.

Table 2. Target (1970) figures for industrial production. (unit : 10^3 tons)

Region / Year / Industry	Regional Production of Osaka Bay Area			National Production		(B)/(D)
	1959 (A)	1970 (B)	P_j (B)-(A)	1959 (C)	1970 (D)	(%)
Flour	389	854	465	3088	5940	14.38
Dairy Product	8	18	10	120	231	7.79
Canning and Bottling	2	4	2	226	435	0.92
Beer Brewery	188	259	71	623	1198	21.62
Petroleum Refinery (include Chemicals)	4249	8555	4306	21935	93621	9.14
Pig Ore Process	6642	15826	9184	22783	39689	39.88
Industrial Machinery	334	1563	1229	1167	5462	28.61
Electric Machinery and Equipment	158	567	409	558	2003	28.31
Electric Apparatus	59	212	153	210	754	28.09
Electric Communication and Related Equipment	29	104	75	104	373	27.87
Rolling Stocks	285	701	416	1380	3395	20.63
Automobiles	1187	2920	1733	5754	14155	20.62
Pulp	318	508	190	3102	8180	6.21
Paper	571	895	324	3670	8912	10.04
Rubber Product	21	72	41	63	251	28.69
Rayon and Staple Fiber	112	132	20	667	1378	9.58
Ammonium Sulphate	187	374	187	2574	2400	14.46
Cement	2472	5020	2548	18540	50000	10.04
Plate Glass	247	465	218	558	1085	42.86

4. Land Suitable for Industry on Osaka Bay and Industrial Water & Electric Power Conditions

As the result of over concentration of industrial plants in the Hanshin Region, land, water and power for industrial use there, are wanting in their absolute quantity. Consequently, land has become an object of speculation, and

an unnatural competition has arisen in securing necessary water and power, which cause a bottleneck in industrial development.

To tide over these difficulties, it will be necessary to draw up a plan for the improvement of the locating condition of industries by abundant supply of cheap land, water and power. The industrial structure should also be fully strengthened.

In the Hanshin Region, big land reclamation works are planned or already under way at Osaka South-Port, Sakai, Kobe, Nishinomiya, etc. from the view point of redevelopment of cities. While, in the surrounding areas of the Hanshin Metropolitan Region, inland industrial zones are being developed.

Further, attention is now drawn to the development of the Harima District and the Wakayama District as substitutes for the Hanshin Region, where industrialization has been supersaturated.

In taking up the problem of the appropriate location of industries along the shore of Osaka Bay, consideration will be given based on 14 divisions of districts, shown in Table 3. In this table are summarized the results of the research on industrial land and water, based on the data presented by the Ministry of International Trade & Industry and the Prefectural Governments concerned.

In Table 3, columns for Osaka South Port District and Sakai District are left blank, because the types of industry, sizes of site, the production levels, etc. of the industries to be located in those reclaimed lands have already been decided on and there is no need to consider new industrial locations. Consequently, the remaining 12 districts are to be considered here.

Table 3. Land suitable for industry in Osaka Bay area and conditions of industrial water supply.

Area		Area of Land Site for Industrial Use (10^3 m^2)	Land Value (¥/m^2)	Annual Water Supply (10^3 tons)	Water Cost (¥/ton)
Akô	Sea Side	8123	1400	43800	4.5
Tatsuno	Inland	1290	610	47450	4.6
Tôban	Sea Side	22995	1100	110000	10.2
Akashi and Kôbe	Sea Side	8307	1500	25915	11.4
Hokusetsu	Sea Side	1960	2000	32850	10.7
Hokusetsu	Inland	1340	1500		
Along Yodo River	Inland	7364	1600	1830	10.5
East Ôsaka	Inland	2707	1800	20805	10.5
Ôsaka South Port	Sea Side				
Sakai	Sea Side				
Sensyû	Inland	2323	910	78110	9.9
Wakayama and Kainan	Sea Side	8757	910	119720	7.0
Shimotsu and Arita	Sea Side	5315	1300	26280	4.7
Gobô	Inland	5328	760	36500	4.7

Table 4 is given as an example to show the industries of which the entry into the Sakai District has been decided on.

As for electric power for industrial use, which accounts for 60% of the entire demand, it is expected to increase at a quick tempo in this region, as shown in

Table 4.

Factory	Site Area 10^3 m^2	Products	Production 10^3 tons/year	Output ¥ million	Stage of Construction
Yawata Steel and Iron	4,017	Pig ore process	3,000	93,600	Under construction
Ôsaka Gas	389	City gas supply, Cokes, Tar	(756,000× 10^3 m^3/year) 1,655	28,100	Site ground under construction
Kubota Iron Works	51	Steel pipes and piles	18	1,080	First stage of the program completed
Yawata Blast Furnace Concrete	17	Ready mixed concrete	(130× 10^3 m^3/year)	650	Completed
Onoda Cement	20	Ready mixed concrete	—	—	Planning
Central Glass	73	Plate glass, transparent & ground: Fancy patterns	80	4,616	First stage of the program completed
Kyowa Ferment	7	Chemical products	—	—	Planning
Nippon Novopan	58	Dry-type hard fiber sheet	12	525	First stage of the program completed
Kôkoku Metal	19	Rolled steel bar	105	4,200	Under construction
Fuji Enamelled Iron Works	24	Anti-acid chemical apparatus	—	—	Planning
Daiwa House Works	57	Prefab. pipe house; Building materials	—	1,200	Under construction
Asahi Steel	31	Various rolled steels	—	—	Planning
Miyachi Salvage	47	Reclaimed steel & iron	38	1,530	Under construction
Okumura-gumi	26	Ready mixed concrete	—	—	Planning
Matsuo Bridge	50	Steel frames, bridges	15	1,410	〃
Matsushita Elec. Works	87	Elec. appliances	—	—	〃
Osaka Shipyard	65	Reclaimed steel & iron	—	—	〃

Table 5. Electric power for industrial use. (unit 10^6 K.W.H.)

1959 (A)	1970 (B)	(E) (B)-(A)
8157	25735	17578

Table 5, from 8.2×10^6 KWH in 1959 to 16.3×10^6 KWH in 1965, and to 25.7×10^6 KWH in 1970.

5. Analysis of Input Coefficients of Prospective Industries

In this study, it is our aim to establish the most reasonable transportation system, based on the results of calculation concerning the appropriate location and the appropriate scale of industry located along the shores of Osaka Bay. Therefore, in the first place, the analysis of input coefficients (in terms of quantity) of prospective industries must be made.

In order to establish the units of land and water, the area of site, the water demand, the production, etc. of a model plant are estimated, based on the research and the data for study conducted by the Scientific & Technical Administration Committee and MITI.

The results are put into the following formulas:

Table 6. Appropriate values of area and water demand of model plants.

Industry	Area of Land Site (10^3 m^2)	Annual Water Consumption (10^3 tons)	Annual Products (10^3 tons)	Land Coefficient a_j	Water Coefficient w_j
Flour	25	50	50	0.5	1
Dairy Product	15	2	2	7.5	1
Canning and Bottling	5	25	5	1.0	5
Beer Brewery	60	2600	130	0.5	20
Petroleum Refinery (include Chemicals)	1000	10000	5000	0.2	2
Pig Ore Process	3300	100000	3000	1.1	30
Industrial Machinery	100	1000	50	2.0	20
Electric Machinery and Equipment	100	350	5	20.0	70
Electrical Apparatus	70	350	5	14.0	70
Electric Communication and Related Equipment	70	350	5	14.0	70
Rolling Stocks	430	1000	50	8.6	20
Automobiles	860	2000	100	8.6	20
Pulp	350	30000	100	3.5	300
Paper	500	14000	50	10.0	280
Rubber Product	30	1500	15	2.0	100
Rayon and Staple Fiber	800	48000	20	40.0	2400
Ammonium Sulphate	550	20000	500	1.1	40
Cement	400	36000	1200	0.3	30
Plate Glass	170	10000	100	1.7	100

Land coefficient:

$$a_j = \frac{\text{Area of model plant site}}{\text{Annual production of model plant}}$$

Water coefficient:

$$w_j = \frac{\text{Annual water consumption}}{\text{Annual production of model plant}}$$

Standards of scale and the coefficient of land and water of the model plants in various industries are shown in Table 6.

$$Z_j^* = \sum_j x_{jj'}^* + Y_j^* = W_j^* + Y_j^* \tag{3}$$

$$X_{j'}^* = \sum_{j'} x_{j'j}^* + V_{j'}^* \tag{4}$$

hence

Z_j^* : Total output of (j)th industry
W_j^*: Intermediary demand subtotal of (j)th industry
Y_j^* : Final demand subtotal of (j)th industry
$X_{j'}^*$: Total input of (j)th industry
$V_{j'}^*$: Value added of (j)th industry

It is considered that values of respective industries to be put in vary as a linear function of the production.

Table 7. Input coefficients of electric power. (in terms of quantity)

Industry	Electric Power Coefficient e_j (10^3K.W.H.)
Flour	0.110
Dairy Product	0.480
Canning and Bottling	0.370
Beer Brewery	0.110
Petroleum Refinery (include Chemicals)	0.030
Pig Ore Process	0.170
Industrial Machinery	0.170
Electric Machinery and Equipment	2.975
Electrical Apparatus	3.030
Electric Communication and Related Equipment	4.190
Rolling Stocks	0.595
Automobiles	0.140
Pulp	0.740
Paper	0.130
Rubber Product	4.560
Rayon and Staple Fiber	0.230
Ammonium Sulphate	0.030
Cement	0.060
Plate Glass	0.030

Let p_j^* and $p_{j'}^*$ represent the amount of production of (j)th industry and (j')th industry per unit (unit ton), then the quantity of (j)th industry to be put in the unit of (j')th industry $\alpha_{jj'}$ will be,

$$\alpha_{jj'} = x_{jj'}/X_{j'} \tag{5}$$

Hence calculations $x_{jj'}=x_{jj'}^*/p_j^*$, $X_{j'}=X_{j'}^*/p_{j'}^*$ in eqn. (5) based on the Input-Output Analysis and the Quantity Table will give us the Quantity Unit of prospective industries. An example is given in Table 7 regarding the input coefficients of electric power in various industries.

6. Industrial Location Model

In preceding article, the types of industry to be located on the shores of Osaka Bay and their goals of production have been determined. There, the target figures for production are represented by P_j $(j=1, 2, 3, \cdots, n)$.

There, $A_i(i=1, 2, 3, \cdots, n)$, availability of land for the construction in suitable districts for industry, W_i $(i=1, 2, \cdots, n)$, availiability of water for industry, and E, availability of power for large industrial users along the shores of Osaka Bay have been determined.

In order to formulate a plan for the allocation model of industries, it will be necessary to analyze the relation among the labor supply, transportation facilities, raw materials, the market for the products and the location of industry.

However, it is not considered that the labor supply situation is so pressing as to exert a bad effect on the development and expansion of industry or on the location of industry. Also no difference of wages is observed throughout the region. Therefore, the labor supply is left out of consideration in this treatise.

Transportation facilities, viz. roads, railroads and ports have a great influence on the location of industries. There could be no time other than this when the problem of poor transportation which is a deadlock to the enhancement of the structure of industrial production would be of more special consideration.

It is most important to improve and replenish existing transportation facilities in the consideration of locating conditions for industry and also for the enhancement of the industrial structure.

However, the convenience of transportation is excluded from the restricting conditions, from the standpoint that transportation facilities shoud be replenished to accomodate the increased volume of traffic that may arise as result of the location model of industry.

Relations among raw materials, markets for products and industrial location are considered, in this model, under the items of freight on raw materials and freight on products, respectively.

Consequently, in this model, it is our aim to blueprint the optimum location of industries to reach the production target P_j making the most use of suitable land, water and power conditions available.

Land, water and power coefficients are represented by a_j, w_j and e_j respectively, which denote land, water and power required per ton of production in various industries.

Further, x_{ij} is given for the production level (unit ton) of (j)th industry at (i)th area.

Then we obtain the following as the restrictive condition:

Land $$\sum_{j=1}^{n} a_j x_{ij} \leq A_i \tag{6}$$

Water $$\sum_{j=1}^{n} w_j x_{ij} \leq W_i \tag{7}$$

Power $$\sum_{i=1}^{m} \sum_{j=1}^{n} e_j x_{ij} \leq E \tag{8}$$

Production $$\sum_{i=1}^{m} x_{ij} = P_j \tag{9}$$

Then, let

$x_{ii'j}$: traffic volume of (j)th industry from (i)th area to (i')th area

Y_{ij} : traffic volume of (j)th industry from (i)th area to satisfy the final demand

F_{ij} : traffic volume of (j)th industry from (i)th area to areas out side

$M_{i'j}$: traffic volume of (j)th industry from outside into (i')th area

$C^{**}_{ii'j}$: transportation cost of (j)th industry from (i)th area to (i')th area

C^{**}_{iYj} : transportation cost of (j)th industry from (i)th area to satisfy the final demand

C^{**}_{iFj} : transportation cost of (j)th industry from (i)th area to areas outside

C^{**}_{iMj} : transportation cost of (j)th industry from out side into (i')th area

then the total supply will be,

$$\sum_{j=1}^{n} x_{ij}$$

and the total demand will be,

$$\sum_{j=1}^{n}\sum_{j'=1}^{n}\alpha_{jj'}x_{ij'}$$

Finally, we obtain the following expression as the restrictive conditions for transportation.

$$\sum_{i=1}^{m}\sum_{j=1}^{n}x_{ii'j}+\sum_{j=1}^{n}Y_{ij}+\sum_{j=1}^{n}F_{ij}-\sum_{j=1}^{n}x_{ij}=0 \tag{10}$$

$$\sum_{i'=1}^{m}\sum_{j=1}^{n}x_{ii'j}+\sum_{j=1}^{n}M_{i'j}-\sum_{j=1}^{n}\sum_{j'=1}^{n}\alpha_{jj'}x_{i'j'}=0 \tag{11}$$

$$\sum_{i=1}^{m}F_{ij}=F_j \tag{12}$$

$$\sum_{i=1}^{m}Y_{ij}=Y_j \tag{13}$$

$$\sum_{i'=1}^{m}M_{i'j}=M_j \tag{14}$$

What kind of industry should be located in what area, on what scale, from the economic standpoint, that the economic "ground subsidence" of the coastal areas on Osaka Bay may be prevented, and further, their economy may be rehabilitated?

Boiled down, the question is to seek for the value of x_{ij} that makes the income brought about by the industrial location the largest, under the restrictive condition (6)~(14). That is, we are to find x_{ij} value that will make the following expression (15) a maximum.

$$f(X)=\sum_{i=1}^{m}\sum_{j=1}^{n}C_{ij}^{*}x_{ij}-\{\sum_{i=1}^{m}\sum_{i'=1}^{m}\sum_{j=1}^{n}C_{ii'j}^{**}x_{ii'j}+\sum_{i=1}^{m}\sum_{j=1}^{n}C_{iFj}^{**}F_{ij}+\sum_{i=1}^{m}\sum_{j=1}^{n}C_{iYj}^{**}Y_{ij}$$
$$+\sum_{i'=1}^{m}\sum_{j=1}^{n}C_{Mi'j}^{**}M_{i'j}\} \tag{15}$$

hence

$$C_{ij}^{*}=p_j^{*}-(\sum_{j'=1}^{n}\alpha_{j'j}p_{j'}^{*}+w_jp_i^{*}+v_{ij}^{*}) \tag{16}$$

p_j^{*} : Production amount of (j)th industry (finished product per ton)

$\alpha_{j'j}p_{j'}^{*}$: Raw material cost of (j)th industry (finished product per ton)

$w_jp_i^{*}$: Water cost of (j)th industry (finished product per ton)

v_{ij}^{*} : Land value of (j)th industry, under the straight depreciation system (finished product per ton)

If we try to formulate the location model of industry in this way, the number of variables will become enormous and the computation is impossible by means of ordinary machines, except for a high class automatic digital computer.

Therefore, the simplification of the model must be made without marring the exactness. In this model, a great number of variables are included in the part labeled restrictive transportation condition.

An approximation is examined as a solution to this part concerning transportation restriction.

As seen from eqns. (10)~(16), the reason that the part for transportation restrictions is very complex and consists of an enormous number of variables is because, in a way, freight is given as a function of x_{ij}. It is possible, therefore, to simplify the matter if freight can be estimated approximately by some methods, independent of x_{ij}.

In this case, the formulas for the ristriction of the model will be,

$$\left.\begin{array}{ll} \text{Land} & \sum_{j=1}^{n} a_j x_{ij} \leq A_i \\ \text{Water} & \sum_{j=1}^{n} w_j x_{ij} \leq W_i \\ \text{Power} & \sum_{i=1}^{m}\sum_{j=1}^{n} e_j x_{ij} \leq E \\ \text{Production} & \sum_{i=1}^{m} x_{ij} = P_j \end{array}\right\} \tag{17}$$

By analyzing the data mentioned above, it is known that there exist the following relations:

We may safely use the following expressions instead of eqn. (17).

$$\left.\begin{array}{l} \sum_{j=1}^{n} a_j P_j \leq \sum_{i=1}^{n} A_i \\ \sum_{j=1}^{n} w_j P_j \leq \sum_{i=1}^{n} W_i \\ \sum_{j=1}^{n} e_j P_j \leq E \end{array}\right\} \tag{18}$$

$$\left.\begin{array}{ll} \text{Land} & \sum_{j=1}^{n} a_j x_{ij} \leq A_i \\ \text{Water} & \sum_{j=1}^{n} w_j x_{ij} \leq W_i \\ \text{Power} & \sum_{i=1}^{m}\sum_{j=1}^{n} e_j x_{ij} \leq E \\ \text{Production} & \sum_{i=1}^{m} x_{ij} \leq P_j \end{array}\right\} \tag{19}$$

Therefore, the job will be to find the maximum for x_{ij} in the objective that follows:

$$f(X) = \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij} x_{ij} \tag{20}$$

hence

$$C_{ij} = p_j^* - \left(\sum_{j'=1}^{n} \alpha_{j'j} p_{j'}^* + w_j p_i^* + v_{ij}^* + C_{ij}^{***} + C_{ij}^{****}\right) \tag{21}$$

C_{ij}^{***} : Transportation cost of raw materials in (j)th industry (finished product per ton)

C_{ij}^{****}: Transportation cost of the finished product per ton in (j)th industry

In contrast with the fact that the principle of "*Threefold Equalization*" prevails in national income for the sake of self-perfection, income by industries, income by distributive shares, and income by expenditures clash with each other when we come to the problem of regional income as in the region on Osaka Bay, because the regional economy does not constitute an independent economic unit.

It will become a critical problem as to what to choose for C_{ij}, the index of the objective.

Upon the examination of the correlation between income by distributive shares and income by industries in the region on Osaka Bay, it has been ascertained that there is an intense linear correlation ($r=0.9$). This means that it will not matter whether the coefficient of income by industries or the coefficient of income by distributive shares is adopted for C_{ij}, the index of the objective.

This is why income by industry has been selected, where data are easier to obtain and which are exact to a great extent.

By formulating the location model for industry in this way, it will become

Table 8. The suffices of x_{ij}. (x_{ij} is given for the production level)

Industry \ Area	Akō	Tatsuno	Tōban	Akashi and Kōbe	Hokusetsu (Sea Side)	Hokusetsu (Inland)	Along Yodo River	East Ōsaka	Sensyū	Wakayama and Kainan	Shimotsu and Arita	Gobō
Flour	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}
Dairy Product	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}	x_{20}	x_{21}	x_{22}	x_{23}	x_{24}
Canning and Bottling	x_{25}	x_{26}	x_{27}	x_{28}	x_{29}	x_{30}	x_{31}	x_{32}	x_{33}	x_{34}	x_{35}	x_{36}
Beer Brewery	x_{37}	x_{38}	x_{39}	x_{40}	x_{41}	x_{42}	—	x_{43}	x_{44}	x_{45}	x_{46}	x_{47}
Petroleum Refinery (include Chemicals)	x_{48}	—	x_{49}	x_{50}	x_{51}	—	—	—	—	x_{52}	x_{53}	—
Industrial Machinery	x_{54}	x_{55}	x_{56}	x_{57}	x_{58}	x_{59}	x_{60}	x_{61}	x_{62}	x_{63}	x_{64}	x_{65}
Electric Machinery and Equipment	x_{66}	x_{67}	x_{68}	x_{69}	x_{70}	x_{71}	x_{72}	x_{73}	x_{74}	x_{75}	x_{76}	x_{77}
Electrical Apparatus	x_{78}	x_{79}	x_{80}	x_{81}	x_{82}	x_{83}	x_{84}	x_{85}	x_{86}	x_{87}	x_{88}	x_{89}
Electric Communication and Related Equipment	x_{90}	x_{91}	x_{92}	x_{93}	x_{94}	x_{95}	x_{96}	x_{97}	x_{98}	x_{99}	x_{100}	x_{101}
Rolling Stocks	x_{102}	x_{103}	x_{104}	x_{105}	x_{106}	x_{107}	x_{108}	x_{109}	x_{110}	x_{111}	x_{112}	x_{113}
Automobiles	x_{114}	x_{115}	x_{116}	x_{117}	x_{118}	x_{119}	—	x_{120}	x_{121}	x_{122}	x_{123}	x_{124}
Pulp	x_{125}	—	x_{126}	—	—	—	—	—	—	x_{127}	—	—
Paper	x_{128}	—	x_{129}	x_{130}	x_{131}	—	—	—	—	x_{132}	x_{133}	—
Rubber Product	x_{134}	x_{135}	x_{136}	x_{137}	x_{138}	x_{139}	x_{140}	x_{141}	x_{142}	x_{143}	x_{144}	x_{145}
Rayon and Staple Fiber	—	—	x_{146}	—	—	—	—	—	x_{147}	x_{148}	—	—
Ammonium Sulphate	x_{149}	—	x_{150}	x_{151}	x_{152}	—	—	—	—	x_{153}	x_{154}	—
Cement	x_{155}	—	x_{156}	—	—	—	—	—	—	x_{157}	—	—
Plate Glass	x_{158}	—	x_{159}	x_{160}	x_{161}	—	—	—	—	x_{162}	x_{163}	—

possible that the solution can be obtained mathematically, as the problem of allocation in the linear programming.

To solve the problem, for the sake of convenience, suffices of x_{ij}, the unit production level of (j)th industry in (i)th area, are added as in Table 8.

In Table 8, a value for x is omitted in the items that fall under any of the following heads:

(1) Inland area where industries of the coastal zone type are not located
(2) Production expansion of an existing industry or the total of the target production of plants, which will be definitely established as the result of the attraction of plants, reaches P_j, the target production
(3) Where land and water are not available to suit the model plant size
(4) Where location is impossible for technical reasons.

7. Calculation of Income Coefficient C_{ij}

In order to find the income coefficient C_{ij}, it is necessary to put in order the data for eqn. (21), then carry out the calculations.

Production amount of the finished products per ton p_j^* is computed from the Input-Output Analysis and the Quantity Table, and likewise, cost of raw materials, which is independent of territorial differences, is to be calculated.

These findings are enumerated in Table 9. Table 10 is obtained by calculating water cost $w_j p_i^*$.

By putting p_i^{**} for the land value by district, under the straight depreciation system, we obtain the land value by district.

$$v_{ij}^* = a_j p_i^{**} i(i+1)^n/(i+1)^n - 1 \tag{22}$$

We take the value of i on the safer side, as $i=10\%$, although it varies according to the circumstance, whether bonds are issued for the reclamation work or loans are made from city banks.

Likewise, n values may vary in different industries, but we take $n=10$ (years) in this calculation. Results are shown in Table 11.

We are now to compute C_{ij}^{**}, the transportation cost of raw materials. The necessary input of (j')th industry is given as $\alpha_{j'j}$ as the result of the Input-Output Analysis. We now take up the transportation cost of raw materials necessary to manufacture one unit of (j)th industry in (i)th district. If we put $C_{Mij'}^{***}$ for the transportation cost on one unit of (j)th industry from (M), the producing district of (j')th industry, to (i)th district, the tarnsportation cost of $\alpha_{j'j}$ of (j)th industry will be given as $C_{Mij'}^{***}\alpha_{j'j}$. Consequently C_{ij}^{**} the transportation cost necessary for the production of one unit of (j)th industry will be,

$$C_{ij}^{***} = \sum_{j'=1}^{n} C_{Mij'}^{***} \alpha_{j'j} \tag{23}$$

Lastly, we must look for C_{ij}^{****}, the transportation cost of the finished products. The sales coefficient of (j)th industry relative to (j')th industry, $\beta_{jj'}^{*}$ can be obtained by dividing $x_{ij'}^{*}$, the supply of (j)th industry to (j')th industry, by Z_j^{*}, the total demand of (j)th industry.

$$\beta_{jj'}^{*} = x_{ij'}^{*}/Z_j^{*} \tag{24}$$

Hence the following relation:

$$\sum_{j'=1}^{n} \beta_{jj'}^{*} + Y_j^{*}/Z_j^{*} = 1 \tag{25}$$

When computing the transportation cost on the finished products, the value of $\beta_{jj'}$, the sales coefficient, will give a key, because it may be considered that a greater value of $\beta_{jj'}$ means a greater amount of sales toward it, and vice versa.

Table 9.

Industry	(A) Production Amount of the Finished Product per ton (10^3 ¥)	(B) Cost of Raw Materials, which is different of territorial differences (10^3 ¥)	(A)-(B) (10^3 ¥)
Flour	41.16	34.20	6.96
Dairy Product	279.49	191.59	87.90
Canning and Bottling	367.42	288.05	79.37
Beer Brewery	90.20	66.88	23.32
Petroleum Refinery (include Chemicals)	18.44	10.94	7.50
Pig Ore Process	31.85	14.27	17.58
Industrial Machinery	99.16	62.73	36.43
Electric Machinery and Equipment	475.22	259.91	215.31
Electrical Apparatus	975.16	525.93	449.23
Electric Communication and Related Equipment	1280.73	623.27	657.46
Rolling Stocks	626.70	352.41	274.31
Automobiles	462.52	239.83	222.69
Pulp	51.64	17.48	34.16
Paper	97.75	58.67	39.08
Rubber Product	1203.85	510.03	693.82
Rayon and Staple Fiber	570.29	255.95	314.34
Ammonium Sulphate	20.52	16.81	3.71
Cement	6.49	2.54	3.95
Plate Glass	53.80	22.92	30.88

Table 10. Cost of industrial water by district. (unit ¥)

Industry \ Area	Akô	Tatsuno	Tôban	Akashi and Kôbe	Hokusetsu (Sea Side)	Hokusetsu (Inland)	Along Yodo River	East Ôsaka	Sensyû	Wakayama and Kainan	Shimotsu and Arita	Gobô
Flour	5	5	10	11	11	11	11	11	10	7	5	5
Dairy Product	5	5	10	11	11	11	11	11	10	7	5	5
Canning and Bottling	23	23	51	57	54	54	53	53	50	35	24	24
Beer Brewery	90	92	204	228	214	214	210	210	198	140	94	94
Petroleum Refinery (include Chemicals)	9	9	20	23	21	21	21	21	20	14	9	9
Pig Ore Process	135	138	306	342	321	321	315	315	297	210	141	141
Industrial Machinery	90	92	204	228	214	214	210	210	198	140	94	94
Electric Machinery and Equipment	315	322	714	798	749	749	735	735	693	490	329	329
Electrical Apparatus	315	322	714	798	749	749	735	735	693	490	329	329
Electric Communication and Related Equipment	315	322	714	798	749	749	735	735	693	490	329	329
Rolling Stocks	90	92	204	228	214	214	210	210	198	140	94	94
Automobiles	90	92	204	228	214	214	210	210	198	140	94	94
Pulp	1350	1380	3060	3420	3210	3210	3150	3150	2970	2100	1410	1410
Paper	1260	1288	2856	3192	2996	2996	2940	2940	2772	1960	1316	1316
Rubber Product	450	460	1020	1140	1070	1070	1050	1050	990	700	470	470
Rayon and Staple Fiber	10800	11040	24480	27360	25680	25680	25200	25200	23760	16800	11280	11280
Ammonium Sulphate	180	184	408	456	428	428	420	420	396	280	188	188
Cement	135	138	306	342	321	321	315	315	297	210	141	141
Plate Glass	450	460	1020	1140	1070	1070	1050	1050	990	700	470	470

Table 11. Cost of industrial land per annum by district. (unit : ¥)

Industry \ Area	Akô	Tatsuno	Tôban	Akashi and Kôbe	Hokusetsu (Sea Side)	Hokusetsu (Inland)	Along Yodo River	East Osaka	Sensyû	Wakayama and Kainan	Shimotsu and Arita	Gobô
Flour	14	50	90	122	163	122	130	146	74	74	106	62
Dairy Product	1709	744	1343	1831	2441	1831	1950	2197	1111	1111	1587	928
Canning and Bottling	228	99	179	244	326	244	260	293	148	148	212	124
Beer Brewery	114	50	90	122	163	122	130	146	74	74	106	62
Petroleum Refinery (include Chemicals)	46	20	36	49	65	49	52	59	30	30	42	25
Pig Ore Process	251	109	197	269	358	269	286	322	163	163	233	136
Industrial Machinery	456	199	358	488	651	488	520	586	296	296	423	247
Electric Machinery and Equipment	4557	1986	3581	4883	6510	4883	5200	5859	2962	2962	4232	2474
Electrical Apparatus	3190	1390	2506	3418	4557	3418	3640	4101	2073	2073	2962	1732
Electric Communication and Related Equipment	3190	1390	2506	3418	4557	3418	3640	4101	2073	2073	2962	1732
Rolling Stocks	1960	854	1540	2099	2799	2099	2236	2519	1274	1274	1820	1064
Automobiles	1960	854	1540	2099	2799	2099	2236	2519	1274	1274	1820	1064
Pulp	797	347	627	854	1139	854	910	1025	518	518	741	433
Paper	2279	993	1790	2441	3255	2441	2600	2930	1481	1481	2116	1237
Rubber Product	456	199	358	488	651	488	520	586	296	296	423	247
Rayon and Staple Fiber	9114	3971	7161	9765	13020	9765	10400	11718	5924	5924	8463	4948
Ammonium Sulphate	251	109	197	269	358	269	286	322	163	163	233	136
Cement	68	30	54	73	98	73	78	88	44	44	63	37
Plate Glass	387	169	304	415	553	415	442	498	252	252	360	210

Next, we will calculate a forecast of the production of (j')th industry in the target year, 1970, that is the purchaser of (j)th industry. Here, we have employed the following *Linear Equation* for the purpose of forecasting.

$$\hat{Z}^*_{j'} = \hat{a} + \hat{b}P^* \tag{26}$$

hence

$\hat{Z}^*_{j'}$=production of (j)th industry in the target year

P^* =gross national product

Arriving at this stage we can technically determine the necessary input of raw materials, required to produce $\hat{Z}^*_j$ against the final demand $(\hat{Y}^*_j)$ for the products of (j)th industry in the target year.

If the input coefficient is represented by $\alpha^*_{jj'}$ the relation will be,

$$\hat{Z}^*_j = \sum_{j'=1}^{n} \alpha^*_{jj'}\hat{Z}^*_{j'} + \hat{Y}^*_j \tag{27}$$

Since $Z^*_{j'}$, the national production of (j)th industry denotes the aggregation of the production of all the districts throughout the nation, we obtain the following equation.

$$Z^*_{j'} = \sum_F Z^*_{Fj'} \tag{28}$$

$Z^*_{Fj'}$: Production of (j)th industry in (F) district

Here, the composition by district is defined as follows:

$$\gamma^*_{Fj'} = Z^*_{Fj'}/Z^*_{j'} \tag{29}$$

If the coefficient $\gamma^*_{Fj'}$ is stable, the production of (j')th industry at (F) district in the target year will be calculated from $Z^*_{j'}$, which has been obtained before.

$$\hat{Z}^*_{Fj'} = \gamma^*_{Fj'}\hat{Z}^*_{j'} \tag{30}$$

There is a tendency for the existing industrial district to decentralize into provinces on the one hand, indications are that in those districts the industry will be more highly advanced by re-development, on the other. Under the assumption that these two factors will offset each other, discussion will be made on the ground that $\gamma^*_{Fj'}$ is stable to a reasonable extent.

Assuming that,

$$p^*_j \cdot P_j/\hat{Z}^*_j = \delta^*_j \tag{31}$$

the sphere of supply of (j)th industry to (j')th industry will be various district on the shores of Osaka Bay, if

$$\sum_{i=1}^{m} \gamma^*_{ij'} \leq \delta^*_j \tag{32}$$

and, inclusive of those districts mentioned above, adjacent districts that satisfy the following equation, adding $\gamma^*_{i'j'}$ successively,

$$\sum_{i=1}^{n}\gamma^*_{i'j'}+\sum_{F}\gamma^*_{Fj'}=\delta^*_{j} \tag{33}$$

if,

$$\sum_{i=1}^{m}\gamma^*_{i'j'}>\delta^*_{j}. \tag{34}$$

When the sphere of supply of (j)th industry to (j')th industry has been obtained, then we are able to calculate $\sum_{F}\hat{Z}^*_{Fj'}$, that is, the production of (j')th industry in the target year, within the sphere of supply of (j)th industry.

In the next, we put

$$\left.\begin{aligned}\hat{Z}^*_{i'j'}/\sum_{i=1}^{m}\hat{Z}^*_{i'j'}&=\eta^*_{i'j'}\\ \hat{Z}^*_{Fj'}/\sum_{F}\hat{Z}^*_{Fj'}&=\eta^*_{Fj'}\end{aligned}\right\} \tag{35}$$

Further, let $C^{****}_{ii'j}$ denote the transportation cost on the one unit of the product of (j)th industry, from the producing district (i) to (i') district, and C^{****}_{iFj} represent the transportation cost when shipping to the districts beyond those on the shores of Osaka Bay, then C^{***}_{ij}, the necessary transportation cost on one unit of the product of (j)th industry will be,

$$C^{***}_{ij}=\sum_{i'=1}^{m}\sum_{j'=1}^{n}C^{****}_{ii'j}\beta^*_{j'i'}\eta^*_{i'j'}+\sum_{F}\sum_{j'=1}^{n}C^{****}_{iFj}\beta^*_{j'i'}\eta^*_{Fj'} \tag{36}$$

By these calculations, p^*_j, $\alpha_{j'j}p^*_{j'}$, $w_jp^*_i$, v^*_{ij}, C^{***}_{ij}, C^{****}_{ij} have been obtained.

Table 14 contains the income coefficient values, that have been obtained by calculating Equation (21), using Table 9~13.

8. Calculations of the Location Model for Industry and Analysis of the Results

Solution of the mammoth linear programming is conducted with a view to find the maximum value of the objective of eqn. (20) based on various values, analyzed beforehand under the restrictive conditions of eqn. (19).

In general, the Simplex Criterion is given as,

$$w_j=z_j-v_j\geq 0 \tag{37}$$

for the problem of linear programming, but in the case of the location model it will be given as,

$$\left.\begin{aligned}z_{ij}-C_{ij}&\geq 0\\ z_{ij}&=a_jC_{Ai}+w_jC_{Wi}+e_jC_{Ei}+C_{Pi}\end{aligned}\right\} \tag{38}$$

Table 12. Transportation cost of raw materials by district. (unit: ¥)

Industry \ Area	Akō	Tatsuno	Tōban	Akashi and Kōbe	Hokusetsu (Sea Side)	Hokusetsu (Inland)	Along Yodo River	East Ōsaka	Sensyū	Wakayama and Kainan	Shimotsu and Arita	Gobō
Flour	548	438	438	438	438	572	231	475	475	475	218	311
Dairy Product	573	874	456	396	425	890	701	674	954	754	772	955
Canning and Bottling	1418	1980	1071	689	880	1721	1393	1191	1853	1074	1254	1861
Beer Brewery	129	296	115	101	95	208	167	163	224	147	152	217
Petroleum Refinery (include Chemicals)	2783	3076	2254	2254	2769	3114	2976	2968	3006	2749	2766	2967
Pig Ore Process	3175	3506	3143	3111	3080	3581	3444	3444	3550	3140	3140	3544
Industrial Machinery	4981	3663	82	54	72	139	1400	104	2635	78	1726	4635
Electric Machinery and Equipment	9753	7640	909	962	1132	1589	3776	1530	6400	1508	4538	10145
Electrical Apparatus	4236	4243	1318	983	1053	2011	2398	1597	3577	1437	2475	4706
Electric Communication and Related Equipment	2145	2252	857	514	682	1229	1289	867	1854	751	1260	2299
Rolling Stocks	317	298	74	58	61	117	160	99	247	86	169	344
Automobiles	183	151	16	20	25	36	76	34	122	31	87	198
Pulp	216	342	232	236	238	394	334	344	417	713	315	399
Paper	946	1325	765	648	470	929	875	862	1125	653	775	1115
Rubber Product	5452	6380	1758	1761	1920	4071	4141	3180	6003	2546	3793	7181
Rayon and Staple Fiber	5763	6919	2831	2612	2439	4952	4806	4078	5798	3351	4446	6588
Ammonium Sulphate	395	305	25	23	26	48	136	39	240	35	160	390
Cement	1156	1650	1153	1153	1153	1806	1541	1541	1789	1346	1346	1676
Plate Glass	75	124	77	76	75	136	114	116	146	106	106	141

Table 13. Transportation cost of products by district. (unit: ¥)

Industry \ Area	Akō	Tatsuno	Tōban	Akashi and Kōbe	Hokusetsu (Sea Side)	Hokusetsu (Inland)	Along Yodo River	East Ōsaka	Sensyū	Wakayama and Kainan	Shimotsu and Arita	Gobō
Flour	135	123	91	41	50	50	72	38	73	90	101	125
Dairy Product	135	123	91	41	50	50	72	38	73	90	101	125
Canning and Bottling	135	123	91	41	50	50	72	38	73	90	101	125
Beer Brewery	135	123	91	41	50	50	72	38	73	90	101	105
Petroleum Refinery (include Chemicals)	326	302	227	119	122	122	135	93	206	187	218	273
Pig Ore Process	439	417	413	220	254	263	248	241	333	374	392	476
Industrial Machinery	142	133	112	85	73	78	104	91	107	119	123	150
Electric Machinery and Equipment	142	133	112	85	73	78	104	91	107	119	123	150
Electrical Apparatus	142	133	112	85	73	78	104	91	107	119	123	150
Electric Communication and Related Equipment	142	133	112	85	73	78	104	91	107	119	123	150
Rolling Stocks	142	133	112	85	73	78	104	91	107	119	123	150
Automobiles	142	133	112	85	73	78	104	91	107	119	123	150
Pulp	230	213	162	84	69	69	87	48	113	138	157	197
Paper	230	213	162	84	69	69	87	48	113	138	157	197
Rubber Product	3	4	6	6	7	7	7	9	10	10	10	11
Rayon and Staple Fiber	250	234	185	113	88	88	86	53	117	141	161	202
Ammonium Sulphate	285	286	265	252	258	279	271	178	193	229	231	272
Cement	184	169	127	60	66	66	75	46	97	117	135	167
Plate Glass	184	169	127	60	66	66	75	46	97	117	135	167

Table 14. Income coefficient C_{ij}. (unit: 10^3¥)

Industry \ Area	Akō	Tatsuno	Toban	Akashi and Kōbe	Hokusetsu (Sea Side)	Hokusetsu (Inland)	Along Yodo River	East Osaka	Sensyū	Wakayama and Kainan	Shimotsu and Arita	Gobō
Flour	6.16	6.34	6.33	6.35	6.30	6.20	6.52	6.29	6.33	6.31	6.53	6.46
Dairy Product	85.48	86.15	86.00	85.62	84.97	85.12	85.17	84.98	85.75	85.94	85.43	85.89
Canning and Bottling	77.57	77.14	77.98	78.34	78.06	77.30	77.59	77.79	77.25	78.02	77.78	77.24
Beer Brewery	22.85	22.76	22.82	22.83	22.80	22.73	22.74	22.76	22.75	22.87	22.87	22.80
Petroleum Refinery (include Chemicals)	4.34	4.09	4.96	5.05	4.52	4.19	4.32	4.36	4.24	4.52	4.46	3.23
Pig Ore Process	13.58	13.41	13.52	13.64	13.58	13.15	13.29	13.26	13.24	16.95	15.21	12.45
Industrial Machinery	30.76	32.34	35.67	35.57	35.42	35.51	34.20	35.44	33.19	35.80	34.06	31.30
Electric Machinery and Equipment	200.68	204.51	209.99	208.64	206.85	208.01	205.49	207.08	205.15	210.23	206.09	202.21
Electrical Apparatus	441.35	443.14	444.58	443.95	442.80	442.97	442.35	442.71	442.78	445.11	443.61	442.31
Electric Communication and Related Equipment	651.67	653.36	653.27	652.64	651.40	651.99	651.69	651.67	652.73	654.03	652.79	652.95
Rolling Stocks	271.80	272.93	272.38	271.84	271.16	271.80	271.60	271.39	272.48	272.69	272.10	272.66
Automobiles	220.31	221.46	220.82	220.26	219.58	220.26	218.21	218.12	218.67	219.22	220.07	220.26
Pulp	31.57	31.88	30.08	29.57	29.50	29.63	29.68	29.59	30.14	30.69	31.54	31.72
Paper	34.36	35.26	33.51	32.71	32.29	32.64	32.58	32.30	33.59	34.85	34.72	35.21
Rubber Product	687.46	686.78	690.68	690.42	690.17	688.18	688.10	688.99	686.52	690.27	689.12	685.91
Rayon and Staple Fiber	288.41	292.18	279.68	274.49	273.11	273.85	273.85	273.29	278.74	288.12	289.99	291.32
Ammonium Sulphate	2.60	2.83	2.92	2.71	2.64	2.69	2.60	2.75	2.22	3.00	2.90	2.72
Cement	2.41	1.95	2.31	2.32	2.31	1.68	1.94	1.96	1.72	2.23	2.26	1.93
Plate Glass	29.78	29.96	29.35	29.19	29.12	29.19	29.20	29.17	29.39	29.70	29.81	29.89

hence

C_{Ai}, C_{Wi}, C_{Ei} and C_{Pi} are shadow prices.

As the Simplex Tableau shown in Table 15 furnishes a feasible basic solution, an optimal solution can be worked out, using this table as a basis.

Calculations have been executed on an automatic digital computer FACOM 128-B.

The resulting optimal solution is shown in Table 15. So far as the result is concerned, according to the location model, planned for the purpose of preventing the "economic ground subsidence" and restore the former economic strength of the coastal region on Osaka Bay, it can be said that various industries have the tendency to concentrate in the East Harima District and the Wakayama District.

By and large, it is desirable to locate those industries that do not require a great quantity of water in the East Harima District. On the contrary, those industries that require an abundant and cheap supply of water are to be located in the Wakayama District.

In the Hanshin District, it is noted that there is a tendency that there do not appear other industries than the petroleum refinery and the petroleum chemicals, which are typical of the industry to be located in consuming areas, and in fringe inland areas, there are located those consumer goods industries, such as, cannery, bottling, beer brewery, rayon and staple fiber, rubber, and light electric industries.

In other words, fringe inland areas of the Hanshin District are occupied mostly by light industries and those heavy chemical industries are finding their sites at East Harima, Wakayama, etc., instead of the Hanshin District.

In order to make further analysis on this matter, in Table 16~18 are shown the feasible basic solution classified by district and industry of the 10th step, 20th step and 30th step of the Simplex Tableau in the process of calculation, made by a digital computer.

As it is clear from these tables, the solution is worked out in the order of the industries that have a greater value of C_{ij}. Generally speaking, consumer goods industries have greater values of C_{ij}, and, conversely, capital goods industries and medium producer's goods industries have lesser values.

It is natural that the location of the industry with a greater value of C_{ij} is first determined, because the Simplex method begins to eliminate the most negative values for C_{ij}.

However, if a capital goods industry or a medium producer's goods industry, which has a great value $(C_{ij} \cdot x_j)$, enters into the same district in a later process

Table 15. Most suitable industrial locations and their scales along the shores of Osaka Bay (unit: 10^3 tons)

Industry \ Area	Akō	Tatsuno	Tōban	Akashi and Kōbe	Hokusetsu (Sea Side)	Hokusetsu (Inland)	Along Yodo River	East Ōsaka	Sensyū	Wakayama and Kainan	Shimotsu and Arita	Gobō
Flour											465	
Dairy Product			10									
Canning and Bottling								2				
Beer Brewery					71							
Petroleum Refinery (include Chemicals)				4306								
Industrical Machinery										1229		
Electric Machinery and Equipment			376.32							32.68		
Electrical Apparatus					45.86	107.14						
Electric Communication and Related Equipment												75
Rolling Stocks		150								266		
Automobiles			1733									
Pulp	54.75									135.25		
Paper				61.76						247.9	14.34	
Rubber Product								41				
Rayon and Staple Fiber									20			
Ammonium Sulphate											187	
Cement	913		1635									
Plate Glass					74.8						143.2	

Table 16. Simplex tableau; 10 th step (feasible basic solution). (unit: 10^3 tons)

Industry \ Area	Akō	Tatsuno	Tōban	Akashi and Kōbe	Hokusetsu (Sea Side)	Hokusetsu (Inland)	Along Yodo River	East Ōsaka	Sensyū	Wakayama and Kainan	Shimotsu and Arita	Gobō
Flour												
Dairy Product												
Canning and Bottling												
Beer Brewery												
Petroleum Refinery (include Chemicals)												
Industrial Machinery												
Electric Machinery and Equipment										163.87		
Electrical Apparatus										153		
Electric Communication and Related Equipment										75		
Rolling Stocks		150								266		
Automobiles			1733									
Pulp												
Paper												
Rubber Product			41									
Rayon and Staple Fiber										20		
Ammonium Sulphate												
Cement												
Plate Glass												

Table 17. Simplex tableau; 20 th step (feasible basic solution). (unit: 10^3 tons)

Industry \ Area	Akô	Tatsuno	Tôban	Akashi and Kôbe	Hokusetsu (Sea Side)	Hokusetsu (Inland)	Along Yodo River	East Ôsaka	Sensyû	Wakayama and Kainan	Shimotsu and Arita	Gobô
Flour												
Dairy Product			10									
Canning and Bottling								2				
Beer Brewery												
Petroleum Refinery (include Chemicals)												
Industrial Machinery										1229		
Electric Machinery and Equipment			358.25	50.75								
Electrical Apparatus										153		
Electric Communication and Related Equipment										75		
Rolling Stocks		150								266		
Automobiles			1733									
Pulp	7.68											
Paper	148.2									81.94	93.86	
Rubber Product			41									
Rayon and Staple Fiber									0.77	19.23		
Ammonium Sulphate												
Cement												
Plate Glass												

Table 18. Simplex tableau ; 30 th step (feasible basic solution). (unit : 10^3 tons)

Industry \ Area	Akō	Tatsuno	Tōban	Akashi and Kōbe	Hokusetsu (Sea Side)	Hokusetsu (Inland)	Along Yodo River	East Ōsaka	Sensyū	Wakayama and Kainan	Shimotsu and Arita	Gobō
Flour											465	
Dairy Product			10									
Canning and Bottling								2				
Beer Brewery				71								
Petroleum Refinery (include Chemicals)				4306								
Industrial Machinery										1229		
Electric Machinery and Equipment			355.65	53.35								
Electrical Apparatus				83.13						69.87		
Electric Communication and Related Equipment												
Rolling Stocks		150								266		75
Automobiles			1733									
Pulp	146		44									
Paper			6.34							303.32	14.34	
Rubber Product			41									
Rayon and Staple Fiber									10.05	9.95		
Ammonium Sulphate			187									
Cement												
Plate Glass											218	

of calculation, it is driven out into other district due to restrictions of land, water supply, power supply, etc. The final result of the industrial location is shown in Table 15.

The process of the forcing out just referred to can be traced by overlapping the intermediate steps, one on another.

It may be concluded that the problem remains to be studied and clarified as to the industrial location of the region which is under the economic influence of the Hanshin area, including the District of the Inland Sea, the Shikoku District, etc.

It has been repeatedly stated that the purpose of this model industrial location is not to look for the maximum profit of an individual enterprise.

From the standpoint of enterprise, in comparison with the C_{ij} value of the prospective districts for plant location and the C_{ij} value of the districts given in Table 15, if the difference is far smaller than the target amount of the rationalization within the enterprise itself, the location of that enterprise may be considered to be under the influence of other factors than have been taken up in this model industrial location. Then, the location of the industrial enterprise should be studied in the proper light.