

Study on Problems of Terminal Site Location

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Abstract

This paper, like previous ones, intends to facilitate the over-all evaluation, expanding the cost-benefit theory by incorporating the problems of surrounding areas.

From the viewpoint of land use, we are able to apply linear programming to mixed land use, while 0-1 mixed integer programming is applicable to the case where mixed land use is not possible. Next, we shall be able to establish a standard of decentralized achievement by the application of duality problems to the model.

Although this paper is unable to provide a direct and complete solution for actual problems, the proposed method in this paper may become a valuable source of information for policy-making.

1. Introduction

In locating large-scale airports, ports and harbors, and truck terminals, a single choice is made after considering several alternative sites. This choice is made after comparing sacrifices required for relief of congestion, changes which will be demanded in the future, improvement of services for the user, improvement of traffic industry management, etc..

In such decisions, terminal location planning has recently tended to recognize systematically that part of traffic network planning which connects the origin and destination of freight.

In many cases, natural, economic and social conditions are listed in the evaluation of sites, and cost-benefit or cost-effectiveness analysis is used as the basis for final judgement.

In some cases, these analyses are criticized, however, because there exists a reality gap in the measuring of benefits and costs, the determination of the social discount rate, and the weighting of importance among multi-objectives.

In particular, these analyses are not satisfactory enough to deal adequately with the external, or the environmental effects on the external surrounding areas.

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This study intends to extend the cost-benefit theory to the problem, and to interiorize the surrounding area problems into the terminal location problem in order to evaluate comprehensively.

2. Interiorizing of Surrounding Area Problem

The evaluation for a traffic network project containing any terminal site k is represented by the following:

$$\begin{aligned} PNB(k) &= PB(k) - PC(k) \\ \text{or} \quad R(k) &= PB(k) / PC(k) \end{aligned} \quad \dots\dots\dots (1)$$

where PB and PC are "benefits" and "costs" by the present value, respectively. PNB and R are the net present value and the cost-benefit ratio, respectively, which are expected to have a positive value or a value greater than 1, respectively. The alternative yielding the largest value is the most desirable.

The following equation classifies an offerer of a terminal by S , a terminal by k , the user by D , the inhabitants affected by positive benefits in the region by E_1 and the inhabitants affected by negative repercussions by E_2 . Then, $PB(k)$ and $PC(k)$ in (1) are rewritten as follows:

$$\begin{aligned} PB(k) &= \sum_j PB_j(k) = PB_S(k) + PB_D(k) + PB_{E_1}(k) + PB_{E_2}(k) \\ \text{or} \quad PC(k) &= \sum_j PC_j(k) = PC_S(k) + PC_D(k) + PC_{E_1}(k) + PC_{E_2}(k) \end{aligned} \quad \dots\dots\dots (2)$$

where $j = S, D, E_1, E_2$.

The offerer of the terminal has to have a profitability and the user has to have an increment in consumer surplus (direct benefits). For the affected parties in the surrounding areas, the indirect benefits accruing from the terminal must outweigh the negative effects such as traffic nuisance etc, created by the increase in traffic. Accordingly, the equation for evaluation needs the following constraint:

$$PB_j(k) \geq PC_j(k) \quad \dots\dots\dots (3)$$

Generally, it is limited to consider only those factors other than $PC_{E_2}(k)$, noise, exhaust gas, vibration, water pollution and changes in the landscape, all of which are separately evaluated as other aspects of the planning. In other words, these many factors are separately evaluated as an environmental effect assessment for a given project.

In this case, the constraint establishes an environmental quality standard for each environmental item; and if the quality of a given item does not satisfy its environmental quality standard:

- 1) The alternative is modified or rejected, or

2) The sources of pollution are controlled.

However, when the project or the given items do not respond to these methods, or when the costs involved in applying them are prohibitively high, a third method is used:

3) The environmentally affected parties take some action.

In this case, it is necessary and sufficient to consider three courses of action: a) behavioral, b) developmental, and c) locational¹⁾.

Behavioral action involves, for example, changes of living style caused by noise pollution, or the installation of noise-proof facilities in buildings. However, the quality of life is not changed. Developmental action involves changes in the quality of life corresponding to changes in land use. Locational action involves not only changes in land use, but the removal of life's activities to land elsewhere.

To explain this in more detail, the objective region is divided appropriately into N meshes square. The following notations are defined in terms of a given one of these meshes, which will be called mesh i . In this case, the environment of one mesh is evaluated by H environmental evaluation items. The weighting or ordering of an environmental evaluation may differ according to the land use in a region.

${}_hL_i$: the present level of environmental evaluation item h in mesh i .

${}_hB_k$: the standard of environmental evaluation item h for land use k (e. g., environmental quality standard).

${}_hY_i$: the degree of planning for environmental evaluation item h in mesh i .
($i=1, 2, \dots, N$, $h=1, 2, \dots, H$, $k=1, 2, \dots, K$)

Hence, if ${}_hL_i \geq {}_hB_k$, it is not necessary to make behavioral, developmental or locational space changes.

$$({}_hY_i =) \quad {}_hL_i \geq {}_hB_k \quad \dots\dots\dots (4)$$

If ${}_hL_i < {}_hB_k$, it is necessary to make behavioral, developmental or locational space changes.

$$({}_hY_i \geq) \quad {}_hB_k > {}_hL_i \quad \dots\dots\dots (5)$$

The environment in a region is evaluated according to the areas of human flow, living conditions and conditions of work corresponding to land use. The environmental evaluation items consist of land features such as geography and geology, and those factors which are affected by other regions. For example, noise pollution, air pollution, water pollution, traffic accidents, the time or cost of commuting to school, work or shopping, all of which fall under the categories of health, safety, convenience and economy and are caused and influenced by factors in regions outside the one under consideration.

This is called the interaction effect between the district i under consideration and the affecting district j . One method of representing this is the following:

$${}_m\phi_i = \sum_{j \in I} \frac{{}_m\psi_{j \rightarrow i}}{R_{ij}^l} \quad \dots\dots\dots (6)$$

where

- ${}_m\phi_i$: the interaction effect on environmental evaluation item m of district i .
- R_{ij}^l : the distance resistance between districts i and j . (e.g., R is the distance, l is the constant.)
- ${}_m\psi_{j \rightarrow i}$: the potential to influence the interaction effect in district i of the environmental evaluation item arising in district j (e.g., noise, exhaust gas, etc.).

${}_m\phi_i$ has the same character as ${}_hL_i$, but they differ in that the former involves mutual influences among distances and the latter is peculiar to a given district.

If, at this point, the conditions are expressible in equation (4), there are no environmental problems, but if the situation falls under equation (5), then some kind of action must be undertaken. When behavioral space-change by people to their environment becomes impossible, or when a project is designed without regard for the district under consideration, then equation (5) is suggested. However, there is an infinite number of solutions which satisfy the conditions for equation (5). The following is one possibility.

Without considering the location at this point, if $C_{i.1}$ is the behavioral cost in district i , and $C_{i.2}$ is the developmental cost, the cost functions are as follows:

$$C_{i.1} = \sum_{k=1}^K \sum_{h=1}^H C_{ih}({}_hL_i, {}_hB_h, {}_hY_i) \quad \dots\dots\dots (7)$$

$$C_{i.2} = \sum_{k=1}^K C_{ik}({}_hX_i, {}_hS_i) \quad \dots\dots\dots (8)$$

where

- ${}_hX_i$: the 0-1 variable representing the planned land use,
 $=1$ if land use k is applied in district i ,
 $=0$ otherwise.
- ${}_hS_i$: the 0-1 variable representing the present land use,
 $=1$ if land use k is applied in district i ,
 $=0$ otherwise.

In addition, there are the following constraints:

$$0 \leq \sum_{k=1}^K {}_hX_i \leq 1, \quad 0 \leq \sum_{k=1}^K {}_hS_i \leq 1 \quad (i=1, 2, \dots, N) \quad \dots\dots\dots (9)$$

In case where mixed land use is forbidden, equation (9) is constrained to allow

only a single land use.

If we rewrite equation (5) using the 0-1 variable, it becomes as follows:

$${}_h Y_i \geq {}_h B_k \cdot {}_k X_i \quad \dots\dots\dots (5)'$$

Further, the factors constraining demand and resources yield the following equations:

$$\sum_{i=1}^N {}_k D_i \cdot {}_k X_i \geq D_k \quad (k=1, 2, \dots, K) \quad \dots\dots\dots (10)$$

$${}_k D_i \cdot {}_k X_i \leq {}_k A_i \quad \dots\dots\dots (11)$$

where

${}_k D_i$: the degree of planning in district i for land use k .

D_k : the total demand for land use k in the region.

${}_k A_i$: the possible capacity for land use k in district i .

Now, if, for purposes of simplification, we do not consider the interaction among districts, the economical action which satisfies the constraints mentioned above is expressed in terms of equations (4) and (5), as follows:

$$\begin{aligned} I_1 &= \sum_{i=1}^N C_{i.1} + \sum_{i=1}^N C_{i.2} \\ &= \sum_{i=1}^N \sum_{k=1}^K \sum_{h=1}^H C_{ikh} ({}_h Y_i, {}_h B_k, {}_h L_i) + \sum_{i=1}^N \sum_{k=1}^K C_{ik} ({}_k X_i, {}_k S_i) \quad \dots\dots\dots (12) \end{aligned}$$

where

I_1 : the arrangement cost.

Also we minimize the value for the objective function (12).

3. Model Formulation

To restate the assumptions behind our model formulation²⁾:

- 1) The total land use demand in the region is constant.
- 2) The locational pattern of municipal facilities such as roads, railways, airports, stations, gas and electrical services, water supply etc. in the region is given. (Note that municipal institutions such as schools and hospitals are classified as residential facilities.)
- 3) The capacity ratio is given as a figure relating only to land use.
- 4) The environmental items can be classified independently of one another, and their levels can be ordered.
- 5) The environmental quality standards are given.
- 6) The environmental quality standard of the objective area is satisfied by a combination of improvemental, developmental and locational space changes.

- 7) The effect on surrounding districts accompanying changes in land use is negligible.
- 8) The costs accompanying developmental or locational changes are not related to distance.
- 9) Cost is proportional to the occupied land area.

[1] Case of Single Land Use.

The notations may be explained as follows:

${}_kZ_i$: the present mix ratio of land use k in mesh i ($0 \leq {}_kZ_i \leq 1$).

A^k : the total floor space with land use k in all of the locational sites.

A : the total area of the alternative site.

${}_kA_i$: the total floor space with land use k in all of mesh i .

A_i : the total usable space in mesh i .

${}_kC_{i,1}$: improvement cost for land use k in mesh i .

${}_kC_{i,2}$: the developmental cost for land use k in mesh i .

(Note: ${}_kC$: developmental cost for land use k , ${}_kC_{i,2} = {}_kC \cdot A_i$)

${}_kC_3$: the locational cost for land use k in all of the alternative locational sites.

${}_kX_i$: the 0-1 variable,

= 1 if land use k is effected in mesh i ,

= 0 otherwise.

W^k : the continuous variable; the mix ratio of land use k in all of the alternative land use sites.

I : the total cost. (Note: This includes only arrangement cost.)

Further, the developmental cost is proportional to the area. This is represented in the conceptional scheme shown in Fig. 1.

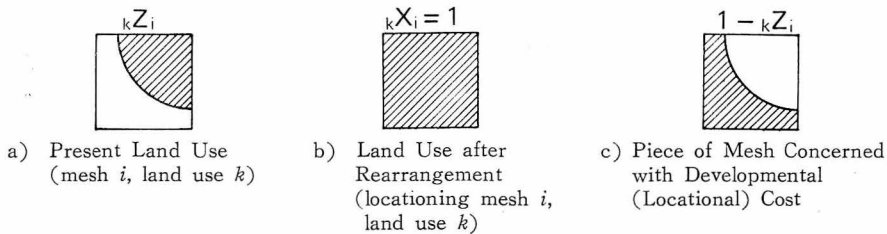


Fig. 1. Conceptional Scheme for Calculating Developmental (Locational) Cost for Single Land Use.

Case of single land use is formulated as follows:

We now have the following 0-1 mixed integer programming ^{3), 4), 5)}.

Minimize I

$$= \sum_{i=1}^N \sum_{k=1}^K {}_kC_{i,1} \cdot {}_kX_i + \sum_{i=1}^N \sum_{k=1}^K {}_kC_{i,2} (1 - {}_kZ_i) {}_kX_i + \sum_{k=1}^K {}_kC_3 \cdot W^k$$

$$= \sum_{i=1}^N \sum_{k=1}^K \{ {}_k C_{i,1} + {}_k C_{i,2} (1 - {}_k Z_i) \} {}_k X_i + \sum_{k=1}^K {}_k C_3 \cdot W^k \quad \dots\dots\dots (13)$$

Subject to :

$$\sum_{i=1}^N {}_k A_i \cdot {}_k X_i + A^k \cdot W^k \geq D^k \quad (k=1, 2, \dots, K) \quad \dots\dots\dots (14)$$

$$0 \leq \sum_{k=1}^K {}_k X_i \leq 1 \quad (i=1, 2, \dots, N) \quad \dots\dots\dots (15)$$

$$0 \leq \sum_{k=1}^K W^k \leq 1 \quad (k=1, 2, \dots, K) \quad \dots\dots\dots (16)$$

[2] Case of Mixed Land Use

The notations are the same as [1]. In this case, however, variable ${}_k X_i$ is a continuous one representing the mix ratio of land use k in mesh i ($0 \leq {}_k X_i \leq 1$). Fig. 2 shows the linear relationship between developmental cost and mix ratio expressed as a conceptual scheme.

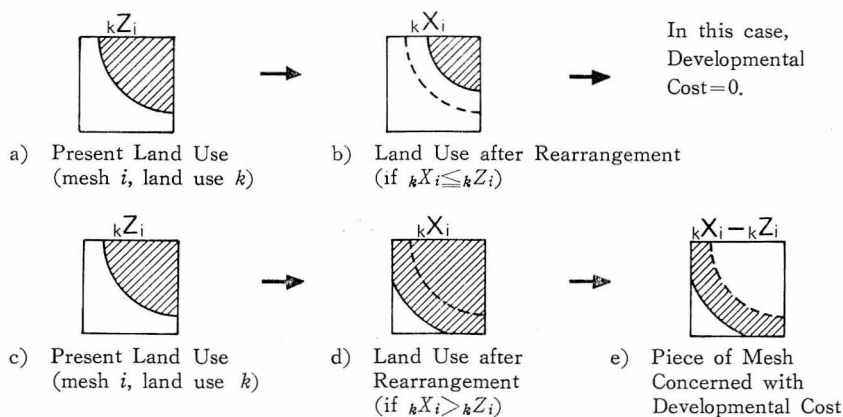


Fig. 2. Conceptual Scheme for Calculating Developmental Cost for Mixed Land Use.

Before formulation, we define the variable ${}_k X_i$ as the variables ${}_k X_{i(1)}$ and ${}_k X_{i(2)}$ separately, and apply separable linear programming.

$${}_k X_i = {}_k X_{i(1)} + {}_k X_{i(2)} \quad \dots\dots\dots (17)$$

$$0 \leq {}_k X_{i(1)} \leq {}_k Z_i, \quad 0 \leq {}_k X_{i(2)} \leq 1 - {}_k Z_i \quad \dots\dots\dots (18)$$

where, if ${}_k X_{i(1)} < {}_k Z_i$, ${}_k X_{i(2)} = 0$.

Accordingly, the formulation is as follows :

We now have the following linear programming^{6), 7)}.

Minimize I

$$\begin{aligned} &= \sum_{i=1}^N \sum_{k=1}^K {}_k C_{i,1} ({}_k X_{i(1)} + {}_k X_{i(2)}) + \sum_{i=1}^N \sum_{k=1}^K {}_k C_{i,2} \cdot {}_k X_{i(2)} + \sum_{k=1}^K {}_k C_3 \cdot W^k \\ &= \sum_{i=1}^N \sum_{k=1}^K {}_k C_{i,1} \cdot {}_k X_{i(1)} + \sum_{i=1}^N \sum_{k=1}^K ({}_k C_{i,1} + {}_k C_{i,2}) {}_k X_{i(2)} + \sum_{k=1}^K {}_k C_3 \cdot W^k \dots\dots\dots (19) \end{aligned}$$

Subject to :

$$\sum_{i=1}^N h A_i (h X_{i(1)} + h X_{i(2)}) + A^h \cdot W^h \geq D_h \quad (h=1, 2, \dots, K) \quad \dots\dots\dots (20)$$

$$0 \leq \sum_{h=1}^K (h X_{i(1)} + h X_{i(2)}) \leq 1 \quad (i=1, 2, \dots, N) \quad \dots\dots\dots (21)$$

$$0 \leq \sum_{h=1}^K W^h \leq 1 \quad \dots\dots\dots (22)$$

$$0 \leq h X_{i(1)} \leq h Z_i \quad \dots\dots\dots (23)$$

$$0 \leq h X_{i(2)} \leq 1 - h Z_i \quad \dots\dots\dots (24)$$

4. Applied Case and Consideration

The objective area of this study is the district east of Osaka International Airport. This district is located beneath the paths of landing aircraft and is affected by various problems such as air pollution, aircraft noise and noise arising from factories and expressways. On the other hand, its location offers convenient mass transportation to the central business district. For this reason, the district has developed as a typical urban sprawl since World War II, and is characterized by densely crowded low-cost apartment houses. In general, therefore, it is a very poor living environment.

We applied the zoning measure of 200 m×200 m square to the objective region mentioned above in this study, and in our calculations, used the data for 400 m×400 m square derived from the data for 200 m×200 m square^{8),9)}. Next, as independent environmental evaluation items, we introduced not only aircraft noise but also natural geographic conditions, the convenience of railways and roads, traffic noise and air pollution conditions.

These have been ranked in Table 1 so that they may be handled systematically. In addition, the environmental quality standard for each land use of the objective region in this study is shown in Table 2.

In setting these standards, we referred to the reports, laws and regulations published or issued by the central and rural governments^{10),11)}.

Further, the values with respect to costs and the total capacity ratio for each land use, shown in Table 3 and 4, were derived from various reference materials^{12),13)}.

Based on the data mentioned above, the optimal solutions and costs for six cases are shown in Table 5.

In addition, the present state of land use in the objective region, the land use by the rearrangement method of case 2, and the land use by the rearrangement method of case 5 are shown in Figs. 3-5, as examples. Further, the computation time for each case is shown in Table 6.

The points made evident by the results obtained above may be summarized as

Table 1. Environmental Evaluation Items.

Rank	Natural Conditions		Traffic Conditions		Public Nuisance Conditions		
	Geography	Ground	Railway	Road	Aircraft Noise	Traffic Noise	Air Pollution
1	Mountainous district	Deep bearing stratum Upper soft	Over 1200 m	Only minor street	Over W-95	Bad for residence	Over 0.05 ppm
2	Hill. Plateau	Shallower bearing stratum Upper soft	700 ~ 1200 m	Compartment street	W-90~95	Good for residence	Under 0.05 ppm
3	Basin. Valley	Deep bearing stratum Upper bearing capacity	300 ~ 700 m	Along main street (both 100 m)	W-85~90		
4	Flat base	Shallower bearing stratum Upper bearing capacity	Within 300 m	Along arterial road (both 260 m)	W-80~85		
5	Marshy land	Deep bearing capacity Firm base		Near interchange (within 1 km)	Under W-80		

Remarks: "Deep" is defined by a depth of over 15 m and upper bearing stratum with about 50 N-value.

Railway: Distance from the nearest station.

W: *Weighted Equivalent Continuous Perceived Noise Level* (WECPNL).

Traffic Noise: The zone within 100 m from arterial road has over 60 dB(A).

Table 2. Environmental Quality Standards.

Environmental Evaluation Items	Residence	Commerce	Industry	Green Space
Geography	2	2	4	1
Ground	3	3	2	1
Railway	2	3	1	1
Road	1	4	5	1
Aircraft Noise	4	3	2	2
Traffic Noise	2	1	1	1
Air Pollution	2	2	1	1

Note: The environmental index values indicate the minimum level which each land use must satisfy.

Table 3. Gross Floor Space Ratio (Present Situation)

Land Use	Residence	Commerce	Industry	Green Space (Sports, Recreation, etc.)
T-City	41%	95.1%	26.1%	100%

Table 4. Unit Costs for Improving, Developmental and Locational Changes.

Developmental Cost

Costs	Removal and Rearrangement of Land	Transfer	Building	Land Purchase	Developmental Cost/Mesh
Land Use	10 ⁴ Yen/m ²				10 ³ Yen
Residence	0.8	0.8	8.0	0.0	153.6
Commerce	0.8	1.0	10.0	0.0	188.8
Industry	0.8	0.7	7.0	0.0	136.0
Green Space	0.15	0.0	0.3	0.0	7.2

Locational Cost

Costs	Removal and Rearrangement of Land	Transfer	Building	Land Purchase	Locational Cost/Mesh
Land Use	10 ⁴ Yen/m ²				10 ³ Yen
Residence	0.8	0.8	8.0	8.0	281.6
Commerce	0.8	1.0	10.0	8.0	316.8
Industry	0.8	0.7	7.0	8.0	264.0
Green Space	0.15	0.0	0.3	8.0	135.2

Improving Cost

Environmental Evaluation Items	10 ⁴ Yen/m ²	10 ³ Yen/Mesh
Ground	0.8	12.8
Aircraft Noise	1.0	16.0
Traffic Noise	0.5	8.0

(It is impossible to make improving change for the others.)

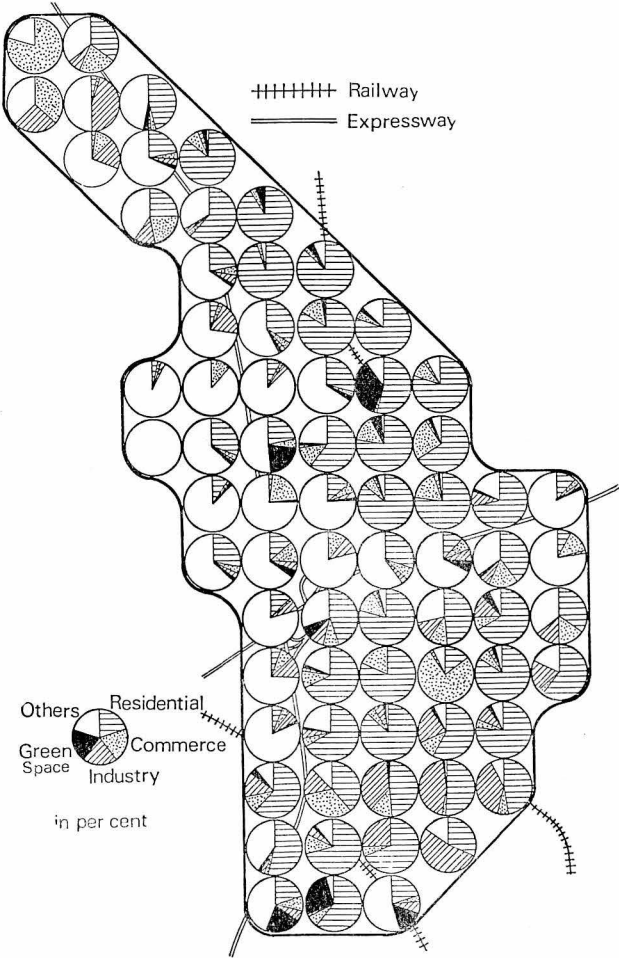


Fig. 3. Present Land Use.

Table 5. Optimal Solutions.

Case with Developmental and Locational Change only	Mixed Land Use	with Airport	Case 1	(10 ⁸ Yen) 6 954
Case with Developmental, Locational and Improving Changes	Mixed Land Use	with Airport	Case 2	2 228
		without Airport	Case 3	2 785
	Single Land Use	with Airport	Case 4	1 827
		without Airport	Case 5	3 661
			Case 6	3 356

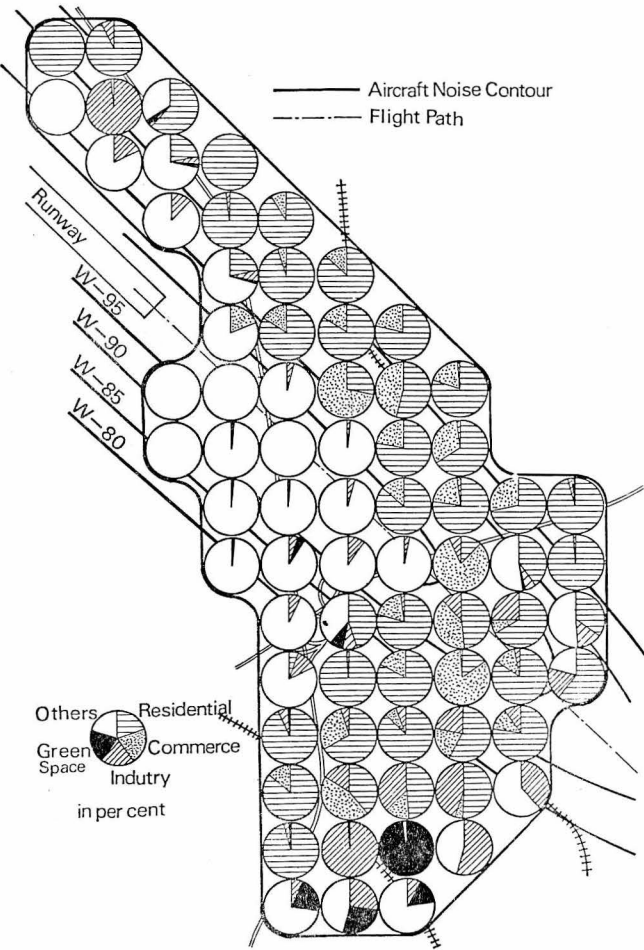


Fig. 4. Optimal Land Use of Case 2.

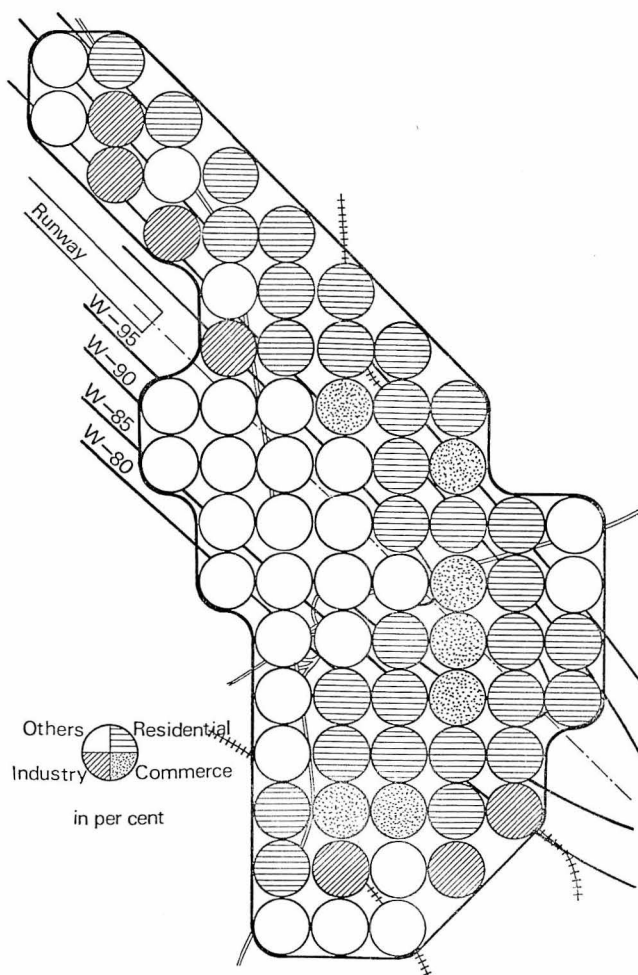


Fig. 5. Optimal Land Use of Case 5.

Table 6. Computation Time.

Model Name	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Number of Variables	588	588	588	608	136	316
Number of Constraints	662	662	662	667	71	83
Total CPU Time (MS)	58 150	133 796	138 075	137 729	11 798	18 700
Total CORE Time (MS)	457 620	694 485	718 956	691 442	87 720	91 233

Note: Cases 1-4 use Linear Programming.

Cases 5-6 use Approximate Integer Programming.

follows :

- 1) When there is an airport involved, the rearrangement cost is about 100 billion yen greater than cases in which there is no airport involved.
- 2) A rearrangement method which ignores the improvemental method is more expensive than one which includes it. This is due to the high cost of developing the land in the surrounding area, which has been selected as the alternative locational site for the objective region under consideration.
- 3) Because total costs have been minimized, the rearrangement pattern of land use in the region is arbitrarily determined. The use of each piece of land is determined without regard to its surroundings. This pattern does not necessarily coincide with patterns which have been previously created by government-designated objective districts for surrounding and relocation compensation. (These designations have been made independently for each land use category.)
- 4) The location pattern of land use for environmental rearrangement tends toward the centralization of each land use in the region. This represents more explicitly the model of single land use.
- 5) The total cost of the mixed land use model is lower than that of the single land use model under the same conditions. However, because the mixed land use model creates land use allocation patterns within each mesh, there are latent costs associated with this type of model. Thus, it is difficult to make precise comparisons between the total costs of single land use models and those of mixed land use models.

Therefore, if we define social cost from aircraft noise as the difference in total cost with respect to rearrangement for land use in objective regions with and without airports, it is possible to roughly establish the social cost of aircraft noise, responsibility for which should be borne by those causing it. The environmental quality standards used in this study were already established. The method by which they were established is beyond the scope of the present paper and thus will not be dealt with here.

Finally, the value obtained in this manner does not always satisfy the conditions that equation (1) is positive or equation (3) is greater than 1. In particular, it is necessary to transfer benefits from the group comprised of user D and affecting party E_1 to the group comprised of S and E_2 , so that the burden of costs is distributed fairly. We can obtain the standards for this decentralization by applying a duality problem to the model mentioned above^{14), 15), 16)}.

As mentioned above, if the transportation and traffic volume at terminal k is

provided, we can forecast the levels of exhaust gas, vibration and noise caused there. We can also calculate the costs required for rearrangement of land use to satisfy the environmental quality standards or demand for pollution prevention corresponding to each land use.

In actual practice, however, the terminal authority body is often undertaken by local public bodies, which must pay close attention to the demands and desires of local residents. In addition, those who use transport services may not always act in the best interests of the national economy, since they operate under institutional restrictions such as the nationwide uniform transport fare system. For example, if a terminal is located on the outskirts of a large city, the external dis-economies thereby created may be great, but they are not borne by the transporter. Rather, transporters will tend to be attracted to such areas by the sizable benefits which can be derived by them from such locations.

In contrast with this, terminal locations having relatively low pollution prevention costs usually are characterized by excessive transport costs, and so tend to be avoided.

Thus, in order to make physical distribution actually follow a path which is favorable to the national economy, it is necessary to adapt and adjust the cost burden, the benefit transfer, the subsidy and surcharge systems.

Next, we consider the following three economic bodies as ones which take action to maximize net benefits:

- a) central planning body (adjustment body).
- b) terminal authority body (body offering facilities).
- c) user or shipper. (We assume that he is co-operating with the transporter in order to satisfy the transportation demand in a region. Here, we will not take up the problem of imputation of benefits among transporters.)

The following six policy headings may be considered as possible adjustment methods of the central planning body.

- 1) That terminal authority bodies levy charges of α ($1 \geq \alpha \geq 0$) times the benefit desired from terminal use upon terminal users.
- 2) That terminal authorities be made to bear α times the cost of pollution prevention made necessary by transportation activity taking place at a given terminal.
- 3) That subsidies be provided for optimal scale planning and optimal site location of terminals for the purpose of maximizing benefits.
- 4) That a penalty charge (or surcharges) be levied, or that plans be made for locational sites which are not truly optimal.
- 5) That traffic congestion charges be levied on those who use terminals which

are operating at full capacity.

- 6) That a fee of $(1-\alpha)$ times the pollution prevention costs necessitated by a given terminal be levied against the users of the terminal.

The above described decentralized achievement is represented in Fig. 6.

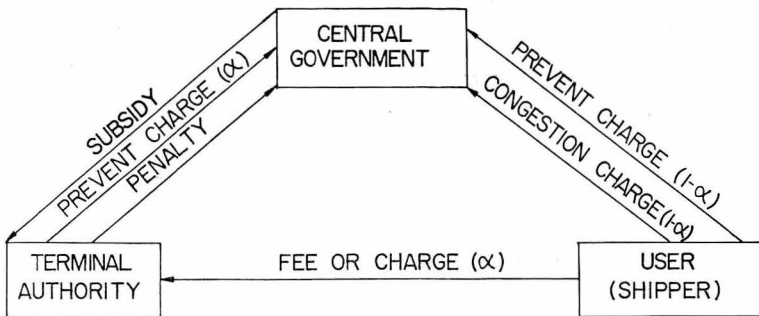


Fig. 6. Decentralized System.

Hence, we may think of α as a policy variable to be determined by the central government.

On the one hand, it would appear that terminal authority bodies should be responsible for maintenance of public facilities such as terminals. Yet, on the other hand, terminal users (shippers) should be responsible for dis-economies arising from terminal use.

In this view, then, it would seem that $\alpha=0$. However, in so far as terminal authority bodies levy charges on users of their terminals, it would seem that they should also carry a share of the dis-economies arising therein and that $\alpha>0$.

5. Problems of Actual Application

Cases in which planning methods have accurately evaluated the net costs and cost allocation, especially as they relate to the areas surrounding the terminals, have been few.

In 1967 it became necessary to take some action with regard to large-scale airports. Accordingly, "The Act for Prevention of Negative Effects upon Areas Surrounding Airports" was established. Following the passage of this act, certain airports were designated by government ordinance as airports whose surrounding areas had to be rearranged. The government demanded that these airports set up public corporations, "Organizations for Rearrangement of the Surrounding Area" in order to formulate rearrangement plans, and to put these plans into practice.

Although these organizations are concerned only with airports, our study has been

undertaken in order to propose a methodology for establishing this kind of terminal planning on a broader basis. However, although the environmentally affected area has a public aspect in the form of roads, railways, ports and harbors and airports, a substantial problem remains as to the degree of control the government can legally exercise over privately owned land. The results of calculation by the model are not intended to support the rationale, based upon a number of assumptions, which has been derived by the government. In addition, it should be pointed out that there is an aspect of uncertainty based on humanity in the readjustment of benefits and costs in these areas. Further, there is a variety of possible responses by the regional inhabitants. Adjustments would create dynamic changes in traffic demand by effecting decentralized achievement, thus creating problems for the surrounding areas. Nevertheless, while this study is not able to provide a direct solution for such problems, we believe that it could serve as a valuable information source to help solve such problems.

6. Further Investigations

As mentioned in Section 5, it is necessary to establish a method for the compensation of losses and defense against pollution by the frequent taking off and landing of aircraft at specified airports. We described one of these methods in Section 2, but further investigations are required in order to make this method useful. These investigations must concentrate on:

- 1) The measurement of effects on the relevant human and social activities and the natural ecosystems in these areas, and also the accumulation of data on direct and indirect benefit-costs created by satisfying the traffic demand.
- 2) Systematization of: a) comprehensive planning methods contained in the problem of rearranging the surrounding areas, and b) terminal location planning as a part of the functional efficiency of the flow of freight from origin to destination.
- 3) Proposals of the methodology of decentralized achievement, the executive organizations, and new institutions created to put this planning into practice.

Although this study will provide the basis needed for these investigations mentioned above, it is also considered to be very useful whenever the functions of a terminal are increased, or new terminals are located in areas of concentrated population and intensive land use such as Japan.

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