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A Case Study on the Residents Response to the Flood Hazards and Flood Control Measures in the Inundated Areas of Sapporo City

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Abstract

In recent years, the nature of floodings have been increasing in urbanized small-scale watersheds. Then the approach to the problem of urban inundation needs to introduce measures suitable for each hazardous area through analyzing the mechanism of urban system and behavior of consciousness of inhabitants. From these viewpoints, the structural modeling method is proposed in order to construct the consciousness structure of flood hazard problem and the living environment. Two modeling methods which are a method using the AIC and a structural method of awareness movement are proposed in this study. As the results, it is observed to be imperative to attach importance to the parameters of disaster and disaster prevention along with the living environment. The residents' experiences of flood hazard are useful to enhance the consciousness of flood hazard prevention. Besides, the public information system of flood hazard have infiltrated ints these areas gradually.

Key Words: Residents response, Flood hazard information, Flood control measures, Residents' participation, Flood insurance, Questionnaire survey Living environment parameters, AIC criteria, Awareness movement, Expected advance.

1. Introduction

Several current records on flood hazards clearly exhibit the nature of floodings and consequent damages that have been increasing in urbanized small-scale watersheds. These damages are mainly caused due to inundation in low lying areas. This indicates that these flood prone areas, however, have been subject to extensive use for residential districts or the industrial and commercial developments.

Such expansion of activities in these areas have increased the potential risk of the flood hazards. The flood hazard in urban area is pointed out by the complex and dynamic characteristics. The complex nature of the factors involved and consequent chain reactions that take place have been corroborated by previous study. [1] Therefore, the approach to the problem of urban inundation needs to introduce measures suitable for each hazardous area through analyzing the mechanism of urban system and the behaviour and consciousness of inhabitants. [2]

The Ministry of Construction has been promoting comprehensive flood control measures since 1979. The measures and projects have been operated in some of urbanizing watersheds.

The distinct characteristics of such measures and projects are to comprehend structural and nonstructural measures.

Main nonstructural measures are to represent the communication of flood hazard information, establishment of flood insurance system and promotion of flood prevention activities. Every measure needs the residents' cooperation and acknowledgment. Therefore it is important to grasp residents' behaviour and their structures of consciousness in order to promote these measures on a rational scale. Besides the residents' consciousness, monitoring system for flood information should be established on the basis of residents' consciousness. [3]

From these points of view, the structural modeling method relevant to the consciousness of flood hazard problem and the living environment is proposed as described below. [4, 5]

2. Background of the study

(1) *The Characteristics of Urban Flood Hazard*

Most of the rivers flow through the urban areas existing on low lying terrain and the rivers have flat bed gradient and complex channel network.

It is therefore difficult to enhance the ability of drainage system. This is further augmented by the fact that the runoff being proportional to the paved area is very high and making the urbanized areas more vulnerable to potential flood damage.

This causes the problem for coordinating flood control program and city planning. Therefore new planning techniques need to be introduced in order to bridge the gap. The new technique should emcompass structural flood control measures, administrative institutions for flood prevention and residents' community participation.

(2) *Residents' Participation in Flood Control — Residents Direct Response System*

As mentioned earlier, the human loss and property damage are very less in the case of inundation, though the frequency is very high. On the contrary, the flooding from the overflow of rivers is less frequent, however causes heavy damage. Consequently, the annual average damage can rise up to a large amount. There are also large influences on the urban functions and residents' living environment. The problems due to inundation not being considered very serious, inundation control measures do not proceed rapidly.

From this viewpoint, residents direct response system consists of the following two aspects :

i) Awareness of people towards the inundation hazards, their response and realization of the flood control measures and the changing views of the people as the flood control projects proceed.

ii) The people's outlook on the living environment and the degree of response to the inundation hazard in their area vis-a-vis the environmental improvement programs under execution.

These questions are relevant to the problem of flood prevention, for instance, opening of information on flooding to the public, flood prevention activities and flood-fighting drills. Furthermore, these aspects are useful to the structural measures and the facility planning exercise for flood hazard prevention.

3. Method and Procedure

The analytical method and its procedure are presented in Figure 1.

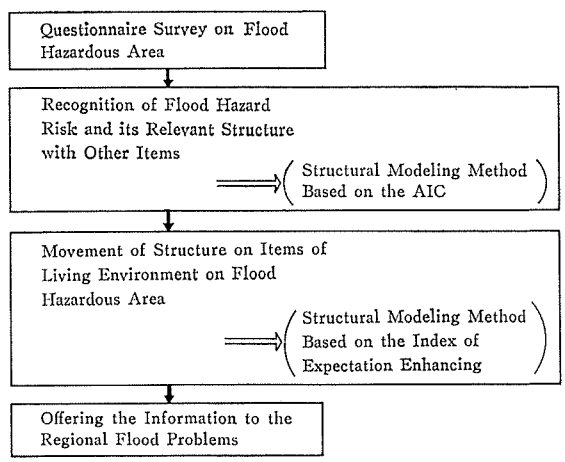

Figure 1. Procedure and Method of Analysis.

This is outlined as follows:

(1) *Questionnaire for Community Response*

Two identical questions were asked from each resident. One was related with the flood risk and structural and nonstructural measures for flood risk mitigation and the other was connected with the consequences on their living environment in flood planes.

The contents of questionnaire are shown in Table 1.

(2) *Interrelated Structure of Flood Hazard Risk and Awareness of Other Contents of the Living Environment*

The data collected through the questionnaire were analyzed and the complex and high-degree awareness structure was constructed by the cross tabulation method. The technique introduced in this procedure is the structural modeling method by Akaike's Information Criteria (AIC).

In this method each interrelational structure among several factors was combined using more than dualistic cross tabulation. The fitness of the models was checked by means of AIC. That is, the relationship among each characteristics is

Table 1. Question Contents of Survey

Contents	Order of Question
1. Recognition of Flood Hazard Risk and its Reasons	1, 2, 3
2. Knowledge of Flood Hazard Map and its Transmission Method	4, 5, 6, 7
3. General Flood Hazard Information and Postersfor Flood Hazard	8, 9
4. Thinking for Causes of Inundation	10
5. Comprehensive Flood Control Measures	11, 12
6. Flood Hazard Insurance	13
7. Flood Control Projects	14
8. Several Improvements after Inundation	15
9. Regional Living Environment in Flood Prone Area	16
10. Inhabitantial Desire of Settlement in Flood Prone Area	17
11. Expectation of Public Flood Control (by National Government and Municipality)	18
12. Independent Variables	19

justified by the difference among these criteria. The analyzed results are linked with each other structurally and formed into a comprehensive digraph.

This algorithm is presented as follows:

The model which the relation between an item i_1 and another item i_2 is independent is defined as

$$M_0;\ p(i_1, i_2) = p(i_1, \cdot)\, p(\cdot, i_2) \tag{1}$$

$$\sum_{i_1=1}^{C_1} p(i_1, \cdot) = 1 \text{ and } \sum_{i_2=1}^{C_2} p(\cdot, i_2) = 1$$

$$\left(p(i_1, \cdot) = \sum_{i_2=1}^{C_2} p(i_1, i_2),\ p(\cdot, i_2) = \sum_{i_1=1}^{C_1} p(i_1, i_2)\right)$$

The other model which is not imposed the above conditions is formulated as

$$M_1;\ p(i_1, i_2) = p(i_1, i_2) \tag{2}$$

$$\sum_{i_1=1}^{C_1} \sum_{i_2=1}^{C_2} p(i_1, i_2) = 1$$

Using Equation (1) and Equation (2), the parameter $p(i_1, i_2)$ is defined in order to maximum the likelihood L.

The AIC is defined by the illness of model adapting as

AIC=(−2) ln (maximum likelihood)+2 (number of free parameters)

The AIC to M_0 is given by:

$$\mathrm{AIC}(M_0) = (-2) \sum_{i_1=1}^{C_1} \sum_{i_2=1}^{C_2} n(i_1, i_2) \ln \left[n(i_1, \cdot)\, n(\cdot, i_2)/n^2\right] + 2(C_1 + C_2 - 2) \tag{3}$$

On the other hand, the AIC to M_1 is given by:

$$\mathrm{AIC}(M_1) = (-2) \sum_{i_1=1}^{C_1} \sum_{i_2=1}^{C_2} n(i_1, i_2) \ln n(i_1, i_2)/n + 2(C_1 C_2 - 1) \tag{4}$$

Hence the model is decided by sign $+/-$ which gained the following equation :

$$\mathrm{AIC}(M_0)-\mathrm{AIC}(M_1)\cong -\chi^2+2(C_1-1)(C_2-1). \quad (5)$$

If the group of explanatory variables F and the objective variables E are given, Equation (5) is generalized as follows :

$$\mathrm{AIC}(E;\ F)=(-2)\sum n(E,F)\ \mathrm{In}\left[n\cdot n(E,F)/\left\{n(E)\ n(F)\right\}\right]+2(C_E-1)(C_F-1) \quad (6)$$

in which $n(\cdot)$ and $C\cdot$ are the frequency and categorical number relatively and $\sum$ is given the total of all cell in cross tabulation.

(3) *Structural Method of Awareness Movement*

Structural models were constructed by analyzing the simultaneous answering for the current and future state of the living environment. The interrelationship between the categorized data for the current and future living environment are shown in the tables of the condition relative cross tabulations. Several indices, for example, the index of advance and the index of aggravation were calculated using these tables.

The relative structures were modeled by calculating the degree of influence and the influenced degree and comparing the interdirection.

In this case, such structures were built using the degree of expected advance which was made on the basis of transitivity from the present satisfaction to the future expectation.

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The algorithm of such a procedure is proposed as follows :

i) The index of expected advance IA is given by Equation (7).

$$\mathrm{IA}(j,k)=\left[P(k|j)-P(k|\bar{j})\right]/\left[1/2\left\{P(k|j)+P(k|\bar{j})\right\}\right] \quad (7)$$

Provided that $P(k|j)=N(k,j)/Nj$ and $P(k|\bar{j})=N(k,\bar{j})/N\bar{j}$ $(j,k=1,2,\cdots,N)$, in which $N(k,j)$ $[N(k,\bar{j})]$; Number of answerers who thought "satisfaction" [no satisfaction] in the present factor j and "better change" in the future factor k and Nj $[N\bar{j}]$; number of answerers who though "satisfaction" [no sarisfaction] in the present factor j.

ii) Upper items by comparing with each other are decided as following equation (8).

$$\mathrm{IA}(j,k)\geq\mathrm{IA}(k,j) \quad (8)$$

iii) The degree of influence and the degree of influenced are given as follows :

The degree of influence :

$$\mathrm{DA}(j)=\sum_{j\neq k}\mathrm{IA}(j,k) \quad (9)$$

The influenced degree:

$$AA(j) = \sum_{j \neq k} IA(k, j) \tag{10}$$

4. Survey Methodology

(1) *Watershed Description and Result of Survey*

The questionnaire was introduced in Kita-ku, Higasgi-ku and Shiroishi-ku of Sapporo City which were inundated in 1975 and 1981.

An universal of sampling technique was considered for the residents in the inundated area. The samples were selected by a random stratified sampling method. Several communities were belonging to the upper layer of sampling technique and the lower was composed of the head of a household within the selected community.

Number of samples were 1,005 in all. The questionnaire was completed on mail basis. In order to select respondents at random, all residential units within such communities were given a number and sample was then drawn on the basis of a random-number table.

Table 2. Number of Sampling and Rate of Answerers

Districts	Number of Households	Number of Samples	Number of Answerers	Rate of Answerers (%)
Kitaku				
1-1 Tonden	717	34	25	74
1-2 Shinoro	4,288	207	139	67
Higahsiku				
2-1 Hokuei	1,172	55	32	58
2-2 Eitoh	3,502	171	107	63
2-3 Shimonaebo	212	12	9	75
2-4 Satsunae	4,015	193	123	64
2-5 Nakanume	791	38	26	68
Shiroishi				
3-1 Kitashiroishi	6,170	295	196	66
Total		1,005	657	65

The collected survey forms were 657 which is 65% of the total sample.

(2) *List of Survey Items*

The survey items were selected as follows information media of the flood hazard, structural or nonstructural measures of flood control and the living environment in the residential area as shown in Table 1.

5. Outline of the Results of the Analyses

(1) *Sample Attributes*

The share of household interviewer was 87% of all. The share of male

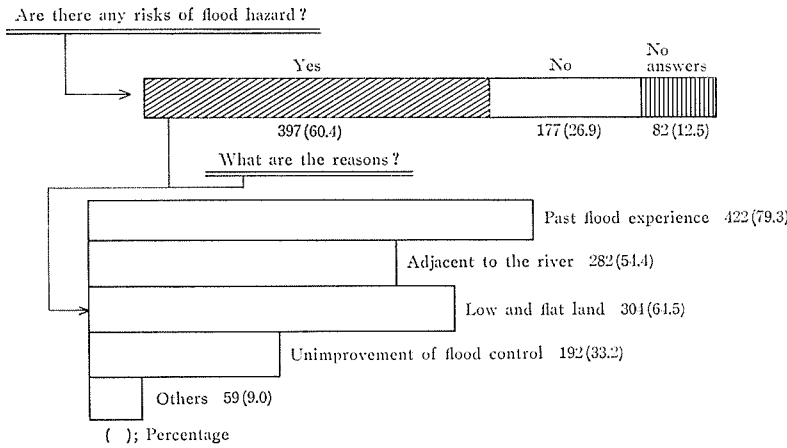

Figure 2. Evaluation of Flood Hazard Risk and Its Reasons.

answerers was 88%. About half of all answerers were in the age group of 40-59 years. The period of residency less than 6-10 years in the area was 77% of all samples. Among the dwelling houses, the private residences were 70% of all. Regarding the structure of buildings, mortared and wooden buildings were 81% of all.

Most of the districts have been developed as housing sites over the years. Besides, the dwelling houses which were constructed with the floodproofing foundations were about 56%. This may be because of apparent caution against flooding damage.

(2) *Flood Hazard Risk and Recognition of Disaster Information*

As shown in Figure 2, 61% of the answerers answered positively towards the question on "the risk of future flood hazards exist." This means that there is a strong fear among the residents about flood hazard. The main reason is because of the past experience of flooding, which consisted for 79% of all answers.

Generally speaking, the answers were composed of various reasons like "past experience", "existance of the river" and "the inadequacy of flood control facilities".

In these districts, some forms of information transmission methods like the flood hazard map and posters illustrating the flood hazard and flood prevention methods have been proposed by the National Government for the past two years.

There were only about 10-25% of all answerers recognized such informations. The contents of information which the residents wanted to known were "estimated area of inundation risk" which consisted 77% of all. The information regarding evacuation facilities, the flood hazard forecasting and warning system were needed by about 46% of all.

The major causes for the serious inundation problem are accumulation of large volume of water in a short time and inadequate drainage capacity.

As far as the interrelationship among the contents of questionnaire, are concerned there were statistical significance among the factors of recognition of flood

Table 3. Cross-Tabulation of Flood Hazard Risk by Other Items

Question	Flood Hazard Risk (%)		
	Yes	No	Unknown
1. Flood Hazard Map			
Known	29.1	21.6	16.0
Unknown	70.9	78.4	84.0
2. General Public Information			
Concerned	27.6	17.6	15.8
No Concerned	72.7	82.4	84.2
3. Permanent Settlement			
Hopeful	57.5	74.1	70.0
Hopeless	34.2	18.8	17.5
Unknown	8.3	7.1	12.5

hazard risk, the awareness of flood hazard map and of signboard for flood control information and other general notices. As shown in Table 3, the more the people informed of the flood hazard, the more becomes the awareness among the people.

(3) *Awareness of Structural and Nonstructural Measures of Flood Hazard*

The flood control measures which have wide acceptance this area are "the levees construction" and "the channel dredging" and both were accounted for 70% of all answerers. "the pumping facilities construction" and "the discharge restraint" were the second-best preference namely 30% and 29% respectively. "development restriction in low land" was expressed by 22% of all answerers and "large-scale floodproofing in low lands" was only supported by 7%.

Meanwhile, "Flood insurance establishment" was agreed by 43% as far as the level of the premium and compensation money are concerned and was required by 22% without any conditions. The answerers who desired "flood insurance system" emphasized the need in view of the attention to the general information about their community.

The Larger the awareness of the settled habitants, the more stronger is the feeling for more programes for old aged people. The desire among the residents to move to other area seemed to be more prevalent for lack of adequate improved sewerage facilities.

6. Study Conclusion

The collected original data were examined using abovementioned procedure and techniques. The conclusions are summarized as follows:

(1) *The Interrelationship between Flood Hazard Risk and Awareness of Flood Prevention*

The interrelation model between flood hazard risk and awareness of flood prevention was constructed as shown in Figure 3.

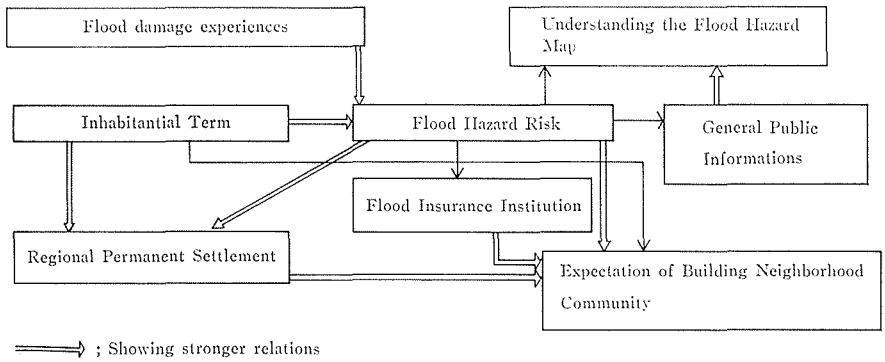

Figure 3. Descriptive Digraph Model of Awareness Structure for Flood Hazard.

(1) The degree of awareness of the flood hazards was observed to be varying with deffernt sections of people in terms of their duration of stay in that area and the frequency of exposure to the flood hazards. The new settlers of the area, though not aware of the hazards, by means of their constant communication with the old residents tend to understand the situation gradually.

Here, it is imperative to make new settlers aware of the hazards in advance with a lot of possible and simple imformations about flood hazards in that area.

(4) *Living environment and Residential Area*

High degree of satisfaction expressed for the parameters on living environment are "sewerage system extension" (44%). "a solid waste disposal system extension" (37%), and "medical service facilities" (21%).

Conversely, the degree of dissatisfaction was high in respect of "cultural facilities", "sports and recreational facilities" and "environmental improvement surrounding the housings".

The level of dissatisfaction with "the sewerage facilities" was also accounted for by 17% in the area fully covered with sewerage facilities and less in the area not fully covered and this disparity of sewerage service was found very large. The satisfaction level with respect to the flood control measures in the area was 12% and the dissatisfaction level was 21% of all ansewerers. As far as the evacuation activities of flood hazard are concerned, the satisfaction level was 1% and the dissatisfaction level was 35%. This result reveals that the residents have strong feeling of anxiety whenever the inundation occurred.

The residents who wished to continue to live in their present residences were 61% and those who wanted to live in other places were 27% of all. The expectation of the community towards improvement of the area were, "promotion of program for old aged" was 37%, for "industry and commerce advancement" 20%, for "flood control measure" 16% and for "sewerage extension" it was 16% respectavely.

2) The present information media like flood hazard map and other general informations are observed to be not very much relevant to the actual situation and also

Table 4. Level Division of Parameters of Living Environment

1. Highest Expected Level
A) Medical facilities
B) Solid Waste disposal facilities
C) Sewerage system
E) Flood prevention measures
2. Second-Highest Expected Level
F) Evacuation facilities
G) Transpotation network
H) Convenient shopping facilities
J) Neighborhood community relationship
K) Neighborhood Association activities
L) Cultural activities and facilities
M) Social order
N) Facilities for aged people
O) Community center activities
P) Disaster evcuation activities
3. Intermediate Expected Level
D) Noise and vibration countermeasures
Q) Sports and recreational facilities
R) Public environmental facilities
S) Availability of green zone
T) Importance of river environment
4. Expected Basic Level
I) Employment and Income

inadequate. In order to provide easy and adequate informations available to the residents in future efforts are needed to make the residents aware of the place, source and media of informations.

3) It is observed that there has been a phenomenal increase in the number of residents who are eager to know more and more details about the flood hazard situation. The existing system of information delivery needs improvement in terms of proper and adequate delivery of informations to the residents' needs.

4) The preference of the people to settle in new areas, not fully aware of the flood hazards, are basically out of the considerations for cheap land, easy accessibility to the downtown etc.. Information regarding flood hazards alone will drive the people to chose a different location. On the contrary, if the people are provided with informations like the future development programs for the area, the efforts that are underway to mitigate the flood hazards and schemes like flood insurance

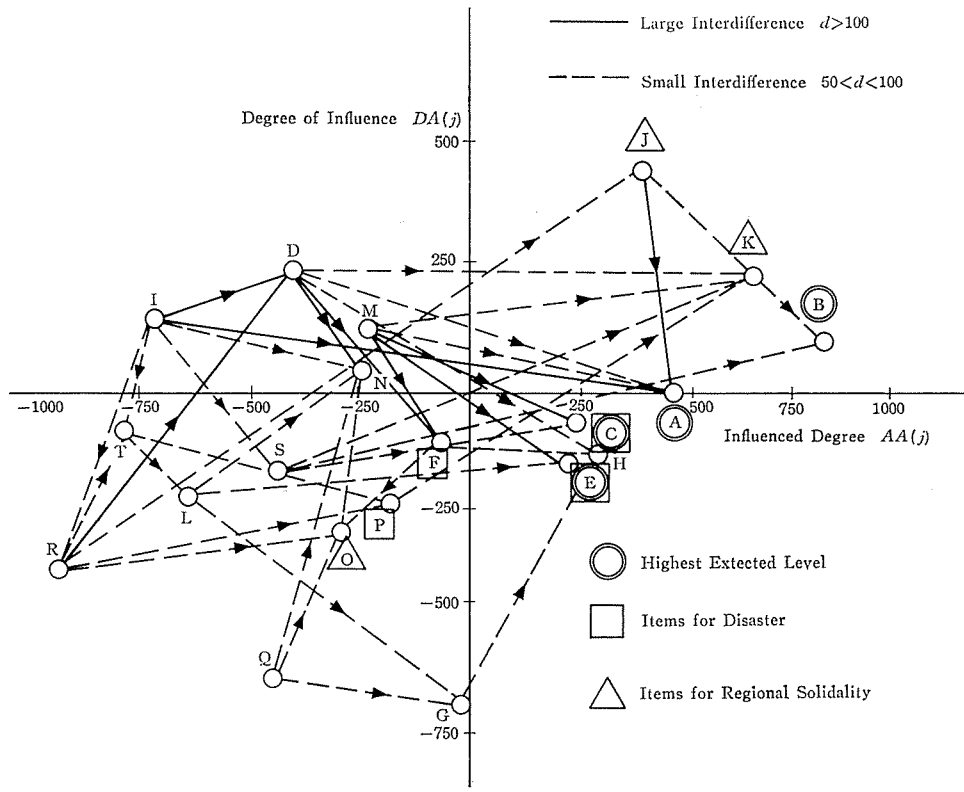

Figure 4. Structure of Items of Living Environment (Total Area).

system etc., the people will be better positioned to analyze carefully the situation before they chose a location. Therefore, it becomes essential to provide comprehensive information to the people.

(2) *Evaluation of Living Environment parameters*

The attributes of living environment considered for the study purposes are safety, health, accessibility, economy, social order, amenities, cultural and nature conservation.

In this survey twenty parameters were considered.

The structural modelings were carried out on the basis of the indices of high-degree level of expectation among interrelated parameters.

The results were shown for the whole study area and subareas.

1) In the case of whole area study, some of the highest degree of parameters were identified as medical facilities, sewerage systems, flood control measures and disposal facilities. These parameters belong to social amenities and were also evaluated highly. Conversely the parameters of employment and income system were ranked to the lowest level. The amusement, recreation activities and community activities were ranked to the low level.

2) Then the zoning regulations and influence were analyzed for both the urbanizing

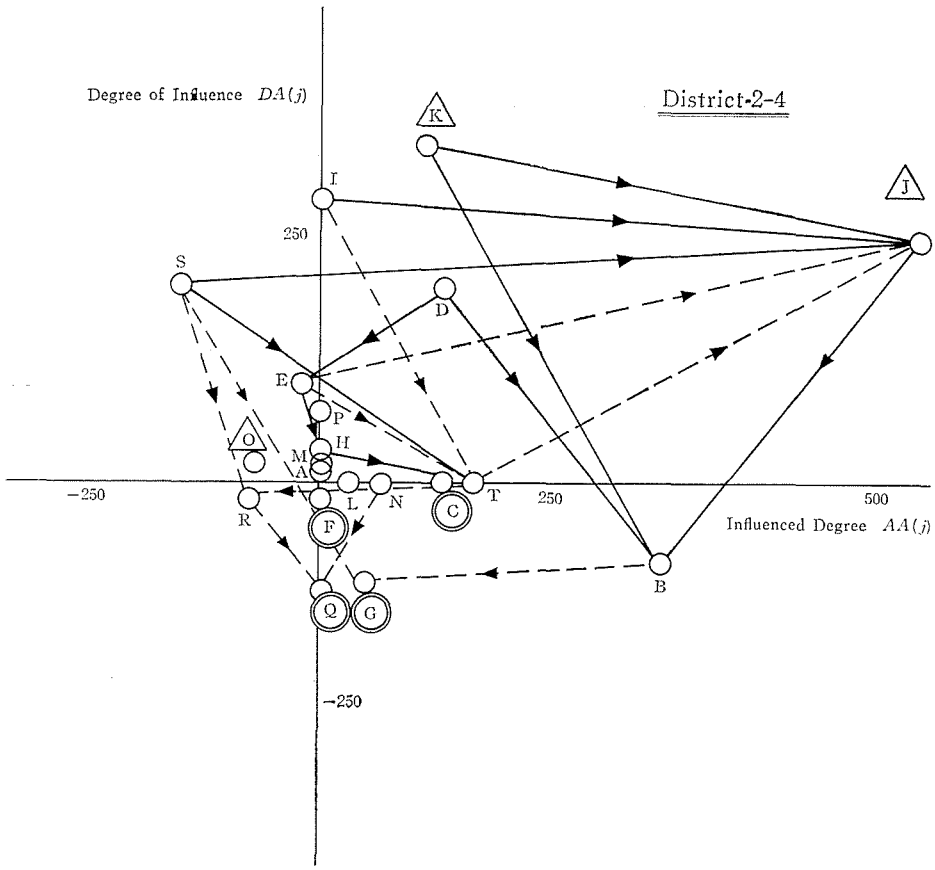

Figure 5. Structure of Items of Living Environment (A Example of a District in Urbanized Zone).

areas and restricted development areas. The comparative analyses of a urbanizing district and a urban development restricted district are shown in Figure 5 and Figure 6 respectively. According to these figures, in the case of the urbanizing area the higher level parameters were sewerage facilities, the transportation network, the sports and recreational facilities and the establishment of evacuation system.

In the case of urban development restricted area, improvement of the medical facilities, the solid waste disposal facilities and neighborhood community services are included.

As for disaster prevention, such parameters as control measures, sewerage facilities promotion, the establishment of evacuation lots were considered as important policies primarily. But the idea of the evacuation activities system was much difficult in both the cases of urbanizing area and the urban development restricted area.

The expectation level in the urbanizing area for evacuation facilities was higher than in urban development restricted area. This is because more often evacuations is done in the former area than the latter and there are many residents who had

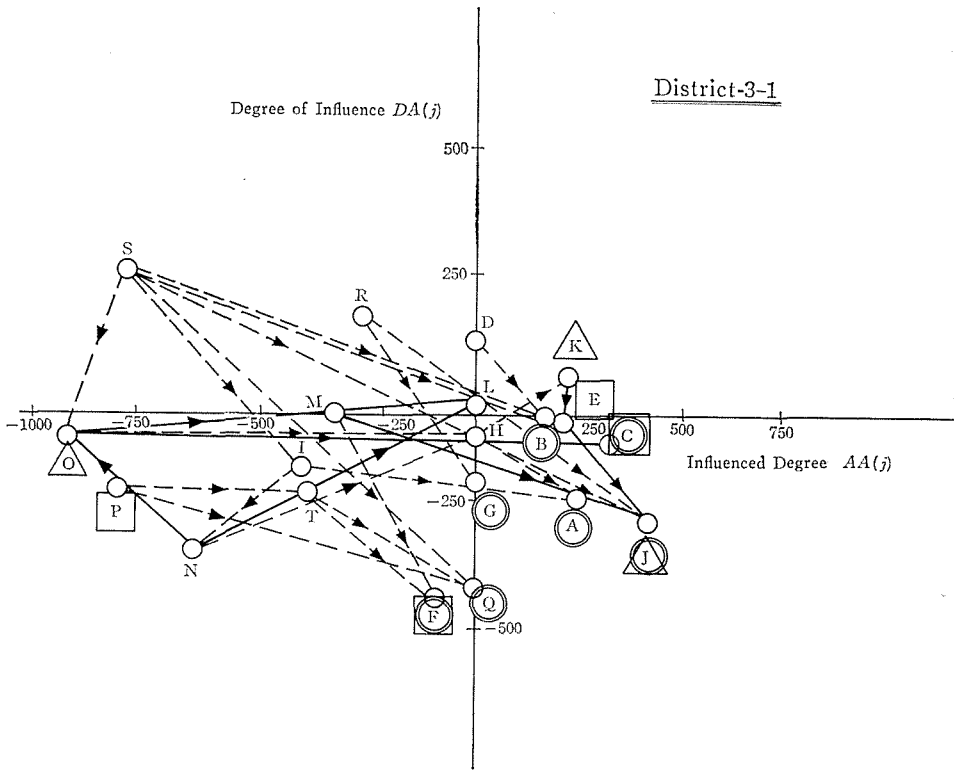

Figure 6. Structure of Items of Living Environment (A Example of a District in Urban-Restricted Zone).

lived in the latter area for a longer time.

Moreover in the urbanizing area the rate of participation in evacuation drill was higher as the residents in that area had many experiences of inundations comparatively.

7. Recommendations

As mentioned above, the opinions for living environment, the flood hazard preventioned and the consequences of disaster information were investigated by means of the questionnaire in the flood hazardous areas. As a result, it is observed to be imperative to attach importance to the parameters of disaster and disaster prevention along with the living environment. The residents' experiences of flood hazard are useful to enhance the consciousness of flood hazard prevention. This means that the public information system of flood hazard have infiltrated into these areas gradually.

The disparities in the knowledge of flood hazard risk and of the eagerness of the residents for flood control have been intensified slowly. The information system in one group is found to have chain of relationships like "the flood hazard risk"-"how to get the information on flood hazard"-"approval for flood insurance system"-

"expectation for community development" etc.. The other group does not seem to have such a system relevant to the flood hazard problem and the regional community development.

According to the survey of the living environment, there appeared greater expectation towards flood hazard control measures and solidarity of neighborhood community in this respect. This should be recognized as important requirement for community development and improvement of its conditions.

In a future study, the method for deciding the long term flood control planning or evacuation planning will be examined by means of the Expert System which composes of quantitative and qualitative data and reasoning theory.

The qualitative data will be mainly monitored by questionnaire form inhabitants in the flood hazardous areas.

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References

1) Kagaya, S. and E. Yamamura (1984): Structure of Flood Hazard and Residents' Awareness —Examples in Higashiku and Kitaku of Sapporo City— *Annual Report of Japan Society of Urban Study*, **17**: 66-83 (in Japanese).
2) Kagaya, S. (1982): Analysis and Evaluation of Structure of Flood Damage Based on Survey of Urban Inundation, *Proceeding of Hokkaido Branch of JSCE*, No. 38, 317-322. (in Japanese).
3) Mckay, J. M. (1984): Community Response to Hazard Information, *Disasters*, 8(2): 118-123.
4) Sakamoto, Y. (1981): Analysis on Categorical Data, *Mathematical Science* (*Suri Kagaku*) No. 213, 24-29. (in Japanese).
5) Toda, M. and Kaya Y. (1982): Structural Analysis of Structure on Awareness of Welfare, *Proceeding of Association of Metrology and Automation*, 18(1)23-49. (in Japanese).

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