Highway Network Performance in the Hanshin-Awaji Earthquake Disaster
Part 2. Assessment method and its application

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Abstract

The measurement of post-earthquake highway system performance in 1995 Hyogoken-Nanbu earthquake is addressed. Four alternative measures of the performance of highway systems are proposed, implemented, and compared. Results suggest that some measures may be used advantageously in further study of the indirect impact of highway damage in earthquakes.

Background

In addition to Hanshin Expressway (see Part 1), Meishin National Expressway and Chugoku National Expressway also suffered major damage in the 1995 Hyogoken-Nanbu earthquake. On Meishin National Expressway, viaducts suffered severe damage between Toyonaka Interchange (IC) and Nishinomiya IC where pre-quake traffic volumes were approximately 50,000 to 70,000 in average daily traffic (ADT). While even the worst-damaged sections were opened to traffic with reduced lanes after February 25, 1995, traffic volume was reduced to 30 to 55 percent of pre-quake levels because the direct connection with Hanshin Expressway Route 3 was lost. On Chugoku National Expressway, damage to the viaduct between Toyonaka IC and Nishinomiya-kita IC (pre-quake ADT=98,700) caused closure of the main connector between the Chugoku/Kyusyu and Kansai/Kanto regions. Despite relatively short-term closure, the nationwide economy had been significantly affected.

Observation

Measures of system performance are useful for indirect impact of disaster, as well as for identifying effective mitigation and reconstruction prioritization strategies. Four alternative measures of network performance are investigated in the analysis: (1) total number of highway sections open (measure *N*), (2) total length of highway open (measure *L*), (3) total "connected" length of highway open (measure *C*), and (4) total weighted connected length of highway open (measure *W*). The simplest measure, *N*, refers to the number of sections of highway that are open to traffic. Measure *L* is similar, but is based on length of highway open. Measure *C* attempts to capture the functionality of the highway system by recognizing the remaining degree of connectedness within the network. Measure *W* is similar to *C*, but further modifes the significance of damage to a particular route according to its importance which is indicated by the share of normal traffic volumes. These four measures require only information on pre-earthquake network configuration, pre-earthquake traffic volumes, and post-earthquake physical damage and restoration patterns. Analysis focused on Hanshin Expressway Routes 3, 5, 7 and 16, Chugoku National Expressway (from Yokawa Jct. to Suita Jct.), and Meishin National Expressway (from Suita Jct. to Nishinomiya IC). Time series of ADT between interchanges or ramps were compiled on monthly basis from October 1994 through October 1996.

Fig.1 shows the restoration of traffic with plots of the four performance measures normalized to each pre-quake level. Although the measures recovered to *N*=0.75, *L*=0.81, *C*=0.69, and *W*=0.52 by May 1995, progress stalled for over a year until July 1996, when reopening of Hanshin Expressway Route 3 began to accelerate until full restoration was completed at the end of September 1996. The four measures are consistently ordered as *L*, *N*, *C*, and *W* from the highest to the lowest. Measure *W* tends to exaggerate the impact of physical damage because of damage to heavy traffic sections on Route 3 and is much lower than the others throughout the reconstruction period. Actual traffic is lower than the performance measures in the initial period. Once conditions become less confused, however, traffic conditions recover rapidly. While seasonal fluctuation is clearly observed on the Chugoku National Expressway in August, it can be seen that measures *L* and *C* serve as an upper bound and an approximately lower bound, respectively.

Conclusions

These observations suggest several areas for further research. For example, account should be made of the impact of detour routes on travel time, the availability of alternative modes of transportation such as railway or perhaps even telecommuting, the changes in highway demand in the post-earthquake emergency period, and network connectivity between OD pairs in the system. Links between system restoration and indirect impact and recovery are also important topics further research. By establishing the relationship between highway damage and economic activity, system performance measures such as those explored here can potentially be used in earthquake loss estimation (e.g., in real-time applications), recovery planning, bridge retrofit prioritization, as well as economic impact modeling.

Acknowledgment

The author would like to thank Prof. S. E. Chang of University of Washington, who is the co-author of the reference "Chang and Nojima (1997 and 1998)" from which the contents of this material are excerpted. In the literature, comparison is made between the results of performance measures applied to 1989 Loma Prieta earthquake, 1994 Northridge earthquake, and 1995 Hyogoken Nanbu earthquake, and detailed discussions are provided.

References

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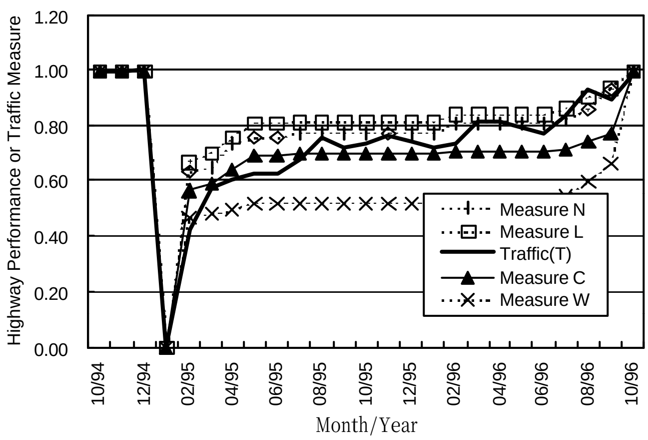

Fig.1: System performance measures and traffic restoration