Paper:

Response to Possible Earthquake Disasters in the Tokai, Tonankai, and Nankai Areas, and Their Restoration/Reconstruction Strategies

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This paper sorts out the problems to be solved for the establishment of individual disaster response and a long term recovery strategies for all the areas assumed to be hit by Tokai, Tonankai, and Nankai earthquakes. It takes into consideration (1) structural changes in the future (e.g. depopulation), (2) regional characteristics of societies (e.g. large urban, small to intermediate urban, and mountainous areas), (3) effects of the earthquakes occurring in a time-lagged manner, and (4) disaster images of individual areas hit by earthquakes occurring in a time lagged manner (e.g. disruption to social systems and effects on zero-meter areas) in order to show the research frameworks for "Tokai, Tonankai, and Nankai earthquake linkage evaluation, Sub-project 2-(4) Disaster Response and a long term recovery strategies reflecting regional and societal characteristics in the future." As the results of sorting out those issues, following things were pointed out. 1) Present frame work for disaster management for Tokai, Tonankai, and Nankai earthquakes does not count on the issues resulting from time lagged occurrence of those earthquakes, 2) According to depopulation in Japan, exposure to those earthquakes will reduced, 3) in western part of Japan, the time lagged occurrence would be worst-case scenario, and in eastern part of Japan, the simultaneous occurrence would be the worst, 4) Tsunami inundation would make serious problems for recovery in under sea level area, where the recovery work starts from un-watering the area, 5) analytical frame work on the long term recovery strategies based on "Program Evaluation" scheme consisted from (1) Assessment of need for the program, Assessment of Program Design and Theory, Assessment of program process and implementation, Assessment of program outcome/impact, Assessment of program cost and efficiency.

Keywords: long-term recovery, program evaluation, depopulation, time lagged occurrence, strategic plan

1. Introduction

It is presumed that the Tokai, Tonankai, and Nankai areas will likely be struck by earthquakes in the first half of this century, and the Japanese government estimates 250,000 deaths and direct and indirect economic damages of 8,100 million yen [1] should these earthquakes occur simultaneously. In the past, an earthquake in the Tonankai region was followed by one in the Nankai region 32 hours later (in the Ansei era) and 2 years later (in the Showa era). There are challenges, when two earthquakes occur in a time-lagged manner, regarding how disaster response activities should be carried out to prevent secondary damages and how adverse effects on economic activities should be mitigated for the damaged areas hit by two earthquakes, the second striking a fairly long time after the first.

The Japanese government has promulgated works entitled "Earthquake Disaster Reduction" (comprehensive disaster reduction measures), "Guidelines for Tonankai and Nankai Earthquake Emergency Response Activities" (guidelines for disaster response activities), and "Policy Framework for Tonannkai and Nankai Earthquakes" (a master plan for the disaster reduction measures). However, each plan provides the government's basic concepts but does not include detailed measures which take into consideration future depopulation of individual damaged areas or effects of Tokai/Tonankai or Nankai earthquakes in the event that they occur in a time-lagged manner.

For the effects of earthquakes occurring in a time-lagged manner, the basic concepts of effects/measures for the Kii Peninsula have been studied in "MEXT Special Project for Earthquake Disaster Mitigation In Urban Areas [2]," in which the authors participate. This study is still ongoing.

This paper sorts out the problems to be solved for the establishment of individual disaster response and restoration/reconstruction strategies for all the areas assumed to be hit by Tokai, Tonankai, and Nankai earthquakes. It takes into consideration (1) structural changes in the future (e.g., depopulation), (2) regional characteristics of societies (e.g., large urban, small to intermediate urban, and mountainous areas), (3) effects of the earthquakes occurring in a time-lagged manner, and (4) disaster images of individual areas hit by earthquakes occurring in a time-lagged manner (e.g., disruption to social systems and effects on zero-meter areas) in order to show the research frameworks for "Tokai, Tonankai, and Nankai earthquake linkage evaluation, Sub-project 2-(4) Disaster Response and Restoration/Reconstruction Strategies Reflecting Regional Societal Characteristics in the Future."

2. Current Status of Disaster Reduction Activites for Tokai, Tonankai, and Nankai Earthquakes

2.1. Earthquake Disaster Reduction

The Japanese government has formulated the work "Strategic Plan for Earthquake Disaster Reduction for Tokai, Tonankai, and Nankai earthquakes [3] "for strategically implementing long-term disaster reduction measures for those areas assumed to be hit by Tokai, Tonankai, and Nankai earthquakes, earthquakes which are considered likely to occur. "Strategic Plan for Earthquake Disaster Reduction [3]" raises a "Performance measure for disaster reduction" of halving human and economic damages in 10 years to deem the measures effective. "Earthquake Disaster Reduction" establishes national strategies, based on which the national and local governments are to formulate specific plans. For example, the Ministry of Land, Infrastructure, and Transport has amended the "Act on Promotion of the Earthquake-proof Retrofitting of Buildings" to establish basic guidelines for increasing the national percentage of earthquake-proof buildings from 75% to 90% in 10 years, requiring each prefecture to formulate measures for the promotion of the earthquake-proof retrofitting of buildings. At the same time, corresponding the performance measures of national government, "each prefecture is to formulate action plans, such as the "Disaster Reduction Strategy" and "Action plan for disaster reduction," which include "Performance measures for disaster reduction."

2.2. "Policy Framework for Tonannkai and Nankai Earthquakes"

The framework provides a master plan, including disaster reduction measures and emergency response and restoration/reconstruction plans, which have been formulated based on anticipated disasters resulting from Tokai, Tonankai, and Nankai earthquakes. Chapter 4 deals with the mitigation of the spread of disasters should the Tokai, Tonankai, and Nankai earthquakes occur in a time-lagged manner. It presents basic concepts for the evacuation of residents from damaged areas for several days and the later lifting of the evacuation orders, but does not include detailed study results.

Chapter 5 deals with adequate restoration/reconstruction measures, presenting basic concepts for restoration activities (the early restoration of damaged facilities, the early restoration of transportation networks, the early securing of lifeline functions and the clearing away of debris) and reconstruction activities, (administrative activities and support to victims). However, it does not include specific plans which take into consideration effects of earthquakes occurring in a time-lagged manner, regional characteristics, or future structural changes of the societies.

2.3. "Guidelines for Tonankai and Nankai Earthquake Emergency Response Activities"

These guidelines are for the activities when the government establishes the "Extreme Disaster Management Headquarters, headed by Prime Minister," in the event of earthquakes in the Tonankai or Nankai areas. Area headquarters are to be established in Aichi, Osaka, and Kagawa Prefectures with Vice Ministers or Parliamentary Secretaries serving as heads. The plan includes basic concepts and measures regarding organizations, information-sharing systems, emergency response (rescue, emergencymedical and fire-fighting activities), emergency transportation systems (for logistics), water and food supply (relief activities), evacuation centers and shelters (e.g., for those for whom it is difficult to return home), emergency restoration of lifelines, health and sanitary activities, disposal of dead bodies, prevention of secondary disasters, reception of volunteers, and emergency restoration of major transportation systems. However, although the plan describes the prevention of secondary disasters resulting from earthquakes occurring in a time-lagged manner, it does not include specific measures.

2.4. Problems Involved in the Current Response Plans to be Taken in the Event of Tokai, Tonankai, and Nankai Earthquake Disasters

The government has been studying countermeasures for Tokai, Tonankai, and Nankai earthquakes, which are considered to likely to occur, based on a long-term perspective. However, there is work to be done regarding 1) the formulation of specific plans in which the effects of earthquakes occurring in a time-lagged manner, regional characteristics, and future changes in social structures are treated, 2) the formulation of specific activity guidelines for responding to earthquake disasters occurring in a time-lagged manner, and 3) the formulation of concepts for restoration and reconstruction should earthquakes occur in a time-lagged manner.

3. Effects of Depopulation

The Japan's population started to decrease for the first time in 2005 (although it increased in 2006) and will surely decrease over the long-term. A white paper [6] on societies with declining birthrates estimates that the population will decrease from the present 127 million to 110

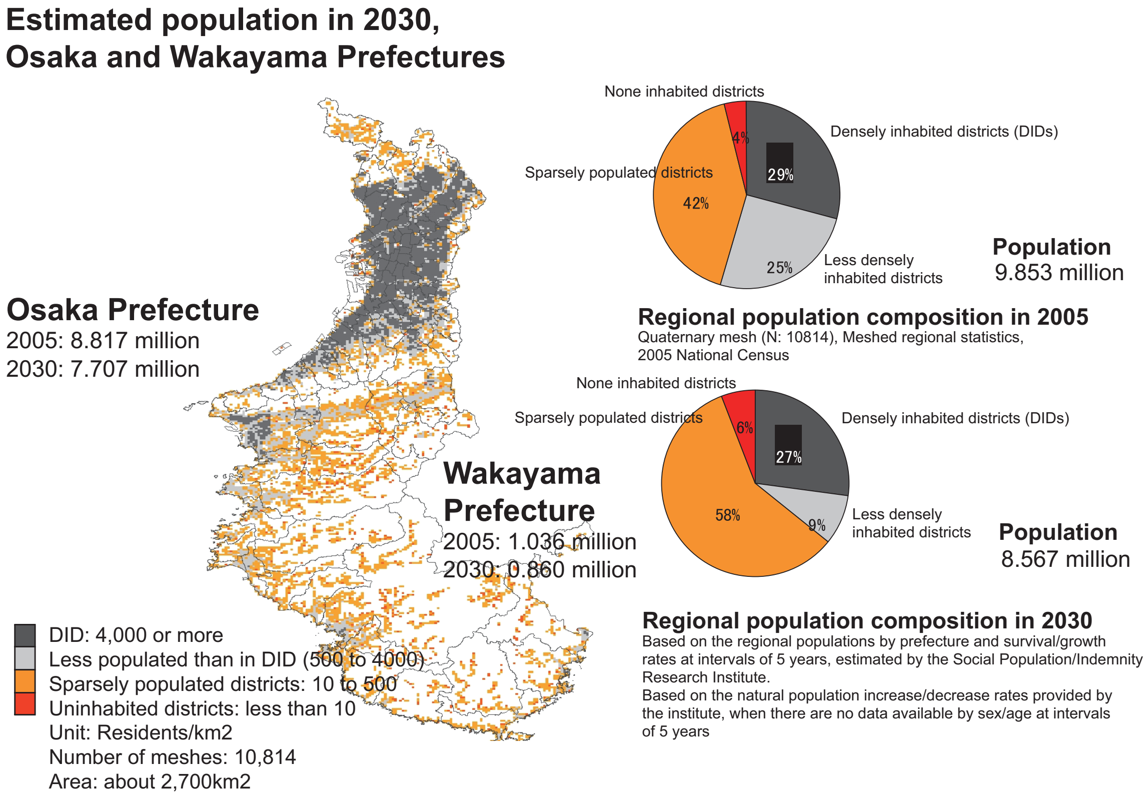

Fig. 1. Estimated population in 2030, Osaka and Wakayama prefectures.

million in 2035, when persons 65 years old and above will account for as high as 37% of the population. Depopulation has significant effects on regional economies. A simulation by a committee of the Ministry of Economy, Trade and Industry's has predicted decreased industrial productivity both within and beyond the region in most urban employment areas. [7] It also estimates that "public services and infrastructures will possibly be difficult to provide in their traditional forms as the population and scale of the economy dwindle and regional financial constraints intensify."

Figure 1 illustrates the population per 1 km^2 in 2030 in Osaka and Wakayama Prefectures, estimated on the assumption that there will be no population migration and using the mesh data obtained by the national census. These estimates, obtained through simple procedures, present a scenario in which most of the population lives in mountainous areas in 2030, because population outflow will probably exceed population inflow in the mountainous areas of the Kii Peninsula. Why would population outflow from mountains result in most people living in the mountains?

The Tokai, Tonankai, and Nankai earthquakes will occur in a situation of depopulation, dwindling regional economic activity, and tight regional finances. It is therefore necessary to consider restoration and reconstruction viewed from the standpoint of how the damaged areas should be "remade." Measures taken would be unlike those taken in the high economic growth period or those taken in the areas hit by the great Hanshin-Awaji earthquake, which occurred in a period of stable economic growth. It is important to do preliminarily studies to determine how to close down or integrate the settlements in the depopulated areas in the formulation of restoration/reconstruction strategies for the damaged areas.

All of the depopulation effects are not negative, however, because there will naturally be fewer victims in depopulated areas.

4. Effects of Regional Characteristics

4.1. Social Characteristics

A large area extending from Kanagawa Pref. to Miyazaki Pref. will be hit by quakes of more tha an earthquake intensity of 5, should earthquakes strike the Tokai, Tonankai, and Nankai regions. The area that may be damaged extends from the mountainous areas in Shikoku and the Kii Peninsula to the large urban areas of Osaka and Nagoya, which have widely varying regional characteristics.

The daily activities of residents (commuting, shopping, receiving medical care, etc.) extend beyond the municipalities in which they live. There is a concept of "urban employment sphere" which represents the area of daily activities, and Japan has 269 urban employment spheres, [8] which vary widely in scale. They fall into 4 general categories by scale: (1) metropolitan cities, which impact the whole world (global cities), (2) large cities, e.g., Sapporo, Sendai, those in the Chukyo and Kyoto/Hanshin

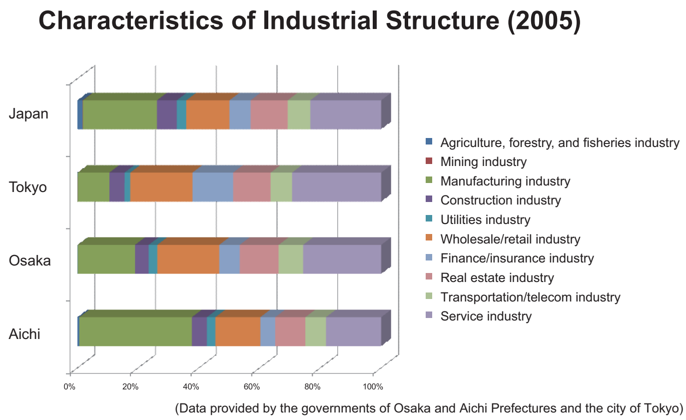

Fig. 2. Characteristics of industrial structure.

areas, Hiroshima and Fukuoka, which impact the whole country (national-class cities), (3) prefectural capitals and the like, which impact several living spheres (regional-class cities), and (4) cities having an impact on each living sphere (community-class cities). [9]

Moreover, Osaka and Aichi Prefectures, although both have cities which fall into the same national-class city category, have very different industrial structures. Aichi Prefecture has an industrial structure specializing in manufacturing, whereas Osaka Prefecture has active wholesale/retail industries (**Fig. 2**). Differences in industrial structure is a key factor to be considered in formulating restoration/reconstruction strategies for damaged areas.

4.2. Effects of Topographical Characteristics on Damages

Each of the three major urban areas in Japan (Tokyo, Nagoya and Osaka) has zero-meter areas, with Nagoya having the most (totaling 336 km^2), in which about 900,000 residents live. These areas will have difficulties with natural drainage should the levees break and the soil liquefy when the Tokai, Tonankai, or Nankai earthquakes hit. New Orleans, which has zero-meter areas, was devastated by Hurricane Katrina (August to September, 2005) when about 80% of its urban area flooded. It was hit again by Hurricane Rita while it was being restored and reconstructed, and the waters took more than one month to drain. The Nagoya area was hit by tsunamis accompanying the Isewan typhoon in 1958, and some areas remained flooded for as long as 120 days. [10]

Mie Prefecture has made projections related to disasters caused by tsunamis when the levees fail to function well (**Fig. 3**). Those areas shown in the figure are at or below sea level; the disaster is represented by depth of water in the inundated areas. The first restoration step is pumping out the water in order to be able to formulate restoration and reconstruction strategies for the areas. Once the Tokai, Tonankai, or Nankai areas, for example, are hit by a great earthquake, drainage is anticipated to take a fairly long time because of limited human and material resources. The disasters will be further aggravated if and when the damaged area is hit by a typhoon while it is being restored, as was the case in New Orleans.

This figure illustrates the distribution of the maximum depth of water at the high tide (T.P. 1.31 m) in the inundated areas after the Tokai, Tonankai, and Nankai areas are hit by simultaneous earthquakes. These results are estimated based on an earthquake/high storm surge model, and earthquakes and storm surge higher in scale than the ones that form the basis for the model are possible.

Therefore, it is necessary to consider that areas adjacent the colored area, which is predicted to be inundated, may also be damaged. Such areas should be regarded as a quasi-risk areas, even though they are not colored.

4.3. Effects of Regional Industrial Characteristics on Disasters

The Tokachi-oki earthquake (September, 2003) caused fire hazards in crude oil and naphtha tanks in the city of Tomakomai, 270 km away from the earthquake epicenter. These hazards are considered to be caused by sloshing resulting from long-lasting earthquakes. There are many oil tanks along Ise Bay and Osaka Bay, and they will sustain similar damage should they be hit by massive, long- period motion shaking. Oil tanks are positioned in special areas which are separated from urban areas by buffers, e.g., green spaces (Special area for Petroleum Industrial Complexes and other Petroleum Facilities), as required by the "Act for Disaster Prevention in Petroleum Industrial Complexes and Other," enacted in December, 1975. Therefore, fires at these tanks are unlikely to spread to the near-by urban areas.

However, there are some legacy oil complexes positioned near urban areas (**Fig. 4**). One example of a fire in one of these areas is the Daikyo Oil fire, which broke out in the in the city of Yokkaichi in1975. The urban area did not actually catch fire, but the residents were forced to evacuate.

5. Effects of Earthquakes Occurring in a Time-Lagged Manner

Tokai, Tonankai, and Nankai earthquakes may occur simultaneously or in a time-lagged manner. The time interval between two earthquakes may vary widely, e.g., 32 hours (in the Ansei era) and 2 years (in the Showa era). Earthquakes occurring in a time-lagged manner pose enormous challenges for disaster response and restoration/reconstruction.

The problems will differ depending on the length of the time interval. To classify the problems caused by earthquakes occurring in a time-lagged manner, the time interval has been classified into three types according to the achievement of disaster response targets: Type 1 is 72 hours or shorter (urgent response period), Type 2 is shorter than 3 months (emergency response period for restoring lifelines, and Type 3 is longer than 3 months (restoration/reconstruction period). Type 1 problems, e.g., those caused by the earthquakes that struck the Ansei era at an interval of 32 hours, can be responded to in a manner

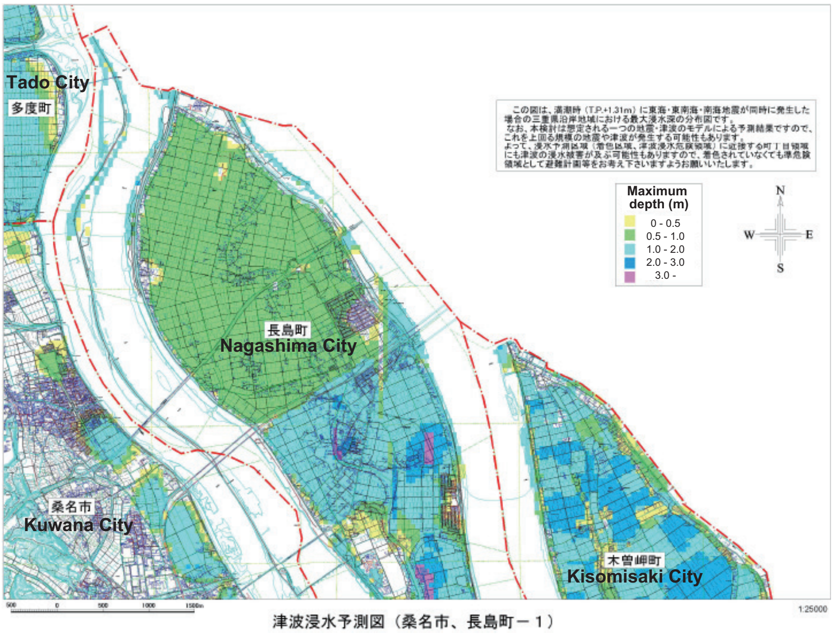

Fig. 3. Tsunami damage estimation without levee at below sea level area (Data provided by Mie prefecture [11]).

Fig. 4. Oil tanks near a residential area (Yokkaichi) (Source: google earth).

similar to that for preventing secondary disasters through urgent response. By contrast, those occurring at a Type 3 interval, e.g., the Tonankai and Nankai earthquakes (in the Showa era) which occurred at an interval of 2 years, cause the biggest problems and have a very great impact on regional economies.

Figure 5 illustrates simulated quake magnitudes in the areas hit by the individually occurring Tokai and Tonankai earthquakes, followed by the Nankai earthquake. The southern part of the Kii Peninsula and Osaka will be hit twice by earthquakes of an intensity of higher than 6 and higher than 5, respectively. Thus, earthquakes will have a larger impact on society if they occur in a time-lagged manner than if they occur simultaneously.

It is necessary to analyze the disasters in more detail while taking into consideration various factors, including the time interval between the two earthquakes. The impacts of the Tokai, Tonankai, and Nankai earthquakes occurring simultaneously or in a time-lagged manner on individual regions have been analyzed in the following way. Shizuoka area: twotypes of earthquakes will have similar impacts, because the area will be hit by massive quakes from the Tokai earthquake center, and to a lesser extent by quakes from the Tokai and Tonankai earthquake centers. Nagoya city area: simultanious occurance will have a larger impact, as the Chita Peninsula will be hit by tsunamis. Osaka, Kii Peninsula, and Shikoku area: a time lagged type earthquakes will have larger impacts than simultaniouly occuance, because apprehensions about the earthquake following Nankai earthquake will stifle economic activities, and the Osaka city area will be hit twice by massive quakes.

These estimated results are based on the assumption that Tokai and Tonankai earthquakes will be followed by Nankai earthquakes, and the results will be reversed when the Nankai earthquake is followed by Tokai and Tonankai earthquakes. In any case, it is considered that the areas that are more apprehensive about earthquakes occurring later will be more affected by earthquakes occurring in a time-lagged manner.

6. Worst-Case Scenario, Taking into Consideration Regional Characteristics and their Effects on Neighboring Areas as well as Disaster Response and Restoration/Reconstruction Strategies

This section discusses worst-case scenarios for individual areas based on the assumption that Tokai and

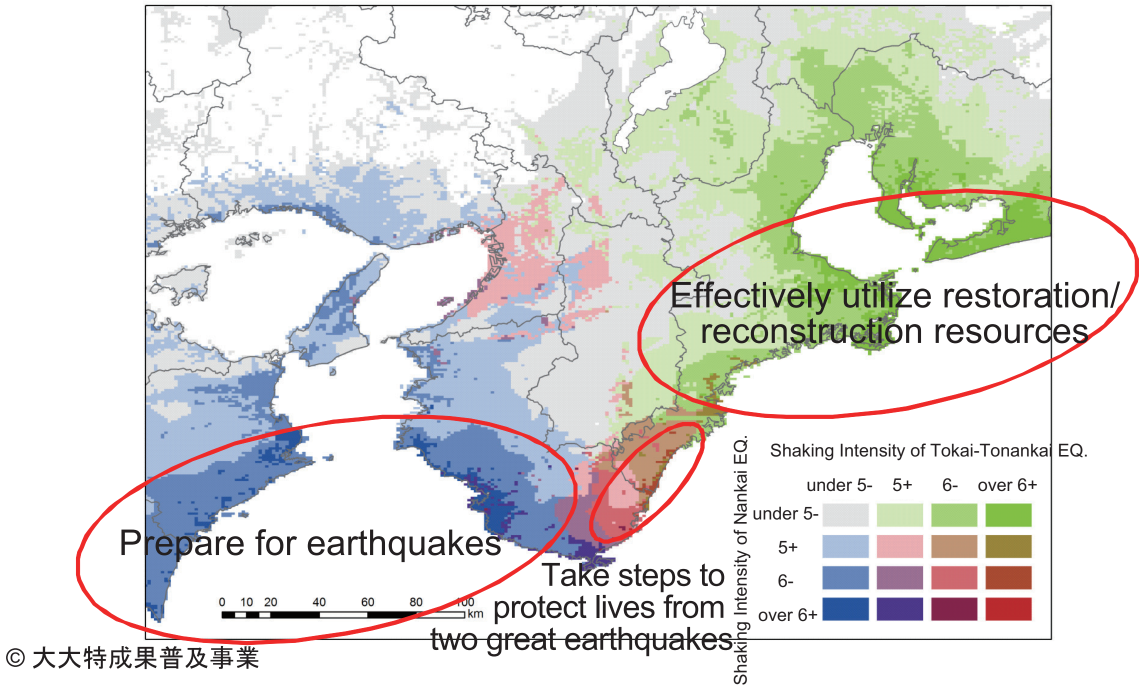

Fig. 5. Disaster response strategies at the time Nankai and To-Nankai earthquake occurred with time interval.

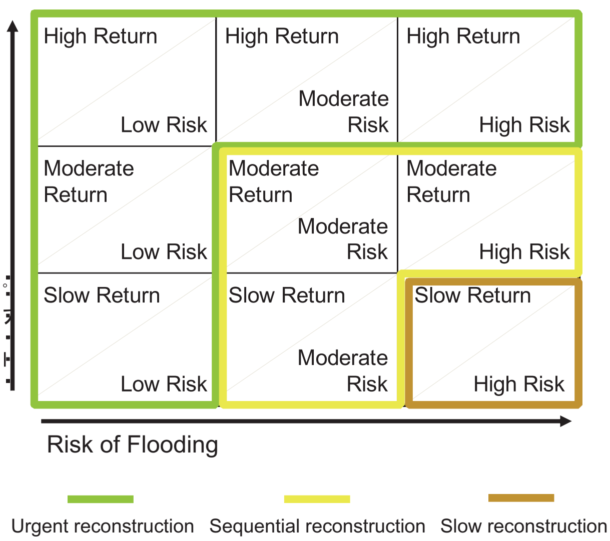

Fig. 6. Strategies for Long term Recovery in New Orleans.

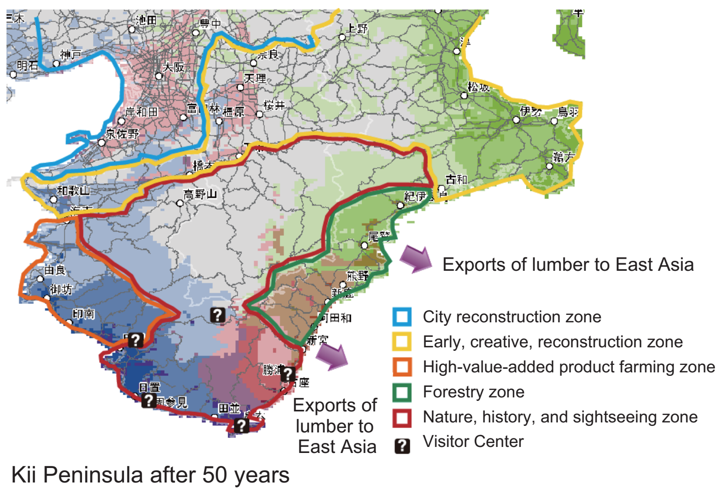

Fig. 7. Proposal of long-term recovery strategies for Kii Peninsula.

Tonankai earthquakes are followed by a Nankai earthquake, and also takes up disaster response and restoration/reconstruction strategies.

6.1. Nagoya Area

The worst-case scenario for the Nagoya area involves simultaneous occurrences of Tokai, Tonankai, and Nankai earthquakes and the collapse of levees, with tsunamis inundating vast zero-meter areas. The first step is to pump the water out of the flooded areas. The strategies taken by New Orleans, devastated by Hurricane Katrina in 2005, may provide a reference for formulating disaster response and restoration/reconstruction strategies for the zero-meter areas. New Orleans classified the areas based on a matrix of population return and regional risk (**Fig. 6**) in formulating reconstruction works. It is important to reconstruct the safer areas in anticipation of a more frequent occurrence of typhoons and tsunamis, a result of global warming.

6.2. Osaka Area

The worst-case scenario for the Osaka area involves the occurrence of earthquakes in a time-lagged manner with a time interval of 3 months or longer, with apprehensions over a subsequent Nankai earthquake stifling economic activities. Big challenges involve how to main-

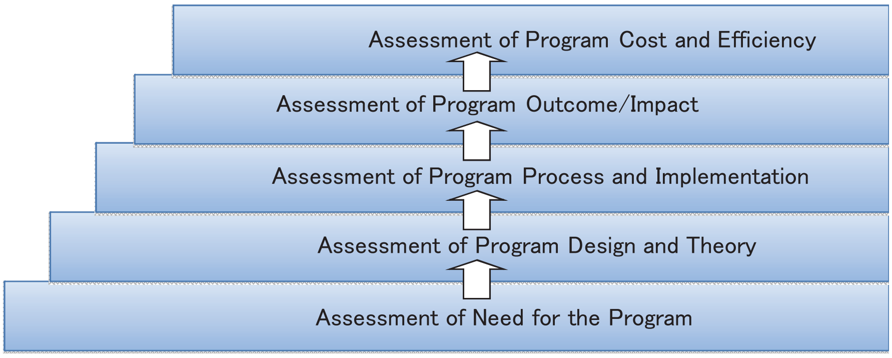

Fig. 8. Assessments process for program evaluation (Rosszi, H. Peter et.al, 2003 [15]).

tain economic activities should the area be hit by Tokai and Tonankai earthquakes. It is also important for the area to take on functions for the Shizuoka and Nagoya areas, whose economies will also be severely damaged. A disaster mitigation project by the Ministry of Education, Culture, Sports, Science and Technology has studied final restoration/reconstruction strategies for the Kinki area and drawn up images of how it might look 50 years in the future (**Fig. 7**).

6.3. Mountainous Areas

Mountainous areas will have a number of isolated settlements, as was the case after the Niigata Chuetsu earthquake (2004) and Iwate Nairiku earthquake (2008). It is estimated that a total of 17,000 or more settlements throughout Japan will be isolated when hit by earthquakes (these may or may not be hit by Tokai, Tonankai or Nankai earthquakes), [13] and the government has established a committee to look into precautions. [14] The mountainous areas have notable problems of depopulation and aging in addition to those related to isolation after being hit by earthquakes, and this should be considered when formulating restoration/reconstruction strategies. In the reconstruction process for the village of Yamakoshi and the Higashiyama district in Ojiya, which was hit by the Chuetsu earthquake (2004), two types of reconstruction works were provided: transfer of residents to flatlands and reconstruction of damaged houses. However, working residents moved out of the reconstructed settlements en masse. It is important to do preliminarily studies on the "closing down Re-organization existing settlements and integration of settlements" in the depopulated areas in formulation of the restoration/reconstruction strategies for the damaged areas.

7. Future Research Themes and Research Procedures

"Tokai, Tonankai, and Nankai earthquake linkage evaluation, Sub-project 2-(4) Disaster Response and Restoration/Reconstruction Strategy Reflecting Regional Society Characteristics in the Future" is being carried out as a 4-year plan (2008 to 2012) to formulate disaster response and restoration/reconstruction strategies reflecting regional societal characteristics of the future and earthquake linkage based on the measure evaluation framework.

This research project uses "program evaluation scheme" as its research framework. Program assessment process is composed of the five assessment items (**Fig. 8**), which are outlined below.

(1) Assessment of need for the program

This item is to assess whether the problems are correctly recognized, and is composed of the essential components of (1) determining stakeholders, (2) determining needs, and (3) verifying the determined need in cooperation with the stake holder. It is therefore necessary to verify participation of the stakeholders in order to verify whether the need has been grasped and the problems have been correctly recognized.

(2) Assessment of Program Design and Theory

This item is to assess whether the "causes and results" of an event in question have been correctly recognized. More specifically, it is whether or not the route for solving the problem has been correctly recognized in relation to the measures taken (**Fig. 9**).

(3) Assessment of program process and implementation

This item is to assess whether or not a measure is being carried out as planned. It is generally referred to as output assessment, and one example would be a project assessment carried out by the administrative office concerned.

(4) Assessment of program outcome/impact

This item is to assess to what extent the problem is solved, and one example would be a reconstruction index proposed by many researchers for a reconstruction plan.

(5) Assessment of program cost and efficiency

This item is to assess to what extent a result is produced for a cost, and one example would be a cost/benefit analysis carried out for a public project.

This research is carried out to assess the need for the program and the program design and theory, as a first step in formulating the disaster response and restoration/reconstruction strategies after the Tokai, Tonankai, and Nankai earthquakes. In order to clarify the needs

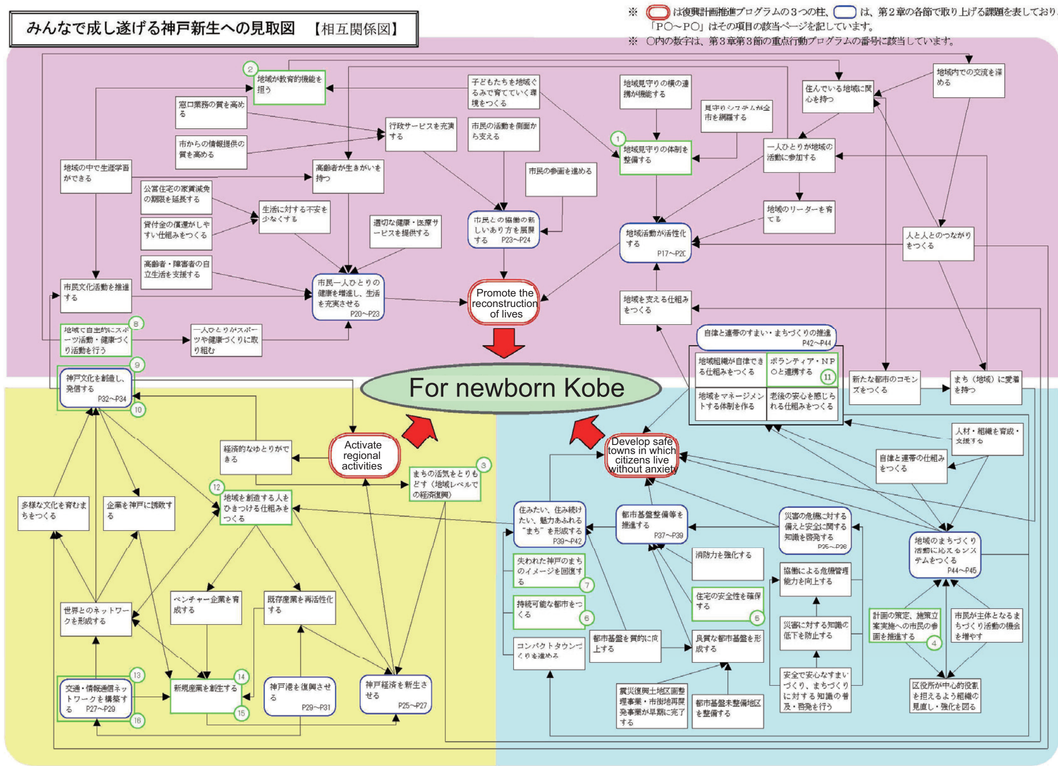

Fig. 9. Example of Assessment on Program Design and Theory, Kobe Long-term Recovery [16].

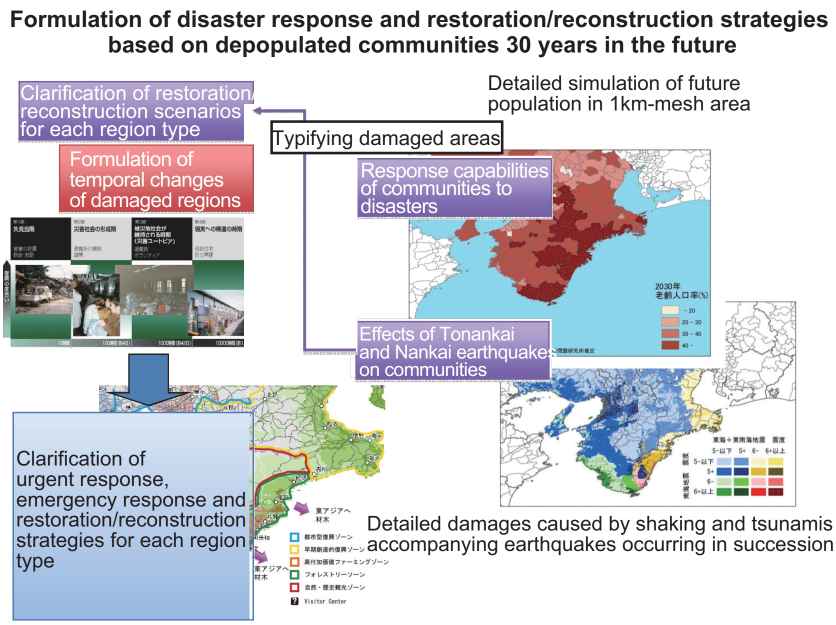

Fig. 10. Holistic framework for the research project.

in formulating the strategies, it is necessary, first of all, to clarify (1) response capabilities of a society to disaster (e.g., future population) and (2) effects on a society of earthquakes occurring in a time-lagged manner (e.g., lifeline damages).

This research establishes the GIS databases for future population simulations in a 1km-mesh area, classifying regions while taking into consideration disasters, population composition, and lifeline damages as the basic data for the needs assessment. At the same time, the research draws up a linkage diagram of measures for restoration/reconstruction for each region type, based on the need assessment results. **Fig. 10** illustrates the holistic research framework.

The Tokai, Tonankai, and Nankai earthquakes will likely strike depopulated areas of Japan. The disasters will shed light on the potential problems of communities and force communities to respond to the problems in a short time. It is essential to preliminarily study what types of problems will occur and how to respond to these problems, as opposed to responding in the event of disasters, in order to adequately solve the problems. The research will formulate restoration/reconstruction strategies for responding to Tokai, Tonankai, and Nankai earthquakes using "program evaluation scheme," in order to study how "the damaged societies should be rebuilt based on the specific disasters and images of regional communities in 2030.

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