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Studies on Analysis and Evaluation of Local Environment Utilizing Knowledge of Residents

by

SAYOKO KAWANO

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Supervisor: Professor Yoshiteru NAKAMORI

School of Knowledge Science
Japan Advanced Institute of Science and Technology

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Abstract

The purpose of the research is to develop methods of knowledge science with which we investigate environmental conditions of the southern part of Ishikawa prefecture. The developed methods include

1. a hard system modeling technique based on statistical data,

2. two soft modeling techniques to evaluate local environment by opinions of residents,

3. an integrated modeling technique that utilizes statistical data and opinions of people complementarily.

Chapter **1** is devoted to introducing the thesis with a special emphasis on management and integration of different types and levels of knowledge. Measurement and statistical data on economy and environment of Ishikawa prefecture in the past forty years has been gathered to develop a comprehensive system model. Three questionnaire surveys were carried out to collect opinions of residents in Ishikawa prefecture to utilize the so-called tacit knowledge in the residents. The former data is called the hard data, while the latter is called the soft data in the thesis.

Chapter **2** presents an integrated assessment model, which is called the environment framework model (EFM). The model expresses the relationships between socio-economic conditions, amount of wastes, resulted environment, and their feedback to the society. Due to the complexity of relationships and the lack of accurate data, we quantify only the first part of the model using the past forty-year data in Ishikawa prefecture. Forecasts by the developed model suggest that it is necessary to change the industrial structure for sustainable development.

Chapter **3** first introduces a questionnaire survey concerning to environment in the Ishikawa prefecture. Among the data, the chapter treats water environment in the southern part of the prefecture. A data mining technique was used to classify local areas and extract knowledge as a set of if-then rules, which evaluates water environment based on several qualitative conditions of local areas. Then, adopting the concept of the context model and the fuzzy set theory, a new model called the context fuzzy model is proposed here, which is useful to express context-dependency of knowledge as well as to estimate evaluation of people.

Chapter **4** uses the data obtained two questionnaire surveys that focus on water quality of a number of points. The purpose here is to grasp how points are evaluated and to

develop a soft model based on the soft data, that is, the model shows the average tendency of evaluation, and at the same time the vagueness in evaluation. The proposed technique is applied to the Hayashi's quantification theory type III. An idea of selecting important attributes in total evaluation is also proposed.

Chapter **5** considers how to integrate hard and soft data, especially to know what is needed for maintaining and improving environment. Results of hard modeling in Chapter **2** and soft modeling in Chapter **3** and **4** are applied to EFM to identify changes of the relation between environment and human activities.

Chapter **6** concludes the thesis. EFM has been treated only processes of human activities. Then, the thesis tried to run EFM with both hard and soft data. The thesis contributed to

1. utilizing EFM in Ishikawa (local authority),
2. proposing methods to extract people's knowledge,
3. combing hard and soft data on EFM.

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Chapter 1

Introduction

1.1 Background

1.1.1 Knowledge Science

We have two tasks as members in School of Knowledge Science. One is to develop each research theme of a member, and the other is to explore knowledge science. These aren't independent works. It means that each member studies his/her own theme with an approach of based knowledge science. Knowledge science is not a branch of learning but a method or methodology to connect plural fields. First, we think of knowledge.

It's said 21st century will be 'knowledge based' society [1]. Researches related to knowledge have attracted social attention. For example, in social society, a theory for knowledge creating in companies has proposed ([2], etc). Knowledge has defined as 'justified belief' and fallen into two types; one is tacit knowledge which shows experiential belief and feelings not expressed by words, the other is explicit knowledge which shows theoretical idea and logic expressed by words [3]. On the basis of these definition, [2] has explained a process knowledge creation and by SECI model and advantages Japanese companies had. In SECI model tacit knowledge of individuals is changed into explicit knowledge of an organization, and the explicit knowledge is changed into tacit knowledge in next step. In engineering, tools and computer systems have been developed for utilizing knowledge. But, researches using knowledge hasn't appeared suddenly. For instance, an interview survey which uses people's knowledge as data has been carried out.

How is knowledge collected? How is knowledge combined and integrated? How is new knowledge discovered and created? They are important problems in not only social science but also natural and information science. Knowledge we have is very subjective. The character makes us difficult to use knowledge, to treat knowledge itself such as understanding and acquirement. The thesis proposes a method of utilization knowledge in environmental problems in local area.

What is knowledge science added science to knowledge? Our School of Knowledge

Science defines knowledge science as 'new initiative that aims to discover both theoretical and practical principles of knowledge management (i.e., management of creating new knowledge and integrating it with existing knowledge), thereby developing new knowledge systems for decision making and problem solving' [4]. It gives specific examples of researches as follows;

- researches of creation and communication process of knowledge from the aspect of social science,
- researches of examination of decision-making and construction of information systems which help knowledge creation such as groupware from the aspect of cognitive science,
- researches of investigation of knowledge by approaches of complex systems and genetic information.

In short, knowledge science means a comprehensive and interdisciplinary approach in which we tackle a problem by combination of plural views and tools, 'integration of literature and science'. 'Synergy of arts and sciences', which means they work together and their synergistic effects generate new concept and paradigm, has been proposed as a concept of upper 'integration of literature and science' [5]. Based on above-mentioned items, a research of knowledge science should try integration first, then synergy of literature and science.

Based on some theories such as knowledge creating theory and data mining technique, we define data, information, knowledge and knowledge science as follows.

[**data**] Facts and recognition such as observation, experience and simulation results expressed by numerical data and text. The thesis divides into two kinds as described later; objective 'hard data' and subjective 'soft data'.

[**information**] It expresses data in an easy-to-understand way such as visualization of data. Data and information are sometimes same and sometimes different. For example, if numerical data are put into a tabular form or on a graph, numerical data changes into information.

[**knowledge**] It is systematized data and information, and acceptable. It is a relation among factors of data. It is useful judgment system and methodology guessed from data, information and existing knowledge easily.

[**knowledge science**] It is a method or methodology which analyzes and integrates objects and treats knowledge. To knowledge includes understanding knowledge itself, to grasp mechanism and to make systems for utilizing and creating knowledge, etc.

We suppose knowledge is obtained from data and information. When Person X transmits his/her knowledge to Person Y ($X \neq Y$), and X's knowledge is data/information for receiver Y. If Person Y accepts data/information he/she received, data/information becomes be Y's knowledge.

Figure 1.1 shows a process of 'data → information → knowledge'.

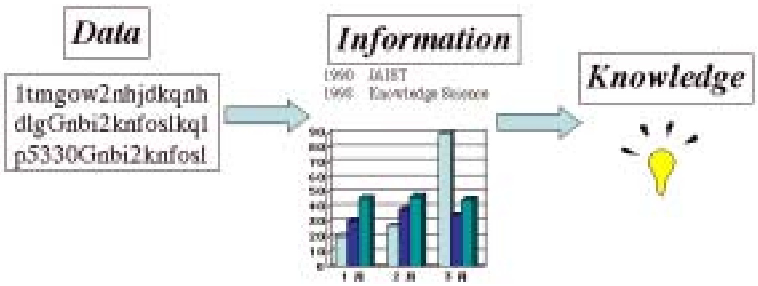

Figure 1.1: Data, information and knowledge.

'Analysis and integration' in above definition is based on [6]. [6] has divided science into two parts, which complement each other; One is analytical stream that emerges from traditions of experimental science, and the other is integrative stream that narrow the range of possibilities by generating and testing predictions. When one researcher tries to construct knowledge science, it is not difficult for him/her to adopt these two approaches compared to other approaches.

Can one researcher deal with a research used plural approaches or related to multiple fields, 'comprehensive research'? Hybrid approach has been proposed as one of comprehensive researches [7, pp.225-233]. It is outlined as follows along with other ideas.

1. collaborative research
   It shows an interdisciplinary research tackled collaboratively by some researchers who have studied different discipline.

2. T-shape model
   A researcher learns one discipline in a field, then expand his/her research to many fields [8]. It is regarded as the most feasible but next-best approach, because there is a possibility that in the model individual discipline constrains us.

3. hybrid approach
   A researcher chooses and uses needed tools (existing discipline, improved them and new developed discipline) from a various fields, then gradually increase tools he/she can use. If chosen tools include individual discipline, we need to understand a system and detail of the discipline to the extent that specialists of the discipline have it.

We believe hybrid approach is suitable for knowledge science which deals with one problem from multifaceted views. Perhaps some researches or fields have been treated with hybrid approach. Example of hybrid approach includes field research [7, pp.225-233]. The reason is that (1) it is necessary to use not one approach but also some methods and techniques in order to grasp condition of fields and explain relationship among factors and (2) field research includes plural works as field survey and data analysis.

This thesis does modeling by using statistical data and subjective data for local environmental problem. It treats local environmental problem as subject of research, then uses data collecting method, data analysis method and data explanation method as tools for analysis. This works contributes to analysis of subject without depending on one kind of data based on an approach of knowledge science.

1.1.2 Environmental Problems

The thesis uses environmental problems in local area as a base for knowledge science.

Today, our society is interested in environmental issues more than ever before. An origin of destruction of environment by human has dated back to ancient times when homo sapience appeared, and environment has been an inseparable part of civilization [9]. But, environmental problems have been treated as problems since Industrial Revolution, especially the World War Ⅱ. "Silent Spring" [10] that cautioned about natural destruction by human activities in U.S. and "The Limits to Growth" [11] that showed a danger of the global environment have roused public opinion for environmental issues. In Japan, after the War, in 1950's–1970's pollution problems ('Kougai' in Japanese) have been greatly social problems. The problems have led to making environment policies, developing environmental technologies and propelling Japan to advanced country in environment. In Europe and United States history of environmental activities has categorized periods into 3 parts; *nature* → *environment* → *ecology* [12]. In Japan *environment* has divided into 2 parts; *nature* → *pollution* → *environment* → *ecology* [13].

In this age of *ecology*, characteristics of environmental problems include as follows [7, pp.25-27];

1. both local problems and global-scale problems are treated,
2. approaches aim at compatibility between economic activities and environmental protection, harmonious coexistence of nature and humans for 'sustainable development',
3. not only cure for individual issue but also solution to problems in the whole social system including economy, society, policy and human is required.

Environmental problems are difficult to solve, because they are problem complex involved human, we can't distinguish between perpetrators and victims of problems, and individual factors interact with each other.

Knowledge and knowledge creation of environmental issues have the following problems;

- even if there are measured data and information, it is hard to grasp what they are, what relation they have, what is the most important of them, and how to obtain knowledge from them,
- some items don't have objective data because the data aren't impossible to measure.

It is meaningful to tackle above problems in the view of both a study of environmental issues and application of knowledge science. The thesis pays attention to the latter meaning especially.

We have two kinds of data in the environmental system. One is called hard data which mean numerical and objective data as statistical data and measurements. The other is soft data which mean subjective data as peoples' feelings.

Most of models for environmental problems have constructed by hard data. But, hard data of environment have some problems, for example, shortage and bias of measurement points, dependence on the property of points, etc. Moreover, hard data isn't familiar to general population although public institutes have had and published many measurements periodically. Researchers need to inform people about hard data and their meaning. Then, if it is possible to correspond hard data with soft data as peoples' feeling, more people understand the environmental condition deeply. Therefore, we try to grasp environmental condition by soft data in addition to hard data. It is important to utilize soft data, that is to say, "knowledge" people have on environmental systems in addition to hard data [14].

We evaluate local environment by using soft data, knowledge of residents. We carried out questionnaire surveys in Ishikawa to collect soft data. Then, we introduce approaches related to these data. First, we explain social survey and outline methods of environmental evaluation. Here, two types of methods are shown; political and economic approach. The following introduces environmental indicator, economic analysis and environmental impact assessment.

Social Survey

Social survey is defined as 'all processes in which we collect data by fieldwork and handle, analyze and describe the data' [15, p.3].

Figure 1.2 shows classification of social survey [15, p.14]. It is classified two types depending on how to handle data, and also classified two types depending on a range of object. There are some methods to collect data in response to methods to handle data.

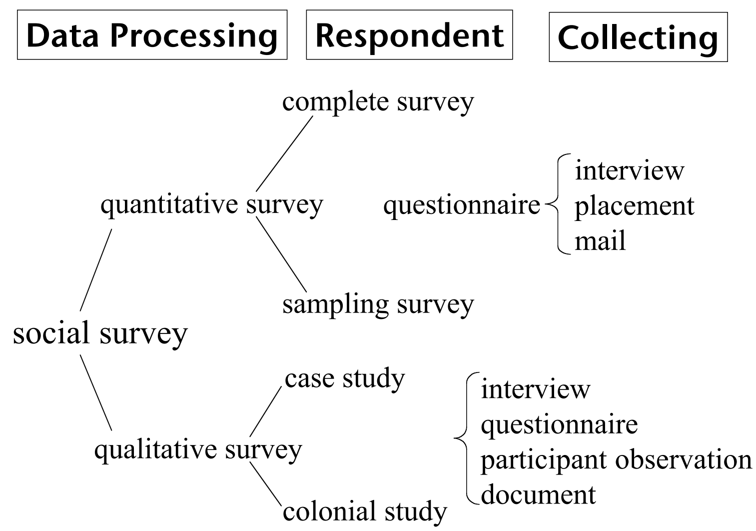

Figure 1.2: Classification of social survey.

But, for example, free association test [16] analyzes sentences which are qualitative data with statistical methods. Then, not all surveys are classified in the figure.

First, we explain a range of objects of each method. Complete survey covers whole of the population. An example is Population Census in Japan. But, it is difficult to take this survey. Therefore, sampling survey, which do survey after taking a sample from population, is often conducted. Case study covers small number of samples chosen from society or groups where a target event is occurred. Colonial study covers the whole region/colony.

Next, we describe methods to collect data. Interview is a method in which an investigator interviews subjects. Placement is a method in which questionnaire is placed to respondents and collected later. Mail conducts circularizing and collecting questionnaire by mail service. Participant observation is a method which an investigator takes part in activities of targeting group. Document is analyzed many documents.

Sampling survey is the most commonly used survey in all surveys. The reason is that the survey is easier to carry out than any other surveys when a survey which have to obtain data from many subjects. Random sampling is the most representative sampling method. But, some researches have been said, ‘It is impossible to get “*completely-random sample*”. Environmental researches have used case study effectively [7, pp.90–106].

We need to select a method of survey and treatment of data in accordance with purpose and application of a survey.

Environmental Indices/indicators

'Environmental indices' is defined as 'a measure to assess environmental conditions as quantitatively as possible' [17]. In environmental administration, environmental standard have played a role as standard to measure effects of policy quantitatively. But, environmental problems have included not only individual condition (ex. water and air quality) but also social items (ex. life environment) as factors. And, numerical data used as environmental standard has a limit depending on their features. Therefore, it has been hard to decide environmental policies by only environmental standard. Then, environmental indices, considered they could complement with or replace environmental standard, have been attracted attention.

The following describes environmental indices/indicators based on [17].

Index (indices) is dimensionless value, which normalizes variables and indicators or projects them to common scale. Here, indicator is a representative variable extracted from many variables and have a unit of original variable.

In 1970's, methodologies in which concentration of substances in water and air are normalized and consolidated developed. In addition to these production indices, social indices also developed to evaluate quality of our lives. For instance, Organization for Economic Co-operation and Development (OECD) proposed urban environmental indicators in 1979.

'Regional environmental management plan' established by local governments in 1980's resulted in adopting environmental indicators/indices to environmental policies. The plan include making integrated indicators/indices of environment by residents' consciousness and feeling in addition to adopting opinions of specialists and researches. Reasons of utilization of residents' knowledge include as follows; residents who are close to regions are utilized as 'environmental sensor', surveys are used as tools of communication with people.

Subjects of environmental indices/indicators have changed with transition of characters of environmental problems;
preventing pollution of water and air, etc → ensuring life quality in which we can maintain minimum health and living → seeking satisfaction to live a more comfortable life and sustainable development. Now is in a stage to seek sustainable development.

1980's, in which researches of environmental indicator/index were activity, was in a stage to seeking satisfaction to live a more comfortable life. In this time the researches were carried out across the country. Examples are as follows.

In Kitakyuushuu, surveys to residents about amenity in city have been carried out [17, pp.37-49]. Based on the answers, scores of satisfaction used statistical data as explanatory variable were estimated, individual indicator and total indicator were made. The result explained residents' consciousness by total indicators of amenity and the whole environment. In Kawasaki, residents have been regarded observers of environmental condition as well as the subject developing the method used the survey in Kitakyushu [17, pp.67-88]. Children and their parents evaluated neutrality such as plants and animals and amenity, then indicators were made by their answers. The research analyzed a relation between urban environment and evaluation of amenity and showed observation of environment was effective in making environmental indicator. Indicator made in Kitakyushu and Kawasaki treated total evaluation, but in Tokyo environmental indicator of water have made [17, pp.89-113]. First, the research typified water based on natural character. Next, specialists and administrators made value functions to evaluate measurement values which existed measurement data in each place. Indicators were calculated by value functions, then verified whether they grasped current condition by using surveys to residents.

In 1980's, Ishikawa prefecture also did researches of environmental indicator in the prefecture. Ishikawa Prefectural Institute of Public Health and Environmental Science [1] have studied environmental problems and carried out questionnaire surveys several times. For example, residents' evaluation for Sai-river and Asano-river [18], concept of amenity in life environment [19] and opinions for watercourses in the city [20] etc were analyzed. In [18], evaluators were taken Sai-river and Asano-river and analyzed the rivers. It was an interesting research.

Economic Analysis

Researches which analyze value of environment economically have attracted attention as one field in environmental evaluation. Environment doesn't have its cost, so that distribution of natural resources by free market causes overconsumption of environment, in other words, environmental problems. Therefore, environment needs to be given money value and be estimated to distribute natural resources appropriately.

The following is described based on [21, 22, 23].

Values are distributed in two values. *Use values* mean we can know the values directly, and *no-use values* is values not included *use values* such as value of eco system.

Environmental valuation methods are divided into two types. One is *revealed preferences* (RP) and the other is *stated preferences* (SP). RP is a method to value environment by asking people, and examples include *contingent valuation method* (CVM) and conjoint analysis. SP is a method to value environment by economic activities, and examples include *hedonic price method* (HPM) and travel cost method (TCM). Each method of SP has plural styles.

In RP, CVM gives respondents suppositive changes, asks willingness-to-pay (WTP) or willingness to accept compensation (WTA) or the changes and estimates environmental value. Example of questions include 'How much money can you pay in order to prevent

[1]http://www.pref.ishikawa.jp/hokan/

deterioration of water quality?', 'How much is money you can allow deterioration of water quality?'. One method makes people to describe cost freely and, the other method makes people to choose cost. Conjoint analysis was created in psychometrics. It has been developed in marketing research and applied to environmental economics etc. The method quotes many profiles which are combined attributes and analyzes respondents' preferences. For instance, cars are evaluated by combinations of color, size, engine displacement and price. Because RP does not use existing data but asks people about environmental value, it can treat *non-use value*. But, evaluation by people generates some weaknesses such as ambiguity and reliability. CVM is often considered that respondents are affected designs of surveys so that the method is not reliable. Conjoint analysis has many profiles if it has many attributes. People are confused and can't estimate important attributes correctly. Both methods have been improved in view of drawbacks.

In SP, HPM is based on consumer theory which postulates that every good provides a bundle of characteristics or attributes [24]. It observes a relation between environmental goods and price of a house or land. Hedonic price function is estimated by using price of land and labor cost as non-explanatory variable and attributes as explanatory variable, then environmental characteristics are valued. Examples of application include effect of improving rivers, park and transportation facilities. Because of much data of price of land, analyses treated urban area have been mainly carried out . TCM is primarily employed to estimate the demand or marginal valuation curve for recreation sites. It uses the cost of traveling to a non-priced recreation site as a means of inferring the recreational benefits which that site provides. SP can utilize existing statistical data and marketing data for estimation of value, but can't estimate *non-use values* such as ecological system.

Environmental Impact Assessment

In [25] Environmental Impact Assessment (EIA) is defined as a process of
(a) surveying, predicting, and assessing the likely impact that a project (hereinafter meaning changes in the shape of the terrain [including dredging being conducted simultaneously], and the establishing, modifying, and expanding of a structure for specific purposes), will have on various aspects of the environment (if the purpose of the project includes business activities and other human activities on the project land or within a project structure after the implementation of a project, the impact of such activities is included) (hereinafter referred to simply as "environmental impact");
(b) studying possible environmental protection measures relating to the project;
(c) assessing the likely overall environmental impact of such measures.
It is also a process in which businesses achieve accountability for society, and is a transparent system of an exchange of information because enterpriser, administrations and residents make decisions about the project.

The following describes EIA based on [26].

In 1969, National Environment Policy Act (NEPA) introduced EIA for the first time in the world. In Environmental Impact Assessment Law was established 1979 and enforced 1999 in Japan. Recently introduction of Strategic Environmental Assessment (SEA) has been considered in some countries. SEA is an assessment of not a project but an upper plan. Strategic means that decisions are made by considering a relation between the project and its purpose.

EIA uses system analysis method. Procedures include
investigation → *selection* → *analysis* → *forecast* → *assessment* → *explanation* → *decision.*

Analysis collects analyzes data of individual items. Some items are mainly used quantitative data such as water and air quality, and others are mainly used qualitative data such as ecological system and landscape. These items are assessed with an approach of environmental indicator and economic analysis. After analysis of individual items, total analysis is carried out. Analysis of the assessment clarifies problems of a project, then solution is considered. We have to consider as many as alternative plans possible. Each alternative is forecasted with a model and evaluated. Finally an alternative plan is selected in forecasted results.

Case examples of EIA include housing development in Netherlands, construction of Channel Tunnel Rail Link (CTRL) in England and a plan of wastewater treatment system in town of Jackson in U.S. Examples in Japan include a plan of Fujimae Tidal Flat (=Fujimae-higata) enforced the assessment law and development of Yebisu Garden Place. These cases were carried out before implementation of the Assessment Law.

Both EIA and the thesis have the following problems; development of methods for assessing items which only qualitative data, utilization of knowledge of specialist, etc.

1.2 Outline of the Thesis

The purpose of the research is to develop methods of knowledge science with which we investigate environmental conditions of the southern part of Ishikawa prefecture. The developed methods include
(1) a hard system modeling technique based on statistical data,
(2) two soft modeling techniques to evaluate local environment by opinions of residents,
(3) an integrated modeling technique that utilizes statistical data and opinions of people complementarily.

We use subjective data to evaluate environment. The approach is based on environmental indicator/index in the approaches of environment assessment introduced in the previous section. We don't aim at estimating value of environmental quality, so that we don't use economic analysis. Researches of environmental indicator/index have been evaluated amenity of our life by residents' consciousness. But, the thesis doesn't consider amenity here. It tries to discover a relation between numerical data and people's feeling by soft data. This is a different point from past researches.

In general, not all points have measured values. Then, we suppose

1. we make models to evaluate points which measured values have by both subjective and objective data,
2. we apply the models to points which only soft data have,
3. we can guess environmental condition of the points by subjective data.

In short, we suppose we obtain a model as follows; "If social situation is X, and geological situation is Y and measured value is Z in point W, then soft data is A there.". Chapter **3** calculates such models. It is hard to get models of all environmental issues, so that we have to narrow our focus. Therefore, we need to know what problems are in Ishikawa.

In accord with above-mentioned supposition, after a preliminary survey, we carried out a sampling survey (the survey in 2000). At first we supposed we would carry out an interview survey. But it depends on skills of interviewers and takes cost and time. Therefore our surveys were performed by mail. Based on the surveys, water problems were regarded as important in Ishikawa prefecture. A survey carried out by mail in 2001 limited an object. The survey had a character which was closer to case study than sampling survey. A survey carried out by questionnaire in 2002 was simple test. We aimed at analyzing data with statistical method, so that questionnaire surveys were meaningful. After the survey in 2000, there was a possibility that utilization of interview in addition to questionnaire would expand analysis.

Soft data of water quality didn't correspond to hard data of that. For instance, however hard data showed good values of environment in some areas, residents didn't give good evaluation there. Then, we examine combination of factors in evaluation of the whole water quality and features of each water environment.

The reasons why we consider environmental problems in Ishikawa (administrative in Japan) are as follows; it is important to deal with the problems in view of local environment management and an idea 'Think globally, act locally', our school is located on the prefecture, and there have been a few researches based on comprehensive approaches, etc. Ishikawa prefecture is introduced in next section.

Figure 1.3 shows outline of the thesis. It consists of 3 parts. Part.1 treats a modeling with hard data, Part.2 treats a modeling with soft data and Part.3 treats both of them.

Contents of each chapter are as follows.

Chapter **1** (this chapter) introduces the thesis.

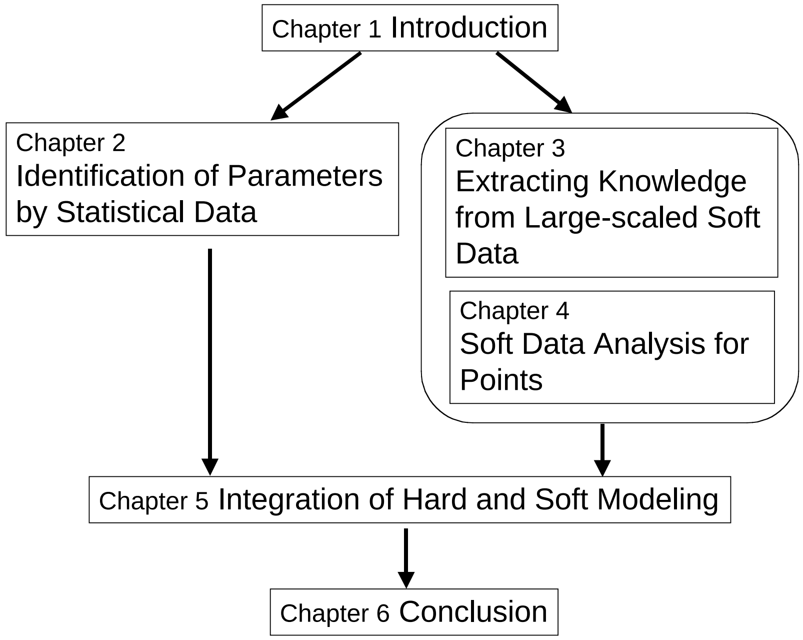

Figure 1.3: Organization of the thesis.

Chapter **2** treats a modeling with hard data. First, we describe Environmental Framework Model and apply it to Ishikawa prefecture. Processes of human activities and wastes are identified, in other words numerical expressions are obtained.

Chapter **3** and **4** treat modeling with soft data.

Chapter **3** first introduces a questionnaire survey concerning to environment in the Ishikawa prefecture. Among the data, the chapter treats water environment in the southern part of the prefecture. A data mining technique was used to classify local areas and extract knowledge as a set of if-then rules, which evaluates water environment based on several qualitative conditions of local areas. Then, adopting the concept of the context model and the fuzzy set theory, a new model called the context fuzzy model is proposed here, which is useful to express context-dependency of knowledge as well as to estimate evaluation of people.

Chapter **4** uses the data obtained two questionnaire surveys that focus on water quality of a number of points. The purpose here is to grasp how points are evaluated and to develop a soft model based on the soft data, that is, the model shows the average tendency of evaluation, and at the same time the vagueness in evaluation. The proposed technique is applied to the Hayashi's quantification theory type III. An idea of selecting important attributes in total evaluation is also proposed.

Chapter **5** considers how to integrate hard and soft data, especially to know what is needed for maintaining and improving environment.

Chapter **6** concludes the thesis.

1.3 Ishikawa Prefecture

This section introduces Ishikawa prefecture we treat in the thesis.

Figure 1.4: The location of Ishikawa prefecture.

Ishikawa is located on the north part in the center of east and west in Japan surrounded by the Sea of Japan and has elongate shape Figure 1.4. The area is about 4200[km^2]. It has the Japan sea side weather and a great deal of precipitation. It has no lack of water resources. More than 60 % of the area is occupied by forestlands, and more than 70% of them is occupied by mountain lands. There are a lot of kinds of plants and creatures including rare species. Ishikawa is the prefecture which richly endowed with nature.

Population is about 1,180,000. It means the prefecture is a medium-scale district. Primary production has reduced, and secondary and tertiary industries have increased. There are many productions of machine industry, textile industry and food [27]. But, recently secondary production has made little increase, so that tertiary production will account for more degree of gross product. Primary : Secondary : Tertiary=1 : 2 : 5. This is a ratio of production by using data in 1996. Energy consumption such as electric power and gas has increased.

Ishikawa prefecture publishes 'White Paper of the Environment in Ishikawa' to report environmental condition every year. In 2000, 'The plan to create eco-friendly Ishikawa' was introduced, which proposed specific strategies to approach to environmental issues. Now the prefecture is discussing constitution of 'Environmental Synthesis Regulation' (tentative name) which unifies plans related to environment and some regulations such as 'Basic Regulation for Environment'. The regulation is the first total regulations in Japan to deal with new measures such as building-recycle and environmental education. Therefore, a trend of this regulation attracts attention. In the prefecture an increase of a number of organizations such as Nonprofit Organization (NPO) addressing environmental problems shows a spread of activities to not only administrations but also citizens.

Environmental issues in Ishikawa have studied by research organizations such as Ishikawa Prefectural Institute of Public Health and Environmental Science, Kanazawa University and Kanazawa Institute of Technology. Researches which treat residents' feelings are introduced in the later chapter. Researches using an integrated model for Ishikawa haven't done. In recent years researches by cooperation of industrial, administrative and academic sectors have progressed, and they will be expanded from now on.

Chapter 2

Identification of Parameters by Statistical Data

This chapter is written based on Publication [2].

2.1 Introduction

Recently environmental problems have been important problems in our society. Researches to solve the problems have been conducted in a various fields. Studies have been divided into many fields, and only a few works have been done to cover plural fields. It is necessary for environmental problems to study a lot of sub problems totally. The reason is that environmental problems are very complex and large-scale problems including humans who are both observers and central players. Moreover, the problems consist of not 1 item but many items interacted each other. We need to consider the relation between environmental problems and sub systems based on economy, policy and nature in a social system.

Some researchers have developed 'Integrated Assessment Models' which are tools to evaluate variable items related to environmental problems on the whole and to make environmental policies. Typical 'Integrated Assessment Models' for the global warming problems are given in AIM [28], DICE [29], MARIA [30], MAGICC [31], NE21 [32], etc. They, one of which has reflected actual policy formation, are meaningful researches.

Studies by 'Integrated Assessment Model' have treated countries or wide regions such as plural countries. In contrast, the researches need to be applied to environmental problems in regions such as local authorities in Japan. The reason is as follows; it is important for us to act in local areas for environment ("Think globally, act locally"), and perception that to deal in only one problem doesn't contribute to improvement of problems on the whole is spreading government, NPO and residents etc. Therefore, a purpose of the research is to propose a method for treating local environmental problems by 'Integrated Assessment Model'.

We treat Ishikawa prefecture where our school is located. The prefecture has tried to not only make individual problems such as water, chemical materials and wastes better but also promote ecological education and business which are approaches surrounding the problems. Developing of methodology and technique to assist policy-making results in understanding a relation between environmental problems and factors which consist of the problems and forecasting the future condition. Major problems relevant to environment in Ishikawa were measures to flood of Tedori-river, pollution of Kakehashi-river by cadmium in 1970 and noise pollution around Komatsu Air Base, etc. Judging from measured values of water quality and air quality etc, environmental problems in the prefecture are not so much serious those in big cities. But, with no satisfaction of current condition, continual activities for maintaining/improving environment are required.

The chapter utilizes 'Environment Framework Model (EFM)' [33] as 'Integrated Assessment Models'. [33] has identified parameters with statistical data and done simulation based on analyses of scenarios. In this chapter, first environmental problems and data in Ishikawa are applied to the model. Secondly, numerical expressions which show human activities are identified and a result are examined. Finally, a limit of using numerical data is described and a method beyond the limit is proposed.

2.2 Environment Framework Model

'Environment Framework Model (EFM)' has proposed by Environment Agency of Japan [33]. The model, which treats human activities and environmental problems, is one of the 'Integrated Assessment Models'.

EFM has been constructed based on past data and current information, so that it has mainly used for analysis of present condition and a short-term prediction. The model has eight processes as shown in Figure 2.1. A matrix structure expresses these processes. Each circle in the figure means that there is a relation between one item and another. The eight processes are explained below:

1. **Basic Production Process**
   Population and gross production, which are initial values, lead primary, secondary and tertiary activities (food, industry, and service).

2. **Production Factor Process**
   Labor, capital, area of land and energy consumption, which are needed for production, are decided by inputs from 'Basic Production'.

3. **Waste Process**
   The amount of wastes generated by production is calculated.

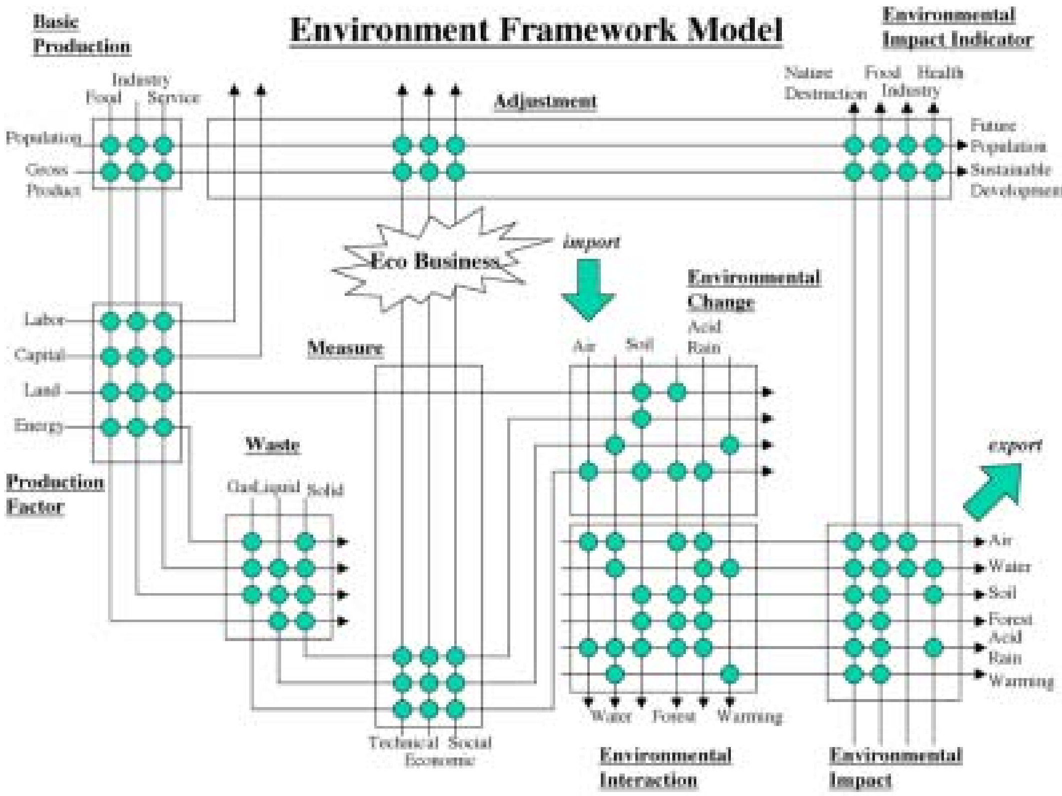

Figure 2.1: The environment framework model.

4. **Measure Process**

   This shows relations between environmental policies, productions and wastes. Policies are expressed by text data and experts knowledge in addition to numerical data as indicators.

5. **Environmental Change Process**

   Relations between environmental changes and human activities are described. Here environmental problems in Ishikawa include air pollution, water pollution, soil pollution, forest destruction, acid rain, and warming temperature.

6. **Environmental Interaction Process**

   The interaction among environmental problems is treated.

7. **Environmental Impacts Process**

   Impacts of environmental change on human beings and societies are presented.

8. **Adjustment Process**

   Adjustment of production activities with environment is estimated.

EFM, which simplifies the society, has some complicated processes. For instance, there are three processes related to environment; changes, interaction with others and impact on/by others. Therefore, it is very difficult for even specialists to grasp all processes of the model. Then some processes are reduced in the model. Figure 2.2 shows 'simple-environment framework model (s-EFM)'.

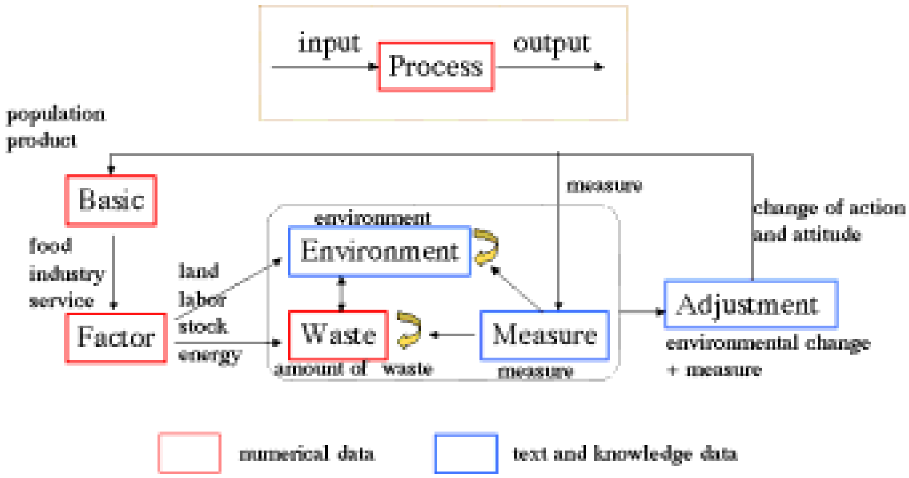

Figure 2.2: The simple environment framework model.

2.3 Parameter Identification

We identify numerical expressions in three processes in the left side of the model; 'Basic Production', 'Factor Production' and 'Waste'. Because these have numerical data, they can be expressed with mathematical models.

'If Industry doubles, energy consumption will quadruple.'. Cobb-Douglas type function formulates this idea as follows;

$$y = Ax_1^{\alpha_1} x_2^{\alpha_2} .....x_n^{\alpha_n}. \tag{2.1}$$

Here, y is an output, $x_1, x_2, \cdots, x_n$ are inputs, and A, $\alpha_1, \alpha_2, \cdots, \alpha_n$ are parameters. For example, in Basic Production process, population and gross production are used as input, food (industry, service) is used as output, and food (industry, service) is formulated by population, gross production and parameters. By the logarithmic transformation, Equation (2.1) becomes

$$\log y = \log A + \alpha_1 \log x_1 + ... + \alpha_n \log x_n. \tag{2.2}$$

By using

$$Y = \log y, \alpha_0 = \log A, X_k = \log x_k (k = 1 \cdots n),$$

we have

$$Y = \alpha_0 + \alpha_1 X_1 + \cdots + \alpha_n X_n. \tag{2.3}$$

Parameters are estimated from Equation (2.3) with a method of least squares.

$$\boldsymbol{\alpha} = (\boldsymbol{X}^t \boldsymbol{X}^{-1})\boldsymbol{X}^t \boldsymbol{y}. \tag{2.4}$$

Here, we used the notation:

$$\boldsymbol{X} = \begin{pmatrix} 1 & X_{11} & \cdots & X_{1n} \\ 1 & X_{21} & \cdots & X_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & X_{m1} & \dots & X_{mn} \end{pmatrix}, \ \boldsymbol{y} = \begin{pmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_m \end{pmatrix}, \boldsymbol{\alpha} = \begin{pmatrix} \alpha_0 \\ \alpha_1 \\ \vdots \\ \alpha_n \end{pmatrix}. \tag{2.5}$$

We use the above-mentioned expressions to identify parameters. For inputs $\boldsymbol{X}$ and outputs $\boldsymbol{y}$, actual measurements [27, 34, 35, 36, 37, 38, 39, 40] in 1955 or 1970–1996 are used.

After identifying parameters, we estimate outputs $\boldsymbol{y}$ by using these parameters and inputs $\boldsymbol{X}$. $\boldsymbol{y}$ is called 'predicted value.' The values are compared with measurements, and the correctness of the mathematical model is verified .

2.3.1 Basic Production

Initial values of the process are 'Population' and 'Gross production' shown in Figure 2.3–2.4. In the prefecture population have increasing for 40 years. There is a possibility that gross production is decreasing from 1996 on because of worsening economic situation.

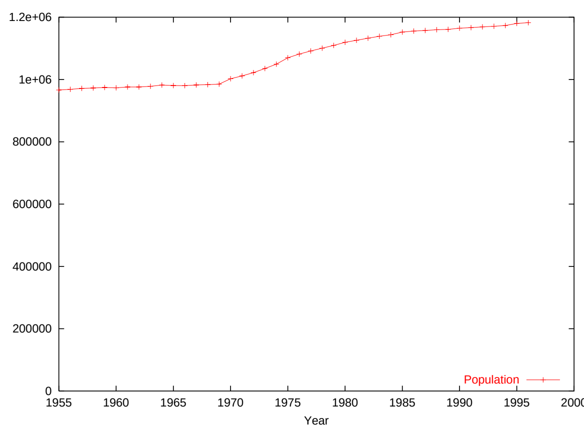

Figure 2.3: The number of population in Ishikawa.

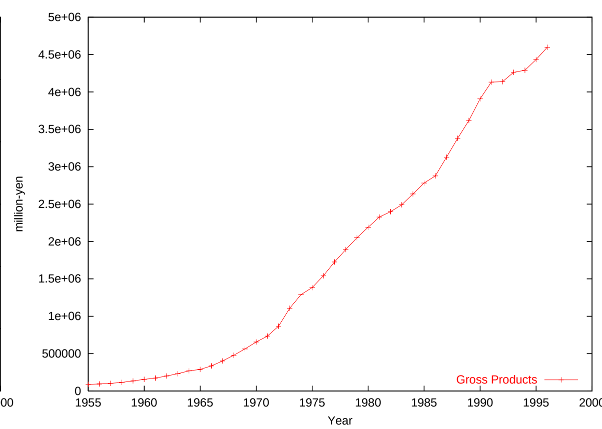

Figure 2.4: The gross production in Ishikawa.

Models in Basic Production are obtained as follows. 'Pop' and 'prod' indicate 'population' and 'production'.

$$Food = 1.721 * 10^{-5} * pop^{4.733} * prod^{0.3707} \ \ (1955 - 77), \tag{2.6}$$

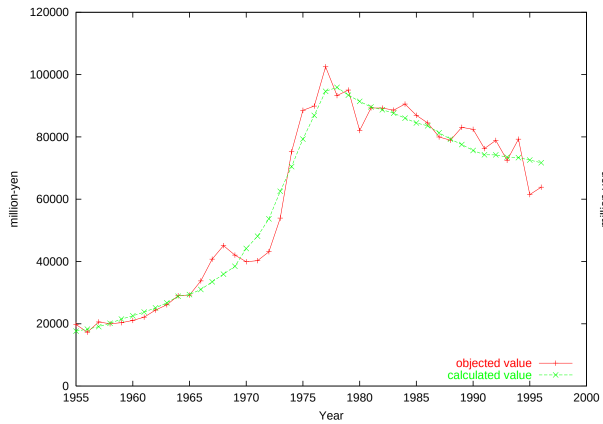

Figure 2.5: The production of *food* in Ishikawa.

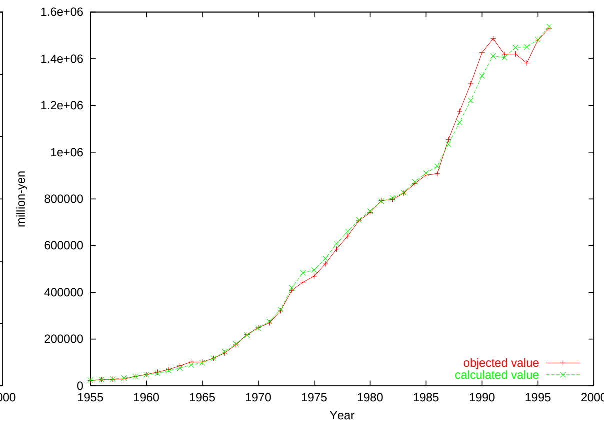

Figure 2.6: The production of *industry* in Ishikawa.

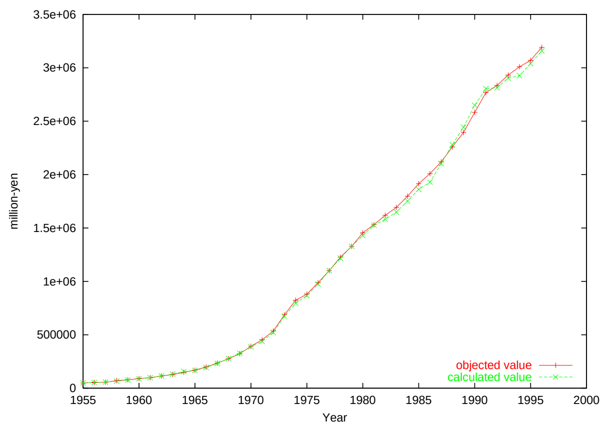

Figure 2.7: The production of *service* in Ishikawa.

$$Food = 5.799 * 10 * pop^{-4.126*10^{-2}} * prod^{-0.3244} \quad (1978-96), \qquad (2.7)$$

$$Industry = 2.296 * 10^{2} * pop^{-3.155} * prod^{1.206}, \qquad (2.8)$$

$$Service = 1.000 * 10^{-1} * pop^{0.7476} * prod^{1.014}. \qquad (2.9)$$

'Food' has two models, because the production of 'Food' has increased until 1978 and decreased since then. 'Food(1955–77)' and 'Industry' are strongly affected by 'Population'.

Figure 2.5–2.7 show measurements and predicted values of 'Food', 'Industry' and 'Service' by the model.

The expressions show that to grow tertiary industry as an industry which can be increased is one of effective measures even if population and gross production increase. In contrast, primary production is predicted decrease, so that clear decision-making and an effective measure are required in wanting what to take primary industry from now on.

Using the gross production in this process in the model identifies the amount of production of individual industries. But, there is an opinion that the reality is opposite to this view. The model has been constructed based on the idea which means production of individual industries is divided after establishing gross production, then we followed the idea.

2.3.2 Production Factor

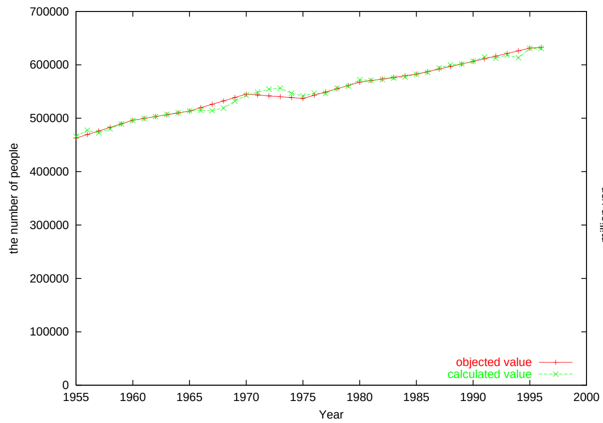

Figure 2.8: The number of labors in Ishikawa.

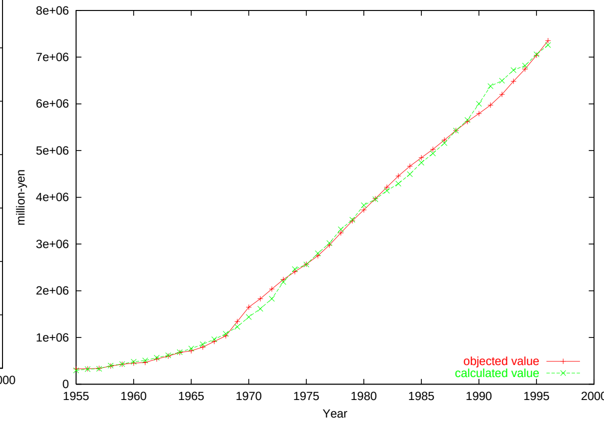

Figure 2.9: The stock in Ishikawa.

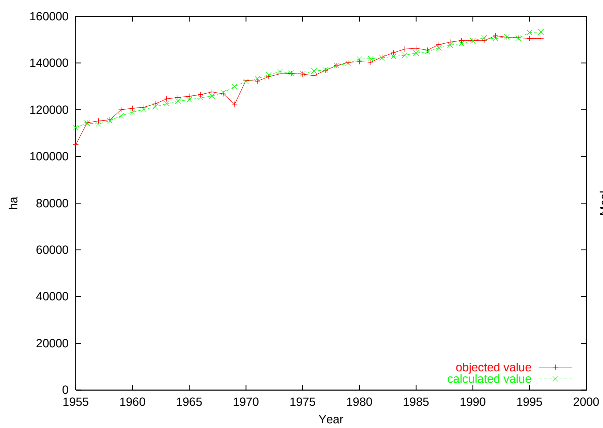

Figure 2.10: The area of lands in Ishikawa.

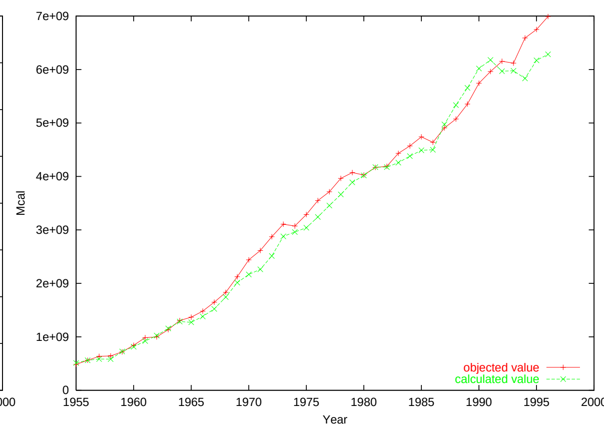

Figure 2.11: The energy consumption in Ishikawa.

We obtained the following models in ‘Production Factor’. Here, ‘Indu’ and ‘Serv’ means ‘Industry’ and ‘Service’, respectively.

Here, data of ‘labor’ interpolated because the data aren’t counted annually. ‘Capital’ hasn’t been calculated. Then, we estimated figures by using capital and gross product in Japan, gross product in Ishikawa and calculations by Socio-economic Research Center in Central Research Institute of Electric Power Industry [1] .

Let us show the interpolation here we used. There are data every k years. Year $Y_m, Y_n(k = Y_n - Y_m > 1)$ has data X_m, X_n. Data X_i in Year $Y_i(Y_m < Y_i < Y_n)$ is

[1]http://criepi.denken.or.jp/jpn/serc/

calculated by the following equation.

$$X_i = X_m + \frac{X_n - X_m}{Y_n - Y_m} * (Y_i - Y_m) \tag{2.10}$$

$$
\begin{aligned}
Labor &= 4.396 * Food^{-9.286*10^{-2}} * Indu^{4.381*10^{-2}} * Serv^{5.420*10^{-2}}, && (2.11)\\
Capital &= 0.887 * Food^{-7.932*10^{-2}} * Indu^{-2.332*10^{-2}} * Serv^{0.8097}, && (2.12)\\
Land &= 1.045 * Food^{-4.873*10^{-2}} * Indu^{4.409*10^{-2}} * Serv^{4.361*10^{-2}}, && (2.13)\\
Energy &= 3.548 * Food^{-3.889*10^{-2}} * Indu^{0.7033} * Serv^{-9.623*10^{-2}}. && (2.14)
\end{aligned}
$$

Figure 2.8–2.11 show the measurements and calculated values by the model.

Secondary production influences 'Capital' and tertiary production affects 'energy' a little greatly. It means it is necessary to reduce secondary production for constricting energy consumption, but this may cause decline of gross production. If we aim to continue increasing gross production, we have 2 measures. One is a measure which changes in industrial structures by increasing primary and tertiary production and decreasing secondary production. The other is a measure which lessens the burden on the environment such as reviews of production process in order to both keep/increase secondary production and reduce energy consumption. In addition these measures, we need to consider developing ecological industry (business) that reduces environmental burden of products and service.

2.3.3 Waste

The models in Waste Process are shown below, where 'IW' means 'Industrial Waste'.

As for carbon-dioxide (CO_2) emission outputs, data have only estimation values for two years in 1990 and 1995. Then, we estimated the data by gross production with a calculation method [40]. An amount of industrial wastes are taken a survey to businesses at 5-year intervals by the prefecture and the data are published. Data in years when it isn't investigated were interpolated. The interpolation is as the same as that used the previous section.

$$
\begin{aligned}
CO_2 &= 1.641 * Labor^{-2.850} * Capital^{0.844} * Land^{1.348} * Energy^{0.8685}, && (2.15)\\
IW &= 5.639 * 10^{-2} * Labor^{1.531} * Capital^{0.1040} * Land^{1.504} &&\\
&\quad *Energy^{0.1089}\ (1970-90), && (2.16)\\
IW &= 2.657 * 10^{15} * Labor^{-2.263*10} * Capital^{1.781} * Land^{-1.122} &&\\
&\quad *Energy^{3.812*10^{-3}}\ (1991-96). && (2.17)
\end{aligned}
$$

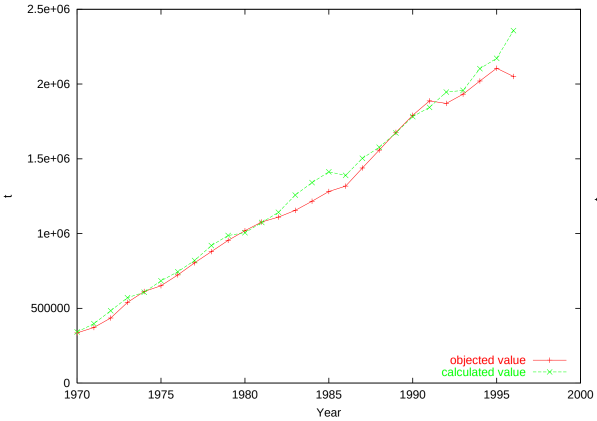

Figure 2.12: Carbon-dioxide emission outputs in Ishikawa.

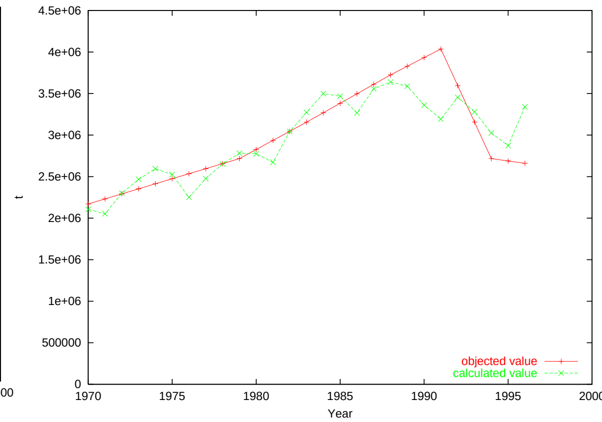

Figure 2.13: The amount of industrial wastes in Ishikawa.

We need to build models after dividing the period of 'Industrial Waste', because amounts of emissions decreased in 1990's.

'Labor' and 'land' influence 'CO_2' and 'Industrial wastes' a little greatly. Both 'Labor' and 'Land' are influenced by all industries almost equally (Equation 2.11, 2.13). As well as energy consumption, to reduce wastes required by coordinating relations among industries. It is possible that not only economy but also changes of how to measure wastes, implement of environmental policies (weight of wastes began to measure more exactly, classification of wastes were wrong, etc) and social interests in environmental issues resulted in reduction of industrial wastes in 1990s. Changes of parameters are regarded as effectiveness of environmental measures to some extent. But, some changes of environmental policies are unexpected. It suggests statistical (numerical) data isn't always corrected, namely there is a limit of statistical data.

Figure 2.12–2.13 show the measurements and predicted values by the model.

2.4 Summary

This chapter introduced Environment Framework Model (EFM) and calculated numerical expressions for processes of production activities and wastes in the left side of EFM by using actual measurements in Ishikawa prefecture.

In each process, we know 'predicted values' are almost consistent with measurements, in other words, models express relations in the real data. The results are effective as models which re-create the past based on the data.

The results show it is essential to change industrial structure and to do productive activities for maintaining environment condition. Not only households and companies but also society as a whole have to try to reduce energy consumption and wastes. To do so, companies and administrations need consider how we develop each industry.

An amount of general wastes which are produced garbage by households or small offices and were not treated in the previous section has leveled off in recent years. Therefore, measures for reducing wastes such as separating trash and using payable garbage bags and for providing awareness of wastes problems have carried out. But, a survey conducted in 2000 (in Chapter **3**) shows a few people do self-activities for environment although many people obey the rules determined by administration. Everyone of us needs change his/her consciousness and behavior as both workers and citizens.

Accuracy of predicted values with EFM are relatively good. We have two methods to forecast the future; One is to estimate presume that the current models are realized as they are. A possible scenario is calculated. The other is to change parameters. Changing combinations of parameters develops plural scenarios. In the chapter we adopted the first case. Calculation in which we presumed population and gross production would increase showed items except food production and industrial wastes would increase. The result is easy to imagine from the models.

If parameters are changed in the model expressions, sets of population and gross production as initial values are needed prepared. [41] predicts population in Japan will reduce from now on. Whether economic growth is needed is difficult to determine. For example, a researcher proposes construction of 'steady-style society', in other words zero growth society [42]. Inputs of gross production depend on how a person using the model considers.

How to determine parameters of model expressions in the future prospects is a big problem as above-mentioned. The reason is that calculation changes greatly depending on choice of combinations of parameters from a large number of sets. It is possible that we calculate with all combinations within a predetermined range of values but very inefficient. To determine parameters by one researcher's subjectivity is a possible method most early. Because it is easy but dangerous to use only one resident, developing a system to collect opinions of some researchers and calculate optimal parameters is required.

We have talked about the left side in EFM. From here, we think of the right side in the model. Models of processes related to only human activities have constructed in the left side. To grasp a relation between environment and our activities, namely to run the entire model, we have to consider influences of measures and environmental changes located in the right side. But, it is hard to identify parameters of these processes by using the method of Section **2.3**. The reason is that there are some items such as performed policies and interaction among issues which have no numerical data or can't be expressed numerically. And, numerical data of environment have the following properties;

1. all items related to environment don't have numerical data,

2. it isn't easy to understand the current condition by numerical data because of excess

and complication of them,

3. some data depend on the property of observation points.

We consider utilization of subjective peoples' knowledge as data except objective and numerical data. It aims to use EFM as an 'intuitive model' [43] to analyze local environmental problems connecting human activities with environment. Peoples' knowledge is usually applied to description of subjects. Even if a model is made from only numerical data, finally we use our knowledge to judge obtained results and their validity.

From next chapters, utilizing feeling residents who relate environment daily have as knowledge treats environmental processes in the right side in EFM. This work involves developing a method to extract knowledge of many evaluators to make evaluation models for environment and applying the method to data. Evaluation by people has the advantage of being capable of grasping points we can't understand by numerical data. But, it has some drawback. For example, even if two persons evaluate the same item, one person's evaluation is different from the others because of its subjectivity. Or even if they evaluate the item by the same expression, each meaning depends on 'context' they have. Considering these nature of subjective evaluation, we make models.

Chapter 3

Extracting Knowledge from Large-scaled Soft Data

This chapter is written based on Publication [1,5,7,8,10,11,12].

3.1 Introduction

In the chapter, we try to make models of environmental evaluation by utilizing results of questionnaire survey to residents as soft data and extracting knowledge which more people support or are convinced. First, we classify a target area in accordance with social properties by using statistical data. Then, rules are obtained in each cluster by SC-Optimality algorithms which is one of the methods for extracting rules of optimal approach in data mining technique. Hereby, we check whether environmental evaluation based on peoples' feeling affect characters of regions where residents evaluate or not, in other words, models depend on 'context' (it means the region) [44, 45].

We treat water pollution in Kaga area in Ishikawa prefecture which is in the south of the prefecture and consists of local authorities in the south part of Kahoku-gun. Now, in Ishikawa deterioration of water quality is one of big problems in the environmental issues [35].

In the following, we explain methods of calculating rules and outline of the questionnaire survey to collect soft data, and show and discuss results obtained from soft data. Established standard values of Biochemical Oxygen Demand (BOD; [mg/l]) which is used as hard data of water quality aren't met by lakes that are closed water area and a part of rivers and seas. Most of water areas are filled with standard values of BOD, so that they are regarded as relatively good condition. But, residents don't feel so judging from the survey.

3.2 Water Problems

3.2.1 Reasons of Treatment of Water Problems

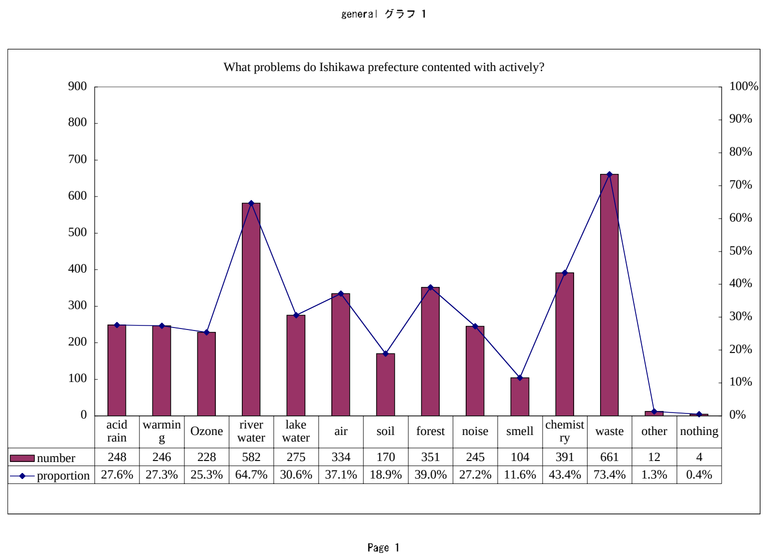

Figure 3.1: The result of problems Ishikawa prefecture contented with actively.

There are a lot of varieties of environmental problems. Ishikawa prefecture thinks water pollution is one of the most important problems, because all lagoons and a part of rivers don't meet standards of water quality [46]. And, a survey carried out in 2000 shows that residents think waste problems and water pollution are problems against which should be taken measures as quickly as possible we can (Figure. 3.1).

Moreover, many points of waterspaces have hard data of water quality, then it isn't difficult to compare hard data with soft data.

Therefore, we regard water problems as important.

3.2.2 Hard Data

In each prefecture in Japan, water quality is measured and published based on 'the Measurement Plan' and 'Water Pollution Control Law' every year. There are two measurement items; one is *life environmental item*, and the other is *health item*. *Life environmental item* includes Hydrogen concentration (pH), Biochemical Oxygen Demand (BOD [mg/l]), Chemical Oxygen Demand (COD [mg/l]), Suspended Solid (SS [mg/l]), Dissolved Oxygen (DO [mg/l]), number of coliform groups and n-hexane extracts, and has strong impact on our life environment. *Health item* includes many materials like cadmium, PCB, etc, and is related to our health directly. Many rivers, lagoons and seas have more than one measurement point of these items. In Ishikawa prefecture, all points of measurement for

Table 3.1: The relation BOD or COD and water conditions.

BOD or COD [mg/l]	conditions
< 1.0	There are no man-caused pollution in the water.
< 2.0	Mountain trout etc can live.
< 3.0	Salmon, Japanese trout and bull trout can live.
$3.0 \leq$	It is difficult to use as clear water.
$5.0 \leq$	Water lose self-purification capacity.
$10.0 \leq$	Water gives off an awful reek.

water quality are filled with standards of *health item*. But, some of points aren't filled with standards of *life environmental item*. For instant, about 80 % rivers meet standards of BOD value decided by the prefecture, but no lagoons meet standards of COD value. Water except lagoons are relatively in good condition from hard data.

In *life environment item*, BOD and COD are more common indices of water quality. 'White Paper of the Environment in Ishikawa' [35] has explained the water quality by BOD and COD. Specifically, BOD is the amount of oxygen necessary for bacteria's to decompose contaminants chemically into harmless matter, and used for rivers. COD is the amount of oxygen necessary when organic constituents present in the water are oxidized by oxidant, and used for lakes, lagoons and seas. The higher these values are, the more polluted the river or the lake or the sea becomes. In general, the relation between BOD, COD and water condition are in the following (Table 3.1. It shows 'Environmental Standard of Water Pollution' based on 'Water Pollution Control Law'.).

Because BOD and COD are used as one of representative indices for water quality, first, the thesis treats BOD and COD as 'hard data'.

Figure 3.2 shows a map of representative water in Ishikawa. Kahoku, Kiba and Shibayama are lagoons, Tedori (lake) is a lake and the others are rivers. The prefecture has many rivers including small rivers and watercourses water which don't appear in the map.

3.3 Data

We had two questionnaire surveys on environmental problems in 2000.

The first one is a preliminary survey to select effective questions which represent environment and supplement hard data. This was carried out as a part of a research project of our laboratory in August, 2000. We have sent questionnaires to about 280 residents in Tatsunokuchi where our school is located and about 300 people living near Kahoku-lagoon that is a highly polluted. Respondents were leaders in each local area of towns and cities. Therefore, most resident were men and more than 50 years old. About

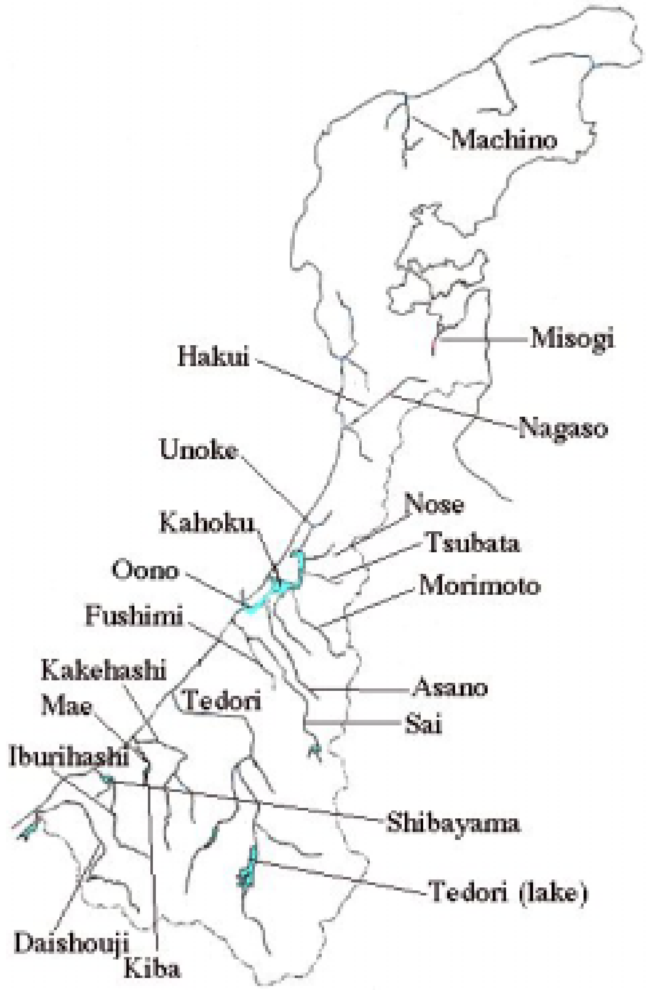

Figure 3.2: The map of rivers in Ishikawa.

200 people in each area answered the survey. Most of questions are multiple-choice tests and consist of small items and the *total evaluation* of water pollution, air pollution, wastes problems, environmental products, etc. The survey has more than 100 questions on the whole, so that it isn't easy to respond to. This is indisputable improvement.

The second one is the main test to collect many opinions and to build models for evaluation of environment. 3000 people received our questionnaire surveys in Kaga area in Ishikawa prefecture in December, 2000. Kaga area is in the south of the prefecture and consists of local authorities (4 cities, 13 towns and 5 villages) in the south part of Kahoku-gun. We selected 3000 people by using a random sampling technique from telephone books and sent questionnaires. 1081 residents replied them. Response rate was 36%. Finally effective replies were 900, because we removed them in which there were any no response questions as invalid. The survey has questions about water, air, wastes, echo marks and environmental policies. All questions are multiple-choice tests on a 1–5 scale. They have determined based on results of the first survey [47].

Hereafter, "survey in 2000" indicates the second one.

Short summary of the result by each field (water, air, etc) are the following.

[**water pollution**] More than 40 % of respondents evaluate water quality as 'bad'.

[**air pollution**] About 40 % of respondents evaluate air quality as 'bad'. But, there are few residents who think air pollution prevent them from living comfortable lives.

[**waste problems**] There are differences between consciousness and behavior. A lot of people play by the rules, but only a part of them voluntarily act environmental behaviors very much.

[**echo marks**] Awareness of newer marks is low. Many residents know major marks.

[**environmental policies**] Waste problems and water problems of rivers are regarded as important in the prefecture. Much supported problems depend on the regions.

The survey contributes to collecting and grasping residents' feeling widely.

Table 3.2 shows questions for making rules used as soft data. The questions are related to water quality and waterside. '0-' means '2000 (year)'. Where words that are *italicized* will be used as abbreviations of questions in the following sentences.

Table 3.2: Questions of survey in 2000.

0-1. Are there any *creature*s in the waterside?
0-2. Can you *play* in the water (ex. swimming, fishing, boating, etc.)?
0-3. Can you eat *fish* which you catch in this water?
0-4. Is the water *brown*?
0-5. Can you do barbecue or *camp* in the waterside?
0-6. Are there are pollutant *source*s near the water?
0-7. Are there any *plant*s in the waterside?
0-8. How do you evaluate the water quality *now*?

Answers are given in the 1–5 scale. The meaning of values 1∼5 corresponding to answers for the questions [0-1]–[0-8] is given in the Table 3.3.

We have used item [0-8]–[0-10] as *total evaluation* and [0-1]–[0-7] as *partial evaluation.*

3.4 Clustering of Regions by Hard Data

Kaga area where we carried out a questionnaire survey is mixed some regions which have different residential environment from others. Then, we divide local authorities (they mean towns, cities and villages) in Ishikawa prefecture and construct evaluation models

Table 3.3: The meaning of values of variables.

Question	Value	Meaning	Question	Value	Meaning
[0-1]	1	no with a high confidence	[0-8]	1	very bad
~	2	no with a low confidence	~	2	bad
[0-7]	3	neutral	[0-10]	3	medium
	4	yes with a low confidence		4	good
	5	yes with a high confidence		5	very good

for environment by every region (it means a cluster) [48]. Specifically, we do clustering regions by using hard data which show social and geological characters, and extract rules described with soft data by each cluster. The reason why we do this work is that we think that residents evaluation for environment are similar within regions where social and geological characters are similar. If we can relate the property of regions with soft data, it is possible to guess the environmental condition in the regions by residents' evaluation. It suggests that soft data can be applied to environmental evaluation as data which complement hard data.

As is well known, the objective of clustering is to divide a set of data objects into clusters such that objects within the same cluster have a high degree of similarity, whilst objects belonging to different clusters have a high degree of dissimilarity. Clustering techniques have been applied effectively in pattern recognition, modeling among others. The hard clustering is described by a conventional crisp membership function. This function assigns each object to one and only one of the clusters, with a degree of membership equals to one. However, the boundaries between the clusters are not often well defined and this description doesn't reflect the reality. Fuzzy clustering is meant to deal with the problem of (not well-defined) vague boundaries between clusters where the requirement of a crisp partition of the data is replaced by a weaker requirement of a fuzzy partition. Generally, the clustering techniques can be divided into hierarchical and nonhierarchical or partitioning methods. In our research, two algorithms in fuzzy clustering, namely the algorithm developed in [49] that is based on Ward's method [50] and the fuzzy c-means algorithm [51], have been used as representatives of these methods. Modelers will make a final selection of clustering results.

The hard data using for cluster analysis consist of statistical data which are collected by [52]. First we calculate the correlation matrix and delete one of the two attributes whose correlation coefficient is greater than 0.8. Finally we have selected 13 attributes by this way. Among them are the rate of diffusion of sewerage, the amount of burnable and recyclable wastes, the proportion of forested land, the proportion of field and rice field, the number of cars, the road length and the work force of primary industry, and so on.

The result by the Ward method is selected because the geological property is reflected well (Figure 3.3). In this result, regions which belong to the same cluster are located

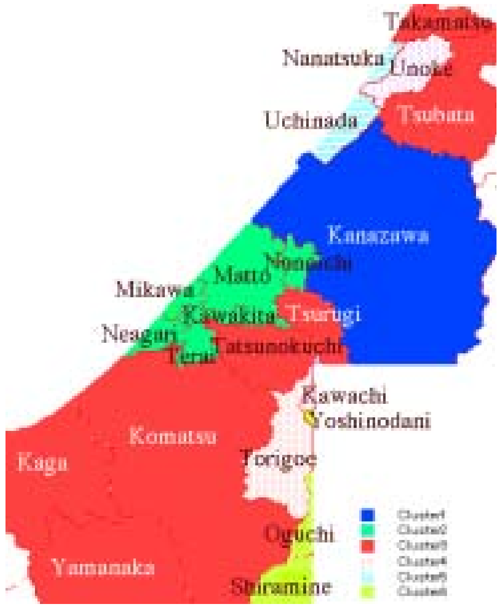

Figure 3.3: The map of Kaga area.

near by. It was difficult to find some meanings or knowledge by other clustering results. A suitable result should be selected by a modeler's subjectivity finally. The clustering result consists of six clusters corresponding to regions in Ishikawa prefecture as depicted in Figure 3.3.

Cluster 1 consists of only Kanazawa which is the biggest city has the most population in Ishikawa. This city has both a downtown area and vast forestlands. Cluster 2 (Matto, etc) gathers marine cities and towns in the southwest part of Kanazawa which develop both industries and agricultures. Cluster 3 (Komatsu, etc) gathers developing towns and cities which are surrounding Kanazawa geographically such as the second biggest city. Cluster 4 (Torigoe, etc) consists of a city and villages near Cluster 3 outside Kanazawa. Cluster 5 (Uchinada, etc) indicates seaside towns which are bedroom communities. Cluster 6 gathers villages at the base of Hakusan (it is the name of a mountain).

3.5 Method to Extract Rules Based on Association Rules and Decision Trees

The section explains a method to extract rules based on association rules [53, 54] and decision trees and shows results. We call the method 'Max Branch Method'. The section is written based on Publication [5,10,11,12].

The max branch method is an algorithm to find rules how *partial evaluation* are combined in the rules supported by more evaluators in the level of *total evaluation* we observe. First we change condition attributes from 5 levels into 3 levels, and repeat exploring rules which meet constraint conditions and decided *support*. In obtained rules by this algorithm, there are no *partial evaluation* whose evaluation values are 3 (neutral). The reason is that evaluation values are converted 3 scale (1 and 2, 3, 4 and 5), so that the number of *partial evaluation* evaluated as 3 are less. And, in this technique each level of *total evaluation* doesn't have plural rules. The reason why we reduced evaluation scales is that we can get only rules which there are a few condition attributes. The reason why we don't use *creature* and *plant* is that good evaluation is extracted from these items so that we can't find differences among rules if these items are used.

The max branch method is calculated as follows [55].

For example, in Cluster1, there are 71 people who evaluated total evaluation as 1 (=very bad). Table 3.4 shows their answers to questions about *partial evaluation*.

Table 3.4: 1st step of total evaluation=1 in Cluster1.

	play	*fish*	*brown*	*camp*	*source*
≤ 2	47	53	21	56	8
3	4	3	9	2	8
≥ 4	20	15	41	13	55
summary	71	71	71	71	71

We compare the number of the most respondents in each item. In this case, 56 (*camp*) >55 (*source*) >53 (*fish*) > 47 (*play*) >41 (*brown*). We select the most number, namely camp≤ 2 (56). The support of the item is 56/71=0.788.

Table 3.5 shows how to answer other 4 items except *camp* of the 56 respondents. We compare 46 (*fish*) > 44 (*source*) >41 (*play*) >33 (*brown*), then select *fish*≤ 2 (46). The support is 46/71=0.647.

Table 3.5: 2nd step of total evaluation=1 in Cluster1.

	play	fish	brown	source
≤ 2	41	46	18	7
3	3	1	5	5
≥ 4	12	9	33	44
summary	56	56	56	56

These works are repeated until support is less than the value we decided (0.4) or all items are selected, and we get rules. The rule of the sample is shown 'If *camp* ≤ 2 and *fish* ≤ 2 then *total evaluation*=1 in Cluster1.'. In the algorithm, to select variables and data from data set at the same time makes it possible to extract 'probable' rules (based on rule of majority) more people support.

We have obtained rules (Table 3.6) by this technique. Here, we take 40% for the support degree. The reason is that we judged this support is optimal in view of balance between support and the number of condition attributes. A rule in the line 1 in Cluster1 shows 'If *camp* ≤ 2 and *source* ≥ 4 and *fish* ≤ 2 then *total evaluation*=1 in Cluster1.'. In the table figures show the number of people.

Table 3.6: Rules by decision tree (Figures mean the number of residents).

condition 1		condition 2		condition 3		condition 4		condition 5		*total evaluation*	
Cluster1											
$camp \leq 2$	56	$fish \leq 2$	46	$play \leq 2$	38	$source \geq 4$	29			$now=1$	71
$camp \leq 2$	115	$fish \leq 2$	98	$play \leq 2$	78					$now=2$	162
$brown \leq 2$	99									$now=3$	139
$brown \leq 2$	86	$source \leq 2$	59							$now=4$	102
$brown \leq 2$	27	$source \leq 2$	26	$play \leq 2$	17					$now=5$	29
Cluster2											
$fish \leq 2$	7	$play \leq 2$	6	$brown \leq 2$	4					$now=1$	9
$play \geq 4$	25	$camp \geq 4$	17		1					$now=2$	38
$brown \leq 2$	24	$fish \geq 4$	16							$now=3$	34
$brown \leq 2$	13	$fish \geq 4$	10	$play \geq 4$	8					$now=4$	17
$brown \leq 2$	4	$fish \geq 4$	3	$play \geq 4$	2					$now=5$	4
Cluster3											
$source \geq 4$	46	$fish \leq 2$	37	$camp \leq 2$	24					$now=1$	55
$source \geq 4$	68	$camp \leq 2$	41							$now=2$	99
$brown \leq 2$	29									$now=3$	46
$brown \leq 2$	26	$camp \geq 4$	19	$fish \geq 4$	15					$now=4$	29
$brown \leq 2$	12	$fish \geq 4$	11	$play \geq 4$	10	$camp \geq 4$	9	$source \leq 2$	7	$now=5$	12
Cluster4											
$brown \leq 2$	2	$camp \geq 4$	2	$source \leq 2$	2					$now=1$	3
$camp \geq 4$	4	$fish \geq 4$	3	$play \geq 4$	3	$brown \leq 2$	3			$now=2$	5
$fish \geq 4$	3	$brown \leq 2$	3	$play \geq 4$	3	$camp \geq 4$	2			$now=3$	3
$brown \leq 2$	4	$play \geq 4$	4	$fish \geq 4$	3	$camp \geq 4$	3	$source \leq 2$	2	$now=4$	4
$camp \geq 4$	6	$fish \geq 4$	5	$brown \leq 2$	5	$play \geq 4$	4	$source \leq 2$	2	$now=5$	6
Cluster5											
$camp \leq 2$	4	$play \geq 4$	3	$source \geq 4$	2	$brown \geq 4$	2			$now=1$	4
$source \geq 4$	9	$play \geq 4$	8	$fish \geq 4$	6					$now=2$	11
$play \geq 4$	7	$camp \geq 4$	7	$brown \leq 2$	6	$fish \geq 4$	4			$now=3$	9
Cluster6											
$play \leq 2$	2	$brown \leq 2$	2	$source \leq 2$	2	$fish \geq 4$	2			$now=5$	2

Obtained rules show their characteristics in evaluation and in clusters. For example, in Cluster1–3, first contribution attribute of rules which have high *total evaluation* is *brown*. It means that evaluation for *brown* is similar, in other words, people who evaluate *total evaluation* as good in these clusters regard *brown* as important. *Source* in Cluster 1 and *fish* in Cluster 2 also are norms of evaluation in high *total evaluation*. In contrast, in low *total evaluation*, *camp* in Cluster 1 and *source* in cluster 3 have similar level. A number of condition attributes which consist of rules is small in *total evaluation*=2, 3 and large in *total evaluation*=4,5. *Total evaluation* which is supported by many residents has a lot of patterns of combination of items.

Most of the rules are acceptable comparing with *total evaluation*. But, there are some rules (ex. *play* ≥ 4 and *camp* $\geq 4 \rightarrow$ *total evaluation*=2 in Cluster 2) in which total evaluation and contribution attributes don't fit.

The method extracted and characterized rules of evaluation supported by more residents in evaluation or cluster. But, the method could obtain only 1 rule in each level of *total evaluation*. We needed to condition attributes (*partial evaluation*) from 5 scale into 3 scale, and consequently there weren't big differences among rules. Then, to improve these points and to obtain more characteristic rules in clusters, the next section extract rules by using SC-Optimality algorithm.

3.6 Method to Extract Rules by Using SC-Optimality Algorithm

The section explains a method to extract rules by using SC-Optimality algorithm [56] and shows results. The section is written based on Publication [1,7].

The purpose of the work in this section is to extract useful knowledge from quite large database in which respondents are 900 and attributes are 8. The knowledge is rule-based models which represent the relation among attributes related to environmental evaluation. We can make such models with existing data analysis as regression analysis, but it is hard to get plural and precision models by our data. Then, we used data mining technique as follows.

3.6.1 How to Extract Rules

Rules

Data mining technique is one step of KDD (Knowledge Discovery in Databases). KDD is the non-trivial extraction of implicit, previously unknown, and potentially useful information from data. In KDD, data mining is an actual discovery phase of a knowledge discovery process [57]. Here, knowledge is defined as 'a collection of interesting and useful patterns in a database relations and rules (patterns) among factors of data'.

A rule is shown as '$A \rightarrow C$ (If A, then C.)'. A is called *antecedent* and C is called *consequent*. When we evaluate rules, *support value* and *confidence value* are mainly used as indicators. *Support value*, denoted by $sup(A)$ and *support*, is equal to the number of records in the data set for which the condition evaluates to true. For example, $sup(A)$ is equal to the number of records in the data set for which A evaluates to true. The *support* of a rule $A \rightarrow C$, denoted similarly as $sup(A \rightarrow C)$, is equal to the number of records in the data set for which both A and C evaluate to true. *Confidence value* of a rule $A \rightarrow C$, denoted as $conf(A \rightarrow C)$ and *confidence*, is then defined as follows;

$$conf(A \rightarrow C) = \frac{sup(A \rightarrow C)}{sup(A)}. \qquad (3.1)$$

The more data are filled with the rules in the data set, the higher *support* is. The more the number of rules which *consequent* are the same are in the data set of the same *antecedent*, the higher *confidence* is. Reliability of rules is considered, *support* and *confidence* are important parameters.

It isn't easy to select better rules from many rules in data mining. Several algorithms to extract rules have been proposed and are classified into 3 categories;

1. constraint-based approach

2. heuristic approach

3. optimal approach

(1) is an approach to select all rules filled with minimum *support* or *confidence*. (2) is a hierarchical approach to select rules as typified by decision tree. (3) is an approach to select only the optimum or the most interesting rules.

SC-Optimality Algorithm

In this section, we try to extract the optimum rules in obtained rules by SC-Optimality algorithm [56]. SC-Optimality algorithm is a method which orders the rules based on SC-order after rules which are filled with the constraint condition are extracted. The reason why we utilize SC-Optimality algorithm is that we want to find important rules and narrow many rules down to opinions or knowledge more residents agree to when we consider that we reflect environmental evaluation by people in making policies.

SC-Optimality algorithm goes through the following process.

1. Rules which are filled with constraint conditions are extracted in the data set.

2. Rules are ordered by SC-order and rule r is compared with all rules in the rule sets R which are assumed to be the optimal rule set. If r is better rule than each rule in R or an incommensurable rule, then r is added to R and rules in R which are worse rules than r are removed from R. This work is repeated for all r. Finally, rules which are left in R are selected.

In step (1), Dense-Miner algorithm [58] which is one of the methods to extract rules are adopted. Dense-Miner is a constraint-based algorithm, which selects rules that are satisfied with constraint conditions in huge and dense data set. In addition to *support* and *confidence*, the notation called improvement are used as an indicator of rules, denoted as follows;

$$imp(A \rightarrow C) = min(conf(A \rightarrow C) - conf(A' \rightarrow C)) \tag{3.2}$$

Here, $\forall A' \subset A$.

Dense-Miner algorithm is the following method;

1. By using set-enumeration tree search program, sets of items are enumerated formed branches of trees.

2. Items are checked whether the constraint conditions (minimum *support*, minimum *confidence* and minimum improvement) are met with or not.

Rules selected by Dense-Miner algorithm are ordered by SC-order.

Based on both *support* and *confidence*, a partial order on rules, denoted as $\leq_{sc}$ (SC-order) is defined as follows. Based on both *support* and *confidence*, a partial order on rules, denoted as $\leq_{sc}$, is defined as follows. Given rulesr_1 and r_2, $r_1 <_{sc} r_2$ if and only if:

- $sup(r_1) \leq sup(r_2)$ and $conf(r_1) < conf(r_2)$, or
- $sup(r_1) < sup(r_2)$ and $conf(r_1) \leq conf(r_2)$.

In addition, $r_1 =_{sc} r_2$ if and only if $sup(r_1) = sup(r_2)$ and $conf(r_1) = conf(r_2)$.

If

- $sup(r_1) < sup(r_2)$ and $conf(r_1) > conf(r_2)$ or
- $sup(r_1) > sup(r_2)$ and $conf(r_1) < conf(r_2)$,

then r_1 and r_2, can't be compared by $\leq_{sc}$ and both rules are selected.

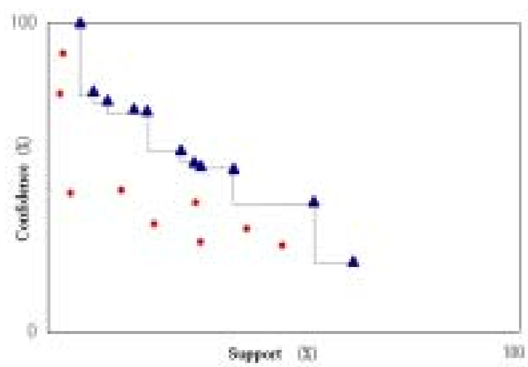

Figure 3.4: The comparison of rules based on *support* and *confidence*

For example, *support* and *confidence* of rules from some data are shown in Figure 3.4. r_i ($i \in \{1, 2, \cdots, m\}$) are rules denoted ▲, and q_j ($j \in \{1, 2, \cdots, n\}$) are rules denoted ●. Because any r_i are compared each other, all are selected. But, any q_j inside the border connected with any r_i aren't selected as optimal rules, because $q_j \leq_{sc} r_i$.

Application to Environmental Problems

Studies of 'environmental indicator' are one of representative studies used soft data [17] in Section **1.1.2**. The researches show environmental condition comprehensively based on data and opinions of specialists and residents. Some of results have utilized to design 'regional environmental management plan' in prefectures and city governments.

And, there are some researches which analyzed water environment based on surveys for residents. [16, 59] have used 'Free Association Test' to analyze water environment. The method had residents written their impressions of water environment freely. Obtained answers were done with cluster analysis based on neighbourhood method which calculates the similarities of words. The studies brought out residents' images of the water. Their images depended on their living places and their values.

Recently, due to the large quantity of data related to environmental issues, data mining techniques have been also used to learn transparent understandable rules from data in environmental studies [55, 60]. Our approach is meaningful as one of the applied instances used data mining techniques.

3.6.2 Results

Rules from Soft Data

We describe forms of rules which have obtained by soft data.

Table 3.7: The proportion of appearing attributes ([%]).

Cluster/attributes	*creature*	*play*	*fish*	*brown*	*camp*	*source*	*plant*
Cluster 1	45.0	25.0	28.3	53.3	33.3	53.3	26.7
Cluster 2	26.7	16.7	53.3	26.7	16.7	26.7	20.0
Cluster 3	39.2	21.6	21.6	37.3	47.1	56.9	39.2
Cluster 4	47.6	23.8	23.8	23.8	23.8	38.1	33.3
Cluster 5	10.0	40.0	10.0	30.0	30.0	10.0	0.0

By using SC-Optimality algorithm in the Section **3.6**, rules are extracted in the region classified in the Section **3.4**. *Partial evaluation* ([0-1]–[0-7]) are regarded as condition attributes and [0-8] are regarded as decision attributes, then we extract rules which show the relation between *partial evaluation* that are factors for judging water quality and *total evaluation*. *Antecedent* of rules consists of condition attributes and their values for evaluation, and *consequent* of rules consists of decision attributes and their values for evaluation.

As noted in the Section **3.6.1**, all rules that can't be compared by $\leq_{sc}$ are obtained. Table 3.8 – 3.12 show the number of data and rules whose *support* is more than 10% and which aren't inclusive relation with other rules in each cluster. But, if there are no rules whose *support* is more than 10%, Table shows rules whose *support* is more than 5%. Here, inclusive relation means as following; If one rule is " *brown* is 1 and *play* is 5." and the other rule is " *brown* is 1.", then they are inclusive relation and Table shows only *brown* is 1 and *play* is 5.". We don't make rules of Cluster 6 and *total evaluation* is 4 or 5 in Cluster 5, because there are a few test subjects.

For example, the 1st line of Cluster 1 in Table 3.8 means that "If *play* is 1 (=people don't want to play in the water), and *brown* is 5 (=water is brown), and *source* is 5 (=there are pollutant sources near the water)", then *total evaluation* is 1 (=very bad). *Support* is 12.7% and *confidence* is 75%.". *support* is the degree of the number of data supporting this rule for the number of data which evaluate *total evaluation* as 1 in Cluster 1. *confidence* is the degree of the number of data supporting this rule for the number of data which meet the *antecedent* (*play* is 1, and *brown* is 5, and *source* is 5') of all data in Cluster 1.

Table 3.7 shows the degree of the number of appearances of *partial evaluation* in each cluster for all rules in the cluster. For instance, 27 rules in 60 rules (60 is the sum of the number of rules which evaluates *total evaluation* as 1, 2, 3, 4, 5.) include 'creature (=$\{1, 2, \cdots, 5\}$)' in Cluster 1, therefore $27/60 * 100 = 45.0\%$. In many cases, one rule consists of plural rules so that in the same cluster the sum of the degree of partial items aren't equal to 100%.

Consideration

In this section, in each cluster rules from soft data are considered.

[Cluster 1 (Kanazawa)]

Rules are shown in Table 3.8.

The number of items which are included in one rule is more than that of other clusters. Especially *source* and *brown* account for more than 50% of the number of appearances. On the other hand, there are a few numbers of appearances of attributes which show the familiarity with watersides such as *play* and *fish*. *brown* and *source* are included in rules of each level of *total evaluation*, and evaluation values of these attributes are different by the level of *total evaluation*. *plant* and *creature* are always given high evaluation regardless of the level of *total evaluation*. It can be guessed that *plant* and *creature* don't affect *total evaluation* very much.

Cluster 1 (Kanazawa) has both a downtown area and vast forestlands, in other words, there are a variety of conditions surrounding water spaces. Therefore, in this cluster, attributes related to watersides and neighbouring in addition to water quality itself have impacts on *total evaluation*.

Table 3.8: Rules of Cluster1 (Kanazawa): Data number 503.

condition1	condition2	condition 3	condition 4	condition 5	condition 6	*now*	*support*[%]	*confidence*[%]
total evaluation=1, data : 71, rules : 12.								
play=1	*brown*=5	*source*=5				1	12.7	75
fish=1	*brown*=5	*source*=5				1	18.3	72.2
play=1	*camp*=1	*source*=5				1	21.1	71.4
fish=1	*camp*=1	*source*=5				1	32.4	53.5
total evaluation=2, data : 162, rules : 13								
play=1	*fish*=1	*camp*=1	*source*=4			2	11.1	85.7
creature=2						2	17.9	52.7
brown=4						2	24.7	50
total evaluation=3, data : 139, rules : 10								
creature=5	*brown*=2	*source*=3				3	7.9	78.6
creature=5	*brown*=2	*plant*=4				3	8.6	54.5
total evaluation=4, data : 102, rules : 15								
brown=1	*source*=2	*plant*=5				4	10.8	64.7
camp=5	*source*=2					4	12.7	61.9
play=5	*brown*=1	*camp*=5				4	13.7	53.8
brown=1	*camp*=5	*plant*=5				4	14.7	53.6
total evaluation=5, data : 29, rules : 10								
creature=5	*play*=1	*camp*=5	*source*=1			5	10.3	100
creature=5	*fish*=5	*brown*=1	*camp*=5	*source*=1	*plant*=5	5	17.2	71.4

[Cluster 2 (Matto, etc)]

Rules are shown in Table 3.9.

fish is an important because this attributes appear in each level of *total evaluation*. '*source*=4 (=There are pollutant sources.)' are included in the level of *total evaluation*=4 or 5. Attributes which are related to recreation don't appear less than other attributes. In cases where *total evaluation* is high value (4 or 5) there are no *play* in rules. It means that evaluation for *play* varies widely.

Cities and towns belonging to this cluster are close to the sea and have a famous river that is familiar for fishing. And, recently this area has developed as both industrial zone and agricultural zone. Therefore it's understandable that *fish* and *source* frequently appears in rules. *Total evaluation* by residents affects regional attributes clearly.

[Cluster 3 (Komatsu, etc)]

Rules are shown in Table 3.10.

Source and *camp* appear more times. And, *creature* and *plant* are given high score in every level of *total evaluation*. These characters are similar to Cluster 1. Cluster 3 includes the second biggest city. It is likely that the features about attributes are common to relatively large regions.

In the level of *total evaluation*=5, evaluation for *camp* are divided. The number of appearances of *fish* is less than that of other attributes. In this cluster there are two types of waters; one has relatively low BOD and the other has relatively high BOD. Properties of

Table 3.9: Rules of Cluster2 (Matto, etc.): Data number 102

condition1	condition2	condition 3	condition 4	*now*	*support*[%]	*confidence*[%]
total evaluation=1, data : 9, rules : 7						
play=1	*fish*=1	*brown*=1	*plant*=5	1	22.2	100
creature=1	*fish*=1	*brown*=4		1	22.2	100
fish=1	*source*=5			1	22.2	100
creature=2	*brown*=1	*plant*=1		1	22.2	100
total evaluation=2, data : 38, rules : 7						
fish=2	*source*=4			2	15.8	100
fish=2	*plant*=4			2	15.8	10
brown=4	*camp*=2	*source*=4		2	21.1	80
plant=2				2	39.4	65.2
play=5				2	44.7	43.6
total evaluation=3, data : 34, rules : 8						
fish=3	*plant*=1			3	11.8	100
play=3				3	17.6	85.7
creature=3				3	26.5	60
fish=5	*brown*=1			3	29.4	55.6
source=3				3	32.4	44
camp=1				3	35.3	41.4
total evaluation=4, data : 17, rules : 6						
creature=4	*fish*=5	*source*=4		4	29.4	100
creature=4	*camp*=5	*source*=4		4	29.4	100
fish=5	*camp*=5	*source*=4		4	47.1	57.1
total evaluation=5, data : 4, rules : 2						
creature=5	*brown*=1	*source*=4		5	50	66.7

'camp, and *fish* indicate the following items; Rules reflects different of waters, evaluation for water quality is one thing and evaluation for recreation is another, and residents don't think in pollutant water they do some fishing and eat fish.

[Cluster 4 (Torigoe, etc)]

Rules are shown in Table 3.11.

This cluster consists of 1 town and 2 villages. The villages are located adjacently, but the town is far from these villages. In the town residents evaluate the current condition (0-8) as 2 (bad) or 3 (medium) . In one village residents give *total evaluation* 4 (good) or 5 (very good). All levels (1–5) of *total evaluation* are given in the other village. Values of condition attributes in rules for the low level of *total evaluation* are good (ex. "*brown*=1 and *camp*=5"). It tends to be given high *total evaluation* for low *partial evaluation*. However there are some water which have good water quality , residents evaluate water quality strictly.

creature is most frequently used in rules of all attributes. However, there are no attributes which the number of appearances is small. Each attribute appears in rules almost equally.

Table 3.10: Rules of Cluster3 (Komatsu, etc.): Data number 241

condition1	condition2	condition 3	condition 4	condition 5	*now*	*support*[%]	*confidence*[%]
total evaluation=1, data : 55, rules : 20							
play=1	*brown*=5	*source*=5			1	10.9	85.7
brown=5	*camp*=1	*source*=5			1	16.4	81.8
total evaluation=2, data : 99, rules : 8							
camp=2	*source*=5				2	12.1	75
brown=2	*source*=4				2	13.1	65
camp=1					2	34.3	48.6
total evaluation=3, data : 46, rules : 6							
brown=3	*camp*=3				3	10.9	100
play=4	*camp*=4				3	13	46.2
creature=5	*brown*=1				3	28.3	33.3
total evaluation=4, data : 29, rules : 7							
brown=1	*source*=4	*plant*=5			4	10.3	100
creature=4	*camp*=5	*source*=2			4	10.3	100
total evaluation=5, data : 12, rules : 10							
play=1	*brown*=1	*camp*=1	*plant*=5		5	16.7	100
creature=5	*fish*=5	*camp*=5	*source*=1	*plant*=5	5	33.3	66.7
creature=5	*brown*=1	*camp*=5	*source*=1	*plant*=5	5	33.3	66.7

[Cluster 5 (Uchinada, etc)]

Rules are shown in Table 3.12.

We show rules in the level of *total evaluation*=1,2,3, because only one respondent evaluate *total evaluation* as 4 (good) and 5 (very good). The number of attributes included in each rule are a few, and there are different evaluation values in *partial evaluation* in the same evaluation value in *total evaluation*. This cluster has the most polluted lagoon and is closed the sea, so that soft data represent which points as the nearest watersides residents evaluate. In the level of *total evaluation*=2 (=bad), each rule consists of attributes which mean 'environment is good' except *brown*=4 (water is a little brown.). Then, in this cluster color of water is main factor to reduce evaluation value of *total evaluation*.

[Totality]

Considering calculated rules by each cluster, we found that condition attributes of Cluster 1 and 3 which include large cities are different from those of other clusters. Table 3.13 compare *support* and *confidence* of some rules in Cluster 1,2,3 (Cluster4 and 5 have a few respondents so that data in these clusters aren't used.). For instance, a rule "*play*=1, *brown*=5, *source*=5 $\rightarrow$ *total evaluation*=1" is extracted in Cluster 1 and 3 marked with ★. Then, *support* and *confidence* of this rule are both 0% in Cluster 2.

In this table, we know that rules selected in Cluster 1 (Cluster 3) are also selected or have high *support* and *confidence* in Cluster 3 (Cluster 1), but have low *support* and

Table 3.11: Rules of Cluster4 (Torigoe, etc.): Data number 21

condition1	condition2	condition 3	condition 4	*now*	*support*[%]	*confidence*[%]
total evaluation=1, data : 3, rules : 1						
play=4				1	66.7	33.3
total evaluation=2, data : 5, rules : 3						
creature=2	*brown*=3	*plant*=4		2	40	100
brown=1	*camp*=5			2	60	27.3
total evaluation=3, data : 3, rules : 2						
creature=5	*play*=5	*plant*=5		3	66.7	33.3
play=5	*fish*=5			3	100	30
total evaluation=4, data : 4, rules : 8						
creature=5	*play*=5	*plant*=4		4	25	100
creature=5	*fish*=5	*source*=1		4	50	66.7
camp=5	*source*=1			4	50	66.7
creature=5	*source*=1	*plant*=5		4	50	66.7
creature=5	*brown*=1	*source*=1		4	50	66.7
creature=5	*fish*=5	*camp*=5	*plant*=5	4	75	50
creature=5	*brown*=1	*plant*=5		4	75	50
total evaluation=5, data : 6, rules : 7						
camp=4	*source*=1			5	33.3	66.7
camp=5	*source*=4			5	33.3	66.7
play=5	*source*=1			5	33.3	66.7
creature=4	*fish*=5			5	33.3	66.7
fish=5	*brown*=1	*plant*=5		5	66.7	44.4

confidence in Cluster 2. Contrarily, rules selected in Cluster 2 have low *support* and *confidence* in Cluster 1 and 3. Put simply, attributes which consist of *total evaluation* in Cluster 1 and 3 are different from those in Cluster 2.

In Cluster 2, 4, 5, residents apt to evaluate water quality strictly, in other words, they feel the water is 'dirty' even though hard data of it isn't bad. In the level of *total evaluation*=2 (=bad) or 3 (=medium) in Cluster 1-3 where many local authorities belong, two kinds of rules are mixed; one consist of condition attributes which have good evaluation values, and the other consist of condition attributes which have bad evaluation values. The formation of *antecedent* of the rules depend on points residents observe.

People regard attributes related to water itself as important in Cluster 4 and 5. But, if these regions are urbanized (ex. population increase, industry are developed, etc) such as Cluster 1 and 3 in the future, waterside and circumstances may be main factors when residents evaluate water quality.

We found rules in clusters affect features each region from the result in this section. Therefore, we can argue that the algorithm for extracting rules is efficient and evaluation by residents is useful for evaluating environment of regions.

We outline the section. SC-Optimality algorithm has been mainly used to extract rules from a lot of subjective data (numerical data) ever. In the thesis, we have used this

Table 3.12: Rules of Cluster5 (Uchinada, etc.): Data number 26

condition1	condition2	*now*	*support*[%]	*confidence*[%]
total evaluation=1, data : 4, rules : 3.				
brown=4	*camp*=1	1	50	100
play=5	*camp*=2	1	50	100
total evaluation=2, data : 11, rules : 5.				
brown=4	*camp*=4	2	36.4	100
play=4		2	36.4	100
fish=4		2	36.4	100
creature=5		2	63.6	46.7
total evaluation=3, data : 9, rules : 2.				
source=2		3	55.6	100
play=5		3	77.8	43.8

algorithm to extract optimal rules from a database including objective data and gotten better results. The reason is that we could obtain more reliable rules based on support and confidence which are important attributes when we judge rules. Obtained rules reflect features of regions, in other words, we can construct models for evaluation of environment which depend on regions as 'context'. And, we could improve problems of max branch method in the previous section.

3.7 Context Fuzzy Model

The section explains a method to extract fuzzy models based on context model (context fuzzy model) and shows results. The section is written based on Publication [8].

3.7.1 Outline

The motivation of a context model stems from the observation that the origin of imperfect data is due to situations, where we are not able to specify an object by an original tuple of elementary characteristics because of the presence of incomplete statistical observations. For example, when water quality is evaluated, there is a difference between 'good' evaluation respondent k_1 who is familiar with River O_1 (not polluted river) gives and evaluation by the same word respondent k_2 who is familiar with River O_2 (polluted river) gives, in other words, 'good' has meanings which depend on 'rivers $\in \{O_1, O_2, \cdots\}$'. We obtain the context model considering the differences of meanings contexts have.

[61] has introduced the context model as an approach to the representation, interpretation, and analysis of imperfect data. Then, [62, 63] have expanded the approach. This theory has been not applied to real problems very much. Examples include a research

Table 3.13: The comparison of *support* and *confidence* of Cluster1, 2, 3

Cluster	*support*[%]	*confidence*[%]
play=**1**, *camp*=**1**, *source*=**5** $\rightarrow$ *total evaluation*=**1**		
★ Cluster 1	12.7	75
Cluster 2	0	0
★ Cluster 3	10.9	85.7
creature=**5**, *brown*=**1**, *camp*=**5**, *source*=**1** $\rightarrow$ *total evaluation*=**5**		
★ Cluster 1	24.1	53.8
Cluster 2	0	0
Cluster 3	41.7	55.6
play=**1**, *fish*=**1**, *brown*=**1**, *plant*=**5** $\rightarrow$ *total evaluation*=**1**		
Cluster 1	2.8	16.7
★ Cluster 2	22.2	100
Cluster 3	0	0
creature=**5**, *brown*=**1**, *source*=**4** $\rightarrow$ *total evaluation*=**5**		
Cluster 1	3.4	7.7
★ Cluster 2	50.0	66.7
Cluster 3	0	0

which have made context models to relate evaluation of water quality by residents with measured data [64]. The research show the relation total evaluation of water quality and BOD in contexts by membership functions.

In this section, we develop a context based fuzzy model for evaluation of local environment, which permits us to incorporate linguistic knowledge learned from soft data into the model with a closely connectedness to hard data.

In [63], the authors have considered a context model for fuzzy concept analysis as follows: $Con = \langle D, C, A_C(D) \rangle$ where D is a domain of an attribute *at* which is applied to objects of concern, C is a non-empty finite set of contexts, and $A_C(D) = \{a | a : C \rightarrow 2^D\}$ is a set of linguistic terms associated with the domain D considered now as vague characteristics in the context model. For example, consider D which is interpreted as the domain of the attribute *water quality*, C is a set of contexts such as cities or towns, and $A_C(D) = \{$*very dirty, dirty, normal, clear, very clear*, $\ldots\}$. Each context determines a subset of D given as being compatible with a given linguistic term. Furthermore, we also associated with the context model a weighting function or a probability distribution W defined on C. As such we obtain a valuated context model $Con_k = \langle D, C, A_C(D), W \rangle$.

By this context model, each linguistic term $a \in A_C(D)$ is semantically represented by the fuzzy set A as follows;

$$\mu_A(x) = \sum_{c \in C} W(c) \mu_{a(c)}(x) \tag{3.3}$$

where $\mu_{a(c)}$ is the characteristic function of $a(c)$. Intuitively, while each subset $a(c)$, for

$c \in C$, represents the c's view of the vague concept a, the fuzzy set A is the result of a weighted combined view of the vague concept.

To obtain membership functions which show linguistic terms $a \in A_C(D)$, we extend the notion of context model by taking into account the soft data distribution in contexts. This can be done as follows.

- $C = \{c_1, c_2, \ldots, c_5\}$:the set of contexts,
- $A = \{A_1, A_2, \ldots, A_7\}$: the set of *partial evaluation* variables,
- $W = \{w_1, w_2, \ldots, w_5\}$: the set of weightings associated with contexts respectively,
- $Q = \{q_1, q_2, \ldots, q_5\}$: the set of values of the total evaluation values,
- $Q_k = \{q_1^{A_k}, q_2^{A_k}, \ldots, q_5^{A_k}\}, k \in \{1, 2, \ldots, 7\}$: sets of values of *partial evaluation* k in total evaluation m.

In the section, C is a set of clusters in Section **3.4**, and W, which is Ω approximation in Equation (3.3), is a proportion in which a number of respondents in each cluster is divided into all respondents. We have not used the soft data collected for cluster 6 as only few residents in this cluster sent back us their answers to questionnaire.

For each $k \in \{1, 2, \ldots, 7\}$, we define a context model as follows

$$Con_k = \langle Q_k, C, Q, W \rangle, \tag{3.4}$$

where for each $q_j \in Q$, we associate a context c_i with the following mapping

$$\begin{array}{rcl} f_{c_i}^{q_j} : \; Q_k & \longrightarrow & [0,1] \\ & \longmapsto & f_{c_i}(q_l^{A_k}), \end{array} \tag{3.5}$$

such that

$$\sum_{l=1}^{m} f_{c_i}^{q_j}(q_l^{A_k}) = 1. \tag{3.6}$$

In fact, f_{c_i} is the data distribution of variable A_k within cluster c_i. It is defined as follows;

$$f_{c_i}^{q_j}(q_l^{A_k}) = \frac{N_i(q_l^{A_k}, q_j)}{\sum_{l'=1}^{5} N_i(q_{l'}^{A_k}, q_j)}. \tag{3.7}$$

Here, $N_i(q_l^{A_k}, q_j)$ is a number of people who evaluate A_k as $q_l^{A_k}$ and *total evaluation* as q_j in cluster c_i.

This means that different contexts have different data distributions of a *partial evaluation* variable A_k for the same *total evaluation* q_j. It should be also worthwhile to recall that in the definition of context model, for each q_j, a context c_i would be associated with a subset of Q_k, and we can consider the uniform distribution on this subset instead of itself.

Under such a consideration, the model Equation (3.4) can be regarded as an extension of the context model.

We define the membership function of a *partial evaluation* variable A_k for the *total evaluation* q_j as follows;

$$\mu_{A_k}^{q_j}(q_l^{A_k}) = \frac{\sum_{i=1}^{n} w_i f_{c_i}(q_{l'}^{A_k})}{\sum_{i=1}^{n} w_i \max_{q \in Q_k} f_{c_i}(q)}. \tag{3.8}$$

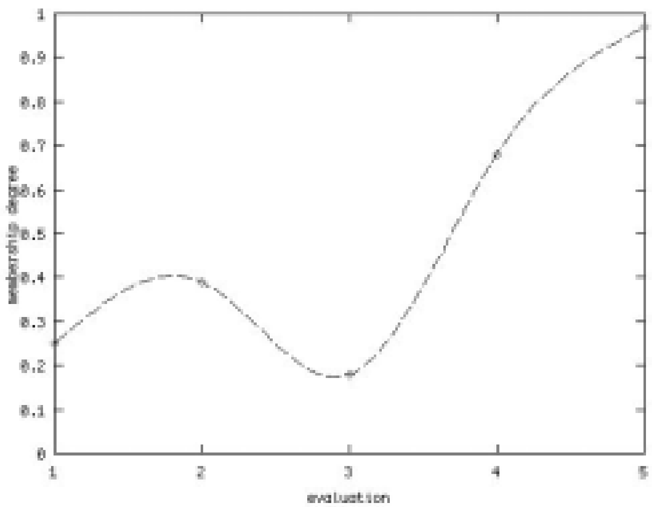

Figure 3.5: An example of a membership function.

Obtained models describe the relation between *total evaluation* and *partial evaluation*. In process of calculating models we consider contexts, but finally one model is obtained in one *total evaluation* level and *partial evaluation* level. There is a small number of these models than that of models in the previous sections. For instant, we obtain a graph shown in Figure 3.5. A vertical axis of the graph means membership value ($\in [0, 1]$) and a horizontal axis means marks of *partial evaluation* ($\in \{1, 2, \ldots, 5\}$). In Figure 3.5, in *total evaluation*=1 membership function of $q_1^{A_k}$=1 is 0.25, membership function of $q_2^{A_k}$=2 is 0.40, membership function of $q_3^{A_k}$=3 is 0.20, membership function of $q_4^{A_k}$=4 is 0.70, and membership function of $q_5^{A_k}$=5 is 0.97. In this case (in *total evaluation*=1), membership value of marks which affirm $q_5^{A_k}$ is the highest.

3.7.2 Results

Here, we show results in each *partial evaluation*. Figure 3.6–3.10 show results of *creature*, Figure 3.11–3.15 show results of *play*, Figure 3.16–3.20 show results of *fish*, Figure 3.21–3.25 show results of *brown*, Figure 3.26–3.30 show results of *source* and Figure 3.31–3.35 show results of *plant*. We don't introduce the result of *camp*. The reason is that we see that people have a similar behavior to the effect of water quality on *partial evaluation fish* and *camp*.

Membership values of *plant* or *creature*=4, 5 are high, in other words, these items are given high score, regardless of values of *total evaluation*. It corresponds to results which obtained condition attributes given high score by using *plant* and *creature* in Section **3.5**. *play*, *fish*, *brown* and *source* have different membership functions in *total evaluation* levels, and it suggests their items have strong impacts on *total evaluation*. The result also corresponds to models that show *brown* and *source* in urban area and *fish* in rural area are important for *total evaluation* in the Section **3.6**. There are two peaks in graphs of *play*. It suggests there are a lot of people who don't want to play in the water that has good evaluation for *total evaluation*. *Play* is affected by features of watersides in addition to *total evaluation*.

This section has obtained context fuzzy models which showed meanings of linguistic terms which *partial evaluation* had in *total evaluation*. We expanded the theory of context model to real problems and constructed models which treated uncertainty and vagueness. Obtained models showed the relations between used items and total evaluation, and corresponded to features of rule-based models in the previous section. We considered the results and selected items which were important for total evaluation.

3.8 Summary

The chapter has analyzed water problem considering soft data in addition to hard data. We discussed methods to extract rules from large-scaled soft data asked water quality. Two models showed how *partial evaluation* combined in the rules evaluated the water condition totally. After local authorities were classified according to social properties, first we used the algorithm to select combination of items which were supported most highly. Next, in order to select 'optimal' rules which were reflected features of clusters, we used SC-Optimality algorithm. We could construct evaluation models for environment depending 'context' by using *support* and *confidence* as indices. Third models, which were applied the theory of 'context model' to real problems, showed meanings of linguistic terms which each item had in *total evaluation*.

The models in this chapter aim at grasping the current condition of water quality to incorporate into environment process in EFM in Chapter **2**. In this respect, rule-based models which show the relation between *total evaluation* and *partial evaluation* in clusters are meaningful. The reason is that we have possibility that we run a part of EFM by relating social property with water quality. We consider it in Chapter **5**.

Models obtained in the chapter evaluate water quality in clusters, in other words in the wide regions. In narrower regions, for example in points or watersides, how water quality evaluated? And, how do the soft data have the relation with hard data? In the next chapter, we will have surveys in which we can specify points respondents evaluated and analyze them.

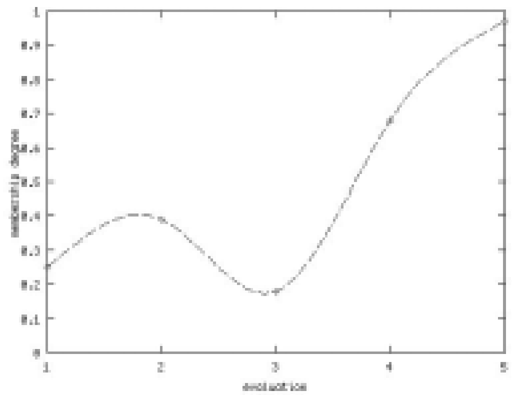

Figure 3.6: *Creature* in *total evaluation*=1.

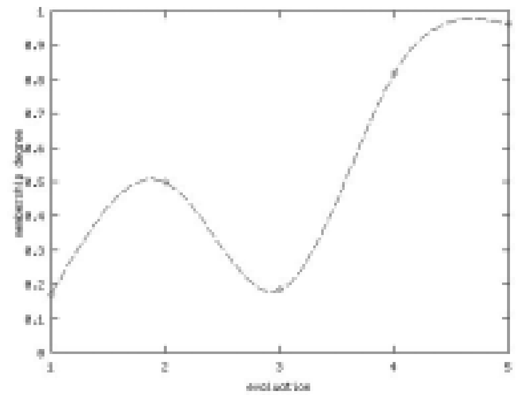

Figure 3.7: *Creature* in *total evaluation*=2.

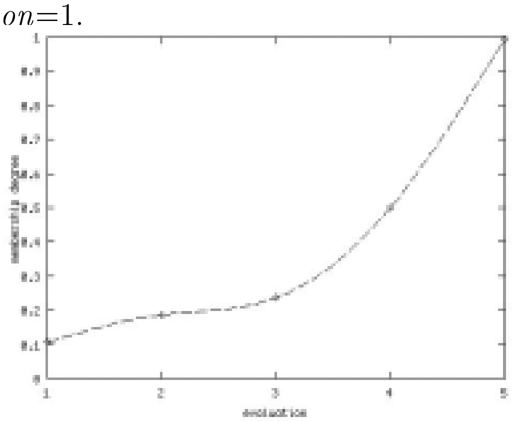

Figure 3.8: *Creature* in *total evaluation*=3.

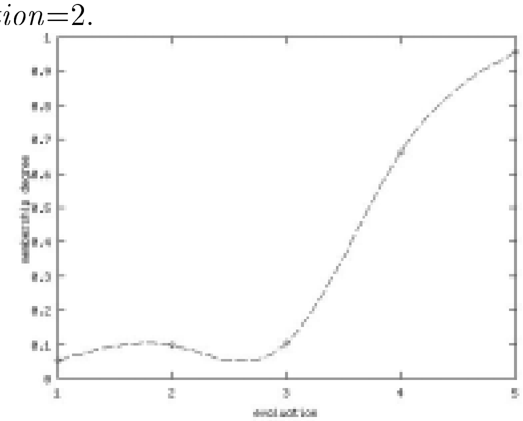

Figure 3.9: *Creature* in *total evaluation*=4.

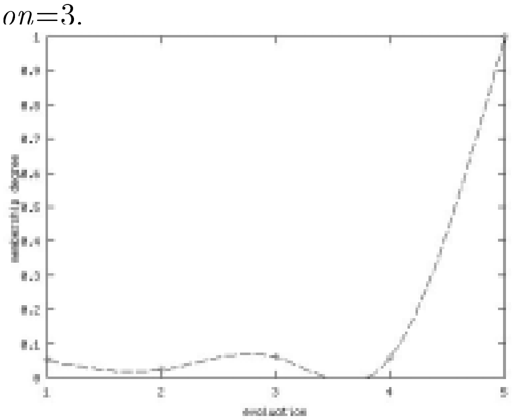

Figure 3.10: *Creature* in *total evaluation*=5.

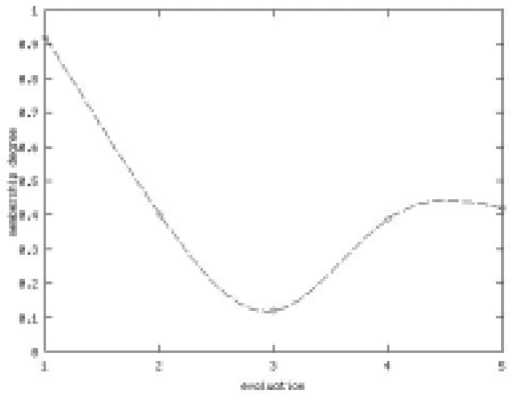

Figure 3.11: *play* in *total evaluation*=1.

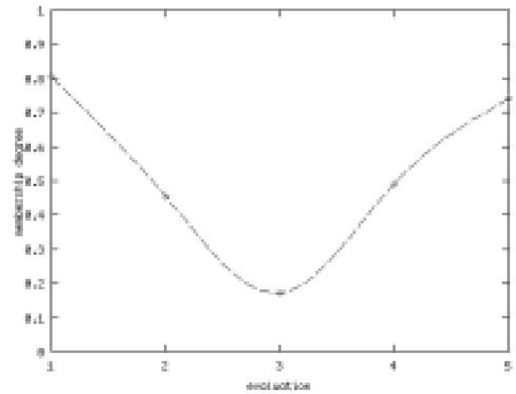

Figure 3.12: *play* in *total evaluation*=2.

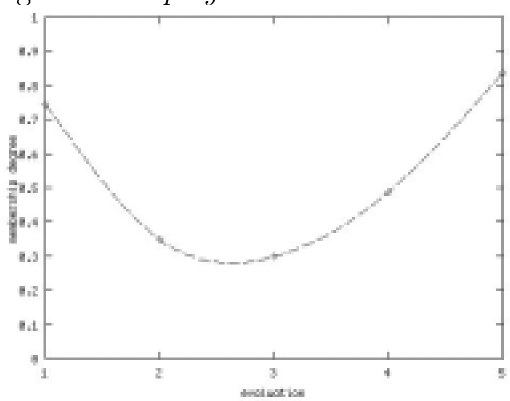

Figure 3.13: *play* in *total evaluation*=3.

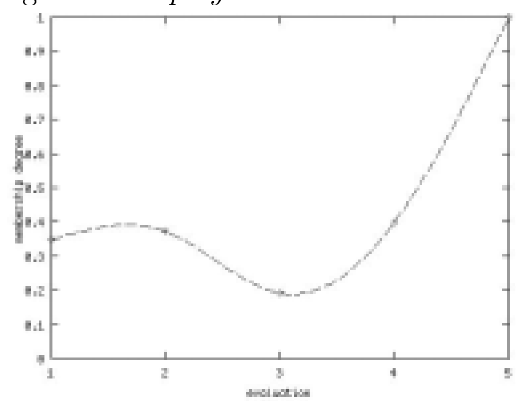

Figure 3.14: *play* in *total evaluation*=4.

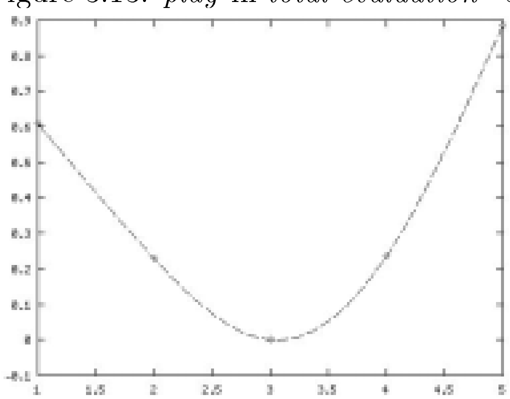

Figure 3.15: *play* in *total evaluation*=5.

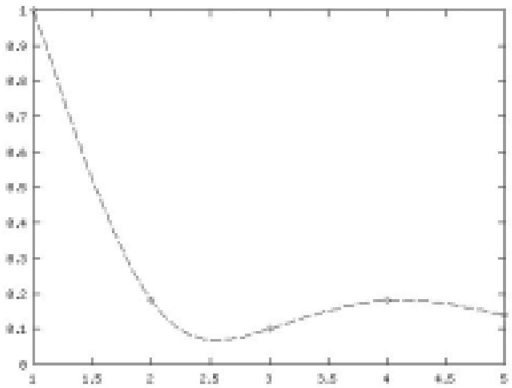

Figure 3.16: *fish* in *total evaluation*=1.

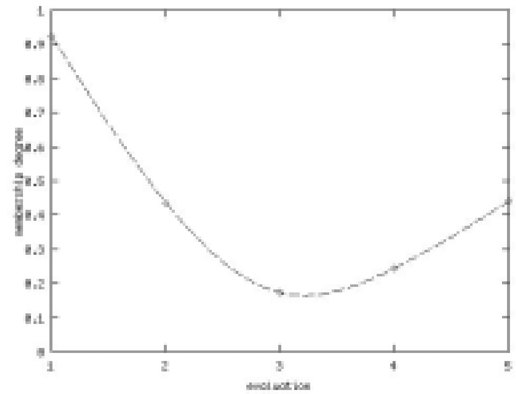

Figure 3.17: *fish* in *total evaluation*=2.

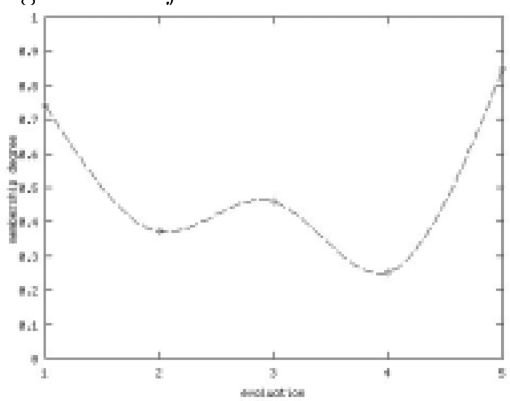

Figure 3.18: *fish* in *total evaluation*=3.

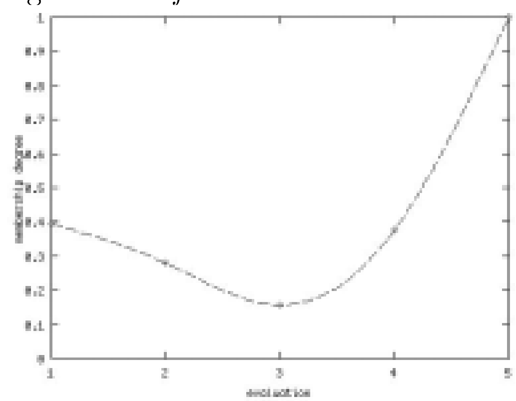

Figure 3.19: *fish* in *total evaluation*=4.

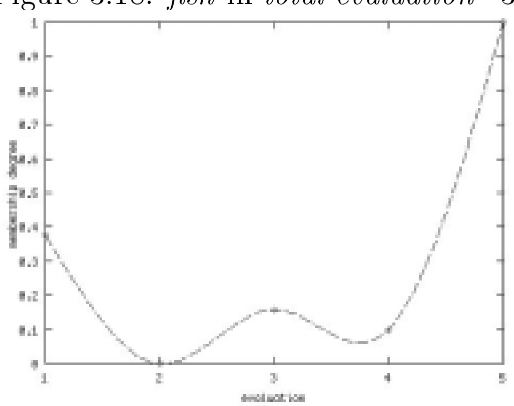

Figure 3.20: *fish* in *total evaluation*=5.

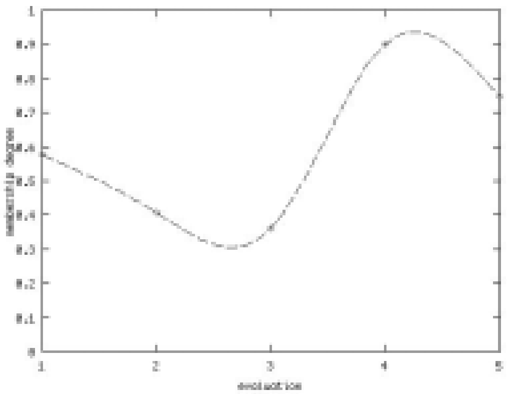

Figure 3.21: *brown* in *total evaluation*=1.

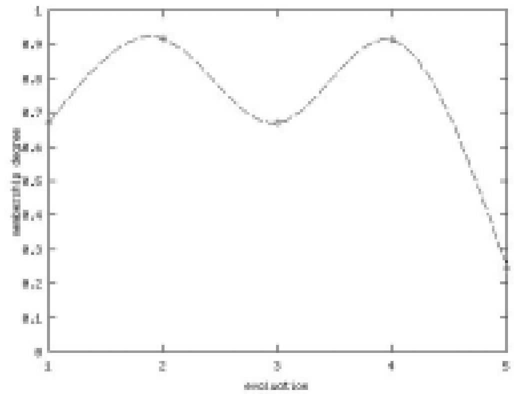

Figure 3.22: *brown* in *total evaluation*=2.

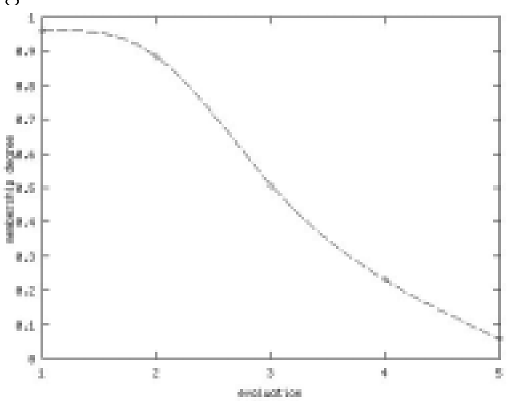

Figure 3.23: *brown* in *total evaluation*=3.

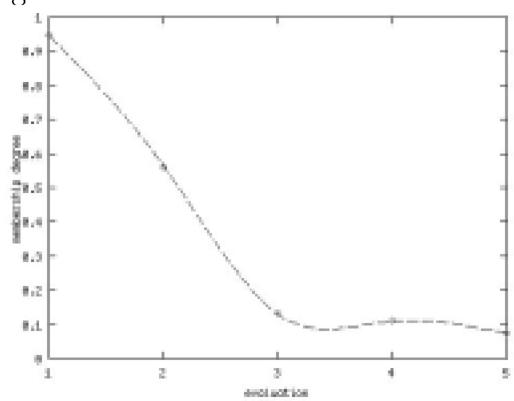

Figure 3.24: *brown* in *total evaluation*=4.

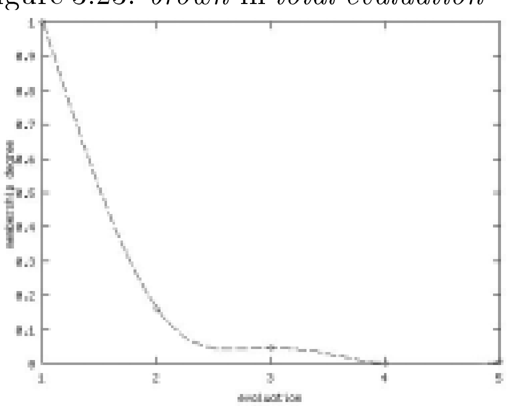

Figure 3.25: *brown* in *total evaluation*=5.

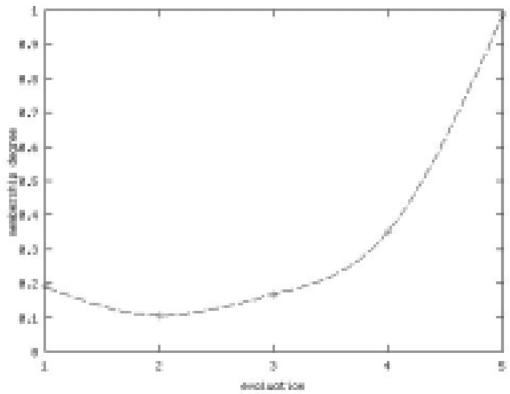

Figure 3.26: *source* in *total evaluation*=1.

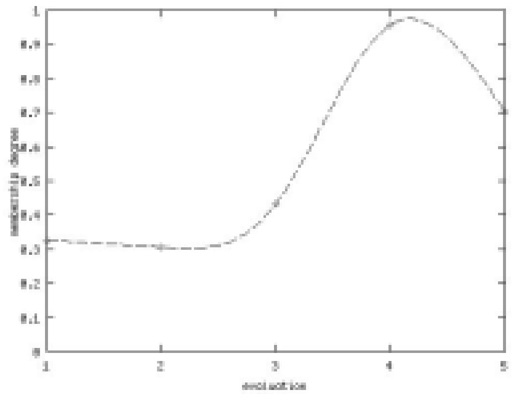

Figure 3.27: *source* in *total evaluation*=2.

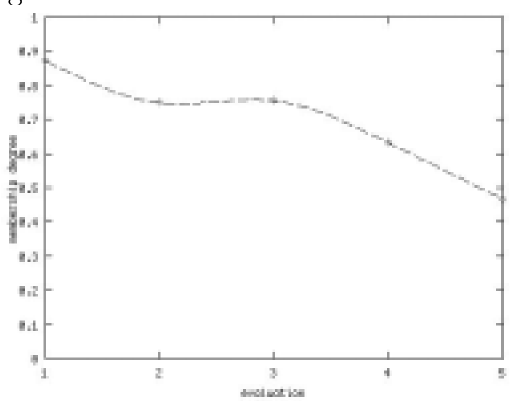

Figure 3.28: *source* in *total evaluation*=3.

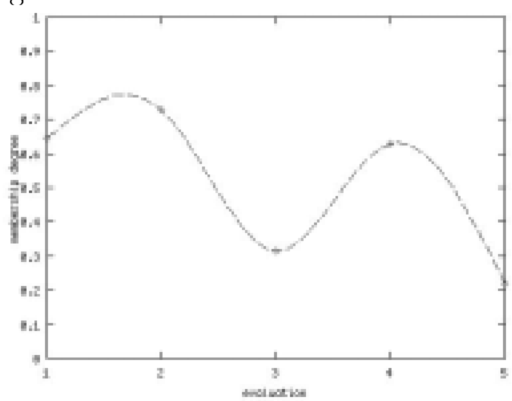

Figure 3.29: *source* in *total evaluation*=4.

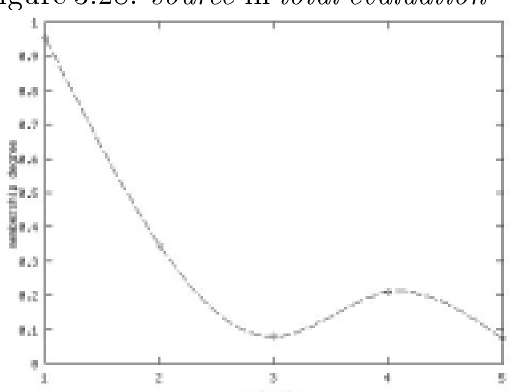

Figure 3.30: *source* in *total evaluation*=5.

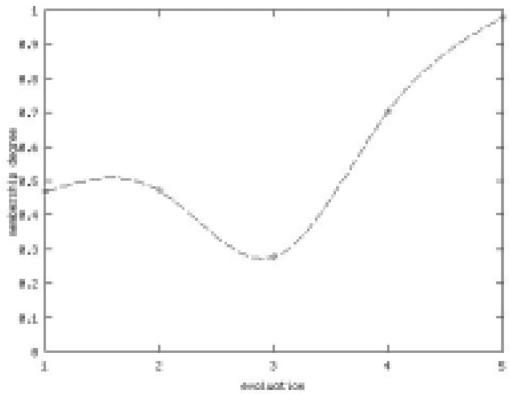

Figure 3.31: *plant* in *total evaluation*=1.

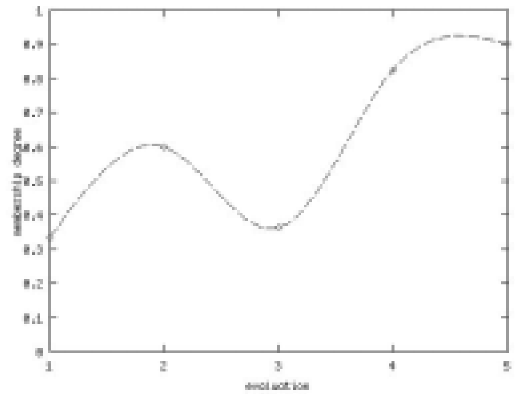

Figure 3.32: *plant* in *total evaluation*=2.

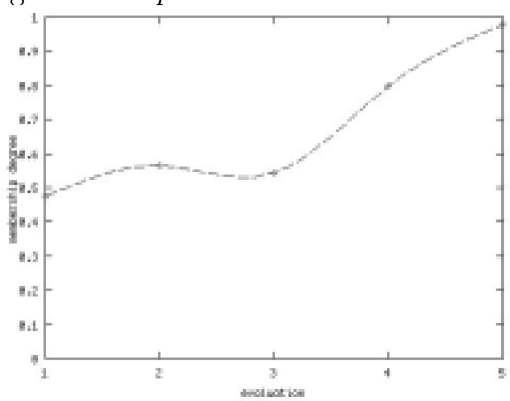

Figure 3.33: *plant* in *total evaluation*=3.

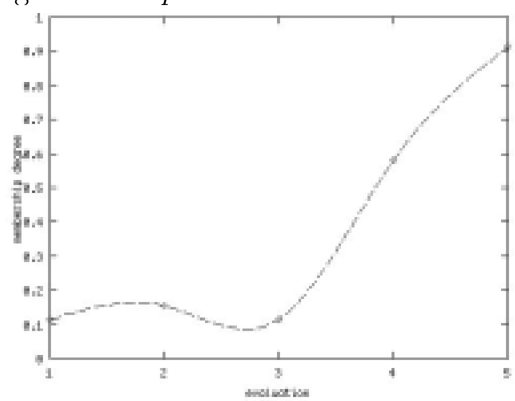

Figure 3.34: *plant* in *total evaluation*=4.

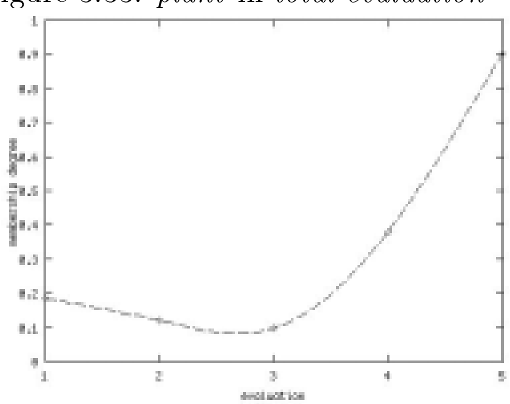

Figure 3.35: *plant* in *total evaluation*=5.

Chapter 4

Soft Data Analysis for Points

This chapter is written based on Publication [2,15].

4.1 Introduction

In Chapter **3**, we have analyzed results of the survey in 2000 and extracted knowledge from large-scaled soft data. We made models which showed the relation between *total evaluation* and *partial evaluations* for clusters classified by social properties and meanings which have linguistic terms of *partial evaluations*.

In this chapter, we have surveys in which we can specify points respondents evaluated and analyzed results. By using the surveys we verify how relation between hard data as BOD/COD and evaluation by residents in points have. When different people evaluate the object, they usually give it different marks. The reason is because we use different languages or meanings (context) based on our subjective values to evaluate anything. It is necessary to consider vagueness in evaluation by people when soft data are analyzed.

Then, in the former of the chapter, we analyze surveys carried out in 2001 and 2002. The surveys have different questions, and they are utilized to confirm whether residents grasp features of water. We count answers of water points evaluated by many residents and used factor analysis. We grasp features of water and show the relation between hard data and soft data.

Then, in the latter of the chapter, we expand a method of the Hayashi's quantification theory type Ⅲ considered vagueness in evaluation and apply to the survey data. We analyze soft data which were asked evaluation for points residents observed. First we treat points where BOD is measured, next treat points where BOD is not measured. We analyze how evaluation by residents' *kansei* as soft data grasp characteristics of water by considering vagueness in evaluation. Moreover, we plot positioning of analysis all items are used on the data space, then verify which evaluation items contribute to total evaluation of water in all questions related to water itself and attributes of points by reducing items.

4.2 Data

4.2.1 Survey Targeting at Residents in Komatsu and Tsurugi (in 2001)

Table 4.1: Questions of survey in 2001.

[water and waterside]
1-1. Are there any *creature*s in the waterside?
1-2. Are there any *plant*s in the waterside?
1-3. Can you *play* in the water (ex. swimming, fishing, boating, etc.)?
1-4. Can you do barbecue or *camp* in the waterside?
1-5. Are there any bank *protection* in the waterside?
1-6. Is the water *clear*?
1-7. Are there any *sound*s of water flow?
1-8. Are there many *river rapid*s?
1-9. How do you evaluate the water quality *in the past* (*now*, *in the future*)?
1-10. How do you evaluate the *amenity in the past* (*now*, *in the future*)?
[circumstances]
1-11. Are there any *forested land*s near the water?
1-12. Are there any *agricultural field*s near the water?
1-13. Are there any *roads* which have a lot of traffic near the water?
1-14. Is the area included the water in the *town*?
1-15. Are there are pollutant *source*s near the water?

We have made some models of water evaluation (ex. described in Chapter **3**) from the results of the survey in 2000 by regions. There were no questions which asked the waterplace respondents evaluated in the survey, so that it was hard to calculate models by points. Then, to compare soft data with hard data in each place in detail and to construct different evaluation models, we carried out a survey in 2001 [64]. Appendix B (in Japanese) includes an original survey form including all questions.

We distributed questionnaires from door to door in Komatsu and Tsurugi. Respondents returned only answer sheets to us. The number of receiver of the survey is 200 in Komatsu and 300 in Tsurugi. 71 residents in Komatsu and 77 residents in Tsurugi sent back. Table 4.4 shows attributes of respondents (figures mean the number of people). We instructed each household to make person who was more than 20 years old to answer the survey. Attributes such as sex and age weren't specified. There were many respondents who were more than 40 years old and men. The reason is that heads of households often answered the surveys. Analysis doesn't consider respondents' attributes. The survey in 2000 didn't generate statistically significant differences in sex or age, so that we justified the survey in 2001 had as the same features.

Table 4.2: Objects we analyzed : (a number of respondents/averages of BOD values in 2000[mg/l])

Tedori-river		Mae-river	
Tsurugi-Nakashima	(2)	Imae-bridge	(2)
Torigoe-bridge	(2)	Imae-aisatsu-bridge	(2)
Hakusangouguchi-entei	(16/0.6)	Imaegata-kantakuchi-yoko	(2)
Ichinomiya-bridge	(2)	Miyuki-bridge	(12/4.9)
Wasatani-bridge	(7)	Mukaimotoori-bridge	(5)
Juuhachi-gawara	(14)	Suehiro-ryokuchi	(3)
Tengu-bridge	(32)	Ukiyanagi-bridge	(9/5.5)
Tatsukuchi-bridge	(14/0.6)		
Mikawa-bridge	(8/0.7)		
Kakehashi-river		other rivers	
Nomi-bridge	(4/0.8)	Haccho-river, Noda-bridge	(3)
Kakehashi-bridge	(4)	Sai-river, Okuwa-bridge	(2)
Komatsu-bridge	(8)		
Tsurugashima-bridge	(10/0.8)		
Gyakusuimon	(2)		

Both Komatsu and Tsurugi have some waters. Moreover, their evaluation for water quality is contrasting in the last survey. Evaluation in Komatsu is as follows; "There are water which are both highly polluted and not. Evaluation for water by soft data match BOD measured at points of waters". In Tsurugi; "It has clear water of which BOD is low and not polluted. But, residents evaluate their water environment strictly by comparing the current condition with the past". That is a prehistory of selecting Komatsu and Tsurugi as the objects of the survey.

The survey asks condition of water and waterside, surrounding and environment of living places. Respondents select and evaluate a point measured BOD and a point not measured BOD. Evaluation of two points by 1 resident makes it possible to identify differences of evaluation by individuals and to guess measured value by soft data in places not measured hard data. [64] have had evaluation models that have estimated points of BOD by Context Model.

Table 4.1 shows questions for making rules used as soft data. '1-' means '2001 (year)'. All questions are multiple-choice tests on a 1–5 scale. The meaning of values 1∼5 corresponding to answers for the questions [1-1]–[1-15] is given in the Table 4.3. Where words that are *italicized* will be used as abbreviations of questions in the following sentences.

Respondents have selected 2 evaluation points which people are familiar with or which are near their living places. One is selected from points where BOD/COD is measured, and the other is from points where BOD/COD isn't measured.

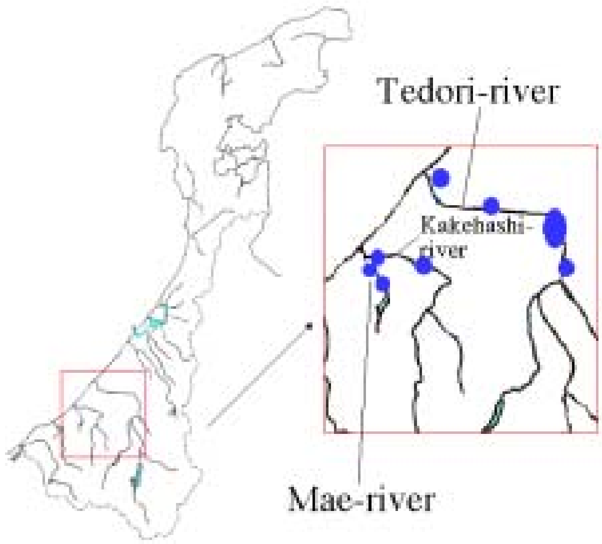

Figure 4.1: The map of rivers.

Figure 4.1 shows a location of Tedori-river, Kakehashi-river and Mae-river in Ishikawa prefecture. Table 4.2 shows points analyzed in Section **4.4** by using Quantification theory type Ⅲ. In the table, points are enumerated from upper points in each river. (X) or (X/Y) is added by the side of the name of points. X means the number of respondents and Y means annual averages of BOD value measured in 2000.

Now, the meaning of BOD have already shown in Table 3.1 in Section **3.2.2**. $0[mg/l]$ means there are no man-caused pollution in the water, $5[mg/l]$ means water lose self-purification capacity and carps can live in the water and more than 10 $[mg/l]$ means water gives off an awful reek. BOD values of most rivers in Ishikawa are about 0–$2[mg/l]$. Therefore, judging from BOD, water quality is evaluated as very good.

4.2.2 Simple Survey around Kanazawa (in 2002)

The survey carried out in 2001 treated two local authorities. Therefore, the number of water was limited. Then, in order to increase objects and compare hard data with soft data we had a simple survey in 2002. The survey has paid attention to Kanazawa which has many rivers and confirmed whether residents grasped features of each water.

The survey was carried out in the 'ecological fair' in Ishikawa and answered by 171 people in August, 2002. Respondents were visitors, members of organizations or companies who displayed their works. The surveys were given and collected soon after respondents answered questions. Respondents were visitors to the fair and members of organizations and companies which displayed their works.

Table 4.5 shows attributes of respondents. A number of ladies are more than that of

Table 4.3: The meanings of values of variables.

Question	Value	Meaning
[1-1], [1-11]	1	no with a high confidence
≀	2	no with a low confidence
[1-8], [1-15]	3	neutral
	4	yes with a low confidence
	5	yes with a high confidence
[1-9]	1	bad (become bad or was bad)
≀	2	slightly bad (become slightly bad or was slightly bad)
[1-10]	3	medium (no changes)
	4	slightly good (become slightly good or was slightly good)
	5	good (become good or was good)

Table 4.4: Attributes of respondents of survey in 2001.

Tsurugi

sex/age	20's	30's	40's	50's	more than 60's	unknown
man	1	2	7	20	19	0
woman	0	3	8	8	7	0
unknown	0	0	1	0	0	1
Komatsu						
man	1	4	2	9	18	0
woman	2	4	6	12	10	0

men. This is a difference with the previous surveys. An average of respondents is high. It is the same as the previous surveys.

Table 4.5: Attributes of respondents of survey in 2002.

sex/age	20's	30's	40's	50's	more than 60's	unknown
man	3	10	9	17	12	3
woman	9	14	15	39	31	0
unknown	0	0	0	0	0	9

Table 4.6 shows results of questions asked about *purpose*, *frequency* and *familiarity*. *Purpose*, *frequency* and *familiarity* are questions; 'What is your purpose going to the waterside?', 'How often do you go to the waterside?' and 'Are you familiar with the waterside?'.

The survey asks level of *familiarity* (1), *total evaluation* for water itself (2) and *amenity*

Table 4.6: Purpose, frequency and familiarity of waters.

Purpose		Frequency		Familiarity	
walking	53	everyday	45	not at all	8
passing	85	1,2/week	38	little	23
observation	10	1,2/month	45	neutral	23
play	6	1/a few months	19	a little	58
fishing	6	less than 1/year	23	very much	52
camp	2				
sports, etc	1				
others	11				

of the waterside (3), and *partial items* (4-19) in Table 4.7. Partial items consist of questions in 5 fields; *water itself* (4-7), *recreation* (8-11), *safety* (12-13), *naturalness* (14-15, 17) and *landscape* (18-19). Since the neighboring situation is asked, Question 15 is a question which is unrelated to waterside directly. Question 20 mentions 11 items, and respondents choose three or less items. These questions referred to the survey used in [18].

The surveys we have already carried out asked 'good or bad', but this survey asks 'satisfaction-dissatisfaction'. Answers are given in the one-to-five scale in Question 1-19. 1 means 'I am not satisfied with,,,,,' (ex. water is clear, water doesn't smell, it is possible to do recreation, etc)', and 5 means 'I am satisfied with,,,,,'.

Table 4.7 shows questions of the survey. '2-' means '2002 (year)'. Where words that are *italicized* will be used as abbreviations of questions in the following sentences.

Table 4.8 shows rivers or lagoons respondents evaluated, and the number of respondents and BOD or COD values of evaluated points. If there are some measurement points on a river or a lagoon, minimum value and maximum value are shown. There are a lot of people who answered the river (Sai, Asano, Fushimi, Morimoto, Kanakusari, etc) flowing Kanazawa which is the biggest city in Ishikawa. The map has shown in Figure 3.2 in Section **3.2.2**.

4.3 Results of Tabulation

4.3.1 Survey Targeting at Residents in Komatsu and Tsurugi (in 2001)

First, we show simple counting of a survey carried out in 2001. In three rivers, points which more than 4 residents evaluated are treated because we think that data whose number is more than 4 are meaningful. Some points have BOD values and the others

Table 4.7: Questions of survey in 2002.

2-1. Are you *familiar* with the water and waterside?
2-2. How do you evaluate the *water quality*?
2-3. Do you feel the waterside is *comfortable*?
2-4. Is the water *clear*?
2-5. Is the *amount* of water enough?
2-6. Does water *flow* well?
2-7. Does water *smell*?
2-8. Is the waterside fit to do sports or *recreation*?
2-9. Is the waterside fit to take a *walk*?
2-10. Is the water fit to *play* (ex. swimming etc.)?
2-11. Is the water fit to do *watersports* (ex. boating, canoe, etc.)?
2-12. Is the waterfront *safe* for flood?
2-13. Is the waterfront fit for *evacuation site* in a time of disaster (ex. earthquake, fire, etc.)?
2-14. Are there sufficient *green* (ex. trees, water plants, etc.)?
2-15. Is the water fit for feeding ground and habitat of *creatures* (fish and birds)?
2-16. Are there any roads or factories or shopping area in the *neighbouring* area?
2-17. Does the waterspace maintain *natural* condition??
2-18. Does the waterspace have good *landscape*?
2-19. Is the waterspace in a *harmony* with the surrounding area
2-20. What do you think the water environment needs? (cleaning water, etc.)

don't have them.

Tedori-river

Tedori-river flows from White Mountain to the Sea of Japan in the south of Ishikawa, and is the longest river in the prefecture (about 72km). It is a rapid river so that it was apt to have floods. Serious damages from floods have reduced since three dams were constructed in 1980 [65].

There are 6 points which residents evaluated; Hakusangouguchi-entei, Wasatani-bridge, Juuhachi-gawara, Tengu-bridge, Tatsukuchi-bridge and Mikawa-bridge (Figure 4.3). They are ordered from the upper reaches to the lower reaches, and points except Mikawa are located in the midstream of Tedori-river.

Hakusangouguchi, Tatsukuchi and Mikawa have BOD values. We show graphs of BOD value data (Figure 4.2) as hard data. The horizontal axis shows year (1990-2000) and the vertical axis shows BOD values. From this graph we know the values of these points haven't changed for 10 years. Figure 4.2 shows that water quality is very good (Table 3.1) because these points have less than 1[mg/l] BOD. Now, how do people feel this river?

Figure 4.4 is a graph of soft data. It shows averages of each item.

Evaluation for water quality is low (=water quality is polluted) in Hakusangouguchi

Table 4.8: Points respondents evaluated.

River	number of people	minimum (hard)	maximum (hard)
Sai-river	42	0.8	3
Tedori-river	26	0.6	0.7
Asano-river	17	0.8	3.1
Fushimi-river	11	1.4	3.6
Kahoku-lagoon	9	7	8.3
Kanakusari-river	7	1.2	1.3
Daishouji-river	6	0.6	3.1
Nagaso-river	6	3.1	-
Misogi-river	4	6	-
Morimoto-river	4	1.3	-
Oono-river	3	2.6	-
Kakehashi-river	3	0.8	-
Kiba-lagoon	3	7.5	-
Yasuhara-river	3	2.8	3.4
Iburihashi-river	2	0.8	-
Utani-river	2		-
Hakui-river	2	2.2	-
Machino-river	2	0.7	-
Tsubata-river	2	1.3	-
Unoke-river	2	3.4	-
Daitoku-river	2	5.4	15
Others, unknown	13	-	-

which is the upper reaches. In Hakusangouguchi residents also have low evaluation for *clear* (=water isn't clear), in other words, *clear* correlates closely with *water quality(now)*. In Tatsukuchi, evaluation for *play* and *camp* are low (=people don't want play and can't do camp). This may reflect impact of rebuilding of the bridge at the point. In Wasatani, Juuhachi-gawara and Tengu, evaluation for *camp* is high (=people can do camp). These points have relatively big riverbeds. Hakusangouguchi is a small embankment so that it is not easy to do recreation there. This property is shown in peoples' feeling. And this point is the nearest to dams. Residents think from dams water including earth and sand flows to the river, then at the point water isn't *clear*. This is an example of mismatch of hard data and soft data.

We asked three researchers who belong to Ishikawa Prefectural Institute of Public Health and Environmental Science about results of our surveys and reasons why some rivers were given strict evaluation by people. The reason why residents aren't pleased with water quality of Tedori-river is a volume of water. In the area on Tedori-river, most of respondents have living for more than 10 years. In previous times, people enjoyed

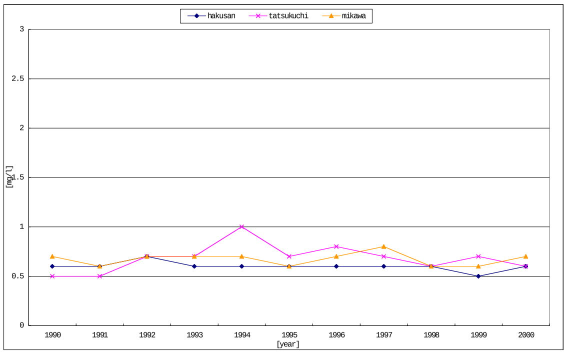

Figure 4.2: BOD of Tedori-river.

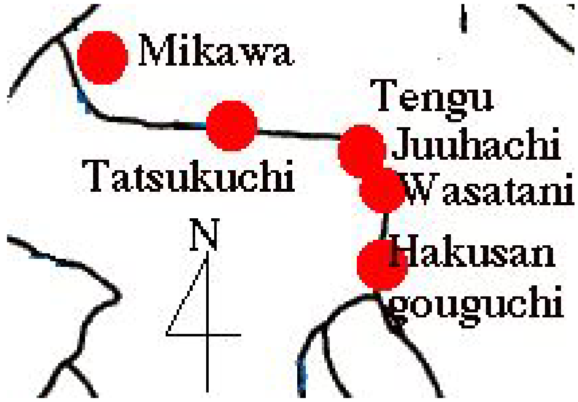

Figure 4.3: The map of points on Tedori-river.

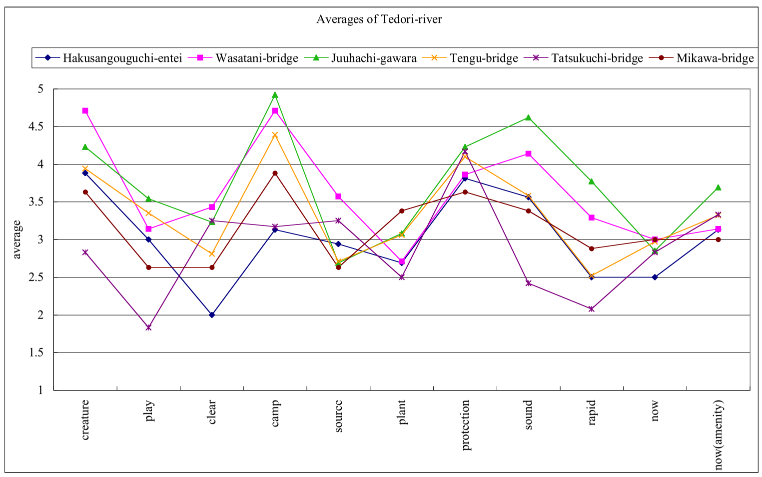

Figure 4.4: Averages of items in Tedori-river.

swimming and fishing in the river. After constructing dams in the upper, a volume of water hasn't adjusted well and decreased. Water includes much earth and sand, then seems not clear but brown. As a result, there have been a little people who are playing in the water, namely people aren't familiar with the water and they have strict evaluation for the river.

Areas on Tedori-river haven't big changes of social condition (population, industry, etc). There are few factors which cause to changes of water quality, then it is possible that impact of dams are very strong.

Kakehashi-river

The river has 0.7–1.4 BOD values. Residents evaluate Nomi-bridge (the middle stream), Komatsu-bridge (the lower stream) and Tsurugashima-bridge (the lower stream) (Figure 4.6). Some respondents evaluated a bridge close to Komatsu-bridge, then their data are

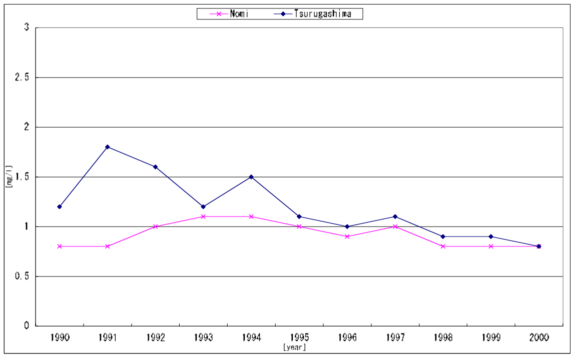

Figure 4.5: BOD of Kakehashi-river.

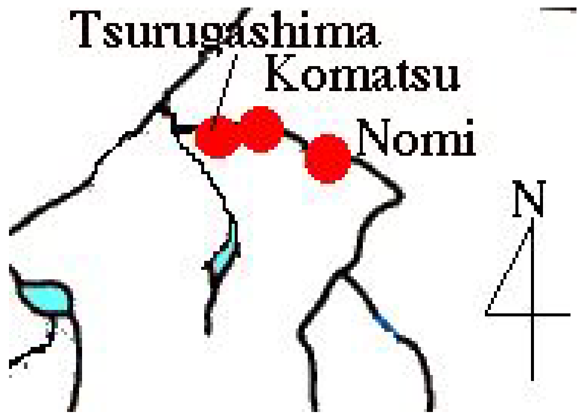

Figure 4.6: The map of points on Kakehashi-river.

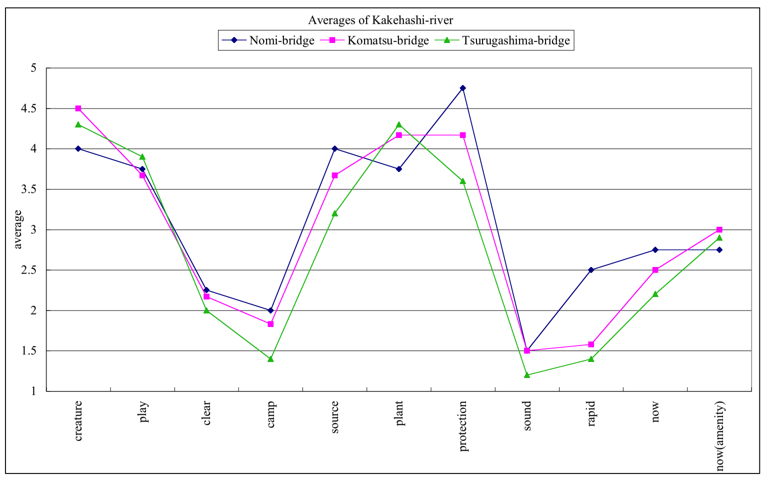

Figure 4.7: Averages of items in Kakehashi-river.

treated with the data evaluated Komatsu-bridge. Figure 4.5 shows BOD values of Nomi and Tsurugashima (1990-2000). BOD of Tsurugashima is getting better. Both points have relatively good BOD values.

Figure 4.7 shows soft data. Although BOD values aren't bad, evaluation for *water quality(now)* isn't good. Many residents aren't pleased with current water condition especially in the downstream. Evaluation for *clear* and *camp* are low (=water isn't clear and people can't do camp). That evaluation for *play* is high (=people play in the water) is characteristic of this river.

However BOD values are the similar at any points of this river, it is probably the result of the drainage from a home or a factory increasing so that it goes downstream that the more nearly downstream point (Tsurugashima) serves as low evaluation by many items.

Kakehashi-river is separated into 2 parts in the upper. One is clear, but the other is not clear and includes copper. The river hasn't had clear water for a long time. Main reason is wastewater from industries and houses and copper.

There was Ogoya mine in the upper of the Goutani-river which is an arm of Kakehashi-river. In the mine copper has dug for near 100 years (1878-1971) [66, 67]. Owing to this mine population increased, a railroad was constructed and the area developed. But, after the mine was closed, it has gone downhill. Now a trace of the miner is a memorial hall.

The mine produced not only copper but also water pollution. Wastewater from the mine included much cadmium and was flowing in Kakehashi-river. An amount of cadmium which was detected in the water was more than it of standard value, then some of residents along the river became sick by cadmium as 'itai-itai disease' which was one of the pollutional-related illness in Japan [68].

The current water in Kakehashi-river is no problem of cadmium etc and perhaps evaluation for water isn't affected on this problem.

Mae-river

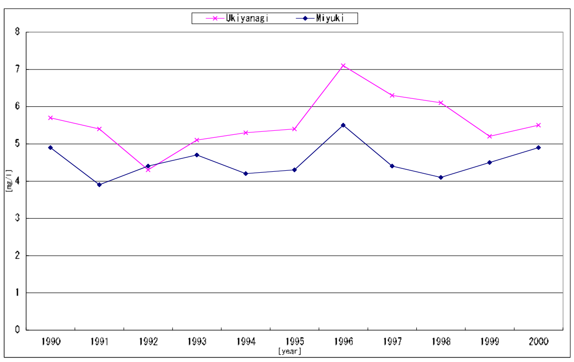

Figure 4.8: BOD of Mae-river.

Figure 4.9: The map of points on Mae-river.

Residents evaluate Miyuki-bridge, Mukaimotoori-bridge and Ukiyanagi-bridge (Figure 4.9). Figure 4.8 shows BOD values of Miyuki and Ukiyanagi (1990-2000). The river flows from Kiba-lagoon which is a polluted lake so that it has high BOD values. The values are getting a little worse.

Figure 4.10 shows soft data. It is natural that residents evaluate this river as bad. Not only water isn't clear but also much people don't think they can do camp in the waterside and play in the water. Evaluation for *creature* and *plant* are a little high (=there are any creatures and plants), but from soft data we imagine that this river is polluted and has many artificial spaces.

Figure 4.11 compares averages of items of points measured BOD values. From the results which we looked at graphs for every river for the foregoing sections and the graph.

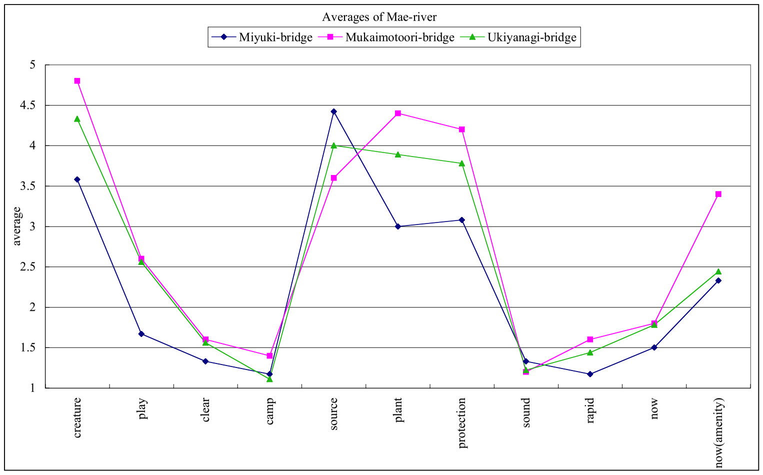

Figure 4.10: Averages of items in Mae-river.

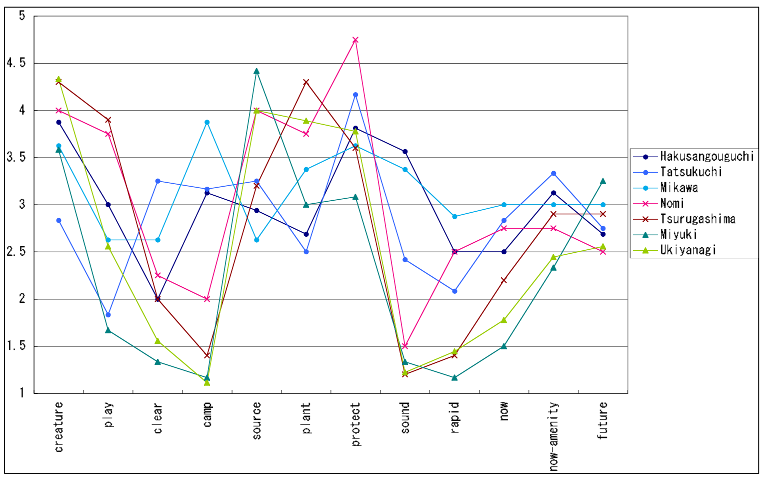

Figure 4.11: Graphs of comparison of averages of soft data at measurement points.

4.3.2 Factor Analysis

Factor analysis is a statistical approach that can be used to analyze interrelationships among a large number of variables and to explain these variables in terms of their common underlying dimensions (factors). The statistical approach involving finding a way of condensing the information contained in a number of original variables into a smaller set of dimensions (factors) with a minimum loss of information [69].

Factor analysis is applied to soft data of three rivers. *creature*, *plant*, *play*, *camp*, *protection*, *clear*, *sound*, *rapid* and *source* are factors. From the relation of the number of data, all the data that evaluated each river regardless of the point is used.

Factor loadings are calculated by the main factor method, and rotated by the Bali

Table 4.9: Factor loadings.

	Tedori-river		Kakehashi-river		
item	1st factor	2nd factor	1st factor	2nd factor	3rd factor
creature	**0.731**	0.310	0.134	0.005	**0.539**
plant	0.405	0.310	0.112	-0.002	0.475
play	0.560	0.188	-0.152	0.196	0.482
camp	0.722	0.317	0.312	0.188	0.273
protect	0.232	0.315	0.082	-0.045	0.058
clear	0.163	0.520	0.472	0.347	-0.126
sound	0.370	0.593	0.131	**0.896**	0.082
rapid	0.098	**0.709**	**0.919**	0.050	0.195
source	0.233	0.032	-0.115	-0.245	-0.208

		Mae-river		
item		1st factor	2nd factor	3rd factor
creature		0.175	0.129	0.388
plant		0.210	0.391	0.330
play		0.195	**0.580**	0.186
camp		0.330	0.426	0.339
protect		-0.056	-0.013	**0.607**
clear		0.613	0.252	0.044
sound		**0.875**	-0.129	-0.007
rapid		0.533	0.091	0.193
source		0.115	-0.576	0.071

Max rotation. Table 4.9 shows factor loadings. Since significant probability was low, we would like the reference grade to look at the result of factor analysis of Kakehashi by the data of Kakehashi, as a result of authorizing.

In Tedori, *camp* and *creature* are strong as 1st factor axis, and *rapid* is strong as 2nd factor axis. Therefore, it turns out that the waterside space is judged by two factors, namely 'recreation and creature' and 'water condition'. In Kakehashi, *rapid* and *sound* are main factors and *creature* is third factor. Axis means 'visual effects' and 'audile effects'. In Mae, *sound* is 1st factor, and *play* is 2nd factor. 'Water condition' and 'recreation' are factors.

Since there are a few used items, there is no big difference in the factor itself that came out. However, by Tedori and Mae, an order of a factor is different and it shows that the difference in the character of these rivers. Kakehashi has different factors from other two rivers.

4.3.3 Simple Survey around Kanazawa (in 2002)

Cluster Analysis by Using Averages of Evaluation

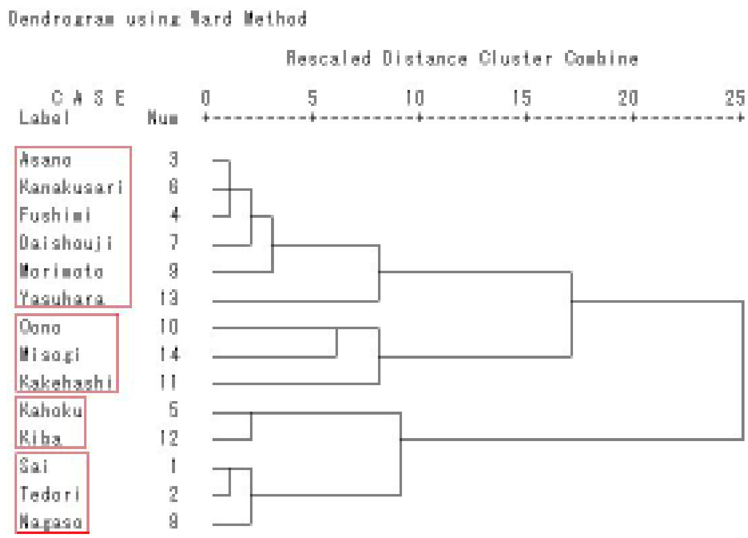

Figure 4.12: The result of clustering by averages.

We cluster water with averages of data of water by Ward method (SPSS) [50]. Each river has more than 3 respondents. A result is shown in Figure 4.12. When clustering, *flow*, *smell*, *neighbouring* and *harmony* aren't used. The reason is that *neibouring* aren't related to the water and waterside directly, *flow* and *smell* are difficult to evaluate because people don't know them when they pass through the waterside by car, and *harmony* has strong correlation with *landscape*.

Kahoku and Kiba which are polluted lagoons are classified into the same cluster. These lagoons have low evaluation for *water quality* and *clear*. *Water sports* and *evacuation* are given better evaluation.

Oono flowing from Kahoku to the sea, Misogi which flowing in Nanao and Kakehashi in Chapter **4** are included in the same cluster. These have low evaluation for *clear*, *play* and *landscape*. Oono has about 3.0 BOD value, Misogi has about 2.7-6 BOD values and Kakehashi has about 1.0 BOD value. Although there is a big difference of BOD values, people's feelings are fairly similar, in other words, people don't have a good impression to Kakehashi. This is the same conclusion as the result in Chapter **4**.

Nagaso gives a good impression to residents in contradiction to Kakehashi. Nagaso have about 2.4 BOD value, but the river belongs to the same cluster as Sai (BOD about 0.7-3.0) and Tedori (BOD about 0.5-0.7). The group has high average of *water quality*, *walk*, *evacuation* and *safe* etc. Items which are related to utilization of water by people have good score.

The result of clustering is interesting and suitable to actual condition. Evaluation by residents is reliable.

Factor Analysis

Factor analysis is applied to 12 partial items on Table 4.7 except *flow*, *smell*, *neighbouring* and *harmony*.

Table 4.10 shows factor loadings. Rivers and lagoons whose number of respondents is more than 12 (=the number of items) are analyzed; Sai, Asano, Fushimi, Tedori, Kahoku and Kiba-lagoon. Kahoku and Kiba-lagoon are gathered because these lagoons belong to the same cluster in the previous section.

Each waterspace has different factors. Generally, *safety*, *recreation* and *naturalness* are usually observed as factors.

Asano in which residents selected *clear* as 1st factor and *green* and *creatures* as 2nd factor and Tedori in which residents selected *landscape* as 1st factor is a little different from others. In Fushimi items related to *recreation* is strong on all axis.

Analysis of Main Water

We show analysis of soft data in each river/lake as follows.

Sai-river The river is the one of most famous rivers in Kanazawa. There are some valuable animals and plants in the upper stream of the river far from town.

Figure 4.14 shows averages of items in Okuwa-bridge, the upper reaches, the middle stream and the lower stream. Okuwa-bridge is located in the upper reaches of the river, but it is separated because the number of data is lot.

In the lower stream evaluation for *recreation*, *play*, *evacuation* and *landscape* etc are clearly low. There are differences of BOD values, but evaluation for *water quality* and *clear* don't have big differences. In the middle stream *safe* has higher score but *naturalness* etc has the lowest. In the upper stream and Okuwa-bridge *flow*, *creatures* and *landscape* etc are better. Especially in the middle stream and upper reaches, it seems that the river is rooted in lives of people. Averages of *water quality* and *clear* are higher than those of the other water. This is the consistent result with low BOD values.

It is said points except the lower stream has maintained good condition to get close to, to utilize and to enjoy the river.

Asano-river Figure 4.15 shows averages of items in the upper reaches, the middle stream and the lower stream. Evaluation for *comfortable* and items related to recreation are low in the lower stream. In the middle stream *water quality* and *naturalness* are low evaluation, but most of evaluators feel familiarity for the river here. *Landscape* and *harmony* have high evaluation, so that this feature is good for tourists. In the upper reaches, there are a few items which have better evaluation. Areas near the upper streams of the river have developed as residential districts. It may reflect on evaluation.

However there is low evaluation for *water quality* by people, it is possible that the relationship between river and residents have been good.

Fushimi-river Figure 4.16 shows averages of items in the 3 points measured BOD values. In Fushimigawa-bridge (the lower stream), evaluation for *safe* is the highest but evaluation for *naturalness* is the lowest. In Yoneizumi-bridge (the middle stream), *walk* and *naturalness* are higher. In Nimandou-bridge (the middle stream/the upper of Yoneizumi), *comfortable* and *clear* are higher.

There are fewer items whose averages are more than 3, so that it seems the river isn't good condition for utilization by people. This result is consistent with the highest BOD value of all rivers in Kanazawa.

Tedori-river Figure 4.17 shows averages of items in the 2 points measured BOD values (Tatsukuchi and Mikawa are treated in Chapter **4**). In two points there are little differences. BOD values are good (less than 1.0 [*mg/l*]), but evaluation for *water quality* isn't good. This is as same result as that of the survey in 2001. Evaluation of many items is better than any other rivers or lagoons.

Evaluation for *water quality* of Tatsukuchi-bridge and Mikawa-bridge is higher than any other waters. This reflects low BOD values. The result is as almost the same as that of the survey in 2001.

Kahoku-lagoon There are no people who feel *water quality* is good and water is *clear* (Figure 4.18). Their thought reflects how polluted water this lagoon has. Only items related to *landscape* have a little high evaluation.

By the way, in Kiba-lagoon, *naturalness* and *walk* is high evaluation. If even water can be cleaned, evaluation of amenity will go up greatly.

There are many rivers and watercourses flowing into Kahoku-lagoon. If water quality of them becomes better, COD of Kahoku-lagoon will be better; COD will decrease from about 8 [*mg/l*] (current value) to 6 [*mg/l*] (estimated value) [70]. But, it is difficult for Kiba-lagoon to clean water. The reason is that there is a small amount of water flowing into and from Kiba-lagoon.

Others In Daishouji-river, evaluation for *water quality* is low in the downstream and high in the upstream. This is a case at which soft data are in accord with hard data.

In Morimoto-river, residents think water isn't clear in the lower stream but water quality is relatively good in all points.

In Misogi-river, evaluation for most of items is low. 3 people evaluated Sentsui-bridge that is famous as the place of a big festival and the point has 6 BOD value. This small bridge is located in the center of the town. It may be natural that evaluation for *play* and *naturalness* is low in addition to *water quality*.

In Kakehashi-river, evaluation for *water quality* is bad, and it is as same as results in survey in 2001. Evaluation for *sports* is the highest. It is the feature of this river.

What Each Water Environment Needs

Table 4.11 shows the degree of residents for items Question 2-20 in each river or lagoon. For example, 41.5% of respondents who evaluated Sai-river selected *cleaning*.

In total, *cleaning* and *naturalness* are selected by high degree. Because *cleaning* is related to other items (ex. *flow and amount*, *places where fish or birds live*), it is natural that this item is supported highly. *safety* has low support.

By the point, in Kanakusari *naturalness* is highly supported although evaluation for items related to naturalness aren't low. In Misogi and Kahoku etc which have very polluted water *wastes* is highly supported.

In Tedori, *fish and birds* are regarded as important. In Tatsukuchi-bridge, *cleaning* collects much support. It is natural because in the area evaluation for *clear* is low. In Mikawa-bridge, *green* and *fish and birds* are the first items.

In Sai and Asano, in the upstream and midstream *naturalness* is, and in the downstream *cleaning*, *green* and *fish and birds* area highly supported. However, in Fushimi, in the downstream *naturalness* and *harmonize* are , and in the midstream *cleaning* is supported highly.

What is needed for every river or lagoon differs. The river management in which the feature of a river was harnessed is called for. It can be said in finding out the feature that it is important to utilize soft data, namely residents' knowledge.

4.3.4 Summary of the Section

In this section, we have analyzed soft data of rivers and points by using surveys carried out in 2001 and 2002. Generally, from judging soft data, residents understood features of water. They evaluated Tedori-river and Kakehashi-river worse than expected from hard data. These rivers were given low evaluation for water clarity and water quality. In other rivers as Sai-river in Kanazawa and lakes, soft data corresponded to hard data. Therefore, as well as results in Chapter **3**, in the section soft data is meaningful to grasp environment.

Evaluation for *amenity* is better than one for *water quality.* This is because not only 'good and bad' but also 'satisfaction level' and 'approachability' should be considered when water and water space are evaluated. People are familiar with water, but they evaluate water quality calmly. Essential factors to evaluate water and watersides are determined by not only one item as *clear* but also combination of plural items. This is the same result as that of Chapter **3**. It is important to focus on the relation between total evaluation and partial evaluation of water quality in order to understand environmental condition and evaluation.

4.4 Quantification Theory Type Ⅲ Considering Vagueness

In this section, we treat watersides as objects of which each person have different evaluation and apply the Hayashi's quantification theory type Ⅲ considering vagueness in evaluation to the result of questionnaire survey to residents. In general Biochemical Oxygen Demand (BOD [mg/l]) and Chemical Oxygen Demand (COD [mg/l]) are used as indicators to evaluate water quality. BOD measures water quality of rivers and COD measures water quality of seas, lagoons and lakes. But, these values aren't measured in all points. And these are difficult to evaluate entire watersides although water quality itself can be measured.

Then, we analyze results of a questionnaire survey which residents answered water points which have BOD and don't have BOD. To know that how much soft data, namely evaluation by peoples' sensitivity can grasp property of objects, we notice difference of residents' answers by calculating variance. Moreover, we plot results of calculation used all items on the data space, and test which partial items of all questions that are related to water itself and attributes of points contribute total evaluation of waterside decreasing items out of consideration of first obtained results.

4.4.1 Outline

Quantification theory type Ⅲ is one of the methods multivariate analysis [71]. It explains similarities and positioning of data which don't distinguish between criterion variable and explanation variable by checking the relation among data. Quantification theory type Ⅱ I is similar to principal component analysis, but it treats categorical data while principal component analysis treats numerical data.

Now, quantification theory type Ⅲ equal to analyse des correspondances (or correspondence analysis) [72] that is a theory which analyzes the relation between two pairs of categorical data in mathematics. Analyse des correspondances was developed to analyze data with a cross-tabulation table, and the purpose of the theory is to approach a distance between any two points on the data space with chi-square distance. But then, quantification theory type Ⅲ was developed to analyze data which show individuals and variables as 0-1 type data, and formulates maximization of the correlation between individuals and variables.

Quantification theory type Ⅲ has used to analyze all kinds of data including attitude surveys in many fields. For example, a research which typified images of lyrics to school songs [73]. Researches about ‘environmental indicators’ are representative of researches which utilized subjective ‘soft data’ for environmental evaluation in the latter half of the 1980’s [17]. These researches used regression analysis and principal component analysis to analyze data. Researches which analyzed the water environment based on the attitude surveys to residents as well as this thesis include papers using ‘Free Association Test’ [16, 59].

The section uses quantification theory type Ⅲ because data of surveys are given marks as the number from 1 to 5 and individual items are treated equally without distinction between criterion variable and explanation variable. The usefulness and freshness of the thesis is to be able to compare results by soft data with hard data and to try to grasp not amenity of waterside but water quality itself from soft data.

4.4.2 Approaches

First, we define the following notations.

- object $m \in \{1, 2, \ldots, M\}$: evaluated points (waterside)
- item $n \in \{1, 2, \ldots, N\}$: questions
- respondent $k \in \{1, 2, \ldots, K\}$: respondents of surveys
- a set of objects O_k: a set of objects respondent k evaluated
- a set of evaluators E_m: a set of evaluators who evaluated object m
- mark $\delta_{mnk} \in \{1, 2, \ldots, 5\}$: a mark of item n at object m by respondent k

δ_{mn} and p_{mn} are calculated by averaging each data for respondent k.

$$\delta_{mn} = \frac{1}{|E_m|} \sum_{k \in E_m} \delta_{mnk}, \tag{4.1}$$

$$p_{mn} = \delta_{mn} / \sum_{m=1}^{M} \sum_{n=1}^{N} \delta_{mn}. \tag{4.2}$$

$|E_m|$ shows the number of items set E_m. Then, a correlation table whose items are p_{mn} are gotten.

$$\boldsymbol{P} = \begin{pmatrix} p_{11} & p_{12} & \cdots & p_{1N} \\ p_{21} & p_{22} & \cdots & p_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ p_{M1} & p_{M2} & \cdots & p_{MN}. \end{pmatrix} \tag{4.3}$$

Next, $p_{m\bullet}$ and $p_{\bullet n}$ are defined.

$$p_{m\bullet} = \sum_{n=1}^{N} p_{mn}, \quad p_{\bullet n} = \sum_{m=1}^{M} p_{mn}. \tag{4.4}$$

The following numerical quantities are given objects and items;

$$\boldsymbol{x} = (x_1, x_2, \cdots, x_M)^t, \tag{4.5}$$

$$\boldsymbol{y} = (y_1, y_2, \cdots, y_N)^t. \tag{4.6}$$

Here, $(\quad)^t$ means transposition.

Quantification theory Ⅲ tries to calculate numerical quantity which maximize the correlation between $\boldsymbol{x}$ and $\boldsymbol{y}$. Variance and covariance of $\boldsymbol{x}$ and $\boldsymbol{y}$ are defined as follows.

$$\sigma_x^2 = \sum_{m=1}^{M} (p_{m\bullet} x_m^2) - \left(\sum_{m=1}^{M} p_{m\bullet} x_m \right)^2 \tag{4.7}$$

$$\sigma_y^2 = \sum_{n=1}^{N} (p_{\bullet n} y_n^2) - \left(\sum_{n=1}^{N} p_{\bullet n} y_n \right)^2 \tag{4.8}$$

$$\sigma_{xy} = \sum_{m=1}^{M} \sum_{n=1}^{N} p_{mn} x_m y_n - \sum_{m=1}^{M} p_{m\bullet} x_m \sum_{n=1}^{N} p_{\bullet n} y_n \tag{4.9}$$

Correlation coefficient ρ_{xy} are calculated from these equations.

$$\rho_{xy} = \frac{\sigma_{xy}}{\sigma_x \sigma_y} \tag{4.10}$$

In the following, we solve the eigenvalue problem based on the solution of quantification theory Ⅲ. The next equations are solved to maximize the correlation between $\boldsymbol{x}$ and $\boldsymbol{y}$ in Equation (4.10).

$$\frac{\partial \rho_{xy}}{\partial \boldsymbol{x}} = 0, \quad \frac{\partial \rho_{xy}}{\partial \boldsymbol{y}} = 0. \tag{4.11}$$

λ_2, λ_3 are the biggest eigen values excluding $\lambda_1 = 1$ of all eigen values

$$\lambda_1, \cdots, \lambda_M; \ \lambda_1 = 1, \ \lambda_2 \geq \cdots \geq \lambda_M$$

. We take λ_2, λ_3 for λ_1, λ_2, and define $\tilde{\boldsymbol{x}}_i$, $\tilde{\boldsymbol{y}}_i$ calculated by eigen vectors for λ_1, λ_2 as

$$\tilde{\boldsymbol{x}}_i = \begin{pmatrix} \tilde{x}_{i1} \\ \tilde{x}_{i2} \\ \vdots \\ \tilde{x}_{iM} \end{pmatrix}, \ \tilde{\boldsymbol{y}}_i = \begin{pmatrix} \tilde{y}_{i1} \\ \tilde{y}_{i2} \\ \vdots \\ \tilde{y}_{iN} \end{pmatrix}, \ i = 1, 2. \tag{4.12}$$

$\tilde{\boldsymbol{x}}_i$, $\tilde{\boldsymbol{y}}_i$ are column vectors normalized from Equation (4.11). Elements of $\tilde{\boldsymbol{x}}$, $\tilde{\boldsymbol{y}}$ are shown by Equation (4.13)(4.14).

$$\tilde{x}_m = (x_m - \sum_{m=1}^{M} p_{m\bullet} x_m)/\sigma_x, \tag{4.13}$$

$$\tilde{y}_n = (y_n - \sum_{n=1}^{N} p_{\bullet n} y_n)/\sigma_y. \tag{4.14}$$

Above-mentioned steps are solving methods of quantification theory Ⅲ. In addition to this, the thesis describes vagueness in evaluation by calculating variances of $\tilde{\boldsymbol{x}}_i$, $\tilde{\boldsymbol{y}}_i$ as follows.

The next quantity which isn't related to i is defined for respondent k.

$$\tilde{x}_{mk} = \tilde{x}_m + \frac{1}{N}\sum_{n=1}^{N}(\delta_{mnk} - \delta_{mn}), m \in O_k, \tag{4.15}$$

$$\tilde{y}_{nk} = \tilde{y}_n + \frac{1}{|O_k|}\sum_{m\in O_k}(\delta_{mnk} - \delta_{mn}), {}^{\forall} n. \tag{4.16}$$

These variances are defined as follows,

$$u_m^2 = \frac{1}{|E_m|}\sum_{k\in E_m}(\tilde{x}_{mk} - \tilde{x}_m)^2, \tag{4.17}$$

$$v_n^2 = \frac{1}{K}\sum_{k=1}^{K}(\tilde{y}_{nk} - \tilde{y}_n)^2. \tag{4.18}$$

Equation (4.17)(4.18) are rewritten by Equation (4.15)(4.16), then Equation (4.19)(4.20) are obtained.

$$u_m^2 = \frac{1}{|E_m|N^2}\sum_{k\in E_m}\sum_{n,n'=1}^{N}(\delta_{mnk} - \delta_{mn})(\delta_{mn'k} - \delta_{mn'}) \tag{4.19}$$

$$v_n^2 = \frac{1}{K}\sum_{k=1}^{K}\frac{1}{|O_k|^2}\sum_{m,m'\in O_k}(\delta_{mnk} - \delta_{mn})(\delta_{m'nk} - \delta_{m'n}) \tag{4.20}$$

s_m, t_n which are vagueness in evaluation for objects and items are defined by constant c_s, c_t as follows.

$$s_m = c_s u_m,\ t_n = c_t v_n. \tag{4.21}$$

If s_m, t_n are filled with

$$\sum_{m=1}^{M} s_m^2 = \sum_{n=1}^{N} t_n^2 = 1, \tag{4.22}$$

constant c_s, c_t are shown the next equations.

$$c_s = \left(\sum_{m=1}^{M} u_m^2\right)^{-\frac{1}{2}},\ c_t = \left(\sum_{n=1}^{N} v_n^2\right)^{-\frac{1}{2}}. \tag{4.23}$$

Figure 4.19 is a sample as in the case of M =5, N =5. We draw the circle which has center $(\tilde{x}_{1m}, \tilde{x}_{2m})$ and radius s_m and other circle which has center $(\tilde{y}_{1n}, \tilde{y}_{2n})$ and radius t_n. We can compare vagueness in evaluation for object m and item n by radius of each circle visually. Comparison among s_m or t_n has special meaning, but comparison between s_m and t_n has little meaning.

4.4.3 Results by Using Items Related to Water Quality

In this section, we analyze data by using items which are considered to be related to evaluation of water quality directly. First points measured BOD are analyzed, next points not measured BOD are analyzed.

Points Where BOD is Measured

Objects are extracted to the point where BOD is measured, i.e., the point which has description of (the number of evaluators / BOD annual average value) in a Table 4.2, because we regard BOD is easy to compare among points.

In the survey, one person evaluates one point where BOD is measured, so that the number of respondents is equal to the number of data in the section.

Features of Rivers Figure 4.20- 4.27 show pictures of a part of points. The features of 3 rivers which the points belong to are as follows.

Tedori-river BOD is about 0.5[mg/l]. Water is clearer than other 2 rivers, and in the waterside a lot of nature is left.

Kakehashi-river BOD is about 1 [mg/l] and it is bigger than Tedori-river's. Judging from BOD, we can't imagine that this river is polluted. Color of water look like brown. There are a few bank protections.

Mae-river This is a branch of Kakehashi-river. Water flows from Kiba-lagoon which is a closed water area. Therefore BOD is about 5[mg/l] and is very high in Ishikawa prefecture. Water looks like brown and smells. Because the river flows in the residential areas, there are many bank protections in the side.

Analysis First, we select and analyze data that were evaluated 7 points (Mikawa-bridge, Tatsukuchi-bridge and Hakusangouguchi-entei on Tedori-river, Tsurugashima-bridge and Nomi-bridge on Kakehashi-river, Ukiyanagi-bridge and Miyuki-bridge on Mae-river). The number of respondents and data are 73) as objects, and Question 2-6 (*plants*, *play*, *camp*, *protection*, *clear*) which are related to the features of water itself in Table 4.1 as items.

Figure 4.28 shows the result. Positions of 7 points on the graph are separated in each river, and positions of each item are suitable for current condition. Therefore, it is can be said that the graph grasp the features of each point.

Next, we analyze data of 8 points including Okuwa-bridge on Sai-river in addition to 7 points on Tedori, Kakehashi and Mae-river, and get Figure 4.29. Okuwa-bridge belongs to group of Tedori-river on the data space, although BOD is almost the same as points on Kakehashi-river. We think that the reason is that Okuwa-bridge has different atmosphere from points on Kakehashi-river, and respondents of Okuwa-bridge live near Tedori-river. This result reflects on the present state, too.

The analysis treats points whose respondents are more than 2. Only 1 respondent is not good for analysis because we can't consider vagueness in evaluation, and there is a possibility that attributes of the respondent have strong impact. It is desirable that there are as many respondents as possible to prevent from biasing evaluation strongly. But, we got the good result as Figure 4.29 in the case of more than 2 respondents, so that from the next section points where respondents are more than 2 are analyzed as objects.

Table 4.12 shows eigen values and contributions of the 1st axis and the 2nd axis in Figure 4.29.

Consideration

Position In both Figure 4.28 and Figure 4.29, horizontal axis (1st axis) shows clearness of water and vertical axis (2nd axis) shows recreation activities or familiarity. Figure 4.28 is easier to understand a meaning of axis. The reason is that *camp* and *clear* which are related to the clearness of water are located in positive direction of 1st axis and that *play* and *camp* are located in positive direction and *protection* is located in negative direction on the graph.

Objects and items have different size of variance, namely large or small of vagueness in evaluation. But, we can read properties of 3 rivers on the graph; Tedori-river is relatively clear and is fit to recreation in the waterside, Kakehashi-river isn't water and people can play in the river, Mae-river has poured concrete into the embankment and isn't suitable for recreation. These results are good because it indicates the current condition.

Vagueness in Evaluation First, we mention vagueness of items. *clear* is a little small (0.359 on Table. Others are more than 0.400), but there are small differences among items. Residents have similar impression of water condition (=*clear*), but different impression of other items. We think that the degree of protection, the amount of plants, the frequency of seeing objects and the experience of recreation as playing and camping cause to increase variance in evaluation for items *protection*, *plant*, *play* and *camp*. Especially residents on Tedori-river are divided over *protection* and *plant*. If we had asked specific questions, for example, "Is the bank covered with asphalt?" "Are plants covered with the waterside?", the variance would have been smaller.

Secondly, we pay attention to vagueness of objects. Vagueness in Okuwa-bridge where the number of respondents is the smallest is the smallest (0.132), in other words, evaluations by 2 respondents are closely similar. Considering the number of respondents, we know vagueness is small at Tsurugashima-bridge (0.227), Ukiyanagi-bridge (0.295) and Mikawa-bridge (0.313) and is big at Nomi-bridge (0.468). Ages and span of residence of respondents who evaluated Nomi-bridge are almost same, then it is possible that the feature of Nomi-bridge near which there are both agricultural fields and residential areas and roads are under construction causes vagueness in evaluation. And by reason of this feature, the position of Nomi-bridge on the data space (center (-0.650, 0.278)) is located near the position of Ukiyanagi-bridge (center (-1.352, 0.310)) on Mae-river near which there are main roads and residential areas.

In three points in Tedori-river group, Hakusangouguchi-entei (center (0.465, 0.291)) which is in the upper stream is distant from item *clear* on the figures. This position proves contrary to our expectations that water in the upper stream is clear and water in the lower stream isn't clear because 'water is clear' means that 'water isn't polluted'. One of the reasons is that three dams were built 20 years ago in the upper stream of Tedori-river. Some residents think that water has gotten worse since these dams constructed. Color of water is not clear but brownish near dams. Nevertheless, BOD is about 0.6 [mg/l] in all points of the river (it means there is little pollution), and this is the lowest of all rivers in the prefecture. Moreover, BOD hasn't been changed for 20 years. From the current condition of the river, in this section results of analysis show soft data can supplement hard data and grasp features which we can't know by hard data.

Points Where BOD isn't Measured

In the previous section, we could classify points where BOD was measured by soft data. From this result, we think we may classify points where BOD is not measured by soft data according to the features and guess BOD and properties of the waterside. Then, we expand analytic objects into points not measured BOD.

Analysis The number of points is 23 (The number of respondents is 125, and the number of data are 165). These points are all points in Table 4.2, which include points measured BOD which were analyzed in the previous section. In the survey respondents evaluated two points, in other words, points where BOD is measured and not measured, so that the number of data is bigger than that of respondents.

We can get Figure 4.30. Items are Q2-Q6 (plants, play, camp, protection, clear) and are the same as those of Figure 4.29.

Consideration

Position On the Tedori-river, only Ichinomiya-bridge is classified into Kakehashi-river group in Figure 4.30. Evaluators of this point apt to give lower score for *clear* than that in other points on Tedori-river. In addition to this the followings are regarded as factors; main road crosses on this bridge, the river width is locally narrow, and two residents gave opposite score for *camp* and *play*.

On Tedori-river, Tengu-bridge, Juuhachi-gawara and Wasatani-bridge are located near Tatsukuchi-bridge and Hakusangouguchi-entei on the data space. Tengu-bridge and Juuhachi-gawara are located adjacently and overlap some partially. Because these reflect geographical positions, it is said or guessed that classification is good and BOD of these 3 points are about 0.6[mg/l]. This value is almost same as Hakusangouguchi-entei.

On Mae-river, Ukiyanagi-bridge, Imae-aisatsu-bridge and Imaegata-kantakuchi-yoko belong to area of Kakehashi-river in Figure 4.30. Common points of Mae-river and Kakehashi-river are that water looks like brownish and many residents think there are any plants in the waterside. Differences are evaluation for *protection* and *play*. That there are a little difference between evaluation for water quality of Kakehashi-river and Mae-river means residents have strict and accurate evaluation as respondents of Tedori-river.

We think Ukiyanagi-bridge doesn't have particular character in points on Mae-river and is located on the border between Mae-river and Kakehashi-river because its feature is similar to that of Nomi-bridge. In the other hands, in two bridges in Imae-town (names of points include 'Imae'), atmospheres of these points are similar to Miyuki-bridge on Mae-river. But the river width is wide, many plants cover the waterside and the riverside near these 2 points are improved as 'flower road' [74]. These may be factors in results of classification. From results of evaluation of these points, we know that items except physical appearance are regarded as important when residents evaluate water and people have knowledge we can't get by only BOD.

Perhaps if points which don't have measurements on Mae-river or Kakehashi-river are classified correctly on the data space, BOD of them may be guessed from BOD of points which have measurements BOD.

In Figure 4.30, horizontal axis (1st axis) shows clearness of water and vertical axis (2nd axis) shows recreation activities in the water or waterside. Table 4.13 shows eigen values and contributions of the 1st axis and the 2nd axis in Figure 4.30.

Vagueness in Evaluation First we make mention of vagueness of items. *play* (0.527) and *plant* (0.481) have a little bigger vagueness and the others have almost same value. Next vagueness of objects are observed, then Suehiro-ryokuchi has the biggest value (0.383). The shape of this area is long and borders on Mae-river and another river, so that there is a possibility that each respondent imaged different points. Nomi-bridge also has big vagueness for the number of respondents (0.302).

Distributed positions of items are fit to the current condition. In view of relative changes of the result according to the data, the result obtained in this section is good as well as Figure 4.28, 4.29, then residents perceive the feature of rivers by subjective evaluation.

Table 4.14 compares vagueness of evaluation items (t_n) in Figure 4.29 and Figure 4.30. The common points are those *play* has big value and *clear* has small value. But, compared to the result of 5 points, in the result of 23points *camp* and *protection* are smaller and *play* and *clear* are bigger, in other words, vagueness of items related to water directly are bigger. It is likely that variation of evaluation for water itself becomes bigger because of increase in points and respondents.

4.4.4 Results by Adding Items Showing Regional Attributes

In the previous section, we used items which are related to water itself or watersides strongly. In this section, we analyze data by using questions both which asked circumstances around watersides and which asked water condition. We examine whether points are classified based on the property of points by two factors (water quality and neibouring) or not. Then, we calculate changing the number of items, and try to find items that can classify rivers, namely contribute total evaluation greatly. Here, we utilize as minimal items as possible. And we select the items which are independent each other and whose vagueness are small.

Results are shown in the next section as the number of items has been changed. Rules to reduce items are following; 'If the circle which shows n_1 overlap more than two circles which show $n_2, n_3, \cdots$, n_1 are removed. If the circle which shows n_1 overlap another circle which shows n_2, the item which have longer radius, it means vagueness are bigger is removed'.

Analysis

First, we calculated correlation among all items in Table 4.1. We think that *camp* replaces *forested land*, *sound* and *rapid* because correlation coefficients of *camp–forested land*, *camp–sound* and *rapid–sound* are more than 0.5. Figure 4.31 is the result of analysis used 10 items (*creature*, *plant*, *play*, *camp*, *protection*, *clear*, *agricultural field*, *roads*, *town*, *source*).

Next, we remove *source*, *creature* and *roads* which overlap other items in Figure 4.31 in accordance with the rules. Figure 4.32 is the result of analysis used 7 items (*plant*, *play*, *camp*, *protection*, *clear*, *agricultural field*, *town*).

Figure 4.33 is the result of analysis used 6 items (*plant*, *play*, *camp*, *protection*, *clear*, *town*) which removed *agricultural field* near both *plant* and *protection* from Figure 4.32. Finally Figure 4.34 is obtained by using 5 items (*play*, *camp*, *protection*, *clear*, *town*), which was removed *protection* near *plant*. This result is called pattern2 because we distinguish it from the result shown in Figure 4.30).

Consideration

In Figure 4.31-4.34 horizontal axis (1st axis) means clearness of water or recreation activities in the water. This is the same as horizontal axis of Figure 4.30. Vertical axis (2nd axis) means attributes points themselves have as *town* (plus) and *agricultural fields* (minus), and these attributes have stronger impact than characters of water have. We know that objects have the following relation (this sounds paradoxical); 'if there are many plants in the waterside, there is bank protection and near agricultural fields'. These features meet current conditions, in other words, soft data are useful for us. *protection* has two meanings; one means 'asphalt paving=artificial space. It is bad for nature.' and the other means 'asphalt paving=esplanade. It is good for people, because they are familiar with the waterside.'. For example, places on Mae-river, there is a possibility that people think *protection* is good.

In Figure 4.34 there are no items which overlap other items. But, it is difficult to find the meaning of vertical axis (2nd axis) because the second eigen values of *town*, *play* and *camp* are the almost similar. Therefore, we conclude the result in Figure 4.33 is better in the respect that this respects attributes of points more strongly and regard 6 items *play*, *camp*, *protection*, *plant*, *clear* and *town* as important items which contribute to total evaluation of objects used in this analysis. Finally, Table 4.15 shows eigen values and contributions of the 1st axis and the 2nd axis in Figure 4.31-4.34.

4.5 Summary

In the former of the chapter, we have analyzed soft data which evaluated points and considered the relation between hard data and soft data. In rivers and lakes in Ishikawa, in Tedori-river and Kakehashi-river soft data differed from hard data. However hard data were less than 1 [mg/l] which was classified into 'good level', there were a few residents who evaluated water quality as good. Because there were a lot of residents who evaluated Tedori-river as 'normal', it is likely that some of them gave evaluation good meanings and others gave bad meanings. But, a number of residents who evaluated Kakehashi-river 'bad' was more than that of residents who evaluated the river 'normal'. Impact of dams constructed upstream of Tedori-river and color of water of Kakehashi-river cause difference between hard data and soft data.

In the later of the chapter, we have analyzed data of subjective data for water quality and water spaces by residents with quantification theory type Ⅲ considering vagueness in evaluation. Results by quantification theory type Ⅲ were classified into collected data which the similar features have on the data space, so that people's feeling (*Kansei* data) revealed not only the current condition as objective data but also facts we can't know from hard data. In regard to vagueness of objects, terrain or geographical attributes affected evaluation. As to vagueness of items, those of items related to water itself were small, but those of related to circumstances or doing recreations were big. If we hope vagueness in evaluation is smaller, we should ask more detailed questions by which we can understand what to be asked.

From the result, we put forward water quality (*clear*), recreation (*camp*, *play*), situation of water or watersides (*protection*, *plants*), geographical attributes (*town*) as items by which we can distribute rivers according to the features and image the characters of the water even if we haven't seen there.

Problems are that respondents belong to only two local authorities. The number of objects is 23, which we think they are sufficient, but the area where respondents live is not wide. The result we obtained, for example items for classification of rivers may be applied to only the points we treated in this chapter. But, generally it is hard to find universal characters or rules for environmental evaluation and natural to change them in accordance with changes of objects and observers. Therefore, we think our analyses are meaningful because we found the characters of the objects adding vagueness in evaluation.

In the chapter, we tried to apply the result of analysis by soft data to BOD (hard data), and to utilize both data in a mutually complementary form. As researchers say in environmental assessment, establishing integrated methods for environmental evaluation with qualitative data and quantitative data are needed. To do so, first we need to develop qualitative models to set the result for hard data.

From now on, if data can be obtained more from the residents of many towns and cities, I could evaluate the point from which it is distributed over the larger range, and think that it is made to research of the environment assessment which has involvement in a policy in a prefecture level.

In the next chapter, we apply soft data and our analysis in the previous chapter and this chapter to EFM shown in Chapter **2**. Then, we consider how we can grasp environmental problems in Ishikawa by using EFM and what data we need to complement with parts which aren't identified in this thesis.

Table 4.10: Factor loadings.

	Sai-river			Asano-river		
item	1st factor	2nd factor	3rd factor	1st factor	2nd factor	3rd factor
clear	0.020	0.045	0.598	**0.744**	0.116	-0.150
amount	0.168	0.159	**0.621**	-0.411	0.612	-0.451
recreation	**0.788**	0.071	0.203	-0.361	0.509	0.124
walk	0.571	-0.133	0.080	0.100	0.055	-0.056
play	0.237	0.255	0.156	-0.113	-0.011	**0.947**
watersports	0.215	0.145	0.497	-0.567	-0.030	0.688
safe	0.744	0.058	0.065	-0.086	0.063	0.049
evacuation	0.677	0.319	-0.094	**-0.865**	-0.093	0.110
green	0.435	0.555	0.052	0.375	**0.893**	0.070
creatures	0.433	0.549	0.292	0.088	0.881	-0.001
natural	-0.200	**0.845**	0.115	0.511	0.635	-0.276
landscape	0.539	0.136	0.262	0.733	0.336	0.001
	Fushimi-river			Tedori-river		
clear	0.724	-0.541	0.199	0.391	0.544	0.225
amount	0.598	0.424	-0.416	-0.182	0.024	**0.744**
recreation	-0.123	0.105	**0.979**	0.709	0.447	0.056
walk	**0.918**	-0.033	-0.254	0.786	0.035	0.109
play	-0.370	0.428	0.775	0.647	0.001	0.186
watersports	-0.025	**0.923**	0.248	0.364	-0.096	0.171
safe	-0.203	0.024	0.078	-0.165	**0.864**	-0.031
evacuation	0.580	-0.048	0.094	0.163	0.500	0.467
green	0.833	0.244	-0.113	0.335	0.404	0.739
creatures	0.377	0.776	0.197	0.295	0.565	0.189
natural	0.894	-0.221	-0.204	0.543	-0.212	0.621
landscape	0.877	0.201	-0.130	**0.896**	0.023	-0.037
	Kahoku and Kiba-lagoon					
clear	0.321	-0.073	0.047			
amount	0.439	0.474	0.252			
recreation	0.340	0.741	-0.315			
walk	0.078	0.120	**0.876**			
play	0.047	-0.152	0.517			
watersports	0.269	0.703	0.543			
safe	0.264	**0.781**	0.356			
evacuation	-0.134	0.752	0.058			
green	0.837	0.285	-0.246			
creatures	**0.907**	0.047	0.313			
natural	0.869	0.111	0.072			
landscape	0.738	0.080	0.621			

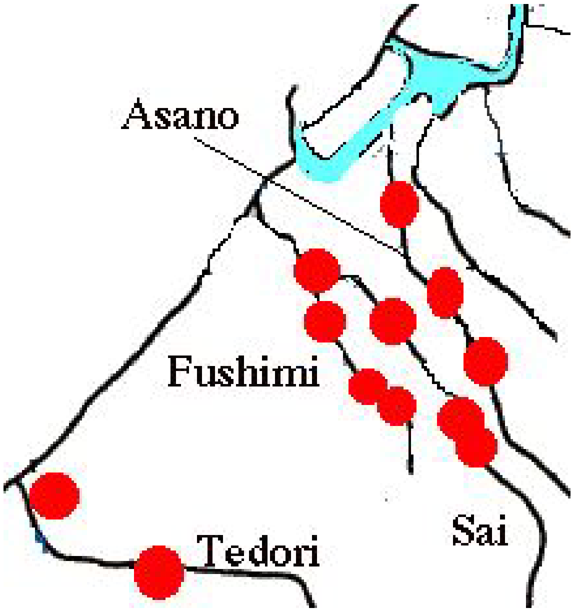

Figure 4.13: Map of points (Sai, Asano, Fushimi and Tedori).

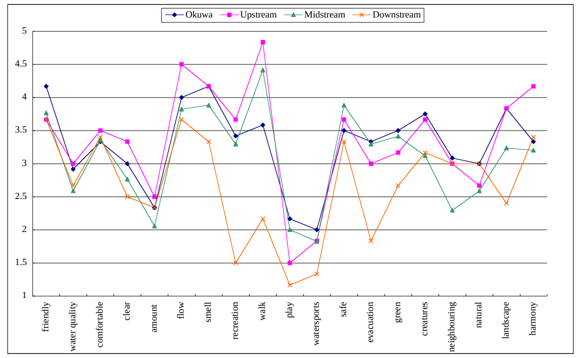

Figure 4.14: Averages of Sai-river.

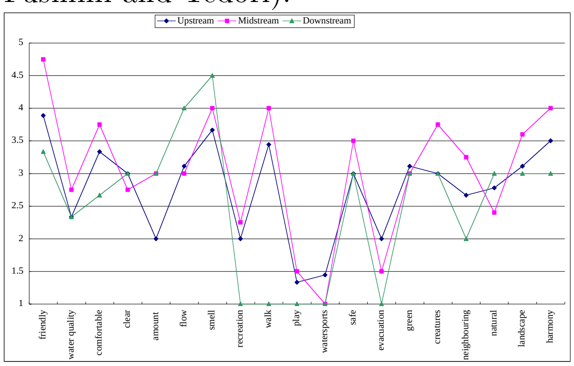

Figure 4.15: Averages of Asano-river.

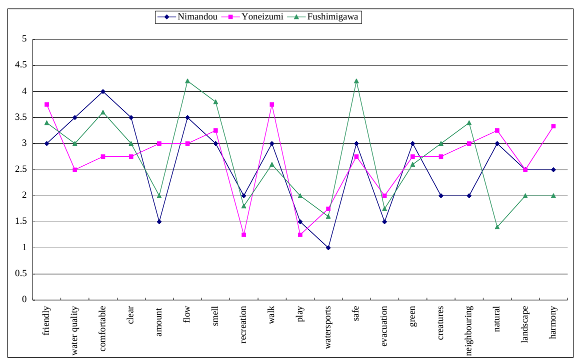

Figure 4.16: Averages of Fushimi-river.

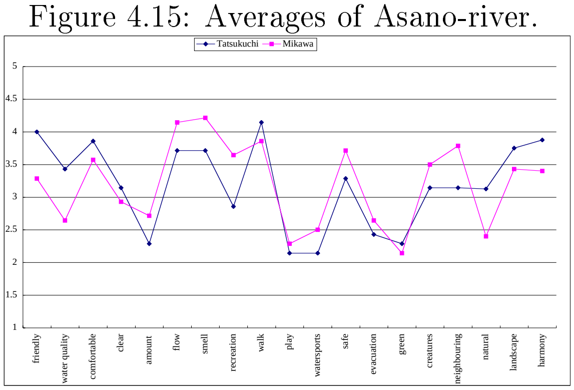

Figure 4.17: Averages of Tedori-river.

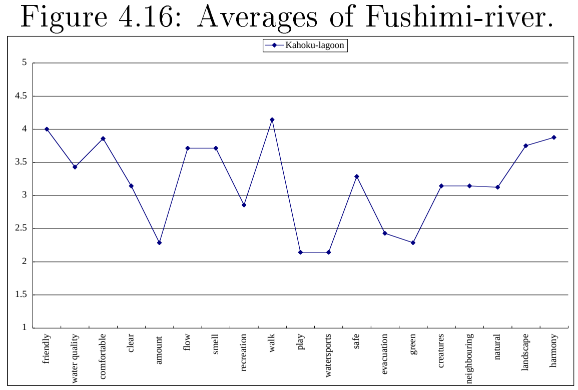

Figure 4.18: Averages of Kahoku.

Table 4.11: The degree of residents for items of Question 2-20.

name	cleaning	flow, etc	recreation	safety	green	fish, etc
Sai	0.415	0.268	0.220	0.073	0.171	0.415
Tedori	0.308	0.115	0.385	0.154	0.385	**0.423**
Asano	**0.412**	0.118	0.176	0.118	0.176	0.353
Fushimi	**0.455**	0.273	0.182	0.182	0.091	**0.455**
Kahoku	0.778	0.000	0.222	0.000	0.111	0.333
Kanakusari	0.286	0.286	0.286	0.143	0.286	0.429
Daishouji	**0.800**	0.400	0.200	0.000	0.000	0.400
Nagaso	**0.600**	0.000	0.400	0.000	0.400	0.200
Morimoto	0.250	0.250	**0.500**	0.250	0.250	**0.500**
Oono	**0.667**	0.000	0.333	0.000	0.000	0.000
Kakehashi	0.333	0.000	0.000	0.333	0.000	**0.667**
Kiba	**1.000**	0.000	0.000	0.000	0.000	0.667
Yasuhara	**0.667**	0.000	0.000	0.333	0.000	0.333
Misogi	**0.750**	0.500	0.000	0.000	0.250	0.000
name	wastes	harmonize	naturalness	others	nothing	
Sai	0.439	0.171	**0.512**	0.049	0.000	
Tedori	0.269	0.115	0.346	0.000	0.000	
Asano	0.353	0.176	0.353	0.059	0.059	
Fushimi	**0.455**	0.364	0.364	0.000	0.000	
Kahoku	**0.889**	0.000	0.667	0.111	0.000	
Kanakusari	0.000	0.143	**0.714**	0.000	0.000	
Daishouji	0.400	0.400	0.400	0.000	0.000	
Nagaso	0.200	0.200	0.400	0.000	0.000	
Morimoto	0.250	0.000	**0.500**	0.000	0.000	
Oono	0.000	0.000	0.000	0.333	0.333	
Kakehashi	0.000	**0.667**	**0.667**	0.000	0.000	
Kiba	0.333	0.333	**0.667**	0.000	0.000	
Yasuhara	0.333	0.333	0.667	0.000	0.000	
Misogi	**0.750**	0.250	0.250	0.250	0.000	

Table 4.12: Eigen values and contributions of the 1st axis and the 2nd axis in Figure 4.28 and 4.29

item	eigen values		contribution	
axis	1st	2nd	1st	2nd
Figure 4.28	0.04	0.001	0.796	0.115
Figure 4.29	0.047	0.01	0.774	0.159

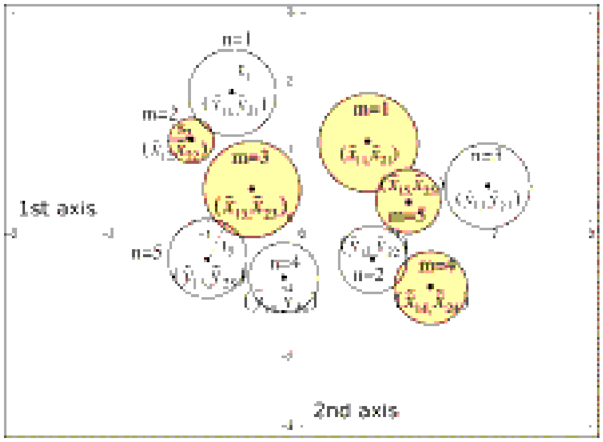

Figure 4.19: A sample. $(M = 5, N = 5)$

Figure 4.20: Mikawa-bridge on Tedori-river.

Figure 4.21: Tatsukuchi-bridge on Tedori-river.

Figure 4.22: Tengu-bridge on Tedori-river.

Figure 4.23: Tedori the 3rd dam on Tedori-river.

Figure 4.24: Nomi-bridge on Kakehashi-river.

Figure 4.25: Tsurugashima-bridge on Kakehashi-river.

Figure 4.26: Miyuki-bridge on Mae-river.

Figure 4.27: Ukiyanagi-bridge on Mae-river.

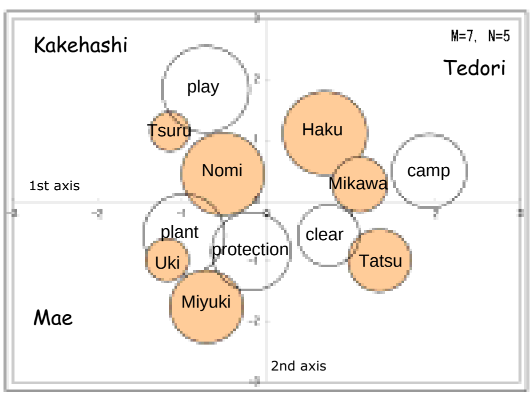

Figure 4.28: The result used data of 7 points and 5 items.

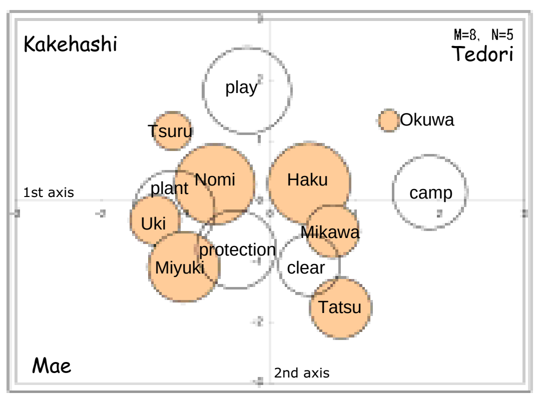

Figure 4.29: The result used data of 8 points and 5 items.

Table 4.13: Eigen values and contributions of the 1st axis and the 2nd axis in Figure 4.30.

item	eigen values		contribution	
axis	1st	2nd	1st	2nd
Figure 4.30	0.042	0.016	0.604	0.226

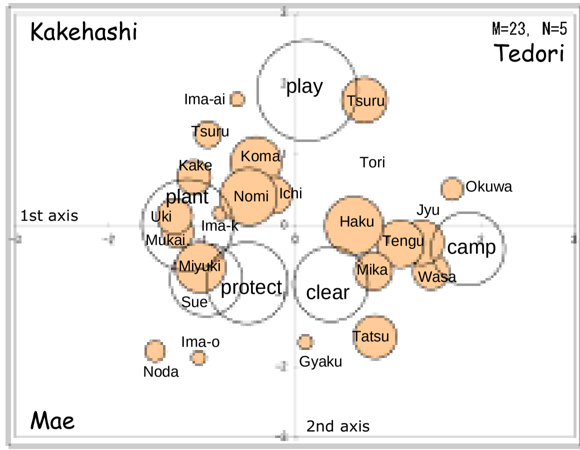

Figure 4.30: The result used data of 23 points and 5 items.

Table 4.14: Comparison t_n of items.

item	$t_n(M = 8, N = 5)$	$t_n(M = 23, N = 5)$
play	0.50	0.53
clear	0.36	0.39
camp	0.43	0.39
plant	0.47	0.48
protection	0.46	0.43

Table 4.15: Eigen values and contributions of the 1st axis and the 2nd axis in Figure 4.31-4.34.

item	eigen values		contribution	
axis	1st	2nd	1st	2nd
Figure 4.31	0.027	0.021	0.364	0.276
Figure 4.32	0.037	0.026	0.431	0.305
Figure 4.33	0.043	0.023	0.487	0.254
Figure 4.34	0.049	0.022	0.535	0.244

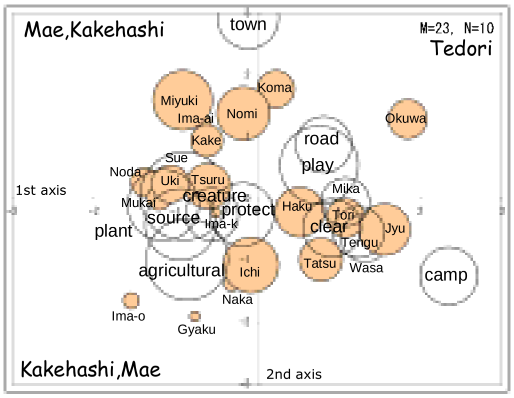

Figure 4.31: The result used data of 23 points and 10 items.

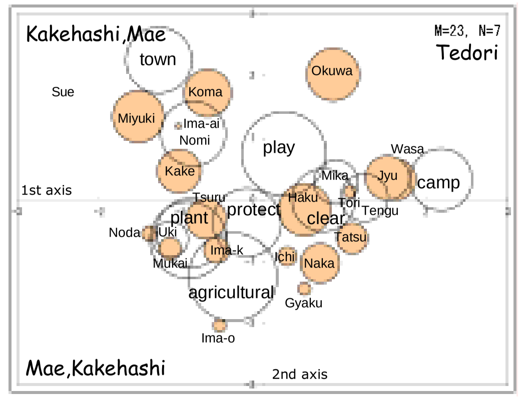

Figure 4.32: The result used data of 23 points and 7 items.

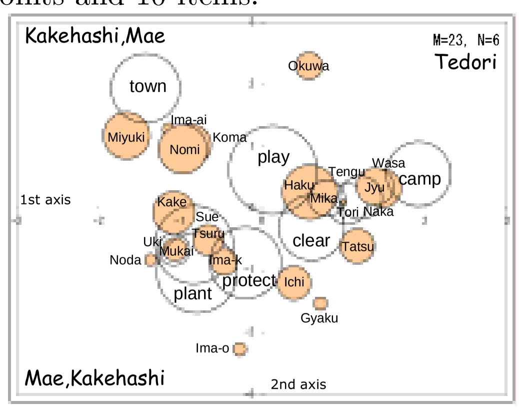

Figure 4.33: The result used data of 23 points and 6 items.

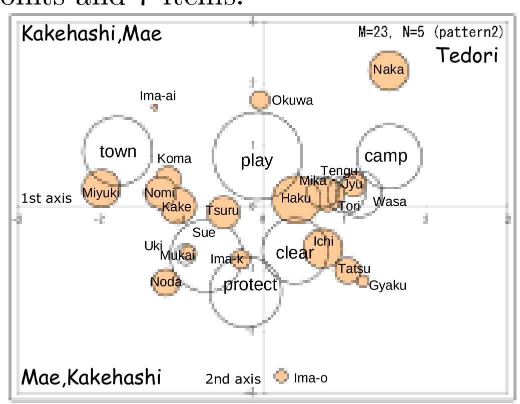

Figure 4.34: The result used data of 23 points and 5 items (pattern2).

Chapter 5

Integration of Hard data and Soft Modeling

5.1 Introduction

Chapter **2** did modeling with hard data. Chapter **3** and **4** suggested methods to extract knowledge from soft data and calculations.

In this chapter, first, we conclude survey results. Next, we propose a method for modeling in future. Finally, we consider what our surveys should be improved and how information should be provided residents with.

5.2 Summary of Evaluation by Residents

The section considers current condition of water environment in Kaga area in Ishikawa by using models gotten from residents' evaluation in Chapter **3** and **4**.

5.2.1 Relations between People and Water Environment

Water is vital for our daily life. It seems that people have felt familiarity with rivers and lakes supplying us such water, and taken a close look at the water condition (Section **4.2.2**). But, many people go to the waterside only for walking and passing, in other words, there are a few people who are contacting with water environment directly or actively. It is possible that this point is related to judgment of water quality from not only water itself but also watersides and circumstances in urban area (Section **3.6.2**).

About half of residents know where tap water comes from and how waste water are treated (Appendix A). One third of population in Ishikawa is using groundwater as tap water. In main cities and towns such as Kanazawa, not rivers there but Tedori-river provides residents with tap water [1] . Moreover, in general, there are a few chances for residents to be involved in water management and to express their opinions for it. These

[1]http://www.pref.ishikawa.jp/densui/tedori/city.html

show that water of rivers/lakes is not really familiar with people but tap water is. 'I realized that I haven't known immediate rivers!' We received the comment after the survey carried out in 2002 (Section **4.2.2**). It indicates that the relation between water environment and residents is distant 'spiritually' although it is close 'physically'.

By the way, some residents said, "Tedori-river was so clear that we could swim, but now it is so dirty that we can't do so.", "There were a lot of children playing in the river, but now very few.", etc (Section **4.2.1**). These opinions also indicate that residents have been distant from water gradually. As the result, residents have given rivers low score probably.

Factor loadings of items (factors) related to *naturalness* were higher than those of other items relatively in evaluation of water quality. And, *clear*, *natural* and *creature* were needed more than *recreation* (Section **4.3.3**). If naturalness has been recovered, people would get acquainted with water spaces.

Many watersides have taken flood control measures such as constructing dams and covering with concrete, and changed flow of water until now. Recently, these measures have been thoroughly reviewed because of financial circumstances and environmental reservation. In Ishikawa, campaign against building Tatsumi-dam has carried on [2] . Policies of social problems including environmental issues are taking a turning point. For example, when we consider flood control measures, we recognize a risk ; a river protected nature stands against XX precipitation [mm/day]. After the risk is shown, we need consider how watersides are and carry out an environmental assessment for the measures.

5.2.2 People's Feeling and Measured Value

Before we carried out the survey in 2000, we supposed that we obtained an unsurprising results (ex. 'evaluation of water quality is bad in the lower stream but good in upper stream', 'evaluation of air quality is good in areas except roadside area and urban area.') and made evaluation models which corresponded with measured data, in concrete terms, which could estimate environmental condition expressed numerical value in points where only soft data existed. But, obtained soft data didn't match BOD/COD in some places such as Tedori-river and Kakehashi-river, and some rivers had similar evaluation in all points. At last, in large ranges such as upper stream, down stream, evaluation by residents weren't connected with numerical data. Therefore, to relate between soft data and hard data was harder than expected.

Then, we proposed the method to check whether residents evaluation depended on regions as context and applied it to our data in Chapter **3**. In Chapter **4**, we narrowed down our subjects to 2 local authorities, then examined similarities of rivers considering

[2] http://www2u.biglobe.ne.jp/ saigawa/

vagueness in evaluation and which *partial evaluation* affected *total evaluation* of environment. These are methods to identify combination of total evaluation for water quality and watersides and partial evaluation. Extraction of items which have strong impact on total evaluation in rivers/lakes characterized them and showed their improvements.

People apt to evaluate past condition as good and to forecast future condition is worse even though environmental condition at the present day and in the past is the same (or the past condition was worse). Some researchers have pointed out that people think 'environmental condition has become worse and worse' is one of misunderstanding about environment [75]. But, in points where there is difference between soft data and hard data, is evaluation by residents wrong? Is thought that 'environmental condition has become worse and worse' misunderstanding?

To consider these respects, we need to rearrange how residents evaluate water quality. When residents evaluate water quality, *water color* and *water clarity* are regarded important in evaluation. But, there is little relation between changes of evaluation for these items and changes of BOD/COD values. For example, if water mixes earth and sand, it doesn't increase organic matters and brown water lowers peoples' evaluation of water color and water clarity. Then, there is difference between people's feeling and numerical data. In addition, we know condition of watersides and circumstance is more important than water itself for evaluation of water quality especially in rural areas. Observed data measure only objects, but people evaluate watersides totally. They apt to evaluate their environment pessimistically and strictly, or sometimes in response to environmental changes, but we can't say their feeling is wrong and it isn't worthwhile. Of course, if residents misunderstand changes of measured values, it is necessary to correct their misunderstanding by providing information.

Based on evaluation by human obtained from our survey results, we summarize water environment in Ishikawa. When *total evaluation* is given high score (=4 or 5 in our surveys), measured data is usually good. Therefore, if *water color* or *water clarity* which affects *total evaluation* greatly in a point is given good evaluation (=water isn't brown, water is clear), we will be able to conclude water quality in the point is satisfactory level. In contrast, if *water color* or *water clarity* is given bad evaluation in a point where total evaluation is normal or bad (=less than 2.5), we need to pay attention to water quality of the point. In the point, if items related to recreation as playing in the water or to circumstance have bad score, it's highly likely that hard data is also bad.

By the way, there are many items to evaluate including BOD and COD. One of items to evaluating is clarity of the water. The item is measured by visual observation and shown in length. But, clarity of the water isn't measured all points. Then, we often use Suspended Solid (SS $[mg/l]$) instead of clarity. SS and clarity have strong correlation [76, 77]. SS is a small particle solid suspended in water. It is treated as an index of 'turbidity'. Table

5.1 shows SS values of main points.

Table 5.1: The relation BOD or COD and SS.

Water	Points	BOD or COD[mg/l]	SS[mg/l]
Tedori-river	Hakusangouguchi-entei	0.6	26
Tedori-river	Tatsukuchi-bridge	0.6	26
Kakehashi-river	Tsurugashima-bridge	0.8	11
Mae-river	Miyuki-bridge	4.9	16
Mae-river	Ukiyanagi-bridge	5.5	17
Sai-river	Okuwa-bridge	0.8	5
Sai-river	JR-bridge	1.1	5
Asano-river	Suzumi-bridge	1	8
Asano-river	Matsudera-bridge	3.1	4
Fushimi-river	Fushimi-bridge	3.6	9
Fushimi-river	Nimando-bridge	1.4	5
Fushimi-river	Yoneizumi-bridge	2.2	5
Oono-river	Awagasaki-bridge	2.6	14
Kahoku-lagoon	-	7.7	25
Kiba-lagoon	-	7.5	21

The higher SS value is, the more suspended solid the river or the lake has, namely, the more turbid the water is. But, speaking strictly, it measures an amount of foreign objects, then SS doesn't always correspond with turbidity. Less than 15 [mg/l] in the lake and less than 25 [mg/l] in the river are standard values.

SS of Tedori-river is higher than those of any other rivers/lakes. Some residents and researchers said dams and outflow of earth and sand from dipping of sands into the river in a heavy rain have affected color and clarity of water. These factors also affect SS probably. Kahoku-lagoon, Kiba-lagoon and Kurabe-river (the last river isn't shown in the table) have high SS value. Both lagoons have high COD, too. SS value and soft data are closely related and we should attach weight to SS value in addition to BOD or COD value when we evaluate water condition.

We calculated regression models in which BOD and SS expressed total evaluation of soft data (the survey in 2001). Points which had BOD/COD and were evaluated by more than 4 people. Dependent variables are averages of total evaluation (Q1-10 in Table 4.1) in each water point, and independent variables are BOD/COD and SS. The following expression has obtained from survey data of 7 points on 3 rivers in 2001. Here, R^2 means the coefficient of determination adjusted for the degrees of freedom.

$$(R^2)^* = 0.696, \text{ data number}=7$$
$$total\ evaluation = -2.526 \quad +0.014 \times SS \quad -0.213 \times BOD$$

Calculation using survey data of 10 points in 2002 was lower R^2 ($R^2 = 0.533$). In a regression model used soft data and BOD, $R^2 = 0.585$. In the models used BOD, SS and soft data a coefficient of BOD is positive and that of SS is negative. It means that 'The less BOD is (=water quality is better) and the bigger SS is (=water is more turbid), the higher total evaluation is (=total evaluation is given better score).'. Only Tedori-river has characteristic of high SS and low evaluation and total evaluation for the river is better than other rivers, so that it is a little hard to explain the relation between SS, BOD and soft data by using numerical expression. But, we guess it is likely that there is some relation between SS and soft data from case of Tedori-river. There are various approaches of index for water quality; for instant, emphasis of clarity which is in proportion to SS [76, 77], utilization of not BOD/COD but natural habitat of creatures in water as index [78].

$$(R^2)^* = 0.533, \text{ data number}=10$$
$$total\ evaluation = 2.970 \quad -0.193 \times BOD \quad +0.005 \times SS$$

Ishikawa prefecture publishes measured values of water quality in [35, 79] every year. But, how many residents grasp measured values of immediate water environment? Do they understand meanings of figures measurement values show?

[35] doesn't explain meanings of BOD/COD as Table 3.1 (Section **3.2.2**). In this summer, a squareflipper (bearded seal) appeared in Tokyo and Yokohama in Japan. Mass media such as newspapers and TV programs have introduced the seal, because squareflippers live in Arctic Circle and rivers where the squareflipper was found were very dirty. There were some reports introduced BOD value but very few ones described meaning of BOD. Showing BOD value is inadequate to provide citizens with environmental information. It was necessary to explain meaning of these measurements in order to show increasing interest in water environment. Thereby people become interested in problems of water pollution in immediate rivers/lakes 'water improvement, and campaign' may have occurred. This case implies that we should build awareness that how to provide with environmental information is important. We apt to have less interest in basic contents than media; 'By what do we provide with information?' is more important than 'how do we convey information?'.

Researchers are in two position; one is an expert, and the other is a performer of environmental issues [7, p.254]. To get people's attention for approaches of issues in latent and noticeable problems in our society brings researches and research organizations closer to citizens. In addition, to increase awareness of issues results in changing our society. A book reporting fields destructed environment [80] has introduced a word of M. Beaud, a French historian; "Indifference decays our world.". To heighten residents' interest in social problems including environmental problems, researchers need not only publish academic results but also give citizens information. Now, a role of researchers is put to the test.

5.3 Relations between Environment and Human Activities

Chapter **3** and **4** focused on water problems and analyzed the condition with survey data and measurements. Original purpose of the analysis was utilization of it as a part of the integrated model (EFM). Then, this section considers a relation between human activities and environment (wastes, water quality) and a method to analyze the model comprehensively.

We show the chart of the model in Chapter **2** again (Figure 5.1).

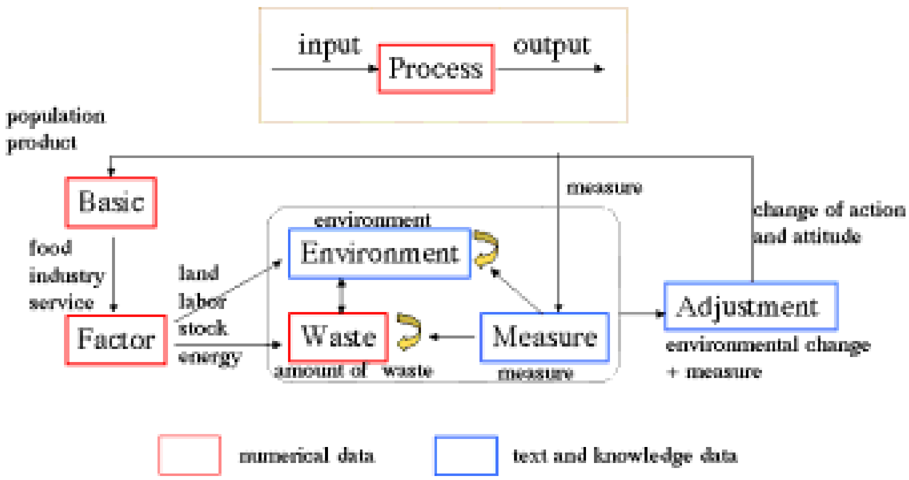

Figure 5.1: The simple environment framework model.

We identify the relation between human activities and environment in Basic process, Production process, Waste process, Environment process focused only water problem, Measure process and Adjustment process in EFM by using hard data modeling in Chapter **2**, soft data modeling in Chapter **3** and **4**, and observed value of water quality (BOD/COD), then consider three stages as follows;

1. Stage 1 (1970-1980's) : "Production activities have flourished → production factors have increased → water quality has been worse, more quantity of water intaken has been needed, an amount of waste has increased → measures for flood control and water pollution have been implemented, people' interest in environmental problems are increased→"

2. Stage 2 (1990's) : "Production activities have flourished → production factors have increased → water quality hasn't been affected (water quality hasn't changed or has been better), an amount of waste hasn't changed or has reduced → creating

friendly water environment have required, leaders' consciousness and actions has changed →"

3. Stage 3 (now–future) : "Production activities will maintain current condition or reduce → production factors will also maintain current condition or reduce → water quality will be improved, an amount of waste will reduce → people's will change consciousness and actions will change, industrial structure and life style will change →".

In Stage 1, environment standard for water quality of each water was constructed. But, judging from environmental condition, the standard didn't affect environment very much. Because our surveys didn't ask the past consciousness and actions and there were no data treating them, we can't identify people's consciousness and actions perfectly based on data. But, we guess (1) EFM has run in Stage 1, (2) that environmental problems became 'issues' generated changes of consciousness and actions as output from Adjustment process at the end of Stage 1, (3) Stage 1 ended and Stage 2 started. In both Stage 1 and Stage 2 gross production and total amount of production factors have increased, but, for example, energy consumption per population has increased and energy consumption per gross production has decreased; energy efficiency of production activities has improved and energy consumption of production and service individual used has increased.

Difference between Stage 1 and Stage 2 is as follows. The first point is impact on environment. It is affected by increasing interest in environment problems and taking various measures (diffusion of sewerage, presentation of target for reducing wastes, etc). Sewerage contributed to preventing water from rising BOD/COD (aggravation of water quality) greatly. The reason is that sewerage can dispose of 90% of pollutant in flowing water and the rate of diffusion of sewerage in Ishikawa has changed from 10% to 60% for 20 years. Moreover, regulation of waste water on business establishment has influenced preservation of water quality. But, it is rare for evaluation of water quality to be better in watersides where water condition has been maintained or improved, because evaluation of watersides and water quality by people is lower when circumstance changes (Chapter 3 and **4**). The second difference is consciousness and actions in Adjustment process. In 1990's environmental policy/measure has changed from direct regulation to spontaneous measure in Ishikawa as well as Japan. It reflects consciousness and actions and measure in the next step.

In Stage 3, we presume production activity reduces with changes of economical situation and life style. Because production activities has affected not water quality but an amount of waste, waste generation will reduce.

[Water quality]

First, it is necessary to prioritize improvement of water quality in points where both

measured value and soft data aren't good (measured value is lower than standard and soft data are less than 2.5 on a scale of 1 to 5). Next, points where observed value meet standard but people don't evaluate as good should be treated. As discussed in Chapter **3**, meaning of evaluation by residents depends on location and characteristics of the point (object). Therefore, finding important items for evaluation of water quality in the region (our approaches contribute to this work) is needed. After that, measures to improve these items are required. We need to consider what residents need for watersides depends on their evaluation of water quality (Section **4.3.3**) then. Recently load from domestic wasted water has been more than that from industrial waste water, so that measures against domestic wasted water are urgent.
[Waste]
General waste from household hasn't changed (hasn't decreased), while industrial waste from industrial activities has reduced. Then, output of Adjustment process includes changes of people's consciousness and actions. As discussed in Chapter **2**, changes of industrial structure is essential for economy's growth and control of energy consumption in addition to environmental measures. Changes of industrial structure are closely related to changes of our life style and our mind. Improvement of our consciousness and actions is one of the important problems for policy makers, companies and organizations that are tackling environmental problems. This is also supported by analysis in this thesis.

We have considered processes on EFM based on analysis in the previous chapters. Hereinafter, we explain what data are needed and how analysis methods are effective to utilize EFM more efficiently.

First, we need data on residents' consciousness and actions in the past which is an output of Adjustment process. It is desirable to obtain or guess data from survey results carried out in the past. But, if these data don't exist, we can only carry out a survey which asks the past. In this case, there is a possibility that we can't get answers reflecting actuality because of failure of memory. To forecast the future and make scenarios, data (pattern) which show the relation between measures and actions are also needed. These data may be more useful than results asked the past. There are many researches which make models of environmental consciousness and actions based on surveys psychologically ([81], etc). Including these approaches, we can assimilate other approaches and sub models into EFM.

Next, we need to run EFM in separated regions or points as making rules in Environment process (Chapter **3** and **4**). It is difficult to obtain data used in Basic Production process and Production Factor process in small unit (region), so that we can apply EFM to smaller regions than local authorities. In Ishikawa as a whole population and gross production have been increased, but these differ in regions. A model in which changes of social condition is related to changes waste and environment in regions, for example, in which antecedent are statistical data and consequent are environmental changes and human behaviors, will make possible our proposal measure and policy depending on local characteristics.

EFM can run with not only all factors related to local environmental problems but also specific factors. Noteworthy items include people's consciousness and actions, ecological business. We have already stated the former. The latter, Ecological business, is paid attention now, and is regarded as important for improving environment in the thesis. Realities of ecological business have grasped by research institutions and companies. Community-based enterprises have brought ecological business to a successful conclusion [82]. Taking advantage of industries which are active in the region and developing the industries into ecological business is the most efficient. For instant, in Ishikawa, textile industry and agriculture have been active. To maintain or increase agricultural production contributes to keeping agricultural fields including nature and self-sufficiency in food products and to changing resident's mind. Utilization of locally grown foods has been promoted [3] . Ecological business is now developing. It is necessary to find a mechanism for expanding ecological business.

5.4 Review of Questionnaire Survey

Points to be reviewed in our surveys are as followings.

- Method

  Questionnaire surveys were effective for obtaining numerical expressions. If an interview survey as a case study had carried out along with questionnaires, the research would has obtained two kinds of models, quantitative and qualitative models, and has been more useful and newer one in the respect we proposed a new modeling method and its utilization.

- Collect rate (response rate)

  Collect rate of mail surveys has risen more than before [15, p.90]. But, in this research the rates were less than 50%. In some surveys, sending collection letters to respondents by the deadline raised collect rate [83]. Because our survey had many respondents or were distributed from door to door, we didn't press returning questionnaires. The survey in 2001 was improved its layout; ex. answer sheets could be put into envelopes without folding the sheets. But, it is likely that this improvement didn't contribute to rising collect rate.

- Questions

  Questions of the survey in 2000 served the purpose of grasping residents' feeling for

[3] http://www.pref.ishikawa.jp/nousei/syokking/

the whole environmental issues. Questions of the survey in 2001 might be changed into those of the survey in 2002. The reason is that questions in 2002 classified into fields were easy to apply some kinds of data analysis methods and answers reflected the current situations by questions asked not possibilities but realities. If we had asked about people's perception of hard data such as measured values of points people evaluated and desirable measurements, hard data and soft data would have interrelated more easily. Environmental evaluation is used for not consensus-building but distinguishing right from wrong. Therefore, it is necessary to establish an evaluation method including both 'good or bad for environment' and 'satisfaction or dissatisfaction with environment'.

- Announcement
  In the survey, to return and publish the results are important processes [15, p.237]. Without follow-up the surveys respondents who answer them distrust of all social surveys. Our surveys could not return their results to the respondents. It is essential to ask addresses of respondents who want to return the results and to send the report. In our research, we are considering that we send local governments in Ishikawa reports of the surveys. There were some opportunities to introduce survey results to people in 'ecological fair', a forum in Kanazawa (APF2002) and a meeting of nonprofit organization (NPO) the author belonged to. The opportunities were important because residents except researchers expressed their opinions and returned their comments and suggestions to us. Having more opportunities to exchange opinions contributes to analyzing of current condition of water quality based on dialogue between residents and citizens and their consensus building.

There have been many studies of making models used questionnaire surveys to residents. Most of them have emphasized methods and approaches to analyze the survey results. Our research is as the same as them.

In the next chapter, we summary the thesis including this chapter.

Chapter 6

Conclusion

The thesis has done environmental modeling of Ishikawa prefecture. The purpose was application of 'Environment Framework Model (EFM)' [33] for the prefecture and a grasp of both human activities and environment. We found out a relationship of them with 'hard data' expressed objectively, proposed methods of knowledge with 'soft data' expressed subjectively and understood the current water condition with both data. At the same time, we considered knowledge science, recognized needs of hybrid approach [7, pp.225-233] and tried to use the approach in our theme.

EFM has been treated only processes of human activities with hard data. Then, the thesis tried to run EFM with both hard and soft data. The thesis contributed to

1. utilizing EFM in Ishikawa (local authority),
2. proposing methods to extract people's knowledge,
3. combing hard and soft data on EFM.

1 means we treated local environmental problems with an integrated assessment models and considered both human activities and environment in Ishikawa prefecture. 2 includes methods to extract knowledge (rules) from large-scaled soft data in Chapter **3** and application vagueness in evaluation to Hayashi's quantification theory type Ⅲ in Chapter **4**. Chapter **3** analyzed soft data which are subjective data by using data-mining technique that has been used for transaction of objective data. Obtained rules were acceptable knowledge in the light of geological properties and current condition, so that our approaches were effective. In Chapter **4** we could see characteristics of evaluation objects more clearly. 3 shows we explained environmental condition and the relation between human activities and environment based on both observed data and soft data.

Each chapter is summarized as follows.

Chapter **1** introduced our research. First, we defined knowledge and knowledge science based on preliminary researches. Next, we explained environmental problems, researches related to the thesis, our purposes and approaches. We showed contents of the thesis, finally described features of Ishikawa prefecture we treated.

Chapter **2** did modeling with hard data. We explained EFM and applied it to Ishikawa. We identified parameters of 'Basic Production', 'Production Factor' and 'Waste' process with statistical data in EFM by using Cobb-Douglas type function, then obtained numerical expressions. For past 40 years, production of primary industry and waste generation (here, waste indicates industrial wastes) have decreased after their increase. But, other items have increased up to now. It is likely that rising production efficiency and taking measures have contributed to reducing waste generation. The model forecasted that it is necessary to change in industrial structures and take environmental measures thoroughly for striking a balance between reduction of wastes and economic growth in the future.

Chapter **3** analyzed water problem considering soft data in addition to hard data. We used a survey carried out in Kaga area in 2000. The survey obtained 900 data, which was large-sized data set. It asked about all-around environmental issues, but answers of water environment were analyzed. We classified target area into clusters in accordance with social properties by using statistical data. Then, we made rule-based models which expressed evaluation for water quality (*total evaluation*) by *partial evaluation* such as creatures and water color in each cluster. Two methods based on data mining technique were proposed for extracting knowledge of residents from the data set. Rules many people support and have confidence in were selected, then models, which reflected classified regions as context, were obtained. It means that *partial evaluations* which are regarded as important for evaluating water quality are different in each region. The other model showed meanings of linguistic terms which *partial evaluation* had in *total evaluation*. We expanded the theory of context model to real problems and constructed models which treated uncertainty and vagueness.

Chapter **4** used the data obtained two questionnaire surveys that focus on water quality of a number of points. One survey was carried out in 2001. The survey based on the result of the last survey asked about only water quality in two local areas (Komatsu and Tsurugi). The other survey, which was simple survey, was carried out in 2002. In the chapter we did two works. First, we grasped features of points people evaluated by counting both soft data. We considered a relationship between BOD and evaluation of residents and checked which field of *partial evaluations* in 5 fields (water, recreation, safety, naturalness and landscape) was regarded as important. We knew that respondents thought *naturalness* and *recreation* were more important than any other items in all. But, people thought water would need 'increasing *naturalness*' and '*cleaning* water' in the future. Next, we proposed a method of quantification theory type Ⅲ considering vagueness in evaluation and applied to the data by using the survey carried out in 2001. Points where BOD was measured were categorized according to the river they belonged to. Points where

BOD was not measured obtained the same result. These results corresponded to the result of simple counting and the current condition. Therefore, we concluded that our method was useful and evaluation of residents grasped features of rivers and points. And, we reduced some items in turn after plotting calculated results which we used all items on the data space, thereby examining which *partial evaluations* of all questions that related to water itself and attributes of points had affected *total evaluation* of waters.

Chapter **5** summarized Chapter **2**–**4**. First, we reviewed our surveys and showed points to be considered in future survey. Secondly, we indicated residents were not closely related to water and considered difference between observed data and people's feeling. Thirdly, we explained a relation between production activities and environment, and considered necessary factors to maintain or improve environment. Finally, we proposed ideas to utilize EFM more effectively.

Future works are as follows; First, we can connect hard data with soft data perfectly although we have used hard data as complementary to soft data. Integration of qualitative data and quantitative data has been studied, and it was one of the purposes of the thesis. Feature of our soft data analysis is to emphasize the relation between measured value or local characteristics and evaluation by residents. Secondly, the thesis changed objects in processes in the EFM. Processes identified by numerical data treated the whole Ishikawa, but Environment process water which analyzed quality treated only Kaga area, the south part of Ishikawa. Therefore, EFM doesn't operate completely. Two approaches are needed. One is top-down approach, which analyzes problems in small area after applied the whole object to the model. The other is bottom-down approach, which runs the whole object after each process analyzes in small regions. Moreover, however we could get hard data and soft data of environment, we could not prepare data of our consciousness and actions and not develop the future scenarios. It is important to predict how we act by changes of environment and our activities. Now Ishikawa prefecture is regarded that it doesn't have very serious environmental problems. But, in this time, we needed to propose some scenarios which imaged deterioration of the environment.

EFM can do modeling of the entire environmental problems in addition to modeling of specify factors in the problems considering the relation with other factors. The thesis used EFM for modeling of the entire problems. In the future, if significance items as ecological business shown in Chapter **5** are separately analyzed and the analysis are built up, a new method of utilizing EFM will be shown and the result will contribute to policy recommendation and decision making. To utilize EFM more effectively is a work for not only the author but also all researchers who tackle environmental issues.

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Appendix A

It includes an original questionnaire of the survey carried out in 2000 and a part of reports of counting.