IV-260

An Evaluation of Nationwide Transportation Network Reliability considering the possibility of Earthquakes happened in the future

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1. Introduction

After the Hansin Earthquake in 1995, a lot of problems were caused to the network, especially if there were a lack of substitute routes. It is very emergent to discern the weak points of the present network. In this paper, Recurrence Interval Model is adopted to predict the possibility of earthquakes. Model parameters are calibrated and tested using actual data. Then a model is used to estimate the influences on the network and the traffic flow and several indices are developed to evaluate the reliability of the network. Each index considers the risks of earthquakes around Japan.

2.The whole structure of this research

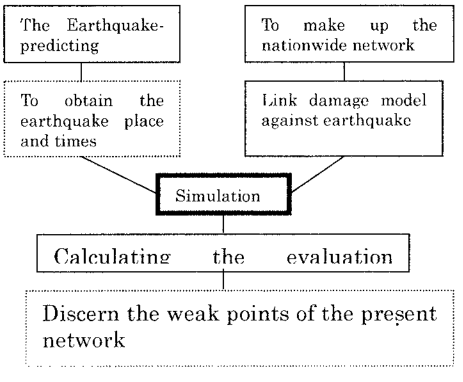

Figure 1 whole structure

This structure can be simplified into three parts: Earthquake-predicting, link damage-model, and simulation, which will be introduced separately as following.

3. Earthquake-predicting model

3.1 Data Processing

The related data of earthquake that happened in the last 1,500 years and magnitude is over 6 were collected. In totally, they are 560 times, which are divided into two groups: inter-plate earthquake (66 plots, group1) and Intro-plate earthquake (34 plots, group2) according to the assumption whether there are sufficient data or not.

3.2 Recurrence Interval Model

The approach used here is based upon a model of earthquake occurrence that assumes that the

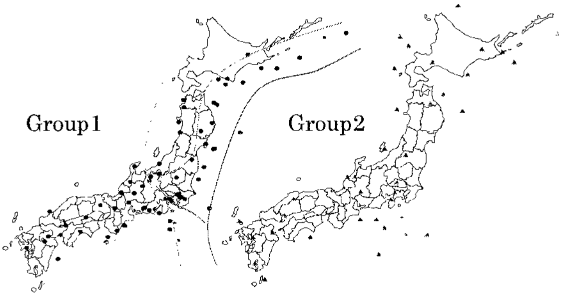

Figure2 the earthquake points

probability of an earthquake along a fault segment is initially low following a large segment-rupturing earthquake and increases with time as stress on the segment recovers the stress drop of the prior earthquake. Probabilities of the occurrence of the next segment rupturing earthquake in some time interval are obtained from a probability density function for the random time of recurrence,△T.

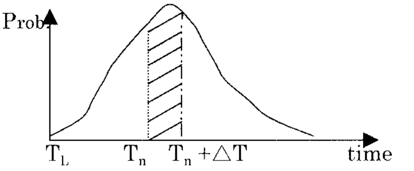

Figure3 Probability density function for earthquake recurrence.

It was proved that the Logrithmic normal distribution is mostly suitable for the recurrence time △T.(Nisheneko and Buland, 1987). It will be adopted for group1. The Poisson process will used for group2. So, the probabilities for once earthquake happen in the future are shown as the following two formularies.

$$\Pr ob1(T,\Delta T) = 1 - \frac{1-\phi\left(\frac{\ln(T+\Delta T)-m}{\sigma}\right)}{1-\phi\left(\frac{\ln T - m}{\sigma}\right)} \qquad \phi(z) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{z} e^{-\frac{u^2}{2}}\,du$$

$$\Pr ob1(T,\Delta T) = 1 - \exp^{-\Delta T/T}$$

Here:
T-----the duration time from last time until now;
△T---The future △T year;
σ ,m—the parameters Which was obtained by the

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Maximum likelihood method from the true data. In addition, for the future the times earthquake happens in each plot are not the same, which can also be expressed by the conditional probabilities. They are explained in the following formularies

$$Prob2(\Delta T)=\int_0^{\Delta T} prob1(x)\phi(\frac{\ln(\Delta T-x)-m}{\sigma})\int_x^{\Delta T}(1-\phi(\frac{\ln(y-x)-m}{\sigma}))dydx$$

$$Prob_n(\Delta T)=\int_0^{\Delta T} prob_{n-1}(x)\phi(\frac{\ln(\Delta T-x)-m}{\sigma})\int_x^{\Delta T}(1-\phi(\frac{\ln(y-x)-m}{\sigma}))dydx$$

Based on one assumption that earthquake happen when the probability is over 0.6, the result of earthquake happen in the future can be gotten.

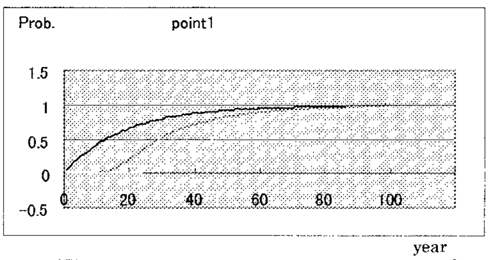

Figure 4 one example: the possibility of earthquake will happened in the point1

4.The link damage model against earthquake

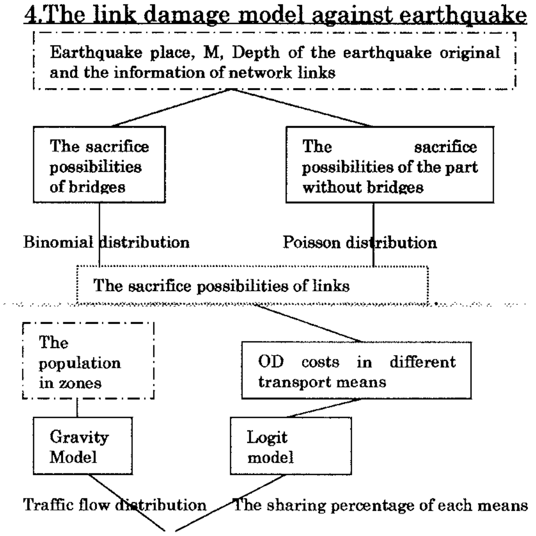

Figure5 The structure of link damage model

There are two main sub-models. One is to get the damage level of links. The other is to calculate the link flow. In this research, 3 networks are discussed. They are railway networks with 1104 links and 402 nodes, road network with 4354 links and 1038 nodes, and aviation network with 2103 links and 263 nodes.

5. Index

A. The reliability of broken link.

$$\sum_{m=1}^{n} d_m / n$$

B. The variation of the traffic flow:

$$\sum_{m=1}^{n}(f_m-f_0)/n$$

C. The quote loss for each OD Pair

$$\sum_{m=1}^{n}\Delta C_{ij}^{m}/n$$

D. Influence level of the broken links

$$\frac{1}{n}\sum_m\sum_i\sum_j \delta_{m,j}\delta_{ij,l}\cdot\Delta C_{ij}^{m}$$

n: The simulation time, 166;
d_m: The damage level in m time (1=broken, 0= normal);
f_m: link flow in No. m time simulation;
$\triangle C^m_{ij}$: the loss for OD pair from I to j in m time simulation;
$\delta_{m,j}$: It is equal to 1 when link l will be broken in m time simulation;
$\delta_{ij,l}$: It is 1 when OD pair ij pass link l in the normal situation.

Taking the railway network as example, influence level in the 20 years later could be shown in the figure 6.

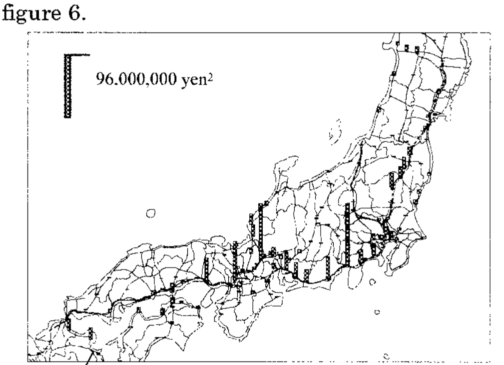

Figure6 The influence level of the broken links

From this figure, it is easy to find that the Tokaidou line will be the most dangerous in the railway network system against the future earthquake in the coming 20 years! As the same with this example, the weak points in road and airport network are also found.

6. Future

In this paper, the weak points of the present networks are discerned, especially for the future 20 years. How to improve the present network and to deal with cost and benefit analysis will become the next step.

Reference:

1) 村木康行(1998)「地震による被災リストを考慮した全国幹線交通ネットワークの信頼性評価分析」，土木計画学講演集２.
2) S.P.Nishenko and R. Buland(1987)「A Generic Recurrence interval distribution for earthquake forecasting」