Japan's Ministry of Land, Infrastructure, Transport and Tourism applied Models I and II to the Tohoku, Chubu, Kinki and Shikoku regions to assess the disaster mitigation functionality of road networks. The hazard level here was set based on tsunami hazard maps created by individual municipalities, and the analysis results are described below.

(1) Component ratios of assessment ranks for different regions (Model I) (Fig. 3)

Rank-A links (exhibiting both disaster resistance and multiplicity) accounted for 59% of the total in Chubu and approximately 30% in Tohoku and Shikoku. Rank-B links (exhibiting disaster resistance only) accounted for approximately 30% of the total in Tohoku and Shikoku and 10% in Chubu and Kinki. Rank-C links (exhibiting multiplicity but not disaster resistance) accounted for 22% of the total in Kinki and 8% in Chubu. Rank-D links (exhibiting neither disaster resistance nor multiplicity) accounted for approximately 30% of the total in Tohoku and Shikoku and 22% in Chubu. The locations of the mentioned regions are shown in Figure 2 below.

Fig. 2 Locations of regions

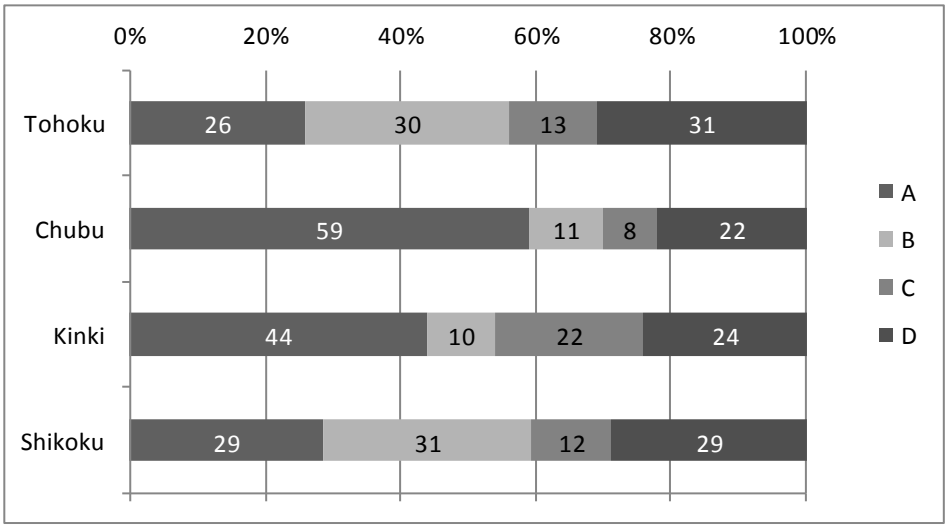


Fig. 3 Assessment rank ratios (Model I)

(2) Component ratios of assessment ranks for different regions (Model II) (Fig. 4)

Weakness levels were indicated by α (travel time in the event of a disaster/travel time in regular driving), and were divided into levels of i) no travel time change in the event of a disaster (α = 1), ii) the need for detours (α > 1), and iii) isolation (α = ∞). The percentage of cases involving isolation was as high as 43%, and was 14 to 23% in other regions with no significant difference.

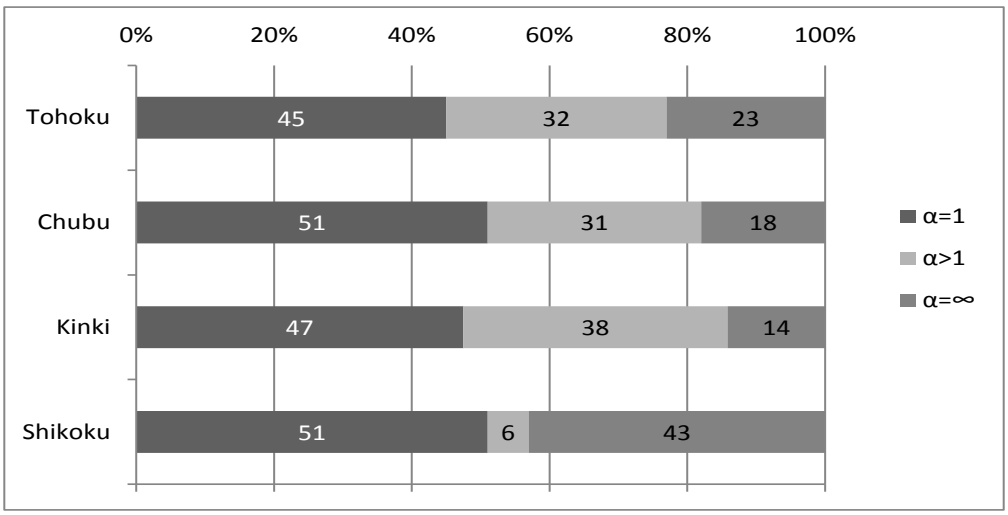
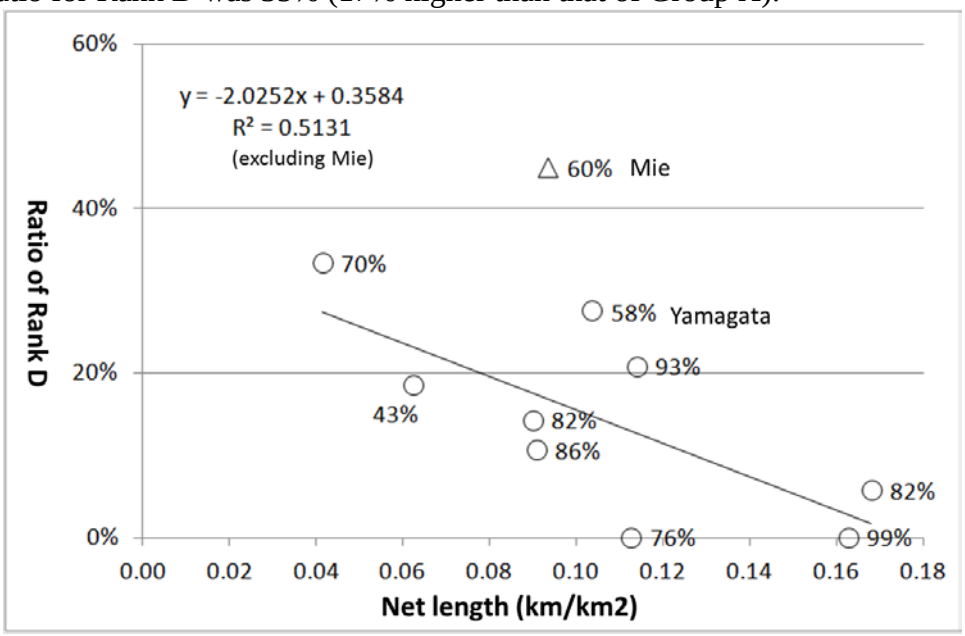


Fig. 4 Assessment rank ratios (Model II)

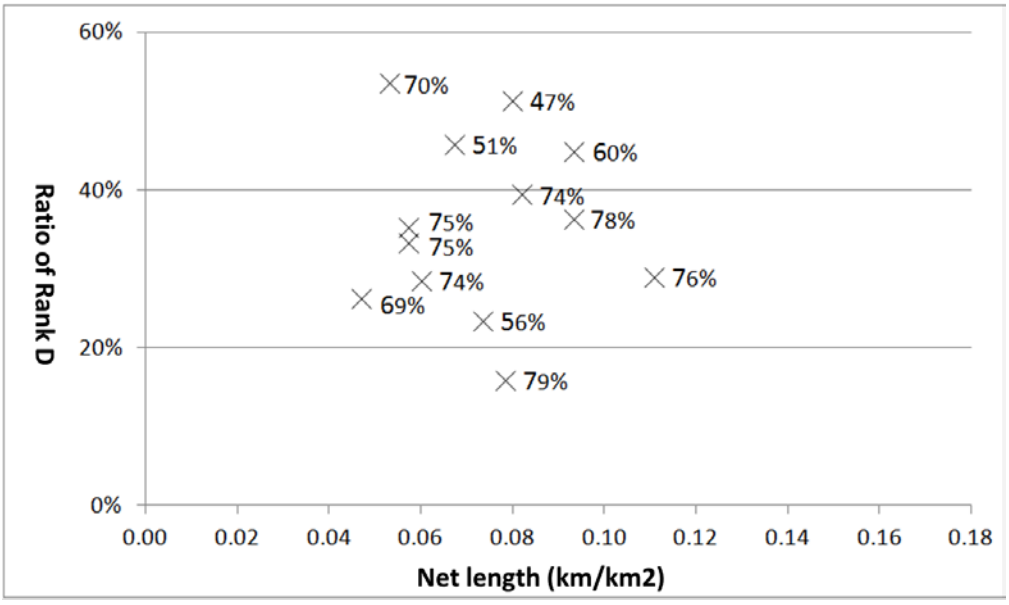
(3) Ratio of Rank-D roads (Model I) (Figs. 5 and 6)

In all prefectures with a habitable area ratio (habitable area/administrative area) higher than the national average (Group X) except for Mie, the ratio of Rank D tended to decrease for regions with greater net lengths (km) of national roads under the direct control of the national government or roads with a higher rank per km^2. While no correlation with the net value was seen for prefectures with a habitable area ratio lower than the national average (Group Y), the average ratio for Rank D was 35% (17% higher than that of Group X).



* The values in the figure indicate the ratios for arterial high-standard highways.

Fig. 5 Ratio of Rank D and net length (Group X)



* The values in the figure indicate ratios for arterial high-standard highways.
Fig. 6 Ratio of Rank D and net length (Group Y)

(4) Discussion

Based on the above results, the following discussion was made concerning methods for the evaluation of disaster mitigation functionality in road projects.

a) Assessment rank ratios for individual regions

Many links in areas where tsunami damage was expected in the event of a large earthquake (e.g., Tokai, Tonankai) were ranked D, indicating that networks lacking disaster resistance and multiplicity are seen in such regions. Conversely, many links were ranked A in urban areas of Chubu and Kinki, which host the Daiichi Tokai Expressway and other arterial high-standard highways and networks characterized by disaster resistance and multiplicity. The results obtained from Models I and II also showed that Shikoku had a high number of roads vulnerable to disasters and areas at high risk of isolation.

b) Ratio of Rank-D roads

In Group X, a negative correlation was found between the net length (km) of national roads under the direct control of the national government and the ratio of Rank-D roads. This was probably because the formation of homogenous links reduces the number of areas expected to become isolated in the event of a disaster in prefectures with extensive flat terrain, and it was possible to determine the disaster resistance and multiplicity of road networks from the results of model-based calculation. However, the ratio of Rank-D roads was high in Mie and Yamagata due to the existence of advance traffic regulations and the presence of expected tsunami inundation areas. In Group Y, the ratio of Rank-D roads was higher than that of Group X, although no correlation was found between the net length of roads mentioned above and Rank D. This was probably because networks lacking disaster resistance and multiplicity are found in prefectures with extensive mountainous terrain.

7. CONCLUSION

The draft outlined by Japan ’s Ministry of Land, Infrastructure, Transport and Tourism in the summer of 2011 is provisional, and improvements, both in theory and practice should still be brought forth.

The findings of this study can be summarized as follows:

- Based on a review of past studies on methods for assessing the disaster mitigation functionality of traffic networks and examination of their advantages and disadvantages, requirements for practical assessment techniques were summarized and a new method was proposed.
- The proposed method was applied to road project assessment in the area stricken by the Great East Japan Earthquake, and the results were used in assessment for the adoption of the project for the construction of the Sanriku- Coastal Road and other new initiatives to contribute to restoration/recovery in the affected region. In this connection, approximately 1 trillion yen in roads over a 10-year period
- The proposed method was applied to the Tohoku, Chubu, Kinki and Shikoku regions for consideration of possible responses to the Tokai and Tonankai earthquakes expected to hit Japan in the future. This approach supported assessment for the disaster mitigation functionality of road networks.

Two key points for restoration from a major earthquake were identified. One was the importance of ongoing efforts to shift the population and various facilities to areas at lower risk of disasters from a mid-to-long-term viewpoint, and the other was the importance of establishing a vision for the status of regional industries 20 years from now. The shift of residential areas characterized by significant personal assets is expected to accelerate if national and local government bodies propose skeletal roads that will affect future regional structures.

Japan now has two new indices that differ from the cost/benefit analysis (B/C) assessment index used around the world. As discussed by the Panel on Infrastructure Development, it is important to decide how to combine these indices in road project assessment. The authors intend to conduct detailed examination to form indices unique to disaster-prone Japan, and will consider the use of these indices in order to eliminate the construction of unnecessary roads.

REFERENCES

Taylor, M. A. P., Sekhar, S. V. C. and D'Este, G. M.(2006) Application of accessibility-based methods for vulnerability analysis of strategic road networks, *Network & Spatial Economics*, Vol. 6, 267 – 291.

D'Este, G. M. and Taylor, M. A. P.(2001) Modeling network vulnerability at the level of the national strategic transport network, *Journal of the Eastern Asia Society for Transportation Studies*, Vol. 4, No. 2, 1 – 14.

D'Este, G. M. and Taylor, M. A. P.(2003) Network vulnerability: an approach to reliability analysis at the level of national strategic transport networks, *Bell, M. G. H. & Iida, Y. eds., The Network Reliability of Transport, Pergamon, Oxford, U.K.*, 23 – 44.

Berdica, K.(2002) An introduction to road vulnerability: what has been done, is done and should be done, *Transport Policy*, vol. 9, 117 – 127.

Jenelius, E., Petersen, T. and Mattsson, L-G.(2006) Importance and exposure in road network vulnerability analysis, *Transportation Research*, vol. 40A, 537 – 560.

The American Association of State Highway and Transportation Officials' Security Task Force (2002) A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection,http://security.transportation.org/sites/security/docs/guide VA_FinalReport.pdf