NATURAL DISASTER AND ROAD NETWORK SYSTEM

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ABSTRACT

The paper describes the road transportation disturbance problems due to natural disaster. As for the risk related to the road, the management process from the risk finding to risk mitigation phase is described with the actual example of countermeasures in the public and private sector in Japan. The public sector usually applies seismic risk assessment when it takes the road transportation disturbance into account. However private sector recognize the importance of the road function as a network system in the standpoint of supply chain management of their business field, the road disturbance impact is not incorporated into their business continuity planning due to lack of the risk assessment information by public sector. Facing the competition in the market private sector and sometimes public sector are forced to reduce redundancy, the society as a whole is more vulnerable to the natural disasters than ever. The private-public relation is important to collaborate to work with making the society more resilience and reducing the risk on transportation disturbance.

1. INTRODUCTION

For disaster prevention, it is extremely important that the function of a road network system is ensured. When we think about the damage by natural disasters, we are often fascinated by the loss of human lives, the amount of damage of buildings / houses. However, the road and the network are required to perform an important function in various phases of disaster such as emergency response, relief activity, recovery and preparation to a future disaster. For example, the following items are given.

- Appropriate quick evacuation just after outbreak of natural disaster
- Secure the transportation for emergency response
- Condition maintenance of smooth economic activities of the recovery period
- Ensure the security / relief of local residents for a new disaster

When administrators in charge of the road maintenance perform maintenance and management for a road, examination of disaster risk management for the road network should be incorporated.

In case of difficulty to ensure the function of the road by natural disaster, malfunction of the road network system will have an influence on speed of physical and economical recovery of the stricken area. In addition concerning for road shutdown of the mountainous and/or snowy areas in the winter season, influence on psychology of area inhabitants is reduced because a road network is ensured in the winter season. In particular, road is better characterised than any other transportation means in terms of the stability and capacity of such services like restoration / recovery of a stricken area.

In natural disaster risk management, it is necessary to identify potential of natural disaster in various levels such as region, nation, or community. With that in mind, the size of the negative impact will be assessed and analyzed for assumed natural disaster, and strategic plan to reduce the negative impact will be examined. In each phase of such a risk management process, the importance of a road network system should not be ignored.

In risk analysis the negative impact on the human lives and property is always taken into account, but the evaluation regarding to the stability of a road network is often ignored. In the case of natural disaster such as earthquake in particular, the damage spreads through a wide area, and a road is cut apart in each place, and a bottleneck due to the damage of the road network will bigger if the damage attacks to a node of a road network, and there can raise big problem to a recovery plan of the whole area. Transportation disturbance due to Great Hanshin Earthquake for example gives the area that was not affected directly the huge economic damage as much as the damage to the stricken area. We can understand that suffering of a road network is not a problem only for a direct damaged area but also for an indirect damaged area.

Importance of business continuity planning comes to be recognized these days in various fields including enterprises. In their business continuity planning, they recognize the importance of the role of road in the infrastructure system, and their plans include the countermeasures to minimize the downtime of their business.

As well as disaster prevention measures for physical meaning of roads, recently, a new approach that relates to the road risk management for natural disaster is introduced on the risk finance field of risk transferring measures such as traditional insurance and risk securitization techniques.

2. A CASE STUDY OF ”GREAT HANSHIN AWAJI EARTHQUAKE”

The transportation disturbance could be caused by road damage due to various natural hazards such as torrential rain, earthquake, heavy snow, landslide, flood etc. However, in particular, when a huge earthquake occurs, the damage extends to the road spread on the large area, and affected area will be put into a serious situation.

Here, a case study of Great Hansin Awaji Earthquake is explained as a transportation disturbance. The main road and the local road categorized depending on the coverage of the area were both examined to evaluate the magnitude of the damage.

In 1995, Hansin Awaji Earthquake was occurred in Kobe, Japan where is the most populated among the cities of Hyogo Prefecture. The earthquake claimed more than 6000 human losses and resulted in heavy property loss in the area including periphery of Kobe. In particular, Kobe City, where is dense populated and property accumulated, is located in the narrow plains part placed between the sea and the mountain. Most of the utility system such as electricity, gas and water as well as the main road were and still are concentrated in the narrow plains.

Main roads, in particular, Hansin Highway were seriously damaged. The 635 m bridge portion of the No.3 Kobe line of Hansin Highway collapsed, and the bridge fall down observed four areas. These damage caused main road heavily disturbance. Relief assistance and transportation by Self Defence Force could not reach the affected areas right after the Earthquake. The main roads suffered the various types of damage such as pit fall and gap seen on the various areas. And also the gas pipeline buried under the road

was ruptured everywhere. Temporary repair works for road were done all over the road in the affected areas. Under these situations, traffic control was introduced, and only special vehicle were permitted to use the road. These conditions could not allow smooth transportation, and detour routes were also congested heavily. Logistic system was completely stopped, and emergency supplies also could not reach to the affected areas. The critical transportation line connected between Osaka and Chugoku area did not work. After a month of earthquake, some emergency repair work and detour routes allowed reviving the part of the road network system, and the volume of the logistic capacity returned to approximately 30% level before the earthquake [1]. However the capacity of the detour routes was not sufficient for the needs of logistic. On Sept 30,1996, after 21 months of earthquake, the logistic capacity could reach to the original level.

The earthquake also damaged local road in the town and city. A large number of collapsed residential houses and commercial buildings after the earthquake disturbed the local road transportation everywhere in Kobe City. And the fire following earthquake due to leakage of gas also happened all over the city. The traffic disturbance by the road clogging caused the access the fire engines to the fire sites. After a while of the earthquake, the city and residents removed the critical portion of the local road covered by the debris of the collapsed building. The cleared road was to be important routes substitute to main roads. And the mal-function of the traffic signals at the crossings due to the electric disturbance also restricted to the volume of transportation.

Above these situations, the disturbance of transportation by damaged road made a negative impact on both the rescue and recovery phase. Delay of the recovery activity decreased the recovery process of the economic activities not only in the local economy but also in the remote areas connected to the main road.

To solve these problems, the countermeasures for the road from the hardware point of view should be taken to ensure the road network system as well as the planning of emergency route with redundancy. It is important to evaluate the risk of the road network and to take a countermeasure for the road along with risk management process.

Following is the explanation on the risk management process.

Figure 1 Damaged Highway by Great Hansin Awaji Earthquake

3. RISK MANAGEMENT PROCESS

In general, the risk management process in the private sector consists of four phases; risk finding, risk assessment, and risk strategy. Firstly, various risks surrounding of the business activity are reviewed from the standpoint of the possibility and size of impact on

subjective basis. After choosing the major risk surrounding the business activity, these risks should be carefully reviewed to prioritize to be tackled. Usually on annually basis, the risk management process should be reviewed and improved with the feedback of the previous incident or accident within their activity. The risk management process is a part of the management process with chain of the cycle so called “Plan- Do – See- Action”, and the process include the crisis management phase as well as disaster prevention and protection phase.

Recently, the risk management process is seemed to be effective and is adopted for Disaster Reduction Activity (DRR) on the national or regional levels in public sector. Asian Disaster Reduction Center (ADRC) and UN/OCHA proposed the Total Disaster Risk Management (TDRM) shown on Figure 2. The feature of TDRM is consists of four phases; Occurrence of Disaster, Emergency Relief Phase, Recovery Phase, and Disaster Prevention & Preparedness Phase. As a matter of course, before initiating the disaster prevention and preparedness, potential natural disaster risk should be assessed as well as enterprise risk management process.

In 2005, the UN World Conference on Disaster Reduction (WCDR) was held in Kobe, Hyogo, Japan, from 18 to 22 January. The WCDR marked the conclusion of the review of the Yokohama Strategy and its Plan of Action. The specific gaps and challenges identified in the review of the Yokohama Strategy were (a) governance; Organizational, legal and policy frameworks; (b) risk identification, assessment monitoring and early warning; (c) knowledge management and education; (d) reducing underlying risk factors; and (e) preparedness for effective response and recovery. Moreover, the WCDR resolved to pursue the substantial reduction of disaster losses, in lives and in the social, economic, and environmental assets of communities and countries for the next ten years. The WCDR adopted the Hyogo Framework of Action 2005-2015(HFA):Building the Resilience of Nations and Communities to Disasters, which provides a clear and authoritative frameworks for pursuing a clear and authoritative framework for pursuing disaster risk reduction and builds on other relevant multilateral frameworks and declarations. The framework provides for a set of priorities for various stakeholders of disaster risk reduction for the decade. These HFA priorities would be categorized to the usual risk management process as follows;

Table 1 HFA Priority Action and Risk Management Process

Item	Priority Action	Risk Management Phase
HFA#1	Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation	Related to Whole Risk Management Process (Commitment of the Top Management)
HFA#2	Identify, Access and Monitor Disaster Risks and Enhance Early Warning.	- Risk Identify - Risk Assessment - Crisis Management
HFA#3	Use Knowledge, Innovation and Education to build a culture of Safety and Resilience at all levels	- Prevention
HFA#4	Reducing Underlying Risk Factor	- Prevention - Protection
HFA#5	Strengthen Disaster Preparedness for Effective Response	- Preparedness - Crisis Management

Above these risk management process and HFA priorities, from standpoint of the multi levels such as national, community and business, the function of the road is situated as an

important role in DRR activity. The road network disturbance due to natural hazard would cause the extremely negative impact to the socio-economic as well as human lives.

Following sections describe how to consider the road network on the risk management process.

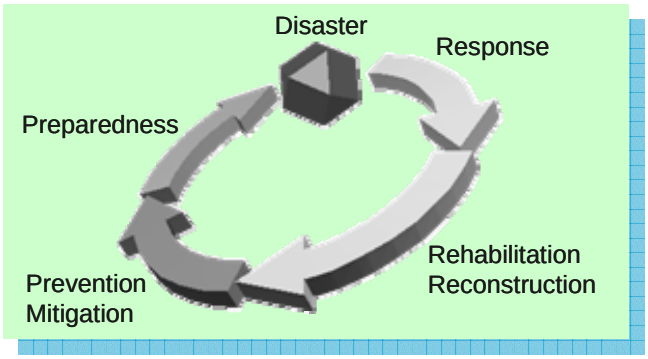

Figure 2 TDRM (Total Disaster Risk Management) Process

4. RISK FINDING AND ASSESSMENT

Finding and assessing the risk is the first phase on the risk management process. In this section, we describe the case study of Hyogo Prefecture, local government in Japan and the enterprise risk management on the road in private sector.

4.1. An Example of Local Government

In case of earthquake prone countries like Japan, local government in highly earthquake prone area pay much attention to the seismic risk assessment of the road network impairment as well as human lives and property.

In the case of the scenario based earthquake simulation study for seismic risk assessment, the extent of the degradation of the road could be considered in the point of the property damage. The targeted for the assessment is the main road. The vulnerability components of the road network; such as bridge, reclaimed, cutting the mountain side and tunnel were assessed as a two class; restricted traffic due to partially damaged and fully restricted traffic due to heavy damage. Based on the assessment result, the main road could be strengthened and maintained to prepare for next disaster on planning basis.
Recently, the seismic hazard analysis was shown geographically on the map using Geographical Information System (GIS) as Figure 3. The GIS helps to understand the vulnerability of the road network visually, and easily to grasp the necessity of the road countermeasures activity on priority basis.

Network System of the road under Emergency Condition

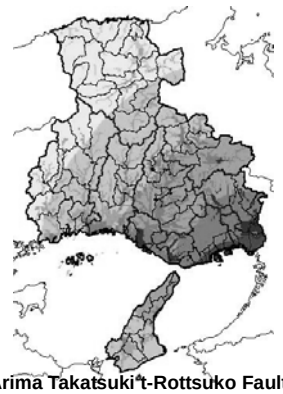

Fig 3-1 Arima Takatsuki t-Rottsuko Fault(M7.7)

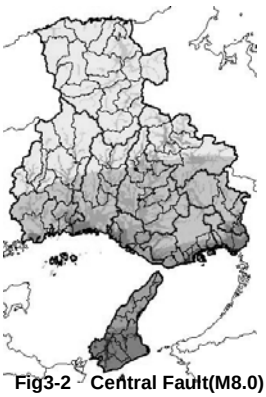

Fig3-2 Central Fault(M8.0)

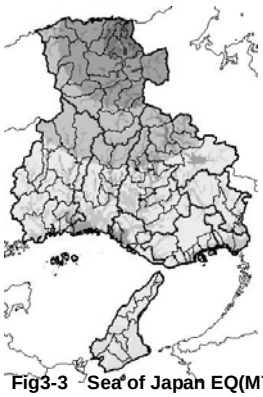

Fig3-3 Sea of Japan EQ(M7. 3)

Fig3-4 Nankai (M8.4)

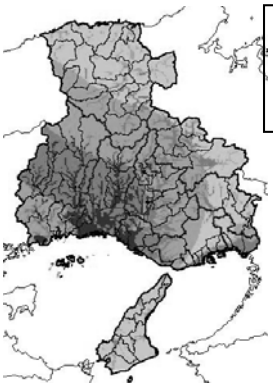

Fig3-5 Yamazaki Fault (M7.7)

Five Highly Potential Occurrence of Earthquakes

Figure 3 Ground Shaking Intensity Distribution of Hyogo Prefecture by Scenario Earthquakes

In US, after Northridge Earthquake in 1994, the seismic risk assessment on the highway transportation system was done positively as well as Japan. While the earthquake risk is not fully assessed by the deterministic method (as-if scenario based risk assessment), the probabilistic method is more appetite for assessing the road transportation risk [2]. Various earthquake scenarios were randomly generated based on much of active fault data, and the bridge vulnerability function that was obtained from past earthquake experience was applied to the seismic risk assessment. And also, the risk assessment on the interruption (downtime risk) of the highway network was conducted to consider the road function recovery.

As shown on Figure 4, the road network is decomposed to the node and link. The vulnerability of the link and node are also assessed to adopt the fragility function and recovery function shown on Figure 5 and 6. Subsequently, the risk curve shown on Figure 7 is obtained to combine these vulnerability information and earthquake hazard data.
Based on the probabilistic approach, the loss due to various potential earthquakes is assessed on the standpoint of down time of the road network system (indirect damage) as well as property damage of the road (direct damage). The result of the probabilistic analysis will be used for cost benefit analysis on the road network retrofitting. An example of the effect of retrofitting on the road network is shown on Figure 5.

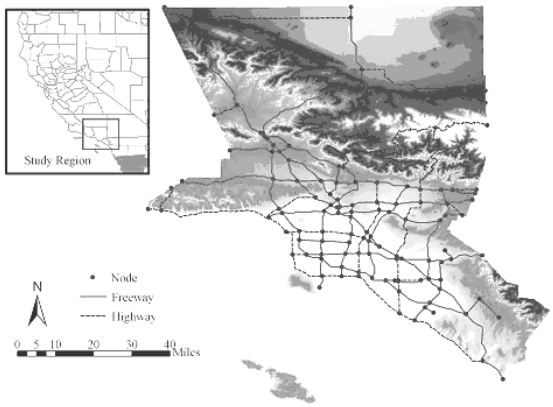

Figure 4 Freeway Network of CALTRAN Bridge

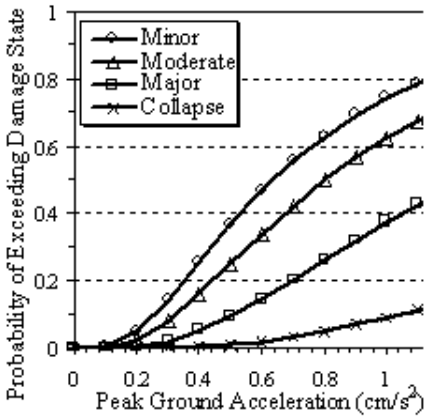

Figure 5 Sample Fragility Curve for Freeway

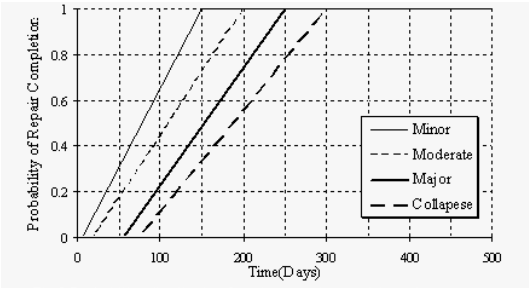

Figure 6 Repair Process Function

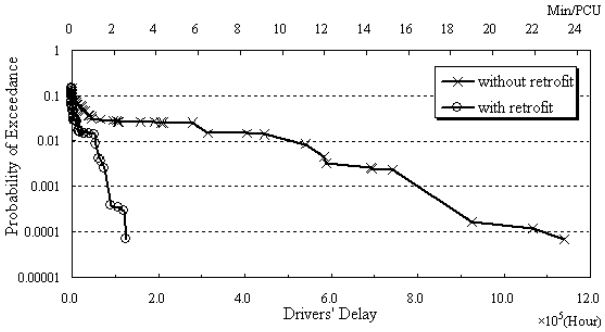

Figure 7 Risk Curve for Driver's Delay

4.2. An Example of Risk Assessment in Private Sector

In case of enterprise risk management, finding the risk and assessing the risk are the first step of the risk management process. The enterprise recognizes the importance of the road on the standpoint of the supply chain management. However the transportation disturbance due to the earthquake will cause the negative impact on their sales and profit, they could not assess the negative impact due to the lack of information on vulnerability and hazard of the road network.

Since the enterprise makes a disaster reduction plan and conducts countermeasures to the natural disasters, they prioritise to strengthen their facility and to transfer their risk with risk financing. Whereas they recognized the importance of the road as a measure of supply chains, they could not take the countermeasures to the road by themselves.
As later mentioned on the business continuity plan (BCP), in particular, the manufacturing industry has pay attention to the road on the standpoint of the supply chain management as well as to the utility such as gas, industrial water and electricity on the standpoint of interruption on their production. Usually, these utility lines set along with the road. If the road bridge fell down, these utility lines are also damaged simultaneously.

5. RISK STRATEGY

5.1. Type of Strategy

There are two ways for risk strategies as follows; mitigating the risk, and transferring the risk. The mitigating the risk is the method to strengthen the vulnerability part of the road to enhance the resilience to the natural hazard as well as to improve the maintenance work during normal condition. The risk transfer is the method to transfer the risk possessed by itself to the others with insurance and/or securitization.

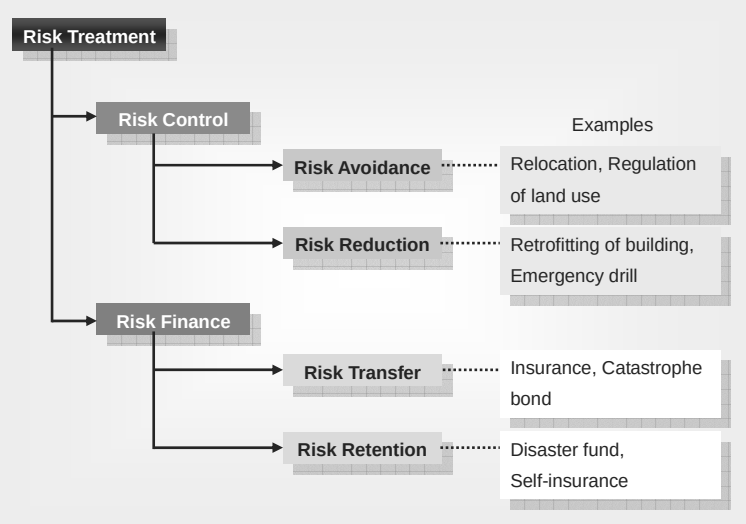

Figure 8 Risk Strategy Methods

5.2. Case study of Local Government as a Road Manager

From the standpoint of the local governments, the risk mitigation measures are taken to strengthen for the natural hazards and to conduct the maintenance activity on the road. Recently, along with the movement of the road privatization, the risk of the road could be transferred to the insurance company and/or risk securitization.
In particular, after Hanshin Awaji Earthquake in Japan, the target level of the road resilience to the earthquake was discussed as follows;

① Set the scenarios with two basic intensity levels of earthquake for assessing the road
② The earthquake resilience of the road is considered to be divided into two items as "the section of the road" and "network system of the road". That is, if the part of the road was damaged, the road network system keeps their function as well as each part of the road facility's safe condition.

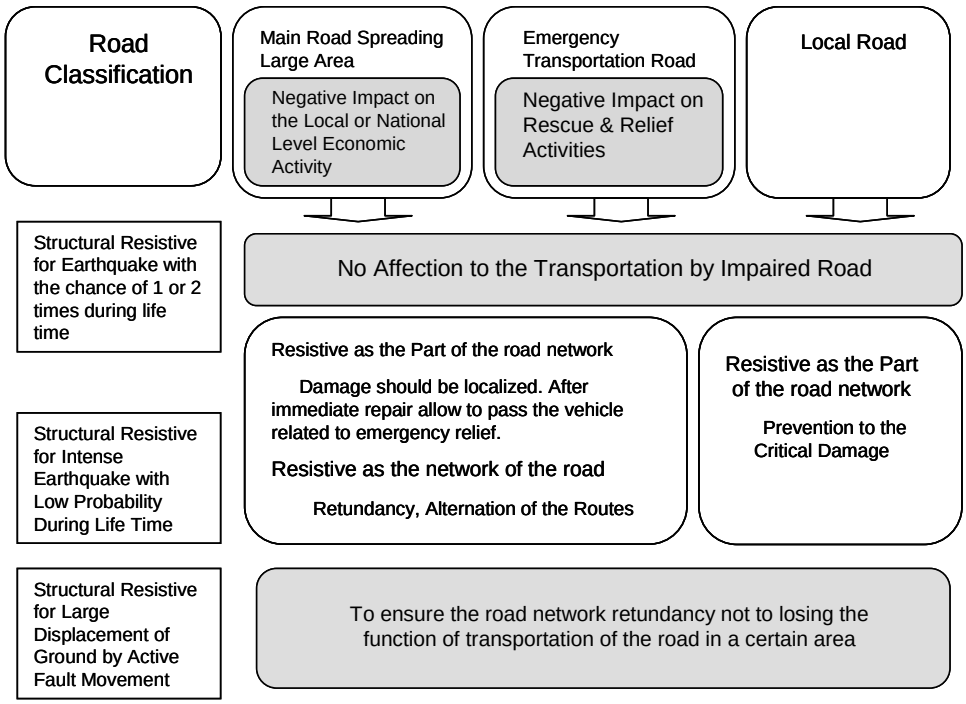

Figure 9 Desirable Earthquake Resistive Level for the Road

It is possible to enhance the redundancy of the road network to strengthen the road to the earthquake along with above targets.

Seismic Intensity	Type "A" Bridge	Type "B" Bridge
(Level 1)	No impairment of the Bridge by Earthquake	
Type Ⅰ (Level 2)	Remaining damaged bridge condition after the earthquake is a no critical condition	Remaining damaged bridge condition after the earthquake is a just a localized and immediately recover the function as a bridge.
Type Ⅱ (Level 2)		

Figure 10 Targeted Earthquake Resistive Level

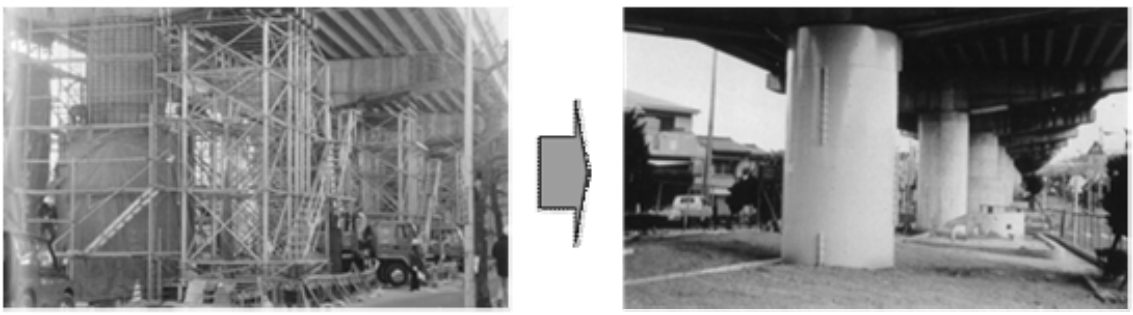

Figure 11 An Example of Retrofitting of Column

In Hyogo Prefecture that had experienced Hanshin-Awaji Earthquake, the countermeasures to the highway on various earthquake scenarios shown on Figure 12 are taken to ensure the emergency route recovery to rescue with time course. Based on the study, the vulnerability part of the main road could be strengthened on timely basis.

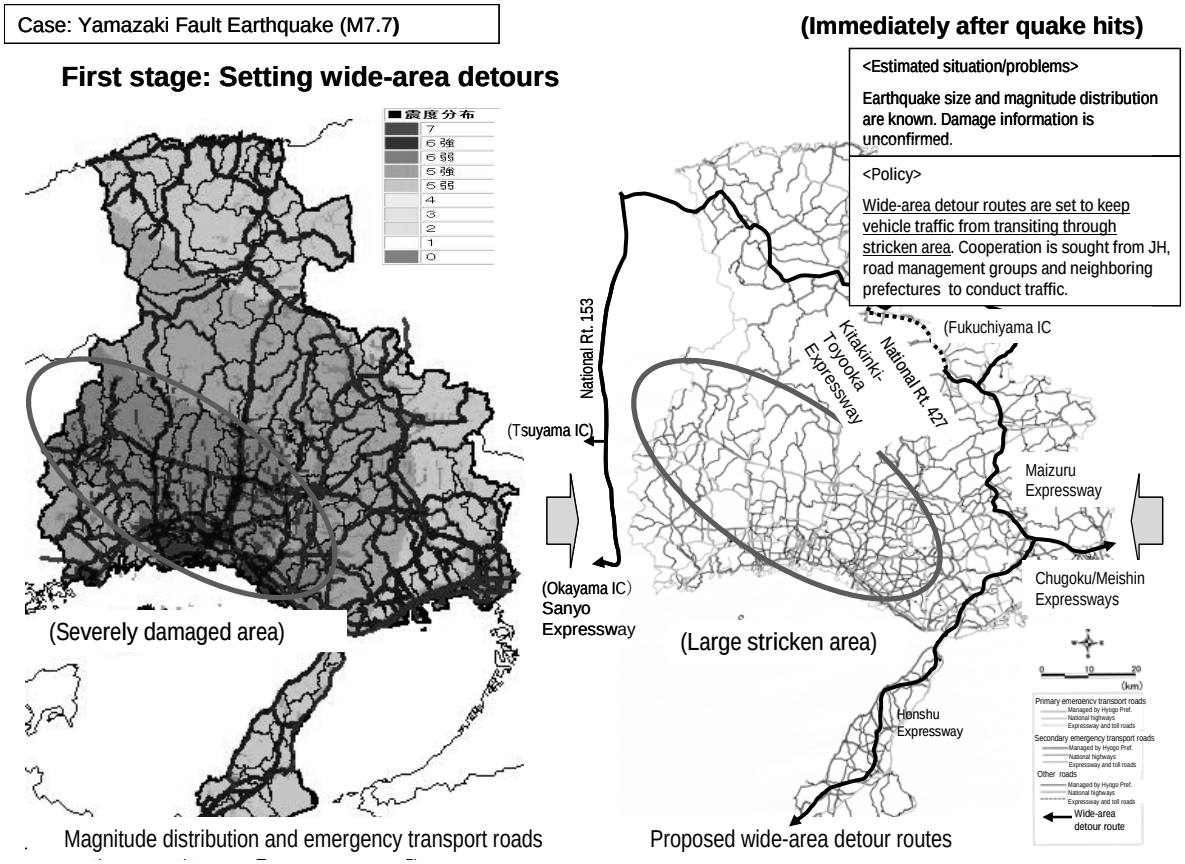

Figure 12 Planning for detour after short period scenario earthquake (Hyogo Prefecture)

5.3. Transportation Disturbance Risk and BCP in the enterprise

Recently, many private companies introduce the business continuity planning (BCP) into their risk management policies [3]. In current complex, competitive, agile and global business environment, they always face to the various types of risks such as terrorism, natural disaster, information security troubles etc. that affects to their business continuity. In particular, for manufacturer, the interruption of supply chain is the most important component to be paid attention as a vital line for their activity.

So far the proposed activity of their disaster reduction is mainly targeted for ensure the human lives of employee and their physical property. On the other hand, the purpose of the BCP is mainly focused on the business continuity as a strategic countermeasure to keep the clients to provide continuity business services under emergency condition and reward to the investors.

Followings are the summarized the items to perform BCP;

① Identify the core business to continue and recover during the emergency situation with priority

② Formulate the target recovery period of the core business at the emergency

③ Consultation of providing service level to the client at the emergency
④ Preparedness of the alternative plan to product and purchase the stock
⑤ Consensus on the business continuity planning with all level of employee

Private business firms pay attention to the infrastructure at the making process of BCP. In particular, manufacturer and utilities of such as gas, water, and electricity are the essential to produce their product. If they conduct risk assessment on the reliability of infrastructures, these infrastructures normally set along with the public road, in particular the vulnerable bridge part is seemed to be critical path. On this case, it is difficult to conduct risk assessment on the infrastructures without their premises. It would be better to share the public risk assessment information on the road with private company.

In some case of a BCP process, the Service Level Agreement (SLA) was contracted among the members of supply chain. In the future, SLA will include the services supplied by the self- governments to ensure the business continuity.

The private business firms could not easily mitigate their risk by themselves due to the road disturbance, however, they find and assess the risk, and they mitigate the risk indirect method.

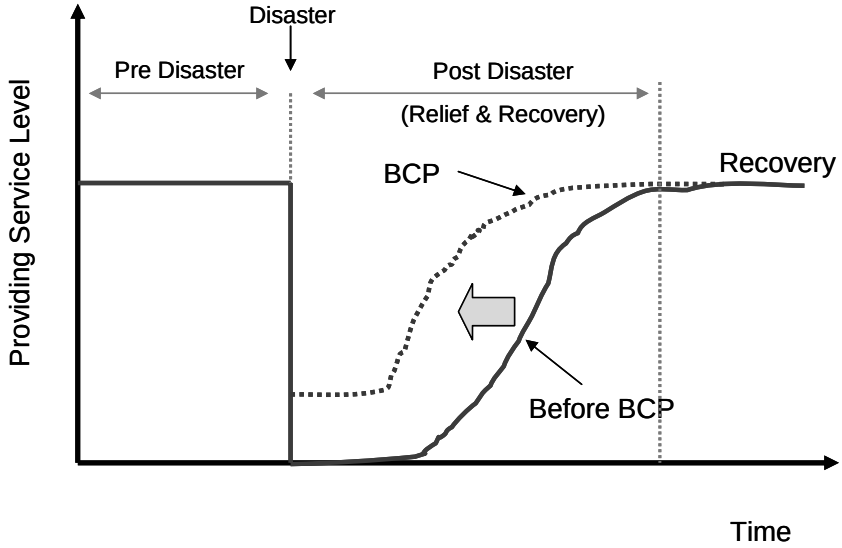

Figure 13 Recovery curve after the disaster

Case #1;
Huge amusement park located in Tokyo bay area takes various countermeasures to the seismic risk. To protect the high amount of the property against the earthquake, they study the plan to strengthen their facility to the earthquake and also buy some insurance coverage.

However, if their facility is no damage as an easily re-open after the earthquake, the customers use mainly highways as means to access the facility. Since the amusement park heavily depends on the vulnerability of the highway. The management of the company recognized the risk that the customers do not have the access to the site due to the highway collapsed, and they issued the Catastrophic Bond to cover the business income loss during the period of re-construction of the highway. If the certain intensity

earthquake hit around Kanto region including of Tokyo area, they receive a much amount of money from the financial market.

Case #2;
Shizuoka Prefecture is known as a highly earthquake prone area in Japan. Traditionally, some major pharmaceutical industry is located in this area. Geographically, the area where is situated between the mountain and sea, is located the same distance from Tokyo and Osaka, the major highway “Toumei” passes through Shizuoka prefecture.

If their production facility suffered no damage and main highway is collapsed by earthquake, they could not dispatch their products to the customers. Since the pharmaceutical product is the special product for the customer not to find alternative easily, they have a plan to maintain excessive stocks for distributing them to the other areas.

6. RISK TRANSFER

6.1. Insurance

Insurance that covers for the road property is so called “Civil Engineering Completed Risks Insurance”. In 1991, the cover started to sell to the client in Japan, at this time, the volume of net premium is 70 billion Yen [4].

The coverage of the loss by this insurance is mainly for wind, flood, mudflow, collapse, failure of workmanship, collision damage from the obstacles, fire and explosion etc. Normally, earthquake is not covered, and in some case, the earthquake coverage is provided with condition of the loss limit attached to the earthquake coverage.
The privatization discussion of the road is active. In the future, the case where the hedge by insurance including the earthquake risk is done is seen about a part of private road.

6.2. Alternative Risk Transfer

Recently, the case where payment becomes difficult comes out in a traditional insurance market along with the frequent occurrence of the natural disaster, and the rejected cases with the undertaking have come to be shown, too. In particular, if the natural catastrophic disaster event happens, the accumulated insured loss will be up to the enormous amount, so the traditional reinsurance company is not able to provide primary insurance company with the coverage of the natural disaster risk due to the limitation of their capacity.

In the above situations of insurance companies, the private enterprises are seeking for another capacity to the capital market. The movement is so called alternative risk transfer (ART) instead of traditional insurance market. Some private enterprise issued the catastrophic loss event linked bond (CAT Bond). In some cases, Cat Bond is very clearly understandable product for the investors, if a certain level of the catastrophic loss event happens, at that time, issuer could recover the necessity of the amount of compensation from investors.

In case of parametric trigger type CAT bond, the payment is usually more prompt than the traditional insurance due to no need of time consuming claim adjustment activities by loss adjusters as a traditional insurance manner.

7. CONCLUSIONS

In the paper, the importance of function of the road network was described based on past experience of earthquake. And the method of the risk assessment for the road disturbance by the earthquake was introduced, and the countermeasures were also reviewed on the risk management processes.

Recently, due to global climate change and increment of urbanization, the number of natural disasters seems to be increasing. On the other hand, in economic-social activity, recent business condition minimizes the redundancy to introduce the supply chain management system, these activity cause the increasing of vulnerability to the disaster situation. For the problem, it is important to have a suitable redundancy to the road network system preparing for the future natural disaster.

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