EVACUATION, POST-DISASTER RECONSTRUCTION AND IMPROVEMENT MANAGEMENT FROM QOL STANDARDS IN DISASTERS

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ABSTRACT: In case of severe disasters, the QOL (Quality of Life) of disaster victims is severely damaged by the lack of residence and infrastructure which can make life inconvenient. But in the phases of evacuation, post-disaster reconstruction, and improvement, there are few ideas as to how to reconstruct new residences and infrastructure in the disaster area. And it is also needed that discuss how to reinforce infrastructure networks in pre-disaster prevention phase.

In this study, we propose the method applying QOL standards for evacuation, post-disaster reconstruction and improvement management in the disaster area. We construct a QOL evaluation method for evaluating the land from a multi dimensional perspective. Taking the physical conditions of the residential areas and subjective sense of the residents into consideration, a QOL indicator is designed. First, with regard to the physical conditions, Life Prospects (LPs) consist of Accessibility (AC), Amenity (AM) and Safety & Security (SS). The QOL indicator is quantified as a sum of the LPs weighted by the subjective sense of residents. And it is also into consideration in weighting parameters that dynamic transition of disaster victim's needs through each post-disaster phase.

Based on this evaluation method, we evaluate the AC to hospital in the Tohoku coastal area where has been suffered severe damage by earthquake on March 11th 2011 and in Tokai area where is expected to suffer in near future. Main findings are as follows: a) About Tohoku case study, AC was much decreased along Sanriku shoreline. On the other hand, in some inland areas the decrease of AC was suppressed. b) Meanwhile, from time series comparison, recovery of AC has been observed. And the recovery is remarkable in central area of Sendai city which has rich road network. c) The analysis about Tokai area reveals that AC in coast areas was much decreased because of collapse of road network and decrease in hospital function. On the other hand, the decrement was suppressed in some urban areas such as Nagoya where many hospitals and tight road networks exist.

KEYWORDS: QOL, Land Use, Urban Planning, Risk management

1. INTRODUCTION

In “the Great East Japan Earthquake” which occurred in east north Japan at 11 March 2011, the earthquake and triggered tsunami cut off transportation network at many places and various type of second damages happened. And consequently, there were many isolated regions where relief supplies could not be delivered. Furthermore, because there were no guidelines to process information in emergency, mismatches had been happened between needs and supply in the phase of relief goods transportation. It accordingly reveals the difficulty to construct support regime which satisfy refugee's needs without any trouble. After that, it is observed that refugee's Quality of Life (QOL), such as accessibility from evacuation site or residential area to hospital, had been low.

In "Tokai-Sanrendou Earthquake" which is expected to occur recently, Tokai region will be assumed to suffer heavy damage as same as "the Great East Japan Earthquake. (Mie prefecture have sawtooth coastline as same as Sanriku region, Aichi prefecture and Shizuoka prefecture is facing the sea). And a management method how protect resident's Quality of Life from disasters have been needed.

Consequently in this study, we develop a refugee's Quality of Life (QOL) evaluation system, which determination mechanisms dynamically change through each phase in post-disaster. And we can discuss countermeasures to decrease QOL damage in each phase, such as road network reinforcement in pre-disaster prevention phase and order of priority of recovering link in post disaster reconstruction phase.

2. POSITHONING

Disaster damages are generally evaluated with the direct index such as economical impact, number of death or broken buildings. Existing disaster simulation system outputs those indexes in the standard[1)]. However, we should take it into consideration that disaster damages give a long term impact to daily life through variety path. In the related previous studies, some simple indicator such as isolated days and disaster vulnerability from food stockpile by the village is evaluated[2)3)]. But, consideration of the residents' life needs and its dynamic changing process in evacuation, post-disaster reconstruction and improvement periods are not enough.

And, the land use and infrastructure development policy must be changed to restrain disaster damages in the regions where are high disaster risk. Different from the disaster areas where villages and infrastructures are collapsed at all, other regions do not have risk consciousness so much. Consequently, it is hard to plan and implement the policy to re-construct residential area gradually for reduce disaster risk. Consequently, it is indispensable to develop the system which evaluates influence of disaster damages from residents' perspective with easy-to-image index.

On the other hand, there are some evaluations of the refugees' residential environment, which is used the real data in the "Han - Shin Awaji Earthquake disaster"(1995) and "Chuetsu earthquake"(2004). These researches are no more than qualitative analysis, quantitative aspect is not sufficient.

Because of the above background, the disaster prevention plans are constructed by each municipality individually. And, there are no common management methods which based on the scientific perspective. And, the method to prioritize in reconstruction and improvement phase is not established.

Therefore, we develop the system to evaluate disaster damage quantitatively and time-sequentially from the viewpoints of residential environment. Although, we concentrate on the AC index which compose QOL indicator in this paper, our final target is to construct total evaluation method of disaster vulnerability by the village and to aid planning in reconstruction and improve management.

3. METHODOLOGY

The framework of this study is shown in figure 1.

Main target of this study is policy evaluation about "Tokai-Sannrendou Earthquake"; however, we additionally evaluate the result of "the Great East Japan Earthquake (2011)" with available real data for comparison. From the result of these analyses, we confirm the availability of developing evaluation system.

And, to represent stochastic event; we apply monte-carlo simulation. The number of trials is set to 20.

3.1 Disaster damage simulation

In this study, evaluation must be done before its occurrence; we must simulate direct impacts of disaster. And thereby, we use the result of an earthquake simulation tool which simulates seismic intensity by the 500m grid[1].

Based on assumed seismic intensity, we set broken rate of housing and infrastructure as equation (1).

$$p_k = \frac{1}{1+\exp(\alpha+\beta x_i)} \tag{1}$$

p_k: broken probability of link k.

x: seismic intensity of mesh i where the link exist.

α and β: parameter.

The parameter α and β are estimated from the results of "the Great East Japan Earthquake (2011)". And if the generated random variable is bigger than the broken probability, the link is assumed to not available. On the other hand, if the generated random variable is smaller than the broken probability, the link is assumed to available. Each link are evaluated whether it is available or not in each trial.

3.2 QOL evaluation

Firstly, available road links or facilities are led by a scenario which describes reconstruction priority of damaged infrastructure. Based on the road network

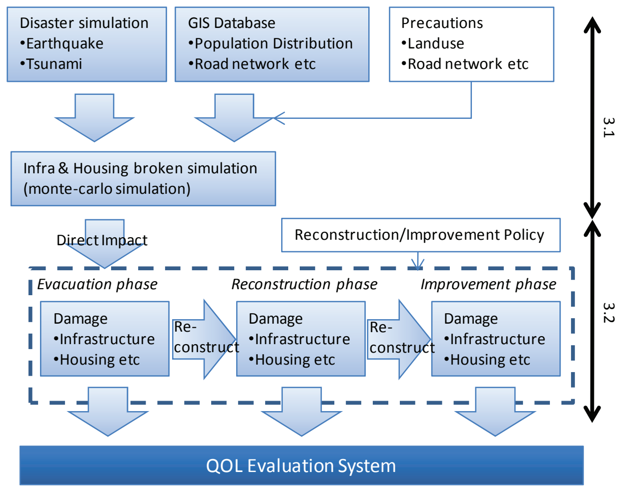

Figure1 Framework of the system

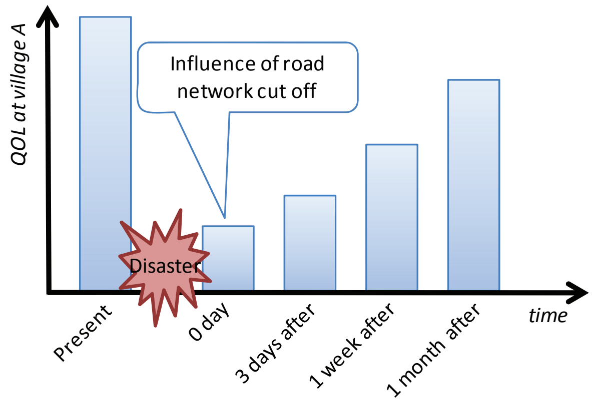

Figure 2 output image

which composed of available links in each phase, QOL index is calculated on GIS with the method introduced in next chapter. And, output image of QOL evaluation is shown in fig2. Average values of 20 trials are set to final QOL index in a village.

4. QOL EVALUATION SYSTEM

4.1 Basic system

Taking the physical conditions in the residential areas and subjective sense of the residents into consideration, QOL indicator is designed. Firstly, as physical conditions, Life Prospects (LPs) consist of Accessibility (AC), Amenity (AM) and Safety & Security (SS) is defined. The hierarchical structure of the LPs is shown in Table 2. And, as shown in eq.

(1), QOL indicator is quantified as a sum of the LPs weighted by subjective sense of residents. For weighting parameters, results of estimation by generation and by sex through conjoint analysis are used, based on a questionnaire survey on the selection of residential area[4].

$$QOL(g,i) = \mathbf{w}^T(g)\mathbf{LP_S}(i) \tag{2}$$

$$\mathbf{w}(g) = \left[w(g, AM), w(g, AM), w(g, SS)\right] \tag{3}$$

$$\mathbf{LP_s}(i) = \left[AC(i), AM(i), SS(i)\right] \tag{4}$$

$\mathbf{w}(g)$: weight parameter vector by attribute group g.

$\mathbf{LP}_s(i)$: Life Prospects vector in mesh i.

Measurement of QOL is adopted QALY (Quality Adjusted Life Year) that is proposed in the field of health or environmental risk. QALY is life years adjusted with QOL, and the unit must be "year" or "day".

4.2 Accessibility

AC which defined in equation(5) as potential type represents the accessibility from residential area to main facilities.

$$AC_i = \sum_j^J \left\{AT_j \exp\left(-\alpha c_{ij}\right)\right\} \tag{5}$$

AC_i: accessibility of zone i.

J: total number of zone which compose study area.

AT_j: attractiveness of facilities in zone j.

α : parameter.

c_{ij} : generalized cost from zone i to zone j.

We apply exponential function to diminish marginal cost. And the parameter is estimated with OD trip distribution which obtained from "Chukyo Person Trip Survey (2001)".

4.3 Application for disaster evaluation

In disaster, survival conditions threatened, the weighting parameters **w** in equation (2) are far different from the normal one. It is thought that the weighting parameter gradually shifts to normal one through evacuation phase, re-construction phase and improvement phase. The image is represented in Figure3. Tendencies of weighting parameter in each phase are described below.

・ <u>*Evacuation phase*:</u> In just post-disaster,

Table1 Components of QOL

Component	Detail of Component	Indicator
AC : Accessibility	Employment	Accessibility for Place of Work
	Education & Culture	Accessibility for School
	Health & Medical	Accessibility for Hospital
	Shopping & Service	Accessibility for Retail
AM : Amenity	Living Space	Gross Floor Area for Living
	Town Scape	Number of Building Story
	Local Environmental Load	Green Space
	Neighborhood Natural Environment	Equivalent Sound Level
SS : Safety & Security	Earthquakes Risk	Loss of Life Expectancy Caused by Earthquake
	Flood Risk	Flood Depth Caused by Flood
	Risk of Crimes	Annual Number of Crimes
	Road Accident Risk	Number of Traffic Accidents

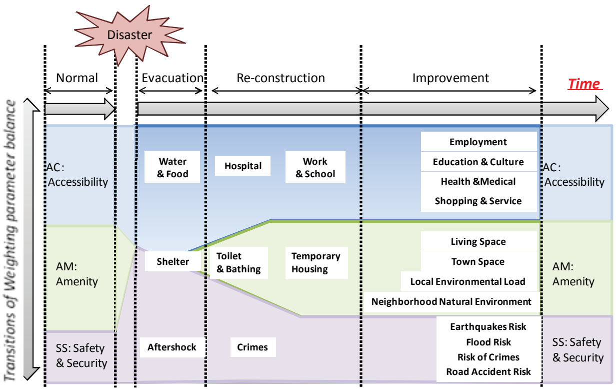

Figure 3 changing of QOL weighting parameters in post-disaster

accessibility to emergency evacuation facilities and medical facilities are attached greater importance. And because of cost that supporting goods are conveyed from other regions, it is also important how many foods water and blanket remain in retail facilities or warehouse which locate in the disaster area. The status of established evacuation site and how many relief supplies have reached is attached greater importance. In this phase, the condition of sanitations such as lavatory and bath are regarded as important too. And Schemes how defiance the second damage by the aftershocks and peace preservation in evacuation site is needed. Furthermore the safety information of missing family and friends is also regarded as importance.

- *Re-construction phase*: Amenity related index such as residential environment in temporary house is regarded important thing. And refugees who are forced to live a long time under poor surroundings need mentally supports.
- *Improvement phase*: Office and school are resuming, the accessibility to those facilities are also regarded important thing. Balances of weighting parameter converge toward the normal one.

To obtain the real weighting parameter, questionnaire survey is planned at the assumed

Table2 data

Data	Source
Road Network	digital road map (2010, Japan digital road map association)
	Driving data(2011, Hond & Pioneer car navigation system)
Location of Hospitals	National Land Numerical Information Download Service, (2005, Ministry of land , infrastructure, transport and tourism)
Seismic intensity in “Toakai-sanrendo Eathquaqe”	The earthquake damage simulation tools (2009, Cabinet Office, Government of Japan)

damage area with “Tokai-Sannrendou Earthquake”. The method mentioned above makes it possible to describe the changing of QOL by the village considering both physical urban conditions such as road network and weighting parameter **w** that change as time goes.

5. CASE STUDY

5.1. Case study area and data

Case studies have been done about Tohoku region (Iwate and Miyagi prefecture) and Tokai region (Shizuoka, Aichi and Mie prefecture). In Tohoku case study, the damage of “Great East Japan Earthquake” is evaluated. And, in Tokai case study “Tokai-Sanrendo Earthquake” is assumed as target disaster. Here, QOL has been estimated with only AC to hospital which is the most important factor of QOL immediately after disaster. Tohoku’s estimation was based on the actual data, but in Tokai area the damage which is predicted by earthquake damage prediction tool was used instead of actual data.

Table.2 shows the used data. In addition, flooded hospitals by tsunami were assumed to lose their function. About "Great East Japan Earthquake", we used actual data. About "Tokai-Sanrendo Earthquake", we put an assumption that areas within 10 km from coast and 10 meters from the sea level are flooded.

5.2. Result of analysis

a) Great East Japan Earthquake

Fig.4 describes the decrease rate of AC to hospital compared to normal AC by the municipality after "Great East Japan Earthquake (11 March 2011)".

Meanwhile this research has used recorded car drive by car navigation systems as opened roads even if the road was motorable but not recorded; it had been regarded as not motorable. Hence this AC result could be undervalued.

Immediately after the earthquake (March 13th), AC had decreased in whole, especially Sanriku coast area. However the decreasing rate in urban areas such as Sendai-city or Morioka-city was comparatively less and in some cost areas the decrement was suppressed differently, because these area's hospitals were located in uplands where are insusceptible to tsunami. Meanwhile disconnecting Route 45 which runs through Sanriku coast area led to complicate the access to surviving hospitals. In the result the gap of AC among regions widens.

1 week after the earthquake (March 18th), most has regions regained AC, especially areas along the Tohoku road connecting to Sendai-city or Morioka-city. Additionally Miyagi prefecture's recovery especially Sendai-city is bigger than Iwate prefecture.

1 month after (April 11th), areas along Tohoku road recovered more, however there were still some municipalities less than 20% of usual.

b) Tokai-Sanrendo earthquake

Fig.5 describes flooded areas from tsunami and location of hospitals. Green part means flooded areas and blue part means hospitals which function is lost. From this figure, severe damages in coastal area are anticipated. Fig. 6 describes the ratio of AC between pre-disaster and post-disaster. As this figure shows, decrease rate in coast areas which lost the hospital function by tsunami is remarkable. In contrast, the AC keeps high level in surrounding of Nagoya city which have intensive road network. These results

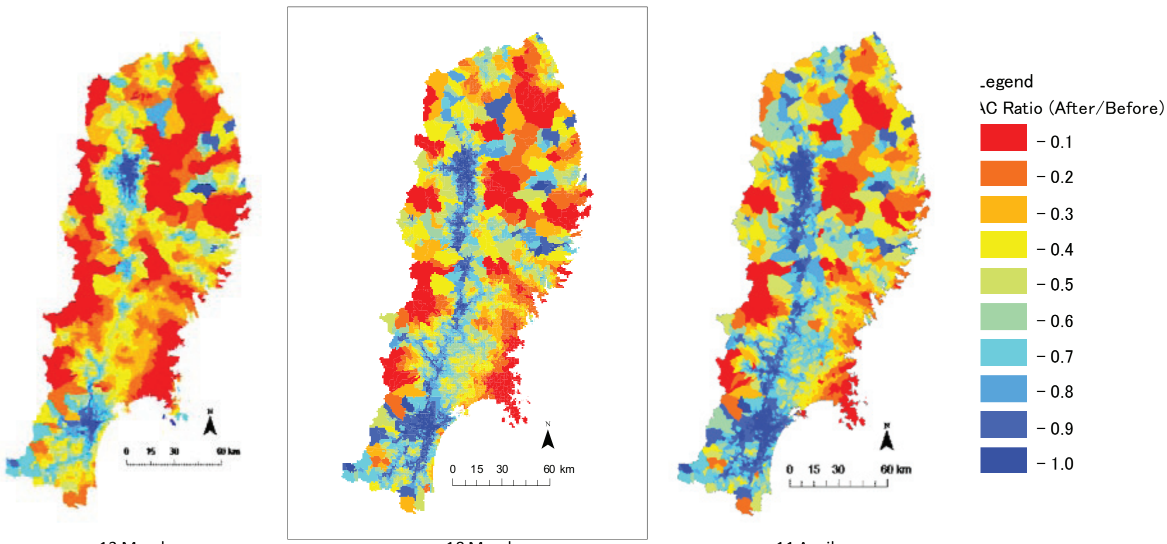

Fig4 time series AC transition in Tohoku region

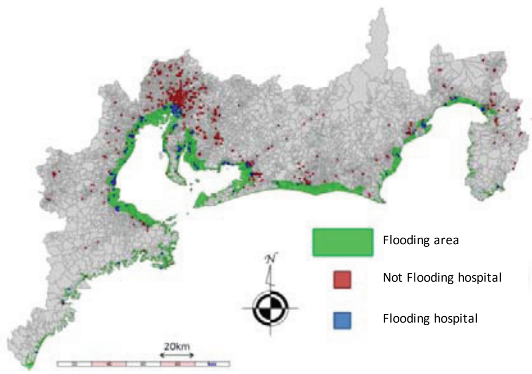

Fig5 assumed tsunami damage area and hospital location in Tokai region

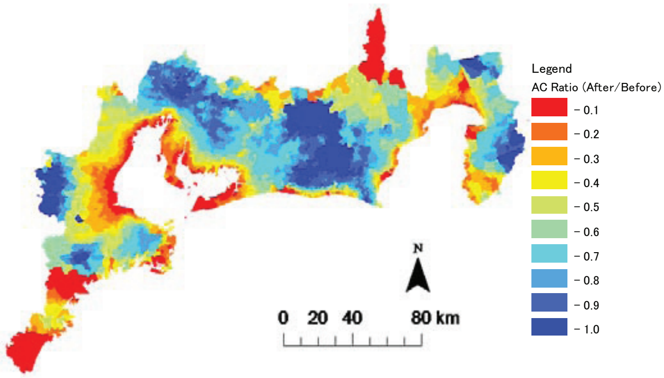

Fig6 AC transition at 0 days after disaster in Tokai region

show same trends as the estimation in Tohoku area.

6. COCLUTION

6.1. Consideration

This study established a system which evaluates disaster damage from the view point of resident's QOL. Then, we apply this system to Tohoku and Tokai area focusing on AC to hospital that is one of the most important factors immediately after disaster. The findings are as follows:

a) About "Great East Japan Earthquake", AC was much decreased along Sanriku shoreline which met big damages. On the other hand, in some inland areas the decrease of AC was suppressed.

b) Meanwhile, from time series comparison, recovery of AC has been observed. And the recovery is remarkable in central area of Sendai city which has rich road network.

c) The analysis about "Tokai-Sannrendou Earthquake" which is anticipated in Tokai area reveals that AC in coast areas was much decreased because of collapse of road network and decrease in hospital function. On the other hand, the decrement was suppressed in some urban areas such as Nagoya where many hospitals and tight road networks exist.

d) This result that shows similar trend to AC changes in the case study about "Great East Japan Earthquake". This indicates a requirement for rapid analyses of "Tokai-Sannrendou Earthquake" influence on Tokai area.

For future countermeasures against earthquake in Tokai area; about coast areas, it needs tsunami prevention, about urban areas which show rapid AC recovery after earthquake, road constructions contribute to suppress the decrease in AC after earthquake.

6.2. Future works

Future works are as follows.

a) There is a necessary of consideration in collapse probability of not only road network but also institutions.

b) The concretization of the most appropriate road construction to keep and recover AC after earthquake and analyses of AC change over time is also necessary.

c) Influence evaluations based on more comprehensive QOL indicator that includes amenity or security and safety contribute future disaster management.

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