(d) indicated a method of estimating the costs accruing from system unserviceability; and
(e) recommended a method of system optimization.

It is noted that the system connectivity and serviceability are not necessarily synonymous. More specifically, in Refs. 7-11, a water transmission network modeled on the Los Angeles City system was analyzed, taking into account the existence of the major faults surrounding and penetrating the system, the topological and structural characteristics of the water transmission network, conditions of the soil and ground in which the system is embedded, and the probabilistic nature of the location, frequency, and magnitude of future earthquakes. The Monte Carlo technique was used to simulate a sample of damaged states of the transmission network. The Newton-Raphson method was then used to analyze each of these damaged states of the network for its flow characteristics. The result of this analysis determines whether or not the network remains serviceable under each simulated state of damage and hence leads to a Monte Carlo estimation of the probability of system serviceability. The system was judged to be serviceable as long as both the flow rates and water heads at prescribed demand nodes remained above certain minimum levels after an earthquake in order to fight possible post-earthquake fires. Finally, procedures were established for optimizing the design of new networks as well as for the optimum improvement of existing systems on the basis of seismic risk and cost-effectiveness considerations.

Dealing with the telecommunications system that extends over the area around Sendai City, Japan (Fig. 1), Miwa and Okumura (Ref. 4) performed a reliability analysis by means of the Monte Carlo simulation method. This area experienced strong ground shaking resulting from the 1978 Off-Miyagi-Ken earthquake. The analysis estimated the probabilities of connectivity between any pair of nodes to remain intact during and after an earthquake of intensity V (in the Japanese Meteorological Agency scale), which is approximately equivalent to an earthquake of intensity VIII in the Modified Mercalli Intensity (MMI) scale. The result of this analysis is shown in Table 1 in the form of a (symmetric) matrix whose i-j element indicates the probability that nodes i and j will remain connective during and after an earthquake of intensity V.

It appears, however, that the analysis in Ref. 4 did not take into consideration the possibility of nodal failure. Since all the nodes in Fig. 1, except for nodes 13 and 14, represent telephone offices, although of various kinds within the hierarchy (RC, EO, TP, TC), the analysis would have been more realistic if the probabilities of nodal failure had been incorporated into the Monte Carlo simulation. Such probabilities of nodal failure can be obtained by performing such analyses as those examplified by Isenberg (Ref. 1). In their concluding remarks in Ref. 4, Miwa and Okumura emphasized the importance of systematic collection of field data in order to determine, with more confidence, the reliability values of cables in various protective modes (see the legend in Fig. 1) under prescribed soil and seismic intensity conditions. To this, the present authors could not agree more, since it is these reli-

revised version considers such an effect; (3) The original FAST does not consider the possibility of nodal failure (e.g., failure of a telephone office). The revised version will incorporate the failure probabilities of the nodes in order to reflect such possibilities in the analysis.

In order to complete such revisions, field data must be more carefully examined so that the failure probability of a cable per unit length is documented, and more research must be carried out to develop techniques for estimating the probability of a nodal (telephone office) failure, particularly that of a functional failure resulting from equipment malfunction due to earthquake effects.

CONCLUDING REMARKS

The current understanding of the seismic performance of telecommunications networks is briefly reviewed. Previous work pertaining to the seismic risk of telecommunications network systems is also reviewed. The use of a revised version of the FAST code has been suggested for the risk analysis with the contents of the revision being delineated.

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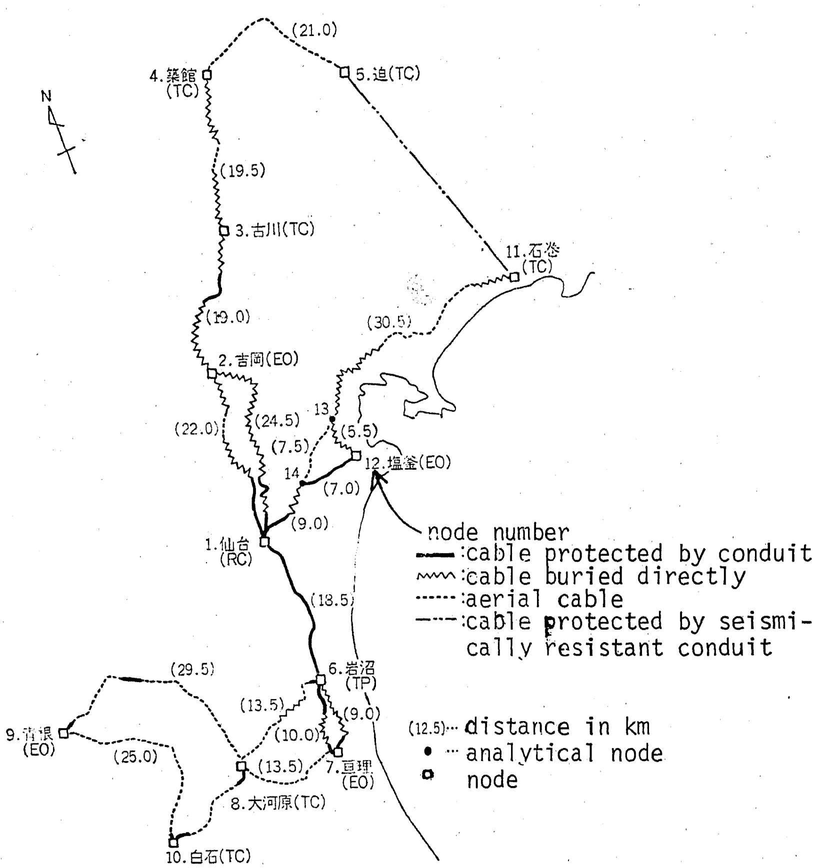

Fig. 1 Telecommunications Network Analyzed (Ref. 4)