Information analysis and risk management by cartography

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Propose: I propose the usage of cartography as an information analysis tool. The objective of this paper is to present the use of cartography for the multi-faceted risk information and its analysis. The cartography is expected to have a significant visual impact in information representation. This study aims to ensure its capability for the analysis of information.

1. Earthquake risk and business

According to the Central Disaster Management Council: The Cabinet Office of Japanese government, the earthquake risk is extremely high in Japan[1]. Furthermore, foreign researchers pointed out that Japan holds an unusually high risk of earthquake outbreaks compared to other countries in the world. The major seismotectonic features for Japan are described in Figure 1. Consequently, the necessity of effective risk management to minimize the influence of such an earthquake is rising.

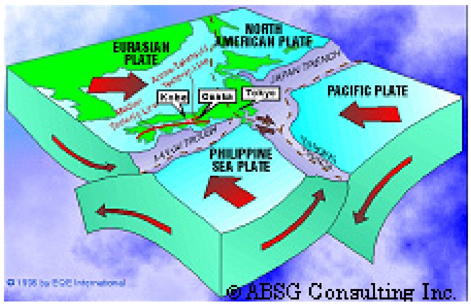


Figure 1.　Major seismotectonic features

Most of the business operations of many companies are consolidated in Tokyo. Past earthquakes have shown that highly consolidated operations can be prone to the risk of severe business interruption. Thus, studies are required to assess the vulnerability due to earthquake.

2. Risk management and backup datacenter

The risk matrix is often used as a technique for risk management. (Figure 2) In this matrix, the order of priority is evaluated depending on the frequency and the size of the damage of the possible risk. Small earthquakes may occur frequently, and the occasional great earthquakes can cause devastating damage (see Table 1 for Seismic Intensity Scale by the Japan Meteorological Agency). It is thought that a great earthquake is in the frame marked ***i*** illustrated in the chart below, and if it is an earthquake of JMA 2, it is placed in the frame labeled ***ii***. When the risk concerned is judged impossible to accept, it is required to work out counter measures.

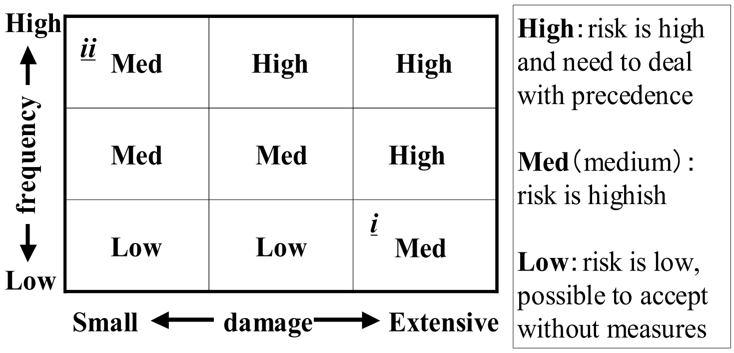


Figure 2. Risk evaluation by matrix

When a great earthquake causes extensive damage to the headquarters of a company, it is quite difficult to continue business as usual. Therefore it is quite natural for a company to have a backup data centre, or a backup office in the light of the risk management. It is especially important for financial industry to not lose their data and to recover quickly in order not to incur a massive loss or inconvenience to their customers. Naturally, it is vital to evaluate the building affected by earthquakes in order to decide where they should have their backup data centre or office. In this paper, the validity of analysis by cartography is discussed by using the case of selecting a backup data centre.

Table 1. Seismic Intensity Scale by Japan Meteorological Agency

	JMA 0	JMA 1	JMA 2	JMA 3	JMA 4
Image					
Scale	Imperceptible to people.	Felt by only some people in the building.	Felt by most people in the building. Some people awake.	Felt by most people in the building. Some people are frightened.	Many people are frightened. Some people try to escape from danger. Most sleeping people awake.
Buildings (Damage)	N/A	N/A	N/A	N/A	N/A
	JMA 5 Lower	JMA 5 Upper	JMA 6 Lower	JMA 6 Upper	JMA 7
Image					
Scale	Most people try to escape from a danger.Some people find it difficult to move.	Many people are considerably frightened and find it difficult to move.	Difficult to keep standing.	Impossible to keep standing and to move without crawling.	Thrown by the shaking and impossible to move at will.
Reinforced-Concrete Buildings (Damage)	Occasionally, cracks are formed in walls of less earthquake-resistant buildings.	Occasionally, large cracks are formed in walls, crossbeams and pillars of less earthquake-resistant buildings and even highly earthquake-resistant buildings have cracks in walls.	Occasionally, walls and pillars of less earthquake-resistant buildings are destroyed and even highly earthquake-resistant buildings have large cracks in walls, crossbeams and pillars.	Occasionally, less earthquake-resistant buildings collapse. In some cases, even highly earthquake-resistant buildings suffer damage to walls and pillars.	Occasionally, even highly earthquake-resistant buildings are severely damaged and lean.

Reference: http://www.jma.go.jp/jma/kishou/know/shindo/shindokai.html.

3. Quantitative analysis

A quantitative analysis of PML (Probable Maximum Loss) is effective for the evaluation of risk. The PML is described as a percentage value. This represents the cost to repair an item (restore its condition to the condition before an earthquake) divided by the replacement value of the item. PML is an index, which is used to deal with real estate or to decide an insurance rate. The PML is originally one of the risk measures for fire insurance. An earthquake event, on the other hand, is difficult to define the worst case scenario as there are many uncertainties, such as principal contributions, in seismic sources, attenuation relationships, soil amplifications, and vulnerabilities of buildings/equipment. In the late 1980's and early 1990's, computer-based models for measuring earthquake loss potential were developed by linking scientific studies of seismic hazards' measures and historical occurrences with advances in information technology and geographic information systems. These models enable us to compute the PML and other risk measures based on a probabilistic analysis. Since then, the PML is used for managing the seismic risk. If I reduced these to the simplest terms, one of the main parts of the probability of PML is the uncertainty of the ground motion. (refer to (a) in Figure 3) And the vulnerability of buildings is another main object of probability, which makes a loss function for a given level of ground motion(b). Then, these two distributions finally make a distribution of damage or loss (c).

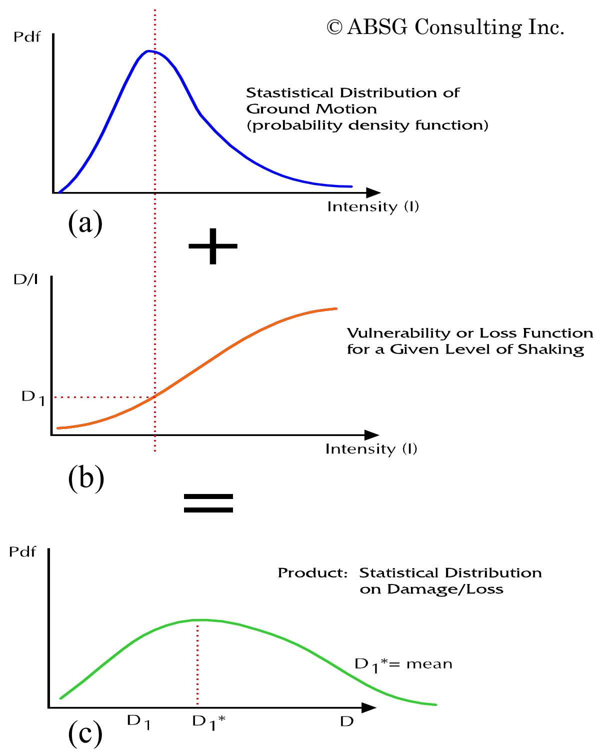


Figure 3. Distribution on damage

In this example, it is required to look for a backup data centre. PML represents the percentage of the restoration cost. Therefore, it is desirable to choose a building whose numerical PML value is low. However, in this case, the problem is that there are similar

PML for some buildings. In what way are those building similar? Are they alike because its ground motion is similar, or because the vulnerability of the building is the same? The resultants PML shows a numeric value that is needed for a effective decision-making. The PML is a numeric value that aggregates some important and heterogeneous information in it. It is therefore difficult to discover essential information needed for effective risk management. It is better that information is consolidated by interpretations, and the importance of the hierarchy of the information concerned. For this situation, I propose to use cartography for information analysis. Especially, I will introduce the Ordonnable Matrix that enables it possible to show (not to read the numerical value), at one glance, a ensemble of an information, including the low-end information.

In the next chapter, I develop an information analysis by using the Ordonnable Matrix as a cartography for the selection of a backup data centre, which is not hit by an earthquake at the same time as the headquarter.

4. Development of result and Ordonnable Matrix

I evaluate 9 candidate sites for the backup data centre which escapes disaster at the same time as the headquarters with the assumption that we are hit by 19 great earthquake scenarios which are likely to occur within 30 years as predicted by Central Disaster Management Council of Japanese government. Now, a supposition is taken that the quality of those candidate buildings will be constructed the same. Thus, the matter is how the scale of the ground motion affects the future building in each candidate site. The 19 earthquakes and 9 candidate sites are as follows:

Table 2. 19 seismic sources (scenarios)

ID	Earthquake name	Magnitude	ID	Earthquake name	Magnitude
1	Chiba inland	6.9	11	Saitama inland	6.9
2	Haneda inland	6.9	12	Tachikawa fault zone	7.3
3	Ibaraki South (plate boundary)	7.3	13	Tachikawa inland	6.9
4	Ichihara inlnad	6.9	14	Tama inland (plate boundary)	7.3
5	Ise fault	7.0	15	Tokyo East inland	6.9
6	Kannawa fault	7.5	16	Tokyo North inland (plate boundary)	7.3
7	Kanto North West fault zone	7.2	17	Tokyo bay West inland	6.9
8	Kawasaki inland	6.9	18	Tokyo bay North inland (plate inside)	7.3
9	Miura fault	7.2	19	Yokohama inland	6.9
10	Narita inland	6.9			

Table 3. List of 9 candidates

	Distance from central office	Soil factor
Headquarter	0.0 km	0.9
candidate site A	3.9 km	0.6
candidate site B	8.0 km	0.3
candidate site C	16.7 km	0.9
candidate site D	22.9 km	0.6
candidate site E	23.0 km	0.6
candidate site F	29.4 km	0.3
candidate site G	35.9 km	0.6
candidate site H	42.4 km	0.9
candidate site J	53.2 km	0.9

The soil factor is the index that represents the solidity of soil.

0.3 firm ⟷ 0.9 soft

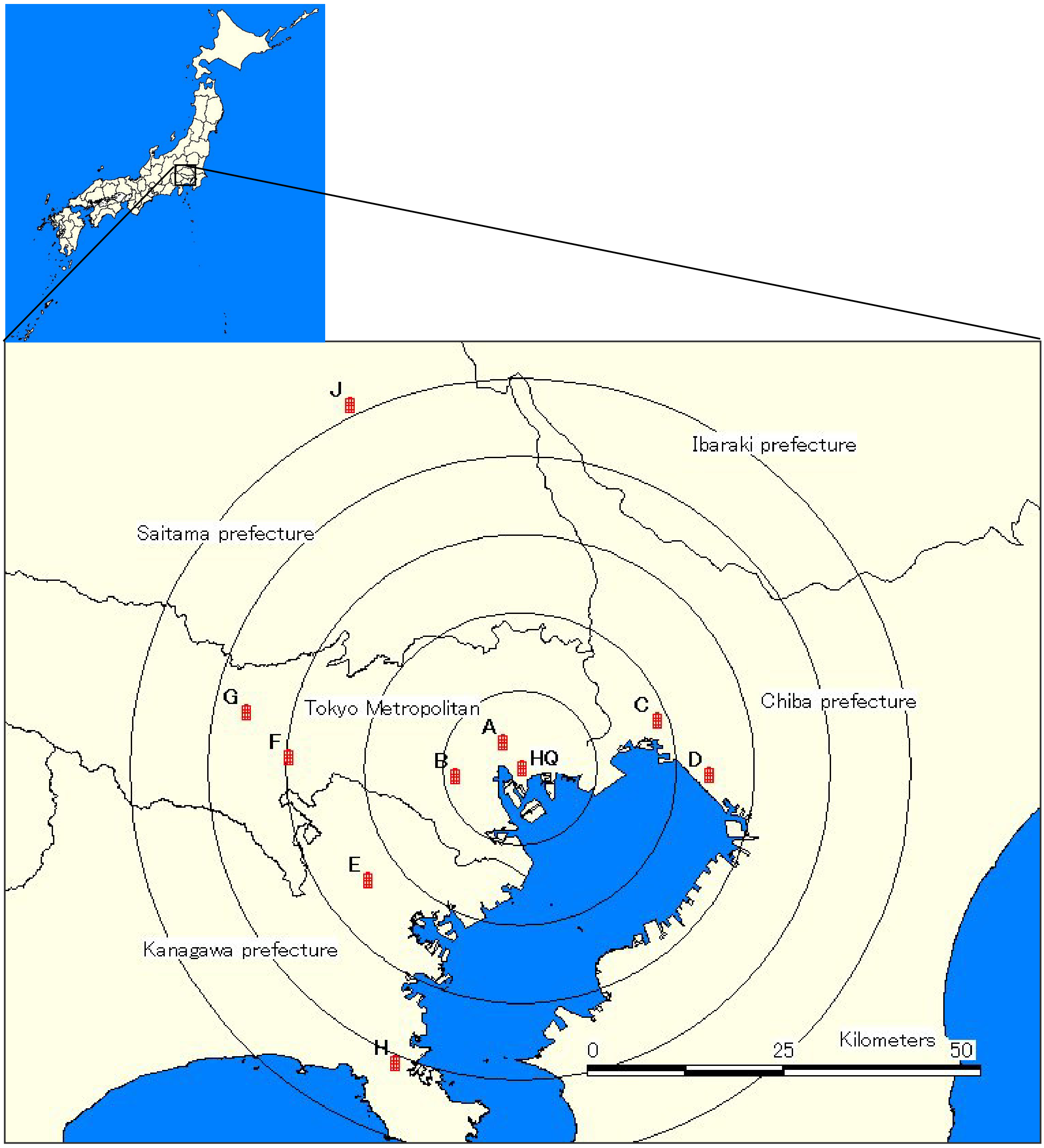


Figure 4. 9 candidates sites

The ground motion of each candidate site is calculated based on the information mentioned above. The value in each cell indicates the seismic intensity based on the JMA seismic intensity scale (Refer to the Table 1). Let the candidate sites be the horizontal axis, and the earthquake sources the vertical axis. The candidate sites are arranged in ascending order of the distance from the headquarter. The source ID (or earthquake scenario) is arranged alphabetically by earthquake names. The analysis will be done based on this matrix table. Now, from Table 2, it is very difficult to sort useful information, compare the candidate sites, and select one site. Futher more, as mentioned before, it is hard to understand what the approximate value means even if we get a answer by a quantification analysis. Then, I propose the analysis by Ordonnable Matrix.

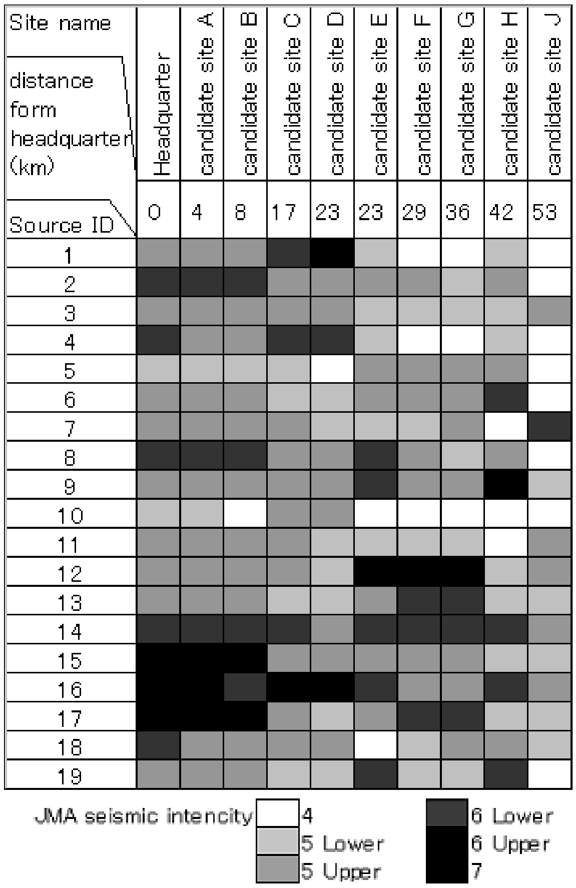
The cartography of Ordonnable Matrix is the illustration of the numerical value of each cell of a tabulation. The table shows that the darker of the colour of the cell becomes, the greater the earthquake is. In this analysis, the understanding of the whole table will be high by the use of the six visual effects equivalent to the JMA seismic intensity scales of registering 4, 5 lower, 5 upper, 6 lower, 6 upper, and seven. This is one

Table 2. Seismic intensity for candidate

Site name / distance form headquarter (km) / Source ID	Headquarter	candidate site A	candidate site B	candidate site C	candidate site D	candidate site E	candidate site F	candidate site G	candidate site H	candidate site J
	0	4	8	17	23	23	29	36	42	53
1	5U	5U	5U	6L	6U	5L	4.0	4.0	5L	4.0
2	6L	6L	6L	5U	5U	5U	5U	5L	5U	4.0
3	5U	5U	5U	5U	5U	5L	5L	5L	5L	5U
4	6L	5U	5U	6L	6L	5L	4.0	4.0	5L	4.0
5	5L	5L	5L	5L	4.0	5U	5U	5U	5U	4.0
6	5U	5U	5U	5L	5L	5U	5U	5U	6L	4.0
7	5U	5U	5U	5U	5L	5L	5L	5U	4.0	6L
8	6L	6L	6L	5U	5U	6L	5U	5L	5U	4.0
9	5U	5U	5U	5U	5U	6L	5U	5U	6.7	5L
10	5L	5L	4.0	5U	5U	4.0	4.0	4.0	4.0	4.0
11	5U	5U	5U	5U	5L	5L	5L	5L	4.0	5U
12	5U	5U	5U	5U	5L	6U	6U	7.0	5L	5U
13	5U	5U	5U	5L	5L	5U	6L	6L	5L	5L
14	6L	6L	6L	6L	5U	6L	6L	6L	6L	5U
15	6U	6U	6U	5U	5U	5U	5U	5U	5L	5L
16	6U	6U	6L	6U	6U	6L	5U	5U	6L	5U
17	6U	6U	6U	5U	5L	5U	6L	6L	5L	5L
18	6L	5U	5U	5U	5U	4.0	5L	5U	5U	5L
19	5U	5U	5U	5L	5L	6L	5L	5L	6L	4.0

JMA seismic intencity			
4.0	4	6L	6 Lower
5L	5 Lower	6U	6 Upper
5U	5 Upper	7.0	7

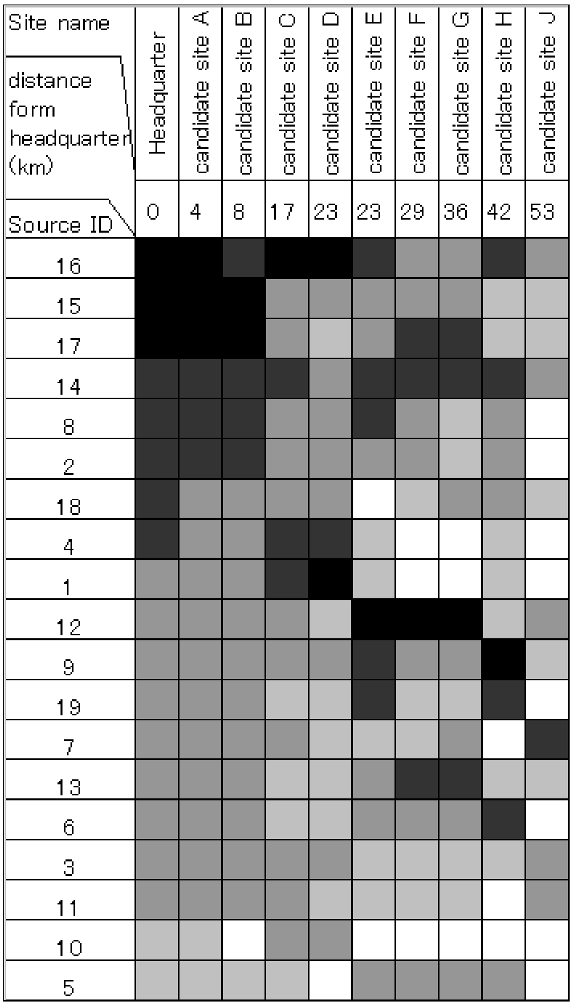
Table 3. Ordonnable Matrix 1



of the advantage of using the cartography compared in trying to understand from the numerical value itself. Table 3 indicates that each candidate site can be effected by (an) earthquake(s) in the capital area concerned.

Moreover, in order to grasp the whole image, it will be possible to improve the visual effect by exchanging the lines of matrix (Table 4). In this matrix, only Source ID of the vertical axis are reshuffled in descending order of JMA seismic intensity scale. Each candidate site are arranged according to the distance from the headquarter.

Table 4. Ordonnable Matrix 2



Site A, which is located only 4 km away from the headquarter, has almost the same earthquake hazard as that of the headquarter against the 19 expected earthquake. That is, there is a strong correlation of the risk between the headquarter and the site A. Naturally, there is weak correlation between the headquarter and Site J, which is about 53 km away from the headquarter. However, the nearer the alternative site is located to the headquarter, the better it is, because it is the backup data centre to continue business operation. (During the earthquake disaster, we are expected to move on foot or by bike, because emergency vehicles have priority on the roads. By and large, it is said to be gradually difficult to move on foot when it is over 20 km.)

Next, I will advance my analysis by adding one more factor. The ground motion is influenced by the depth of a hypocenter, magnitude, and the firmness/softness of the ground. The depth of a hypocenter and the magnitude depend on each prospected earthquake, and each candidate site has them in common. Then, I take the last factor, the solidness of the ground, into account and add it into the Ordonnable Matrix as the width of each column of matrix (see Table 3 for the soil factor). So, each candidate site has a different width corresponding to the solidness of the ground. The solidness is given in terms of 3 levels; firm, average, and soft. The softer the ground is, the easier it is to shake, I make the matrix wider so that it seems to do more harm visually (Table 5). Whether ground is easy to quake or not is an important factor as it has to do with not only the earthquake hazard of the building taken up for this evaluation but also with the damage of the utilities such as electricity, communication, or water system that connect to the building, and support its functions. The candidate site H or J is far away from the headquarter, so the possibility of a simultaneous damage by the same earthquake is low between them. However, the earthquake hazard about the lifelines is high because they are easy to quake. Then, as a result, Site F is highly recommended to be a good candidate for the backup data centre. Because Site F does not have disaster simultaneously with the Headquarter, and the earthquake hazard in that site is low.

Table 5. Ordonnable Matrix

Site name / distance form headquarter (km) / Source ID	Headquarter	candidate site A	candidate site B	candidate site C	candidate site D	candidate site E	candidate site F	candidate site G	candidate site H	candidate site J
	0	4	8	17	23	23	29	36	42	53
16										
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I tried, in this study, choosing a backup centre out of 9 candidate sites which makes it possible to avoid to suffering from earthquakes at the same time as the headquarter in the case of 19 earthquakes. It naturally would be possible to get an answer if I did some quantitative analysis. Though, this time, I present how an appropriate candidate site would be picked by the use of cartography: Ordonnable Matrix. Furthermore, this analysis by the cartography shows a possibility to develop analysis by adding other factors. In effect, the Ordonnable Matrix as a cartography shows all information (from ensemble level information to detail information) to all the concerned observers.

5. Issue about the cartography for information analysis

In recent years, the advancement of technology and media has greatly increased the amount of information accessible as well as methods of information collecting. The advancement of technology has also accounted for improvement in the accuracy of data analysis. In the next future, it will be increasingly important to manage information effectively. In that case, the integration information will be important. Organizing information is similar to the processing of knowledge and incoming information in the human mind. Therefore, in future, I think that the cartography will be a useful method to select the necessary information as I have present in this paper. The information presentation by cartography is not any more a simple presentation of results, it is can also be proposed as an effective communication method among the people concerned. Even if there are diverse user, objectives, technical development, the cartography can be used to support in selecting useful information by using its essential characteristic: i.e., show the vital information instantaneously.

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1 Central Disaster Management Council http://www.cao.go.jp/en/importa ntcouncil.html

References:

BERTIN Jacques. Sémiologie graphique. Paris: Mouton, 1966, 432p.

BERTIN Jacques. La graphique et le traitement graphique de l'information (japanese)Tokyo: Heibon-sha, 1982, 277p.

Headquarters for earthquake research promotion. Result of Long-term evaluation, (http://www.jishin.go.jp/main/), 2006.

DE SAUSSURE Ferdinand. Cours de linguistique générale. Paris : Payot, 1992, 520p.

Research Group for Active Faults in Japan. Active faults in Japan, Sheet Maps and Inventories (Revised Edition). Tokyo, Univ. Tokyo Press, 1991, 437p.

STEINBRUGGE Karl V. Earthquakes, Volcanoes, and Tsunami; An Anatomy of Hazards. New York: Skandia america group, 1982, 392p