https://doi.org/10.20965/jdr.2012.p0190

Paper:

A Basic Study of Open Space Information as Social Infrastructure for Wide-Range Cooperation in Large-Scale Seismic Disaster

Takashi Furuya[*1], **Munenari Inoguchi**[*2], **Go Urakawa**[*3], **and Haruo Hayashi**[*4]

[*1]Center for Risk Management and Safety Sciences, Yokohama National University
79-5 Tokiwadai, Hodogaya-ku, Yokohama, Kanagawa 240-8501, Japan
E-mail: t-furuya@ynu.ac.jp
[*2]Research Institute for Natural Hazards and Disaster Recovery, Niigata University
8050 Ninomachi, Igarashi, Nishi-ku, Niigata 950-2181, Japan
[*3]Center for Disaster Reduction, University of Hyogo
1-5-2 Wakinohamakaigandori, Chuo-Ku, Kobe 651-0073, Japan
[*4]Disaster Prevention Research Institute, Kyoto University
Gokasyo, Uji, Kyoto 611-0011, Japan

[Received September 1, 2011; accepted December 8, 2011]

The open space area is necessary for disaster operation such as evacuation, clean-up, and logistics and temporary housing. Tokyo Metropolitan Earthquake will cause enormous damage and have far-reaching consequences. Therefore, local governments have to regulate wide-range cooperation for use of available open space area. In this study, 1) the problem schemes of open space is clarified based on the logistic process of Theory of Constraints, and 2) Geospatial distribution and size of open space area is analyzed quantitatively based on land-use database, 3) the conceptual design of the comprehensive open-space database management system is formulate considering decision-making process.

Keywords: Tokyo Metropolitan Earthquake, open space, large-scale seismic disaster, wide-range cooperation, disaster response, geospatial information analysis

1. Introduction

Japan is well known for earthquakes. According to specialists, the probability of the occurrence of M7 earthquakes within 30 years for the Tokai Earthquake, Tonankai Earthquake, Nankai Earthquake, and Metropolitan Epicenter Earthquake is extremely high. It is estimated by the national Central Disaster Prevention Council that earthquake occurrence rates within 30 years for a "Metropolitan Epicenter Earthquake" is as much as 70%, and the estimation of damage for a North Tokyo Bay Earthquake is about 11,000 casualties and ¥112 trillion in economic loss. This is the worst scenario simulated among 18 types of earthquake motion [1, 2].

In response to this, the "Countermeasure Outline for Tokyo Metropolitan Earthquake" was enacted in September 2005 [3]. It was modified when the "Emergency Operation Procedure for Tokyo Metropolitan Earthquake" was enacted in January 2010 [4]. One of the additional countermeasures is "the response to an enormous number of evacuees and temporal housing." Specifically, they describe the importance of assessment of the situation for existing evacuation shelters to ensure function and to utilize facilities, not only public but private, as a countermeasure to make up for the current shortage of evacuation shelters. They also describe the importance of a logistic strategy for the smooth provision of relief supplies and the importance of the utilization of vacant houses and apartments instead of building prefabricated houses as a countermeasure for temporal housing. It describes problems of waste disposal as well.

As observed above, each countermeasure and emergency response requires a physical site first. It is therefore necessary to manage open space in order to achieve each countermeasure.

At the same time, wide-range cooperation among local governments is promoted. Already, several agreements have been made by the research council of 9 municipalities' disaster prevention summit. They have been stated explicitly in each Regional Disaster-Prevention Plan. There are, however, different degrees of interest and perception gaps, so it is not clarified how much open space can be used or shared among local governments. An action assignment has been pointed out by Dr. Itsuki Nakabayashi that "Cooperation of local government is necessary, but redesign of a system is not enough. This is because the current Regional Disaster Prevention Plan tends to organize within their organization" [5].

On another front, after the Great Hanshin-Awaji Earthquake, many local governments have facilitated the introduction of disaster information systems to manage large amounts of data effectively. In a previous study, for example Dr. Mitsunori Hatayama took the lead in developing the Disaster Management Spatial Information System: DiMSIS as a spatial temporal information system to try

1. This manuscript is based on the paper published in the Journal of Social Safety Science, No.13, pp. 293-303, 2010.11 in Japanese.

© Fuji Technology Press Ltd. Creative Commons CC BY-ND: This is an Open Access article distributed under the terms of the Creative Commons Attribution-NoDerivatives 4.0 International License (http://creativecommons.org/licenses/by-nd/4.0/).

to manage postdisaster information retaining continuity in business routines using GIS [6, 7]. Regarding the "Open-Space Management," however, it is anything but an administrative task to collect and store basic information. In another example, Dr. Nagahisa Hirayama considered wide-range cooperation for managing waste disposal. In this research, analysis was based only on total waste disposal of each prefecture.

To recap what has been explained above, in response to huge earthquakes such as a "Tokyo Metropolitan Earthquake," it is necessary to manage available space to deploy various countermeasures and to ready strategic plans to maintain and effectively utilize social infrastructures including "Open Space." In order to do this, not only handle information of open spaces after earthquake occurred but also preliminarily plans are needed for managing and sharing information. There is, to our knowledge, no study that takes a comprehensive, panoramic view of "Open Space."

The purpose of this study was to clarify the usefulness of wide-range utilization of an open space database, and to clarify issues in its overall management.

2. Outline of the Study

To accomplish the above purpose, we investigate the problem schemes of open space based on the logistic process of the Theory of Constraints (TOC). It is an overall philosophy, developed by Dr. Eliyahu M. Goldratt, usually applied to running and improving an organization. The TOC consists of Problem Solving and Management/Decision-Making Tools called Thinking Processes. The TOC is applied to logically and systematically answer following three questions essential to any process of ongoing improvement: 1) What to change?, 2) To what to change?, and 3) How to cause the change?. We also investigate the geospatial distribution and size of open space area quantitatively based on a land-use database. Then we suggest a basic decision-making concept model for the location and allocation of open space as a total management system.

3. Identifying the Problem Structure of "Open Space"

First of all, we clarify the core issues behind the relation to each problem concerning open space by describing the problem structure as a current reality tree (CRT). The CRT is one of the parts of the "thinking process" in the TOC. It is a sufficiency-based logic (if. . . then. . .) tool that is used to fully describe the relation of the existing situation and the current problematic reality. Its purpose is to enable users to understand how the various issues and problems they face are related to each other, to their policies, measurements, and practices and to the core conflict identified through the process described above.

In 2008, several workshops were held to sort out problems involved in the "Metropolitan Epicenter Earthquake." Ms. Jie Cheng reported that attempts were made to correct the statement of "Undesirable Effect (UDE)" and structured 22 functional layer models by integrating super structure of social model into TOC [9]. In this framework, the "open space" category is positioned as one of the important concepts that is totally involved in the "Individual," "Private Sector Activities," "Infrastructure" and "Environment."

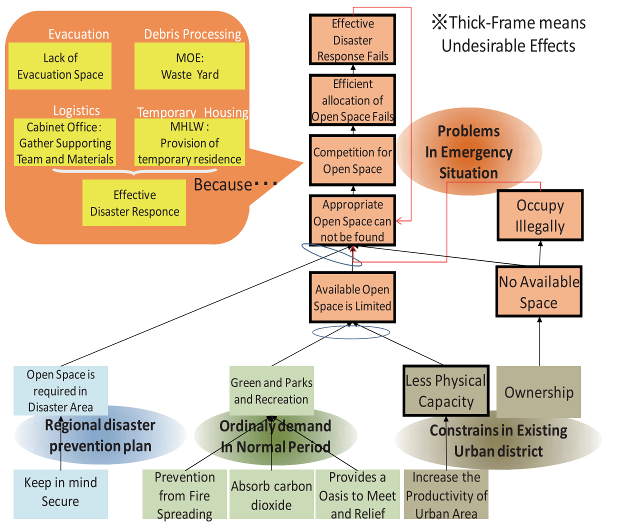

Fig. 1. CRT of open space derived in workshop.

In this study, we attempted to clarify the problem structure concerning "Open Space" by using statements of UED that was corrected by Ms. Cheng. We made a CRT based on causality.

3.1. The Current Reality Tree (CRT) of "Open Space"

The CRT shows the linkages that describe why situations exist or why we believe particular actions will result in certain outcomes (**Fig. 1**).

In normal times, open spaces represented by greenery, parks and recreation are in demand in the formation of a good urban environment such as "heat island" mitigation, ensuring biodiversity and pollution prevention and mitigation. They are also necessary in terms of culture and social and mental health. Urban parks have been established based on law and standards for the purpose of contributing to the promotion of public welfare.

They are also in demand from the aspects of disaster prevention, such as the prevention of fire spreading, emergency shelters. This is why open spaces have been maintained before the occurrence of disaster such as earthquake, fire etc.

Urban areas are, however, developed to satisfy convenience and productivity growth, driven by advanced land use. Even now in Japan, there are high-density areas of old wooden houses spilling over from Building Standards Act during high economic growth in the post World War II period. It is assumed that there are not enough sites to ensure open space which then causes a lack of open space to explore several activities after earthquakes. Even if there is temporarily vacant land, it is usually difficult to receive permission from owner for usage. This is because owners can be private and public sectors, and for private sectors, negotiating with landowners for the permission may be troublesome. Worse yet, some people will start to occupy available space illegally, which spurs the threat of a lack of open space.

Activities that require open space in order to implement an effective disaster response are evacuation space (municipalities), debris processing (Ministry of Environment) and provision of support and collection of relief supplies (Ministry of Home Affairs, Cabinet Office), provision of temporary residences (Ministry of Health, Labour and Welfare), and so on. In an unprecedented large-scale seismic disaster, multiple prefectures will be suffered at the same time and the above activities are expanded to overlap in time and space. This means that the efficient allocation of open space beyond local governments to outside of current regional disaster prevention plans is not possible. That is to say, each division scrambles for open space, but every corresponding delays will cause negative effects.

3.2. Solution of Core Conflicts

Next, following the steps of the TOC, we found core conflicts based on the results of the CRT, and considered the "Evaporating Cloud" method in the TOC to solve each conflict.

Setting the "living of a happy life" as the common goal of the general public, there is no conflict between demands for "ensuring the safety and security of urban space" and "increasing the productivity of urban space." It is more like a desirable eventuality. But at the stage of accomplishment to meet these demands, a conflict emerges between "open space needed in affected areas" and "no open space in affected areas." This dilemma can become a bottleneck in the execution of operations that can safely and quickly set up the organization when disaster strikes. To consider countermeasures against this, three methods are derived based on the CRT: 1) Relocate victims to suburban area, 2) Create a new open space, and 3) Manage overall open space.

We made a new proposal for considering these three countermeasures.

For the first one, relocate victims to suburban area, after the "Great Hanshin-Awaji earthquake (1995)," difficulties and issues are pointed out in relocating to areas away from the prior residences of those who lost their homes. As a matter of fact, however, the Central Disaster Management Council Meeting of experts reported that Tomakomai city and Niigata Prefecture offered to accept as high as 1 million evacuees [10]. This should be kept in mind as one of the possible options for countermeasure considering the number of demolished or burned buildings which were eight times more than that of 1995 Great Hanshin Awaji Earthquake.

For the second countermeasure above, i.e., creating new open space, there are several proposals based on conventional town planning or the new concept of a compact city. Grandiose projects such as the construction of super levees are also among the proposals, but the effectiveness of any of these options is low if it is to be constructed in built up areas. There are, moreover, contradictory entities such as "how much open space exists and where it is." This means the situational awareness has not been established.

We therefore focused on the third option, "managing overall open space," performing further analysis considering quantitative understanding of the open space at present.

4. Quantitative Understandings of the Open Space Present

Following the World Trade Center attack in New York City on September 11, 2001, a "national incident management system" (NIMS) was formulated at the end of February 2003 in the US. NIMS is determined through reference to the "standardized emergency management system" (SEMS) originating in California. An "incident command system" (ICS) is considered as an element of NIMS. In the ICS, resource management including open space has been clearly defined as a function to be provided by headquarters.

In Kobe, Japan, for example, which was the site of the 1995 earthquake, the city has developed a manual and forms to manage open space in its regional disaster prevention plan [11]. It lists applications for open space needed after a disaster as follows: Sites for 1) lifeline restoration, 2) recovery conducted by disaster-related organizations, 3) parking, 4) interim heliports, 5) evacuation shelters, 6) trash and debris, 7) relief aid, 8) temporary housing and 9) miscellaneous. In general, information and needs of more than 1,000 square meters of open space are supposed to be kept track as post event operations at Kobe city.

Moreover, the "Countermeasure Outline for the Tokyo Metropolitan Earthquake" recommends that local governments record and update information on open space before earthquake occurs. To do so, for instance, Yokohama and Kawasaki cities have explicitly listed open space that not only has the name, address and area of an available site, but also the classification by use for emergency situations in their "regional disaster prevention plans." We mentioned however in the previous chapter that current planning is based on ownership of open spaces. In the "Metropolitan Epicenter Earthquake," it is considered that wide-range cooperation beyond local governments is necessary that leads to the long-term collaboration. That is to say, we are able to put tasks ranging from "managing overall open space" to "managing the list of open space among local governments and organizations" as one of the major solutions to post-earthquake open-space management. A comprehensive database of open space is indispensable for accomplishing this solution.

Ministry of Land, Infrastructure, Transport and Tourism (MLIT) (2003) has simulated the amount of de-

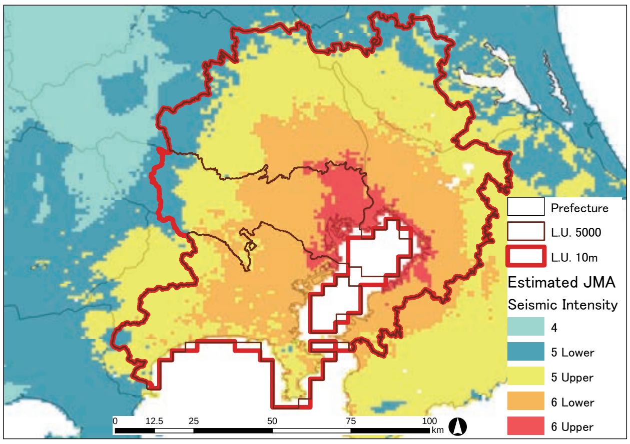

Fig. 2. The seismic intensity estimation for North Tokyo-Bay Earthquake overlaying with the extent of land-use data.

mand and allocation of open space for reconstruction-restoration by aggregate data per municipality, but MLIT point out that investigation on spatial distribution is necessary [12].

4.1. Aggregation of a Dataset of Open Space

Most "regional disaster prevention plans" of municipalities do not provide enough information to identify open space spatially. This means it is too difficult to collect and compare information on open space comprehensively throughout the entire metropolitan area. It is easily predicted in using land-use data that each municipality should have correct urban planning, but it is not developed to the same accuracy in digital format and it is not available for all academic researchers, depending on the municipality.

We therefore decided to aggregate land-use data that anyone can purchase at a reasonable price. "Digital Map 5000 (Land Use) Tokyo metropolitan district 2000 [13]" is chosen for Kanagawa, Saitama, and Chiba prefectures, and "Detailed Digital Information (10 m Grid Land Use) 1994 [14]" supplements the missing part, Tokyo. We also combined "School Point Data [15]" and the data equivalent of "Digital Map 2500 [16]" in order to expand and improve the classification accuracy of attribute information that caused the difference in spatial resolution and date of issuance.

Figure 2 shows the seismic intensity estimation for the North Tokyo-Bay Earthquake overlain by the extent of land-use data. Land-use data is not developed for mountainous regions west and east of the map, but these undeveloped areas can be eliminated as available open space from the standpoint of usability, accessibility, and the degree of seismic intensity. We developed a GIS database for open space in metropolitan areas using the following procedure:

1) Convert XML files with standards appropriate for "Japan Profile for Geographic Information Standards" (JPGIS) to the shapefile format.

Table 1. Exposure area per estimated JMA seismic intensity.

Area[ha]	4	5 Lower	5 Upper	6 Lower	6 Upper	Total
Tokyo	19,637	32,303	37,133	60,053	32,850	181,978
Kanagawa	0	20,903	129,446	96,848	2,201	249,398
Chiba	732	56,647	295,679	143,294	22,932	519,283
Saitama	90,243	112,563	113,806	59,901	6,684	383,197
SUM	110,612	222,416	576,064	360,096	64,668	1,333,855

Table 2. Exposure population per estimated JMA seismic intensity.

Population	4	5 Lower	5 Upper	6 Lower	6 Upper	Total
Tokyo	2,888	36,643	1,832,453	7,311,142	3,315,157	12,498,283
Kanagawa	0	41,849	1,792,393	6,243,801	193,220	8,271,263
Chiba	9,554	178,371	1,276,538	3,608,545	877,192	5,950,200
Saitama	107,041	859,187	2,805,431	3,322,513	527,144	7,621,316
SUM	119,483	1,116,050	7,706,815	20,486,001	4,912,713	34,341,062

Table 3. The number of open space categories per JMA seismic intensity.

Count	4	5 Lower	5 Upper	6 Lower	6 Upper	Total
Unused		6,906	88,653	168,725	168,664	299,765
Park and Recreation	9	2,041	17,578	29,693	29,675	55,972
School	29	462	3,208	6,482	1,380	11561
Public Facilitiy		1,338	18,462	34,879	10,853	65532
Other	17	161	652	716	57	1603
Sum	55	10,908	128,553	240,495	240,403	434,433

2) Extract "Unused," "Parks and Recreation," "Land for public facilities," and "Miscellaneous" based on the code value of the land-use type.

3) Subtract cemeteries and shrine and temple grounds from polygon data in the previous step.

4) Calculate area for individual polygon data items.

5) Spatially join the attribute table of polygons with seismic intensity and the name of the municipality.

Tables 1 and **2** show the results of tabulation analysis of exposure area and population per seismic intensity using "Total population by gender (2005) [19]." The methodology is similar to that of Dr. Nobuoto Nojima [17] or Dr. Shingo Suzuki [18].

4.2. Trends in Categorized Open Space

In this section, we reclassified, in detail, the types of open space into five categories: "Unused land," "Parks and Recreation," "School Property," "Land for Public Facilities," and "Miscellaneous" such as defense facilities, U.S. military areas, training grounds, golf courses, and other facilities related to imperial residences. Then, determine the characteristics of spatial distribution, number, and size in each category quantitatively. To minimize confusion, this result does not consider the area of built facility. This is because calculated data is based on land use. Also, the error tolerance level is relatively higher in the Tokyo area because of the resolution (10 m square) of the data source.

The number of open space categories per seismic intensity scale is shown in **Table 3**.

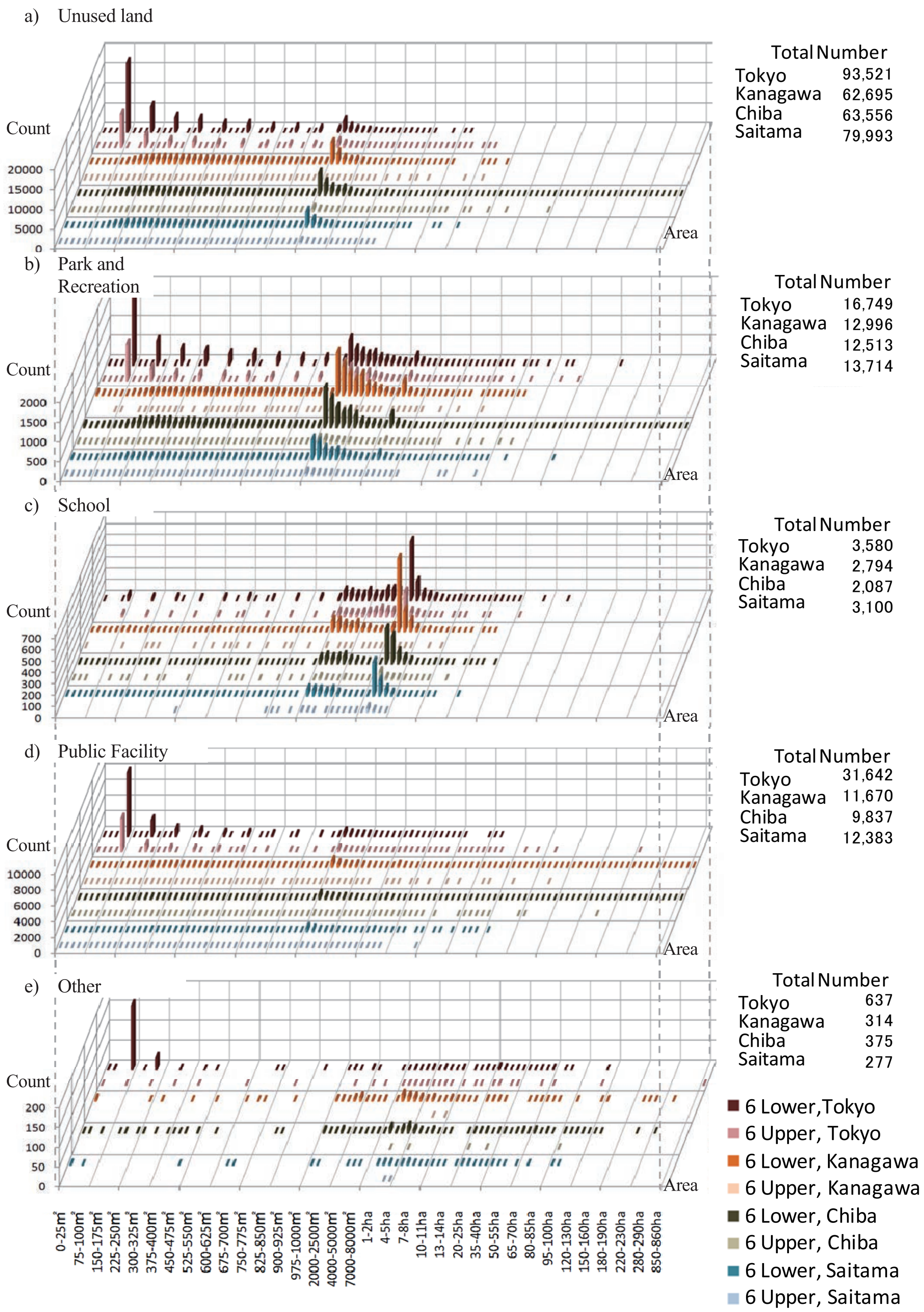

Fig. 3. Count of each open space per Area [m] at JMA seismic intensity 6 upper and 6 lower.

Table 4. Compiled area of unused land by JMA estimated seismic intensity.

AREA [ha]	4	5 Lower	5 Upper	6 Lower	6 Upper	Total
Tokyo	0	60	2,087	3,048	1,781	6,975
Kanagawa	0	7	2,013	5,245	164	7,429
Chiba	0	7	2,674	8,040	1,518	12,240
Saitama	0	1,004	4,805	3,511	415	9,736
Sum	0	1,079	11,579	19,843	3,878	36,380

4.2.1. Trends in Unused Land

This category includes vacant land which is made by artificial arrangements such as roofless parking lot and sites to keep equipment. The most of this category belongs to private ownership. The calculated area of each open space per JMA seismic intensity is shown (**Table 4**). And the calculated number of each open space size per JMA seismic intensity of 6 upper and 6 lower is shown (**Fig. 3a**)

Table 5. Compiled area of park and recreation land by JMA estimated seismic ntensity.

AREA [ha]	4	5 Lower	5 Upper	6 Lower	6 Upper	Total
Tokyo	0	79	1,484	3,288	2,199	7,050
Kanagawa	0	16	1,679	4,238	162	6,095
Chiba	2	39	1,268	3,742	776	5,827
Saitama	15	1,372	3,103	2,146	221	6,856
Sum	17	1,507	7,533	13,415	3,357	25,829

Table 6. Compiled area of school property by JMA estimated seismic intensity.

AREA [ha]	4	5 Lower	5 Upper	6 Lower	6 Upper	Total
Tokyo	0	23	1,135	3,300	1,083	5,542
Kanagawa	0	11	1,001	2,801	86	3,899
Chiba	4	132	954	2,536	436	4,060
Saitama	60	768	2,050	1,501	122	4,500
Sum	63	934	5,140	10,138	1,726	18,001

Table 7. Compiled area of public facilities land by JMA estimated seismic ntensity.

AREA [ha]	4	5 Lower	5 Upper	6 Lower	6 Upper	Total
Tokyo	0	44	798	1,518	1,770	4,130
Kanagawa	0	5	876	3,369	319	4,568
Chiba	0	9	818	2,095	1,048	3,969
Saitama	0	253	1,707	1,341	123	3,424
Sum	0	310	4,199	8,323	3,259	16,091

Table 8. Compiled area of others by JMA estimated seismic intensity.

AREA [ha]	4	5 Lower	5 Upper	6 Lower	6 Upper	Total
Tokyo	0	403	1,560	1,277	1,630	4,870
Kanagawa	0	325	3,220	2,497	16	6,058
Chiba	9	178	3,999	4,395	170	8,750
Saitama	361	2,615	1,984	1,257	8	6,226
Sum	369	3,522	10,763	9,425	1,824	25,904

where there is expected to be especially serious damage. A relatively small area is likely to be used as temporary shelters or site for debris at the community level. In addition, any overflow of population from evacuation sites or people who do not want to experience evacuation shelters where no privacy is possible are considered to live in their cars.

4.2.2. Trends in Parks and Recreation

This category contains public facilities such as parks, zoos, and botanical gardens and sports and athletics facilities such as multi-purpose stadiums and baseball stadiums. The area calculated for each open space per JMA seismic intensity is shown in **Table 5** and the calculated number of open space size per JMA seismic intensity of 6 upper and 6 lower in **Fig. 3b**. Generally, there are criteria of area size for each kind of park in urban planning, e.g., greenery spaces are 0.1 ha, street parks are 0.25 ha, and community parks are 2 ha. Comparatively for their size, these areas are likely to be used as wider area evacuation sites, construction sites for temporary housing, site to store rescue equipment or debris, and staging sites for Japan Self-Defense Forces (SDF). According to the Japanese government's cabinet office, the location of temporary housing is often assumed to be constructed at evacuation sites or wide-area evacuation sites that are not specified as other use by local governments [20].

4.2.3. Trends in School Property

This category contains space for educational facilities such as schools, laboratories, libraries, and museums. All kinds of public and private educational facilities are identified by school data represented as point [16]. The area calculated for each open space per JMA seismic intensity is shown in **Table 6** and the calculated number of each open space size per JMA seismic intensity of 6 upper and 6 lower shown in **Fig. 3c**. The most regional disaster prevention plan considers the public open spaces as evacuation sites or shelters and high school grounds are supposed to be used for emergency heliports. Public educational facilities in Tokyo, Saitama, Chiba, and Kanagawa number 6,735. If all education facilities following an earthquake with a JMA seismic intensity of 6 or over were opened as evacuation shelters, the total number of open space will increase by 955, rising to about 1.7 times.

4.2.4. Trends in Land for Public Facilities

This category contains space for public service districts such as sites for national and local government facilities and space for supplying/processing facilities such as water/sewage treatment plants, incinerators, and electric transformation station. This category also contains space for social welfare facilities such as hospitals, sanatoriums, and nursing homes. Transportation facilities such as bus garages, ports, and airports belong to this category. Roads, railways, and other spaces categorized in the previous step have been excluded. The area calculated for each open space per JMA seismic intensity is shown in **Table 7** and the calculated number of open space size per JMA seismic intensity of 6 upper and 6 lower shown in **Fig. 3d**.

4.2.5. Trends in Others

This category contains space such as defense facilities, the U.S. military areas, training grounds, golf courses, and facilities related to imperial residences. The area calculated for each open space per JMA seismic intensity is shown in **Table 8** and the calculated number of each open space size per JMA seismic intensity of 6 upper and 6 lower shown in **Fig. 3e**. Absolute numbers are lower compared to the other four categories, but large land areas of over 1 hectare ($= 10,000$ square meters) is dominant, so these areas are likely to be used as staging areas for large scale troops and temporary towns. Currently, several golf clubs have agreements with municipalities for emergency use such as helicopter airfields and providing meals and baths. This does not allow full use of such courses for now. Considering golf courses alone, there are 443 sites and a total area of 14,854 ha. The amount of remaining available open space is said to have the potential for other applications.

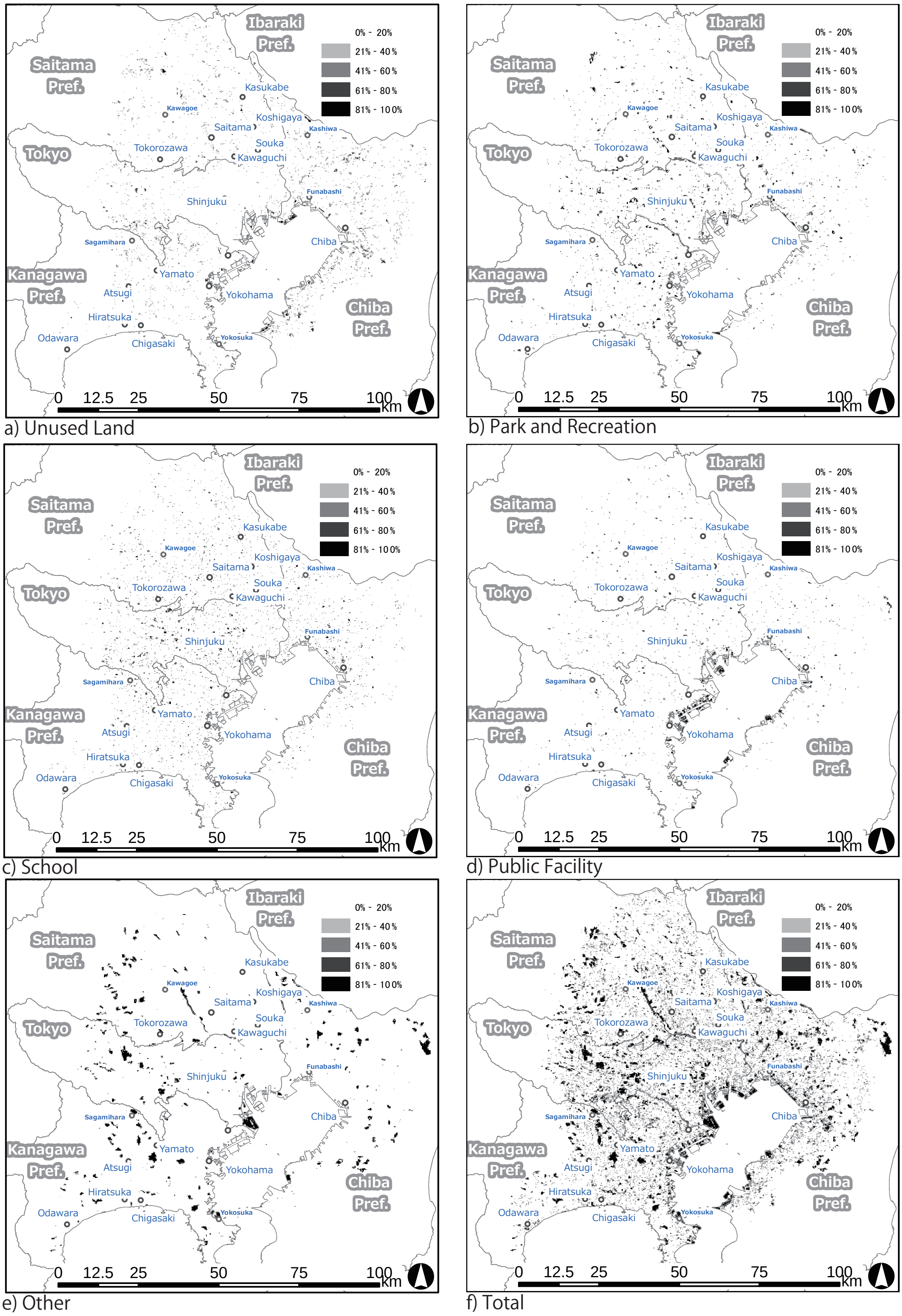

Fig. 4. Spatial distribution of categorized open space with percentage of area in 250 meter square mesh.

4.3. Amount and Spatial Distribution of Categorized Open Space

Mesh analysis is done to clarify the spatial distribution of open space as shown in **Fig. 4**.

Each category of open space is aggregate in a unit mesh, i.e., squares 250 meters on a side. The area aggregated is divided into five grades: the darker the color, the higher the occupation ratio for each mesh.

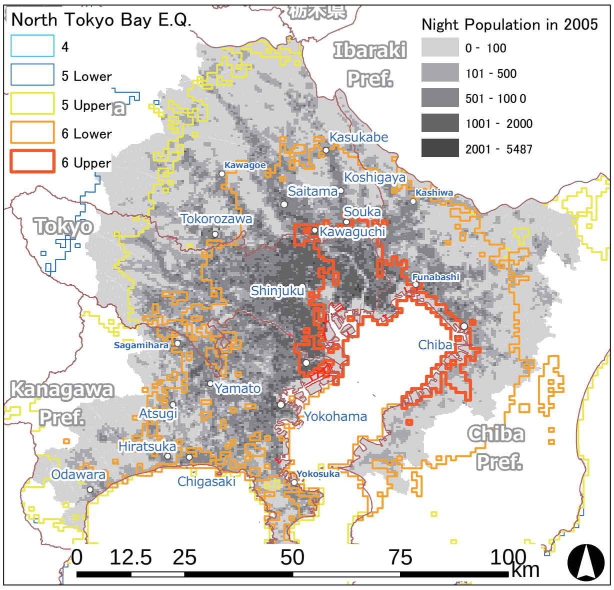

Fig. 5. Night population and JMA estimated seismic intensity.

Results clearly identify several characteristics as follows:

In the case of "Unused Land" in Tokyo, there are spots of light grey color that have over 20% occupation around old parts of towns and away from central districts. There are also relatively high occupation areas around Tokyo Bay as shown in **Fig. 4a**. In the case of "Parks and Recreation," there are spots of deep color both small and wide. There are long strings along borders between prefectures with first-class rivers as shown in **Fig. 4b**. In the case of "Schools," there are many scattered sites. In particular, away from central Tokyo are wide areas as shown in **Fig. 4c**. In the case of "Public facilities," there are widespread areas around Tokyo Bay as shown in **Fig. 4d**. In the case of "Miscellaneous," there are wide spots of deep color in suburban area in each prefecture in **Fig. 4e**. Similarly, aggregate calculation of total open space is shown in **Fig. 4f**. As explained above, open space and their area are identified by mapping visualization in GIS.

In considering not only the supply of open space but also the demand for it, the map that describes the relationship to night population and boundary line of JMA Estimated Seismic Intensity is shown in **Fig. 5**.

Compared to previous spatial distribution maps, spatial characteristics are confirmed such as low-vulnerability and rich open space districts such as in Chiba prefecture or highly vulnerable and poor open spaces such as Tokyo Metropolitan Prefecture. Total open space area per person by prefecture and JMA estimated seismic intensity is shown in **Table 9**. It is thus possible to accommodate certain countermeasures with necessary open space in and out of individual prefectures.

To further verify the effect of wide-range coordinated use of open space, the distance between open spaces and to the nearest boundary is calculated, together with cumulative existing rate based on distance from boundaries as shown in **Fig. 6**.

Table 9. Total open space area per person by prefecture and JMA estimated seismic intensity.

	Estimated JMA Seismic Intensity	Open Space per Person[m^2]	
Tokyo	5 Lower	221	23
	5 Upper	41	
	6 Lower	17	
	6 Upper	23	
Kanagawa	5 Lower	150	31
	5 Upper	47	
	6 Lower	28	
	6 Upper	26	
Chiba	5 Lower	552	63
	5 Upper	132	
	6 Lower	55	
	6 Upper	47	
Saitama	5 Lower	145	44
	5 Upper	51	
	6 Lower	33	
	6 Upper	22	
Total		35	

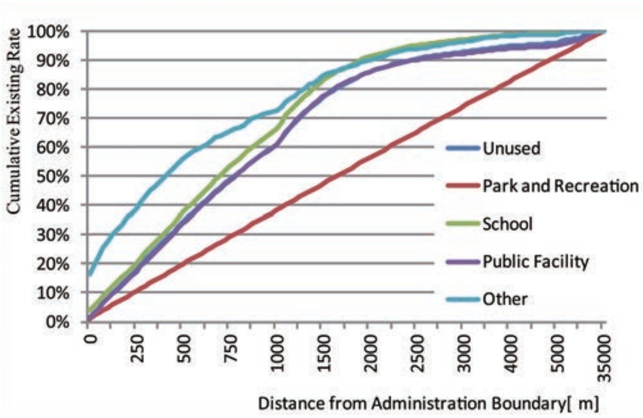

Fig. 6. Cumulative existing rate based on distance from administration boundary.

Open space, except for the category of parks and recreation, occupies 60% to 70% of 1 kilometer from an administrative boundary. Trends in the unused site and public facilities categories are very similar. The biosphere in disaster prevention and emergency response is usually considered within 1 kilometer square, which means that more than half of open space is assumed to be unavailable because it is in different administration. In other words, applying the merit of scale could be possible by managing a broad perspective beyond the municipal framework.

Looking back here, it is better to exclude vegetation and building footprints in determining actual available area, but we were able to clarify the absolute amount of open space and distribution around metropolitan Tokyo by combining available land-use data to make do with what we have. It is thus clear that Tokyo has quite a bit of open space. Because we are thinking about open space with perception gap, out thought lose touch with the realities in the world. This means that comprehensive database management is the only way to share a common operational picture with stakeholders.

5. Proposal for Open Space Database Management

Decision-making and problem resolution concerning open space in disaster response requires two conditions under in a situation of constraint-free application of population as mentioned earlier. The first condition is whether there is open space that meets the conditions necessary for a stated purpose. The second condition is whether the government can cordon off open space, including municipalities in the varying support done chronologically. It is, for example, important to bridge the perception gap between realities leveraging a database [21].

"To utilize a database of open space in a disaster response" is nothing but a process of whether open space exists and how to allocate limited resources considering multiple aspects of open space while setting the amount of available resources at the time as a state variable. It can also be regarded as a mathematical model such as in stochastic optimization or multi-period planning. To execute these decision support methods, comprehensive management is important in utilizing an open space database.

In this chapter, we propose a conceptual information management model for decision-making on open spaces and summarize the need for evaluation axes. To construct and operate a database, in addition to organizing tasks required in these processes, we discuss feasibility.

5.1. Conceptual Model of Information Management for Decision-Making

Gathering information about open space is necessary to make decisions on the use of open space, and such information is selected based on to criteria such as the capability of the application and created alternatives. We therefore propose the multitier model shown in **Fig. 7**. The first tier is the goal, the second is criteria for application, the third is the criteria of function, the fourth is the criteria of use period, and the fifth is alternatives. A specific example from Dr. Sato involves optimum resource allocation for temporary housing [22]. This refers to the reasonability of optimum resource allocation rather than conjoint analysis.

Following the example provided by the city of Yokohama, elements making up the second, or application, tier is as follows [26]:

1) Temporary evacuation site,
2) Heliport,
3) SDF camp,
4) Assisting troop's camp,
5) Supplies depot transport,
6) Site for temporary waste,
7) Site for household waste,
8) Site for recovery material,
9) Site for temporary housing,
10) Temporary shop and business office,

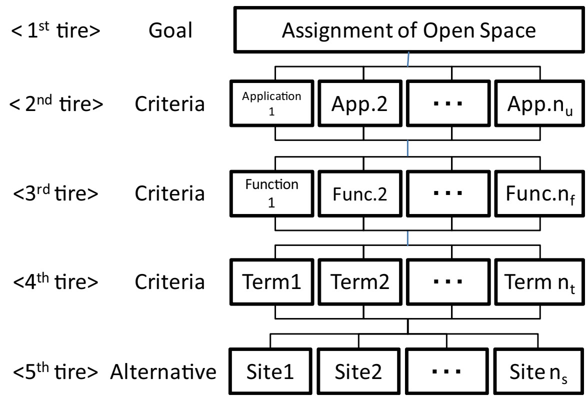

Fig. 7. Multitier decision-making model of open space.

11) Urban development,
12) Disaster public housing, and
13) Site for restoration material.

The elements that make up the function, or third, tier include type of land use such as available area, current occupation, infrastructure development, and ownership. Kanagawa prefecture, for example, determined the site for temporary housing to match conditions, such as "no flooding, landslides, or other hazards," "water and electricity can be maintained easily," "construction materials can be easily transported," "no hindrance exist to daily life," and "if other requirements are equivalent, priority is in the order of public, state, private land." Guidelines on area size exceed 2,000 square meters for public land and over 4,000 square meters for private land [27].

The regional disaster prevention plan for each municipality includes guidelines on area size exceeding 1 hectare for debris handling and for wide evacuation areas to be at least 10 hectare in size.

Elements making up the use period, or fourth, tier is imperative in addressing a time schedule. Dr. Noboru Masuda mentioned that post-earthquake park usage patterns have been changing gradually in the first motion stage, and application is segregated by park area size and location [23]. Time-oriented zoning is also necessary for the use of Metropolitan Park in disaster periods [24]. Hens, the chronological order of scenes that require open space is organized as follows:

In the first motion, evacuation shelters and relief centers are prioritized. Second, in the emergency period, recovery facilities are prioritized. Third, in the recovery period, needs for temporary and recovery housing and temporary sites for reconstruction or demolition waste increase. As can be seen, the weighting ratio for the use of open space is also affected by time series variations in need.

5.2. Proposal for the Construction and Operation of a Database

Paper-based business processes are useless in a "metropolitan epicenter earthquake" due to the damage scale, range of influence, and diversity of persons or organizations supporting post-disaster services. To take advantage of ICT technology, wide-range database systems for open space management should be developed based on the model we have proposed. In order to allocate available open space, preliminary data correction, integration, and post management/organization are required based on the needs of users. We organized tasks required in these courses of proceedings and studied the feasibility of implementation.

5.2.1. Preparation Before Earthquakes

Basically, characteristic values used in the assessment of open space is should be filled in as much as possible in the planning stage. It is also necessary to make an effective mechanism that reflects the results of field surveys after a disaster. Most municipalities assume the use of public land alone, but private land must be used in a large-scale disaster. Land-use data on urban planning in every municipality is required and must be reviewed once every five years. It is possible to easily and accurately identify the population of existing open space by use. It is a waste not to use and consider the relations with such a database as a part of open space management for nation-wide countermeasure and response.

Local governments should review how public information is used. Most municipalities have official websites and upload regional disaster prevention plans, but formats and disclosure may differ greatly with the individual organization. To benefit fully from a digital format, data should be shared freely and made freely available. Given database use, excessive "protection" should be avoided in database use.

Address data or *x-y* coordinates are very useful for indicating locations on maps. Japanese address system is complex, so it is hard to join tabular data of *x-y* coordination with character strings of address. Standardizing information processing, Dr. Go Urakawa has proposed a technique using geo tagging spreadsheets, which have number codes for each address as a uniform rule. If it is difficult to apply the same method as above, a world-wide location code system is useful, e.g., Local Point or N code by private companies. "Ucode" developed by the Geographical Survey Institute is useful. A coordination mechanism linking IDs helps in making an immediate wide-range disaster response. When it comes to sharing information on a national scale, however, remote systems and services such as WebGIS may be developed but it is difficult to use it interactively for everyone.

To improve this situation, it is necessary to improve information literacy and appreciation for the protection of personal information to provide information.

5.2.2. Managing Reception Tables

Applicants should fill up the application forms including purpose of using open space and duration in addition to contact information. For data entry operators, this involves the process of expanding attribute tables that can link master sheets of an open space database using unique IDs as Primal/Foreign keys.

5.2.3. Allocating Open Space

Allocating open space matches the entity of an applicant list to the entity of available open space reasonably. It should be remember in management to consider both the results of matching and the reference process to avoid duplicating efforts. This means using the concept of log management, e.g., date of inquiry, permission, and start/end.

When choosing open space from available space, some cases are expected to accept multiple functions simultaneously, such as putting evacuation shelters, site for disaster waste, and restoration material for a former factory site. Other cases may require the assignment of similar functions on small open space available existing nearby considering cost benefits and efficiency of transportation. Handling these cases requires spatial query capability in addition to attribute query capabilities. Dr. Keiko Inagaki, for instance, proposed a method of making zonal classification to ensure the autonomy of disaster prevention centers when lifelines are disrupted and suggesting the existence of complex usage in terms of spatiality, functionality, and usability of open space [28].

It is also essential that the period of use accommodate responses to changing needs over time and with changes in the disaster phase. If, for example, open space is insufficient for a required amount, it is desirable to continue to optimize all disaster response operations by adjusting the time period of use. It is an effective approach, for example, to implement functions to check automatically whether open space has been reserved and to exclude such space from search suggestions by marking already reserved space. To understand the situation at the city, district, and individual levels, functions to work with the Gantt charts often used in project management are effective.

5.2.4. Management and Operations

To guarantee the quality of decision-making, in addition to information and decision-making criteria, people and organizations must manage and operate open space information. Organizations must manage overall situations by overlooking municipalities and local government and supporting metropolitan cities. Plans have been developed for an institutional wide-area disaster prevention base. A central base of operations for disaster prevention in the Tokyo metropolitan area, called the Ariake no Oka Core Wide-Area Disaster Prevention Base was complete in June 2009 at the Tokyo Rinkai Disaster Prevention Park This base houses emergency response facilities, including local disaster management headquarters and institutions that compile disaster-related information and coordinate emergency disaster measures. It is reasonable for an open space management system to be operated in such a facility. To support system continuity with normal flexible

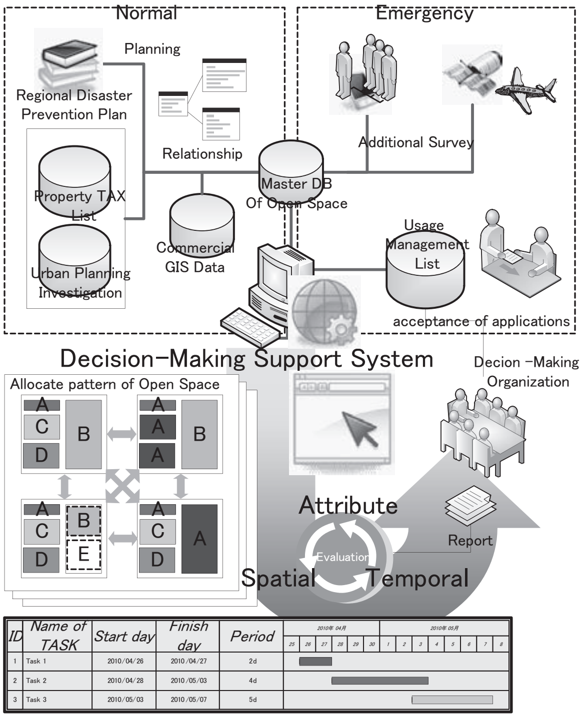

Fig. 8. Overview of the decision-making support system.

cooperation with organizations or independent administrative institutions consisting of experienced experts and practitioners should be considered or, alternatively, they may be outsourced.

The following is an overview of the concept of use derived from above, as shown in **Fig. 8**.

6. Conclusions

We have analyzed the development and implementation of an open space database for comprehensive wide-range management of applications for a metropolitan epicenter earthquake targeting Tokyo, Kanagawa, Chiba, and Saitama Prefectures.

We developed a current reality tree to clarify core issues behind relations with individual problems with open space. Open space is required in various disaster responses, but is assumed to involve a shortage from the perspective of physical and usage constraints in built-up urban areas. We demonstrated the importance of managing Open space as a highly feasible solution to resolve conflicts.

Based on validation for developing a basic database, data entities for open space can be constructed relatively easily and comprehensively using land-use data. We performed geospatial processing to extend attribute data and analyzed the amount and spatial distribution of open space based on the categorized type. Although more advanced quantitative evaluation should be developed, we have indicated the importance of open space supply and demand.

We proposed a conceptual model of information management for decision-making to utilize the database with decision-making theory. We then discussed evaluation criteria and other requirements for a feasible management system.

Since we used only land-use data from different publications, available space should be more fully analyzed taking into account other geospatial data such as building footprints. Updated regional disaster prevention plans should be checked to verify weighting factors of criteria in a decision-making model.

Acknowledgements

This work was done within the framework of the "Special Project for earthquake disaster mitigation in the Tokyo Metropolitan Area (PM: Prof. Haruo Hayashi, DPRI, Kyoto University)" supported by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT). "The vulnerability assessment and development of a comprehensive public management system for social infrastructures (Prof. Koichi Fujie, Yokohama National University) was supported by the MEXT.

References:

[1] Central Disaster Prevention Council, "Conceivable Disaster Situation," pp. 2-3, 2005.
[2] Headquarters for Earthquake Research Promotion, "Evaluation for seismic activity along the Sagami Trough," Earthquake Research Committee, 2004.
[3] Central Disaster Prevention Council, "Countermeasure Outline for Tokyo Metropolitan Earthquake," 2005.
[4] Central Disaster Prevention Council, "Emergency Operation Procedure for Tokyo Metropolitan Earthquake," 2010.
[5] I. Nakabayashi and R. Odagiri, "The present and issue on governmental measures against compound disasters and mega disasters in Japan," Journal of Institute of Social Safety Science, No.11, pp. 33-42, 2009.
[6] M. Hatayama, F. Matsuno, S. Kakumoto, and H. Kameda, "Development of Spatial Temporal Information System DIMSIS," Theory and applications of GIS, Vol.7, No.2, pp. 25-33, 1999.
[7] M. Hatayama and S. Kakumoto, "Development of Risk-Adaptive Information Management System for Local Government and its Application to Disaster Drill in Nagata Ward, Kobe City," Journal of Institute of Social Safety Science, No.5, pp. 155-160, 2003.
[8] N. Hirayama and Y. Kawata, "Wide-Area Cooperative Measures in the Emergency Debris Operation on the Huge Earthquake Disasters," Journals of the Japan Society of Civil Engineers G, Vol.63, No.2, pp. 112-119, 2007.
[9] J. CHENG, et al., "Applying the TOC logistic process to clarify the problem schemes of near-field earthquake in Tokyo metropolitan area based on the TOC logistic process," Journal of Institute of Social Safety Science, No.11, pp. 225-233, 2009.
[10] Central Disaster Prevention Council, "52th Committee on Disaster Research," 2009.
[11] Kobe Conference on Disaster Reduction "Manual for the Management of Open Space," pp. 86-91, 2009.
[12] Geospatial Information Authority of Japan, "Summary Report on broad-based study in urban earthquake reconstruction measures metropolitan areas in 2003," 2003.
[13] Geospatial Information Authority of Japan, "Digital Map 5000 (Land Use) Tokyo metropolitan district 2000," Japan Map Center, 2007.
[14] Geospatial Information Authority of Japan, "Detailed Digital Information (10 m Grid Land Use) 1994," Japan Map Center, 2002.
[15] ESRI Japan Co., "ArcGIS Data Collection Standard Pack," 2008.
[16] Japan planning System Co.,LTD, "School Point Data," 2007.
[17] N. Nojima, M. Kuse, M. Sugito, and Y. Suzuki, "Population Exposure to Seismic Intensity for Assessment of Seismic Disaster Potential," Journal of Natural Disaster Science, Vol.23, No.3, pp. 363-380, 2004.
[18] S. Suzuki and H. hayashi, "A Study on the Disaster Exposures to Tokyo Metropolian Earthquake and the Areal Characterization Based on Them," Journal of Institute of Social Safety Science, No.10, pp. 97-107, 2008.
[19] National Statistics Center, "Total population by sex," 2005.

[20] Department of Disaster Management in Cabinet Office, "Measurement Status about Evacuees and Issues," pp. 56-64, 2007.

[21] M. Inogushi, K. Tamura, and H. Hayashi, "Development of efficient method for victims certification process to manage the victims master database management system effectively," Journal of Institute of Social Safety Science, No.12, pp. 81-91, 2010.

[22] K. Sato and K. Ishibashi, "Development of Temporary Housing Allocation Planning Method: A Case Study of Odawara city, Kanagawa prefecture," J. Archit. Plann., AIJ, No.616, pp. 121-128, 2007.

[23] City of Yokohama, "Regional disaster prevention plan of Yokohama City; Material Edition," pp. 575-578, 2007.

[24] General Affairs Section of Public Health and Welfare Bureau, Prefectural Land Development Bureau, "Manual on Supply of Temporary Housing," 2006.

[25] N. Masuda, "Urban Park Planning from the Point of View of the Safe and Secure Urban Environment," Journal of the Japanese Institute of Landscape Architecture, Vol.66, No.3, pp. 180-184, 2003.

[26] K. Oguchi, "Parks in Case of Disaster in Tokyo; Construction and Plan for Use of Rescue and Shelter," Journal of the Japanese Institute of Landscape Architecture, Vol.66, No.3, pp. 208-212, 2003.

[27] G. Urakawa and H. Hayashi, "Building standardized information processing based on location information to implement emergency response and management effectively," Journal of Institute of Social Safety Science, No.11, pp. 299308, 2009.

[28] K. Inagaki and S. Sadohara, "Clustering Distributed Self-sustaining Zones for Disaster Management: Research and Analysis of Public Facilities in Yokohama City," Journal of Institute of Social Safety Science, No.12, pp. 21-30, 2010.

Name:
Takashi Furuya

Affiliation:
Externally Funded Academic Staff (Lecturer), Dr. Eng., Center for Risk management and Safety Sciences, Yokohama National University

Address:
79-5 Tokiwadai, Hodogaya-ku, Yokohama, Kanagawa 240-8501, Japan

Brief Career:
2004- Graduate School of Yokohama National University, Environment and Information Science
2004- Center for Risk management and Safety Sciences, Yokohama National University

Selected Publications:
- T. Furuya, M. Inoguchi, K. Tamura, G. Urakawa, and H. Hayashi, "Ex-post Analysis for Location / Allocation of Temporary Housing Unit and Demand after the Niigata-Chuetsuoki Earthquake," Journal of Institute of Social Safety Science, No.12, 2010.
- T. Furuya, H. Hayashi, G. Urakawa, K. Fujiharu, K. Tamura, M. Inoguchi, H. Sakai, and M. Nukazuka, "Practical Utilization of Maps with Geo-Referential Relational Database to Support : Measures for Recovery and Reconstruction at EMC-K, Niigata-ken Chuetsuoki Earthquake 2007," Journal of Institute of Social Safety Science, No.10 , 2008.

Academic Societies & Scientific Organizations:
- Architectural Institute of Japan
- Institute of Social Safety Science
- GIS Association of Japan

Name:
Munenari Inoguchi

Affiliation:
Assistant Professor, Ph.D. Informatics, Research Center for Natural Hazard and Disaster Recovery, Niigata University

Address:
8050, Ikarashi Nino-cho, Nishi-ku, Niigata city, Niigata 950-2181, Japan

Brief Career:
2008- Research Center for Natural Hazard and Disaster Recovery, Niigata University

Selected Publications:
- M. Inoguchi, et al., "Implementation of Management System for Supporting Victims' Life Recovery Process Based on the Victim Master Database – Lessons Learned in Kashiwazaki City from 2007 Niigata Chuetsu-oki Earthquake –," Journal of Social Safety Science, No.10, pp. 553-564, November, 2008.
- M. Inoguchi, et al., "Coaching Effective Operation Procedures using GEOINT Database for Local Disaster Responders based on Short-term Education Model, Journal of Social Safety Science," No.9, pp. 177-187, November, 2007.
- M. Inoguchi, et al., "How should local government integrate the information of affected people to support their life recovery continuously and effectively? – A case study at Kashiwazaki City, Niigata, Japan –," 14th World Conference on Earthquake Engineering Proceedings, CD-ROM(8pp.), October, 2008.
- M. Inoguchi, et al., "Development of Logistic Estimation System based on HAZUS Damage Estimations for Rational and Effective Decision Making in Disaster Response," 2nd International Conference on Urban Disaster Reduction Proceedings, CD-ROM (6pp.), November, 2007.

Academic Societies & Scientific Organizations:
- Institute of Social Safety Science (ISSS)
- Japan Society for Natural Disaster Science (JSNDS)
- GIS Association of Japan (GISA)
- Japan Emergency Management Association (JEMA)
- Japan Society of Civil Engineers (JSCE)
- The Institute of Electronics, Information and Communication Engineers (IEICE)
- Information Systems Society of Japan (ISSJ)
- Japan Association for Earthquake Engineering (JAEE)

Name:
Go Urakawa

Affiliation:
Associate Professor, Dr. Eng., Education Center for Disaster Reduction, University of Hyogo

Address:
1-5-2 Wakinohamakaigandori, Chuo-Ku, Kobe 651-0073, Japan

Brief Career:
2000- Laboratory of Urban Safety Planning
2002- Disaster Research Institute, Kyoto University
2007- Institute of Sustainability Science, Kyoto University
2011- Education Center for Disaster Reduction, University of Hyogo

Selected Publications:
- "Useful Mobile GIS on site," Kokonshoin, 2005.

Academic Societies & Scientific Organizations:
- Architectural Institute of Japan
- Institute of Social Safety Science
- GIS Association of Japan

Name:
Haruo Hayashi

Affiliation:
Professor, Ph.D. (UCLA), Research Center for Disaster Reduction System (DRS), Disaster Prevention Research Institute (DPRI), Kyoto University

Address:
Gokasho, Uji-shi, Kyoto 611-0011, Japan

Brief Career:
1983-1988 Assistant Professor and Associate Professor, Faculty of Humanities, Hirosaki University
1988-1994 Associate Professor, Faculty of Integrated Arts and Sciences, Hiroshima University
1994-1996 Associate Professor, Disaster Prevention Research Institute, Kyoto University
1996-present Professor, Disaster Prevention Research Institute, Kyoto University

Selected Publications:
- H. Hayashi et al., "Effective method for disaster prevention, 'Disaster Ethnography' – unrevealed witnesses of Hanshin-Aawaji Great Earthquake," ISBN: 9784140814055, Japan Broadcast Publishing Co., Ltd, 2009 (in Japanese).
- Kyoto University/NTT Resilience Joint Research Group (H. Hayashi et al.), "Creating Disaster Resilient Society – protecting lives, livings, businesses from disasteres and risks," ISBN: 9784861304255, Nikkei BP Consulting, Inc., 2009 (in Japanese).
- H. Hayashi, "Earthquake Disaster Prevention Study saving life," ISBN: 4000050486, Iwanami Shoten, 2003.

Academic Societies & Scientific Organizations:
- Institute for Social Safety Science (ISSS)
- Japan Society for Natural Disaster Science (JSNDS)
- Japan Emergency Management Association (JEMA)