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Yoshimi NAGAO and Takayuki MORIKAWA

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Yoshimi NAGAO* and Takayuki MORIKAWA**

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Abstract

In order to plan the efficient utilization of coastal zones considering preservation of the environment, an activities allocation model in consideration of their interactive effects is proposed in this paper. Here, agglomeration economies are considered as a positive interactive effect, and external diseconomies are treated as a negative effect. This model is formulated by the n-person non-cooperative games and solved by computer simulation. First, the concerned area should be divided into small grids, and a potential analysis should be conducted. Then, the proposed model is applied to frame an activities allocation plan. As a case study, this model is applied to actual coastal waters and its usefulness is examined.

1. Introduction

Since Japan has little flatland suitable for residential and productive activities, coastal zones have been utilized for those activities. Recently, the demand for coastal waters as well as lands has rapidly increased. However, since there is no rational methodology of the coastal zone use planning, an appropriate planning of those zones has not been developed. As a result, random development of coastal zones yields to an environmental disruption and sprawling of the zones. Under these circumstances, a methodology for rational coastal zone use planning is strongly required. For the rational planning of coastal zone use, the effective utilization of limited space and the decrease of the negative interactions among activities should be considered. In order to establish this methodology, it is necessary to develop an activities allocation model which considers the interactive effects explicitly.

Activities allocation models which have been developed in previous coastal

* Professor, Department of Transportation Engineering, Kyoto University, Sakyo-ku, Kyoto, Japan

** Research Associate, Department of Transportation Engineering, Kyoto University, Sakyo-ku, Kyoto, Japan

zone use studies can be classified into two groups: mathematical programming models and simulation models.

Mathematical programming models can make persuasive plans because of their clear logic. However, there is a limit to express the complicated problems on account of the restriction of the solutions. There are a few studies using mathematical programming models. For instance, there are the study of The 4th District Port Construction Bureau of Ministry of Transport,[1] which formulates the problem by linear programming, and the study of Kashiwadani and Amano,[2] which formulates it by multi-objective programming.

On the other hand, simulation models can accept the complicated problems easily. However, they have the defect that it is difficult to make a rational process. Amano and Kashiwadani[3] and The 5th District Port Construction Bureau of Ministry of Transport[4] propose the simulation models in their studies.

This research aims to build an activities allocation model which considers the interactive effects among activities explicitly, and to propose a method of coastal zone planning. This model is a simulation model. Here, the interactive effects mean the following two concepts. First, the positive interactive effect is agglomeration economies which occurs when similar activities are gathering. Next, the negative one is external dis-economies mainly caused by environmental pollution. It occurs when incompatible activities are gathering.

In Chap. 2, the background, the basic conception and some premises of this model are described. In Chap. 3, the simulation process of this model is explained. Chap. 4 is a case study and Chap. 5 has concluding remarks.

2. Basic Conception and Premises for Modelling

2-1 Basic Conception for Modelling

The activities allocation model proposed in this paper is a simulation model formulated by the n-person non-cooperative games. This model is characterized by treating the positive and negative interactive effects among activities explicitly. The reason for treating them is that coastal waters are susceptible to environmental change on account of their geographical and ecological distinction. This model is formulated on the basis of the following recognition of the use of coastal waters.

Each of the activities demanding space in coastal waters wants to locate at an advantageous point to itself, namely, the point with high locational potential value of the activity. However, since coastal waters are of limited space, there should be competition among activities in locating. And if there are interactive effects among activities, the locational potential of a point will be changed according to the location of the adjacent points. Thus, the condition that each activity competes with each other for maximizing its locational potential value can be recognized as the state of n-person non-cooperative games. That is to say, if the locational point is considered as a strategy, the potential value of that point can be regarded as the payoff of the strategy. Further, the condition that a payoff is changed by the interaction of other activity's location can be considered the essence of the games. Namely, in the games a payoff of a strategy varies according to other players' strategies.

On the other hand, the planner will aim to utilize the coastal waters efficiently and impartially among activities. The efficiency and the impartiality are expressed in this model as follows. First, for efficiency each activity predicts other activities' strategies stochastically and chooses the strategy which brings the maximum expected payoff. Next, for impartiality this game has a rule that when two or more activities want to locate at the same point, the activity which relatively has fewer points with high potential values can locate there.

In this model, the process of the activities allocation is simulated by a computer. This is because simulation models are easier than mathematical programming models to adopt the complicated conditions such as interactive effects. Though this model is explained in detail in Chap. 3, the outline of framing an allocation plan is as follows. First, the concerned area is divided into small squared grids. Next, a potential analysis is conducted for every grid in regard to every activity. Potential analysis is the analysis of the attractiveness for each activity, which each place has as its inherent characteristics. Finally, the proposed activities allocation model is applied to the concerned area, and an allocation plan is framed.

2–2 Premises and Assumptions for Modelling

(1) The concerned area is coastal waters where no plan of utilization is fixed.

(2) The concerned area can be divided into squared unit grids where natural and social conditions can be regarded as uniform. Thus, the potential value is evaluated for each of these unit grids.

(3) Mixed use of a unit grid is prohibited, that is, a grid is used for only one activity.

(4) The area demanded by each activity is apriori given by an appropriate forecasting.

(5) The potential values of each grid for concerned activities are scored by professional evaluations. This score is calculated by the linear combination of the

Table 1 Evaluation Tree for Potential Analysis (Industrial Type Activity)

1		2		3		4		category and its utility
weight	attribute	weight	attribute	weight	attribute	weight	attribute	
0.45	construc-tional conditions	0.6	natural conditions	1.0	waters	0.65	depth	over 20 m 0.0 20～10 m 5.0 below 10 m 10.0
						0.15	geological featuer of the sea floor	stone, rock or coral 10.0 sand 5.0 mud 0.0
						0.2	wave height	appearance probability of wave height below 1 m 0～50% 0.0 50～70% 3.3 70～90% 6.7 90～100% 10.0
		0.4	social conditions	1.0	regulation of the law	1.0	harbour area	exist 10.0 not exist 0.0
0.55	utilization conditions	1.0	hinterland conditions	1.0	traffic conditions	0.35	distance to the important horbour	0～5 km 10.0 5～15 km 7.5 15～30 km 5.0 30～50 km 2.5 over 50 km 0.0
						0.25	distance to the inter-change	0～2 km 10.0 2～5 km 6.7 15～30 km 3.3 over 15 km 0.0
						0.2	railway	exist 10.0 not exist 0.0
						0.2	distance to the national road	0 km 10.0 1 km 9.0 2 km 8.0 3 km 7.0 4 km 6.0 5 km 5.0 6 km 4.0 7 km 3.0 8 km 2.0 9 km 1.0 over 10 km 0.0 the first class 0.6 the second class 0.4
	exclusive conditions		natural conditions		beach area		rivers	the first class river exists
							tideland	exist
					waters		tide	over 1.1 knots/hour
			social conditions		the present state and regulation of the law		algae area	exist
							bathing beach	exist
							fishery port area	exist

(quoted from bibliography[5])

weighted attributes' scores, as illustrated in Table 1.

(6) When an activity is allocated at a certain grid, its interactive effects influence the surrounding eight grids.

(7) The interactive effects are expressed by the change of the potential values. The changes of the potential values can be also estimated based on the profes-

sionals' judgement.

3. The Formulation of the Allocation Model

3-1 The Outline of the Model

As mentioned before, this activities allocation model is formulated as the n-person non-cooperative games where each activity plays the part of a player. Hereafter, in order to correspond to the terms used in the theory of the games, we will call an activity a player and a potential value a payoff, respectively.

Each player gets one grid at each play. The process of getting a grid is as follows: each player decides his strategy of the play, every player presents his strategy simultaneously, conflicts of strategies are managed if there are any, and the grid given to each player is determined. Here, the strategy of a player means the grid he selected as the most advantageous one out of all the grids in the play. Each player decides his strategy at every play according to the following process. At a certain play he has as many strategies as remaining grids, which

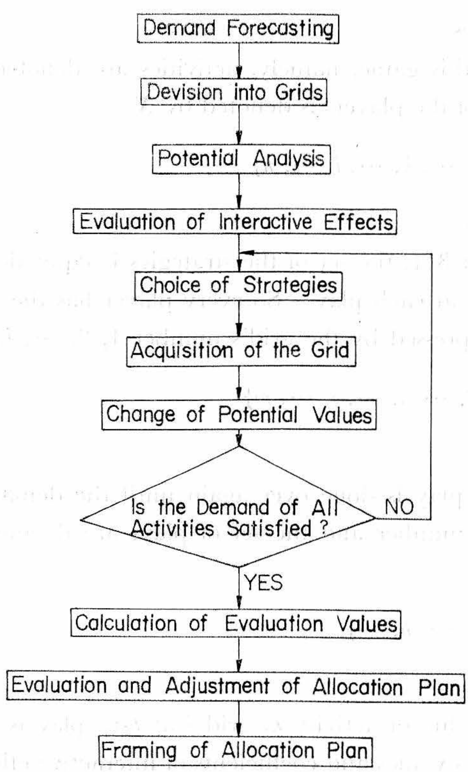

Fig. 1 Flowchart of Framing an Allocation Plan

have their own payoffs namely potential values. But those values will be influenced by other players' strategies. Because the values will be changed owing to the interactive effects of the grids other players will get at that play. Therefore, he forecasts other players' strategies stochastically, that is to say, he assumes other players will take mixed strategies, and he chooses the strategy which brings the maximum expected payoff.

After one play finishes and every player gets his grid, the potential values of the grids adjoining those grids change, owing to their interactive effects. The above-mentioned play shall be done over again until the demand of all activities is satisfied, and eventually an allocation plan will be made. Naturally the demand varies from activity to activity, so the activities which satisfy their demand drop out of the game.

Some alternatives based on policies can be easily made by means of changing the initial potential values. Fig. 1 shows the above-mentioned flow of allocation planning.

3–2 Notation and Definition

a) Players (Activities)

The players of this game, namely, activities are denoted by $1, 2, \cdots, k, \cdots, l, \cdots, n$, and the set of the players is denoted by N.

$$N = \{1, 2, \cdots, k, \cdots, l, \cdots, n\} \tag{1}$$

b) Strategies (Grids)

As mentioned at 3–1, the set of the strategies is equivalent to the set of grids the activities can get at each play. So every player has the same set of strategies and this set M is expressed by the grid's number $1, 2, \cdots, i, \cdots, j, \cdots, m$, as

$$M = \{1, 2, \cdots, i, \cdots, j, \cdots, m\} \tag{2}$$

c) Plays

In this game a play is done over again until the demand of all activities is satisfied. The play number and the set of plays are denoted by $1, 2, \cdots, h, \cdots$ and H, respectively.

$$H = \{1, 2, \cdots, h, \cdots\} \tag{3}$$

d) Potential values

The potential value of activity k, grid i at h-th play is denoted by $p_h^k(i)$.

e) Interactive effects values and coefficients of interactive effects

The interactive effect value is defined as the change of the potential value.

The interactive effect value that activity l at grid j affects activity k at grid i is given by Eq. (4). This equation is based on the gravity model, and that value is assumed to be inversely proportional to the square of the distance between two grids. The numerator of Eq. (4), f^{kl}, denotes the coefficient of the interactive effect, which represents the effect value at a unit distance. The denominator $r(i, j)$ represents the distance between grid i and grid j.

$$a^{kl}(i, j) = f^{kl}/\{r(i, j)\}^2 \tag{4}$$

f) Demand for space

The number of grids activity k demands is denoted by d^k.

3–3 The Procedure of the Simulation

The procedure of the simulation of the activities allocation will be explained in accordance with the flowchart shown in Fig. 2.

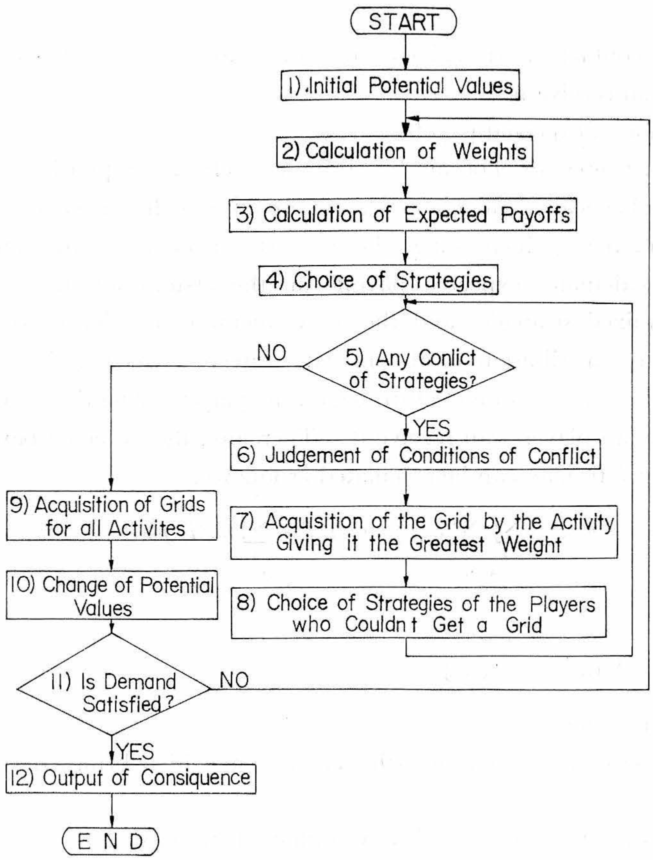

Fig. 2 Procedure of Simulation

1) Initial potential values

The potential values which are obtained by means of the potential analysis are used for the first play as $p_1^k(i)$.

2) Calculation of weights

Here, weights mean relative potential values which sum up to a unit. Namely, the weight of activity k and grid i at h-th play is given by

$$w_h^k(i) = p_h^k(i)/\sum_i p_h^k(i) \tag{5}$$

therefore

$$\sum_i w_h^k(i) = 1.0 \tag{6}$$

These values can be considered as how the activity attaches importance to the grid, and are used in the following two situations.

a) As the probability of the strategy when a player predicts other players' strategies.

b) When a conflict of strategies occurs, the player who weighs that grid with the greatest can receive it.

3) Calculation of expected payoffs

As stated before, in choosing his strategy, each player predicts other players' strategies stochastically, calculates the expected payoff for each strategy, and chooses one of them which brings the greatest expected payoff. That is to say, each player calculates expected payoffs on the assumption that other players would take mixed strategies and the above-mentioned weights are regarded as the probability distribution of the mixed strategies. As will be mentioned in detail at 7), if there is a conflict of strategies, the player giving that grid the greatest weight among all players can receive it. Therefore, the expected payoff of player k and grid i at h th play can be calculated as follows:

$$e_h^k(i) = p_h^k(i) + \sum_{\substack{l \\ l \neq k}} \sum_{\substack{j \\ j \neq i}} w_h^l(j)\, a^{kl}(i,j) - \sum_{\substack{l \\ l \in L}} w_h^l(i)\, p_h^k(i) \tag{7}$$

where

$$L = \{l \mid w_h^k(i) < w_h^l(i)\} \tag{8}$$

4) Choice of strategy

The strategy of player k at h-th play is that which brings the greatest $e_h^k(i)$ in Eq. (7).

5) Judgement of whether there is any conflict of strategies

A conflict of strategies means that two or more players take the same strategies. If there is a conflict, go to 6), and if not, go to 9).

6) Judgement of a condition of a conflict

When there is a conflict, how many activities participate in it at how many grids should be searched.

7) Acquisition of the grid by the activity giving it the greatest weight

If two or more players conflict for a grid, the player who gives it the greatest weight among them can receive it. The reason is that the player who gives it a smaller weight has relatively more grids with high potential values.

8) Choice of strategy of the player who couldn't get a grid

The players who couldn't get grids at 7) have to change their strategies. They once more calculate the expected payoffs considering the interactive effects of the grids allocated at 7) and choose their strategies, then go back to 5).

9) Acquisition of grids for all activities

When there is no more conflict, all grids to which all activities are allocated at that play are determined.

10) Change of potential values

When all allocated grids at that play are determined, all potential values around them change owing to their interactive effects. These changed values shall be used at the next play. Therefore, the potential value of activity k and grid i at $h+1$-th play is,

$$p^k_{h+1}(i) = p^k_h(i) + \sum_l \sum_j a^{kl}(i,j)\ \delta^l_k(j) \tag{9}$$

where

$$\delta^l_h(j) = \begin{cases} 1: & \text{when activity } l \text{ was allocated to grid } j \text{ at } h\text{-th play} \\ 0: & \text{otherwise} \end{cases}$$

11) Judgement of whether demand is satisfied

The activity whose demand is satisfied with the grids it has received drops out of the game. If all activities satisfy their demand, go to 12); otherwise, go back to 2) and begin the next play.

12) Output of consequence of allocation

When all activities satisfy their demand and the allocation finishes, the map and the evaluation values are put out.

4. A Case Study

4–1 Premises of the Example

As a case study, the model proposed in this paper is applied to the coastal

Table 2 Activities in Coastal Zone

Recreational Type Activities	
	Parks and Green Zones Bathing Beach Waters for Pleasure Boats Marina
Industrial Type Activities	
	Industrial Land Port and Harbours Land for Disposal of Waste Matter Sewage Disposal Plants
Fishery Type Activities	
	Waters for Coastal Fishery Fish Farms
Residential Type Activities	
	Residential Land Commercial Land

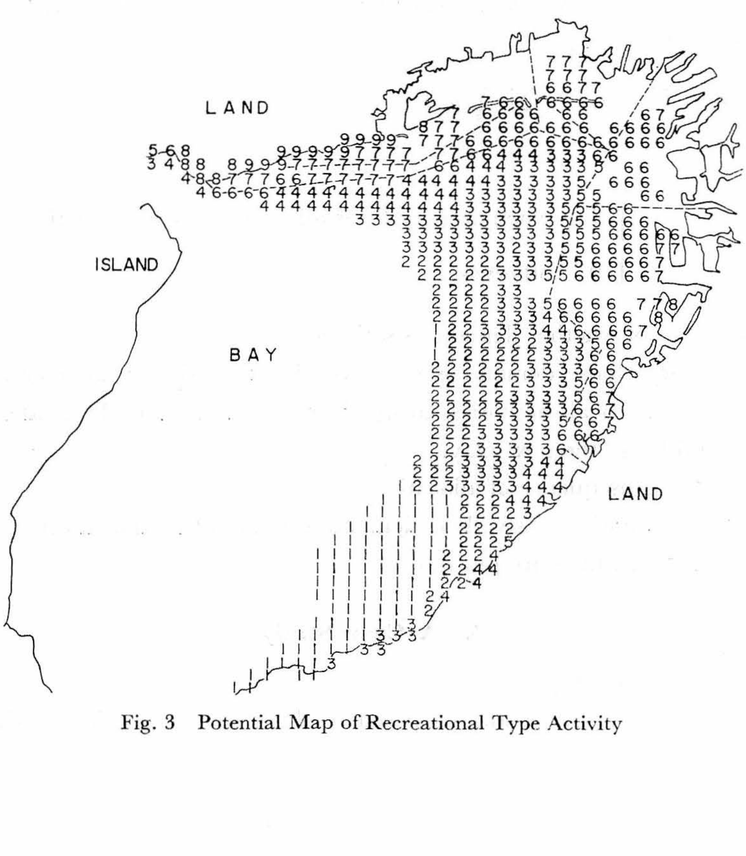

Fig. 3 Potential Map of Recreational Type Activity

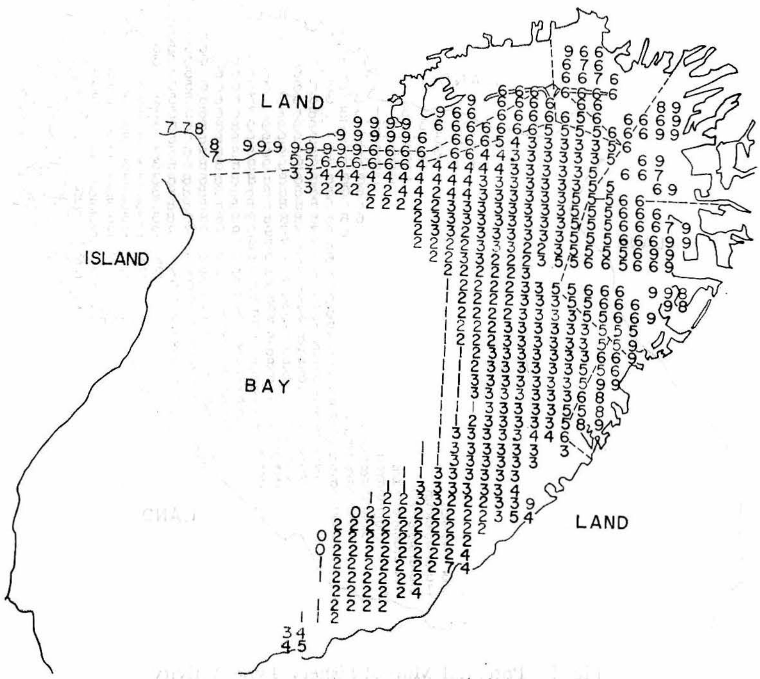

Fig. 4 Potential Map of Industrial Type Activity

waters in the Osaka Bay area. Some premises of this example are as follows.

(1) Concerned area

The concerned area is the coastal waters at a depth of less than about 20 m. The area is divided into small grids (about 1 km^2), and the number of them is about 600.

(2) Activities

The concerned activities are the following four activities: recreational type activity, industrial type activity, fishery type activity and residential type activity. Each activity consists of some groups as shown in Table 2.

(3) Demand forecasting

Demand of each activity for space in the concerned area is estimated from the demand for land area behind Osaka Bay in the fifteen years from 1986 to 2000.[5] Consequently, the number of grids of demand is 24 grids for recreational type activity, 40 grids for industrial type activity, 32 grids for fishery type activity and 30 grids for residential type activity, respectively.

(4) Potential analysis

The consequences of the potential analysis[5] for each activity are shown in Figs. 3, 4, 5 and 6.

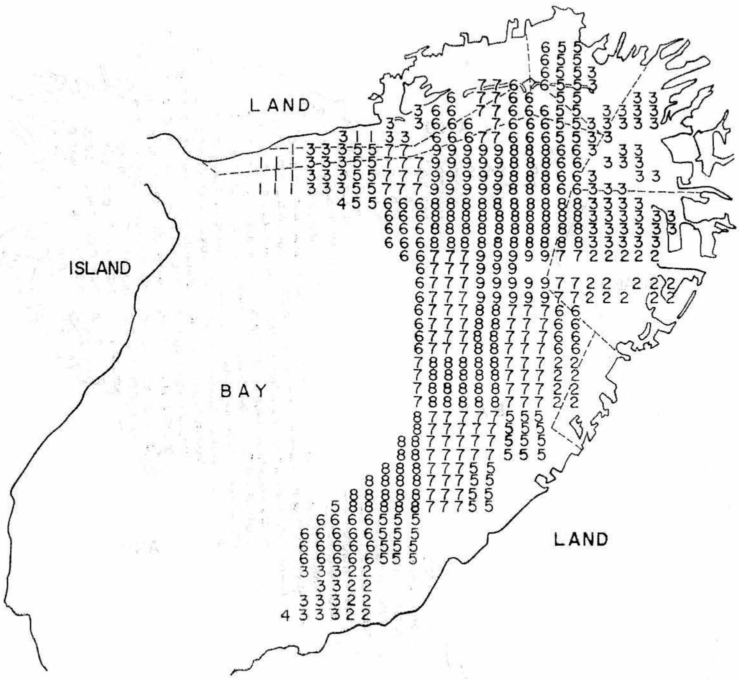

Fig. 5 Potential Map of Fishery Type Activity

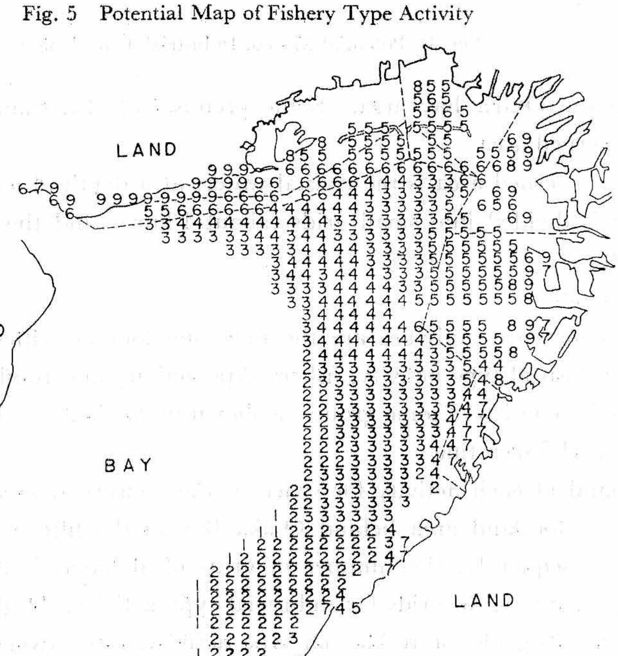

Fig. 6 Potential Map of Residential Type Activity

Table 3 Coefficients of Interactive Effects

k \ l	Recreational Type Activity	Industrial Type Activity	Fishery Type Activity	Residential Type Activity
Recreational Type Activity	0.3	−0.4	0.0	0.0
Industrial Type Activity	−0.2	0.4	−0.2	−0.2
Fishery Type Activity	−0.1	−0.4	0.2	−0.2
Residential Type Activity	0.2	−0.4	0.0	0.2

(5) Coefficient of interactive effects

The coefficient of interactive effects, f^{kl}, namely the change of potential values that activity l affects activity k at a unit distance is defined as shown in Table 3.

4-2 Consequences of Simulation and Discussion

On the basis of the above premises activities were allocated by the proposed model. The map of consequence is shown in Fig. 7. In Fig. 7, the grids on

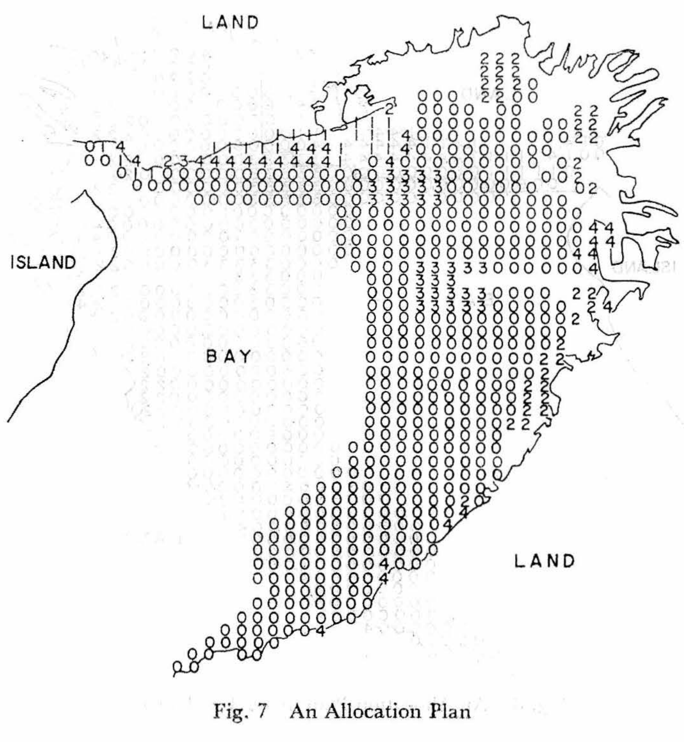

Fig. 7 An Allocation Plan

Table 4 Evaluation Values of the Allocation Plan

k	Recreational Type Activity	Industrial Type Activity	Fishery Type Activity	Residential Type Activity
PSUM (k)	206.5	358.5	312.3	251.0
PSUM	1128.3			

which 1, 2, 3 and 4 are printed express those to which recreational type activity, industrial type activity, fishery type activity and residential type activity were allocated respectively. The grids on which 0 is printed express those to which no activity was allocated. In Table 4, PSUM(k) represents the sum total of potential values activity k obtained after the allocation finishes, and PSUM represents the sum total of PSUM(k) in regard to k.

Next, as an alternative which accepts the intention of the supply side, the activities were allocated on the condition that some use districts are assigned. Fig. 8 shows the map of the consequence. In this figure, the top-left area from the line is regarded as the environmental preservation area, so industrial type

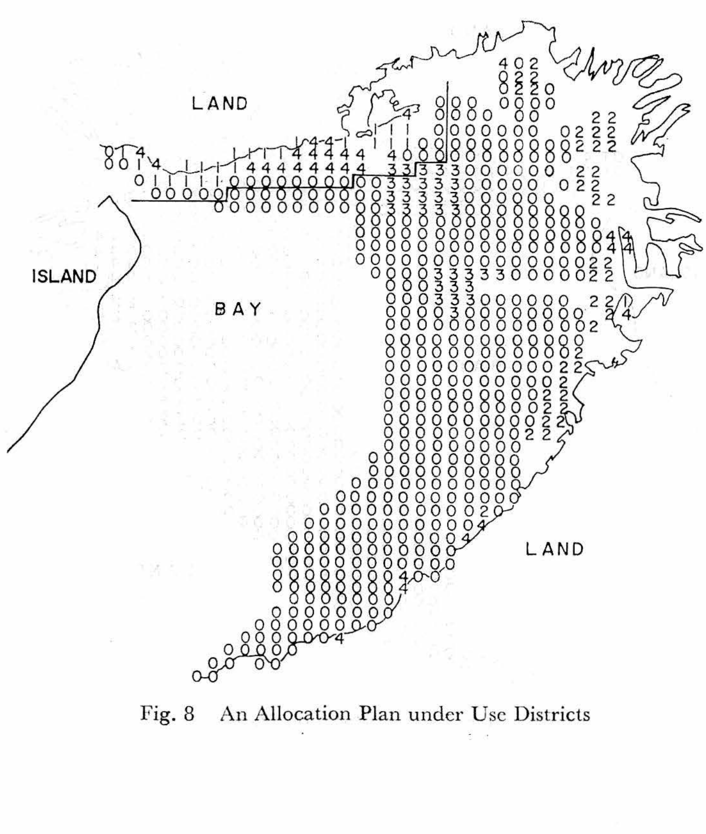

Fig. 8 An Allocation Plan under Use Districts

Table 5 Evaluation Values under Use Districts

k	Recreational Type Activity	Industrial Type Activity	Fishery Type Activity	Residential Type Activity
PSUM (k)	209.5	356.5	313.1	250.6
PSUM	1130.3			

activity cannot be allocated there. The evaluation values are shown in Table 5.

When the evaluation values in Table 4 are compared with those in Table 5, the sum total of the potential values in Table 5, namely on the condition that a use district is assigned, is greater than that in Table 4, namely without a use district. However, the sum total of the potential values of the industrial type activity in Table 5 is smaller than that in Table 4. So it is considered that industrial type activity would not be satisfied with this assignment of the use district.

Finally, as the sensitivity analysis of the interactive effects, activities were allocated without consideration of the effects, and the consequence is shown in

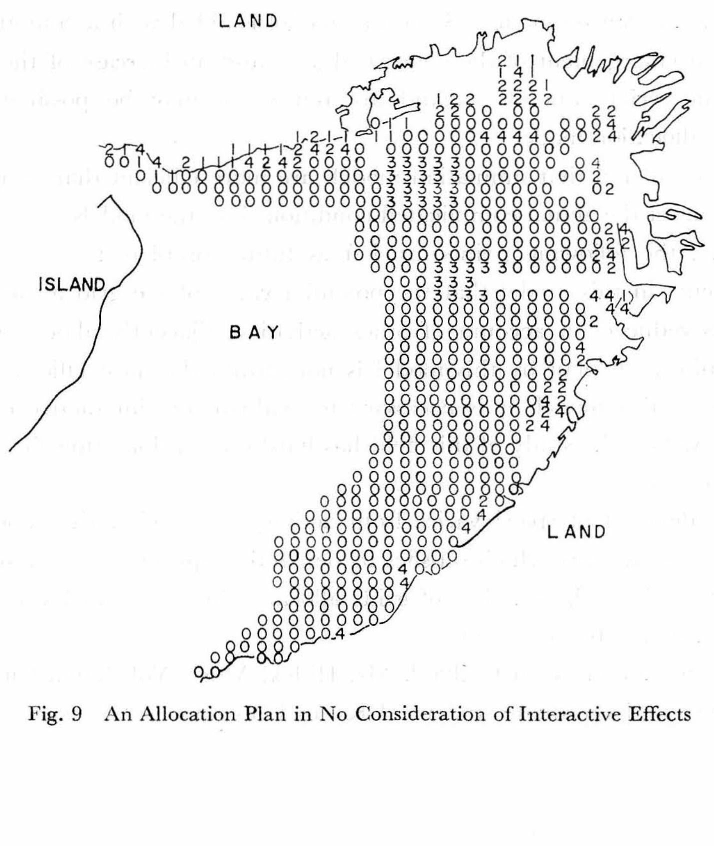

Fig. 9 An Allocation Plan in No Consideration of Interactive Effects

Table 6 Evaluation Values in No Consideration of Interactive Effects

k	Recreational Type Activity	Industrial Type Activity	Fishery Type Activity	Residential Type Activity
PSUM (k)	191.0	318.0	288.0	238.0
PSUM	1035.0			

Fig. 9 and Table 6. As shown in this figure, every activity was allocated so scatteringly that there would be problems of efficiency and environment. Further, the sum total of the potential values is fairly small, so we can justify the significance of considering the interactive effects in allocating activities.

5. Concluding Remarks

In this paper, an activities allocation model in coastal waters is proposed considering the interactive effects among activities. The results we obtained through this research may be summarized as follows:

(1) By means of the activities allocation model considering both the positive and negative interactive effects, which have hardly been considered so far, efficient allocation plans can be made. Since this model is aided with a computer, it can be fit for an enlargement of the concerned area and an increase of the activities.

(2) If time serial data of demand are put in, it may be possible to make a dynamic allocation model.

(3) It is considered that simulation models are more efficient than programming models to adopt the actual complicated conditions into the models.

Finally, the following points are left as future problems:

(1) It occurs in this model that the potential value of the grid an activity had obtained is reduced on account of other activities adjacently allocated. Therefore, the allocation plan by this model is not always the most efficient one.

(2) In using this model, it is necessary to evaluate the interactive effects precisely. However, the study of this field has hardly been done thus far, so further study is necessary.

(3) Since demand of space varies from activity to activity, this model adopts the rule that an activity which satisfies its demand drops out of the game. Many other rules, such as the number of grids allocated in a play varies according to the activity, should be examined.

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