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The estimation of the urban damage based on the systematical reliability

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ABSTRACT: Generally, It is divided into two parts, the building structure and the lifeline, to estimate the earthquake damage of the engineering structure of a city or a town. And boththe calculating proceedings and the estimating results are less relevance. Here, a generalweighted network method which considers the failure correlation is applied in urbanengineering systems, by which the damages of the lifelines as well as the building structuresare estimated systematically. And a simplified method, the gradation method, is suggested forthe damage evaluation of the large city.

1 NETWORK MODELLING OF THE URBAN ENGINEERING SYSTEMS

Lifelines are always considered having theproperties of the networks and treated as theedge weighted networks. Building structuresare less involved in (Kitaura, M., 1985).

In fact, the post—earthquake behaviors ofthe lifelines could be directly shown by theirvarious terminals which are always installedin the buildings (Wang Dongwei 1990). Itgenerally means the water services are notdamaged when the users' taps (which are inthe buildings) have the water flow out andalso the telephone lines are in goodconditions when the subscribers could put thecalls through (the telephones are in thebuildings too). Moreover, lifelines must beprovided with several kinds of constructionsor building structures to perform their designfunctions (Wang Dongwei 1991). Power systemneeds power plants and distribution stationsto supply and distribute the electriccurrents. Heating system needs boiler rooms toafford the heat sources.

Therefore, lifelines set up a variety oforganic relationships among their terminals orthe building structures of a city. Then allthe relevant engineering facilities andinstallations including lifelines as well asbuilding structures form a succession of urbanengineering systems, the transportationsystem, the communication system, the water—supply system and so on.

So, taken the lifeline segments as the edgesand the related building structures as well asthe joint parts of the lifeline as thevertexes, and taken the failure probabilitiesof the line segments or the structures as theweights, each of the urban engineering systemcould be treated as a general weighted network(including or part including edge weights aswell as vertex weights) but not a edgeweighted network (only including edge weights). And then it is possible to estimate theearthquake damages of the lifelines and the building structures systematically.

Here, we note the related lifeline segmentsas a edge set E(p), and relevant buildingstructures or joint parts of the lifeline as avertex set V(p). Then a urban engineeringsystem S is noted as a general weightednetwork G, and expressed as:

$$S = G (V(p), E(p)) \qquad (1)$$

in which, p is the weight or the failureprobability of the lifeline segment or thebuilding structure.

In the practical engineering systems, someof the failure events are correlative and someof the line segments (edges of the network), building structures or joint parts (vertexesof the network) are so safe or unimportantcomparing with other parts of the network thattheir failure probabilities could beneglected. The specific ways to treat suchproblems are shown in the illustration indivision 3.

2 THE GRADATION MODELS FOR THE LARGE CITY

Any of a network model of engineering systemsof a large city, even a medium—sized city, hasnearly innumerable terminals. It is impossibleand unnecessary to examine the connectivitiesfrom the source points to all the otherterminals.

Here we notice that one of the distinguishedproperties of the urban engineering systems istheir gradations (Singh, M, G., 1974 and XuNanrong, 1988). And this property isspecially remarkable after the earthquakeoccurred (Wang Dongwei 1990). The relief issend form the railway station, airport, orwharf (grade one vertexes of thetransportation system) to the goods yards (grade two) of every district and then everyunit (grade three) in the districts andfinally every user (grade four) of the unit. The centre telecommunication bureau (gradeone vertex of the communication system) administrates the line segments which link toevery branch office, and a branch (grade two) manages the parts connected with every unit(grade three) in its definite area, and thenthe users (grade four) have their extensionsjoined with the switchboard of their workingplace, the unit. The gradation graphs of otherkinds of the urban engineering systems areshown in Fig. 1.

These gradation graphs point out that wecould estimate the earthquake damages ofaforementioned engineering systems of a largecity grade by grade, region by region.

3 CALCULATING STEPS AND ILLUSTRATION

Fig. 2 shows a part of transportation systemof a region of a large city, its warehouse isin the area W. From the airport A, there areseveral main lines which could reach the areaW. And there are two bridges B1 and B2, agrade separation bridge G, a tunnel T, aactive fault F, a liquefied area L and a stripof steep slope S between A and W. It is knownthat the failure probability of the fault F isP(F), and if the fault breaks, the failureprobabilities of the other sectors of theregion or the structures are known as P(A), P(T), P(G), P(B1), P(B2), P(L), P(S), P(W)respectively. Still there is a main line M inthe urban district, it has underwent theaseismic design, so its reliability P(M) is 1. Then according to division 2, the networkmodel of the transportation system from A(grade one) to W (grade two of the region) could be simply set up and shown in Fig. 3. Considered not the weights of the safety partsand the unimportant parts of the network, thegeneral weighted network G1 is been drawing inFig. 4.

It is common knowledge that if the fault isbroken, the two of the highways which acrossthe fault F will generally cease to beeffective at the same time . Also the twosegments settled in the liquefied region Lwill subside simultaneously. These appearancesare so called failure correlation.

It is difficult for a computer to redraw anetwork considering the failure correlation. The authors find out that it

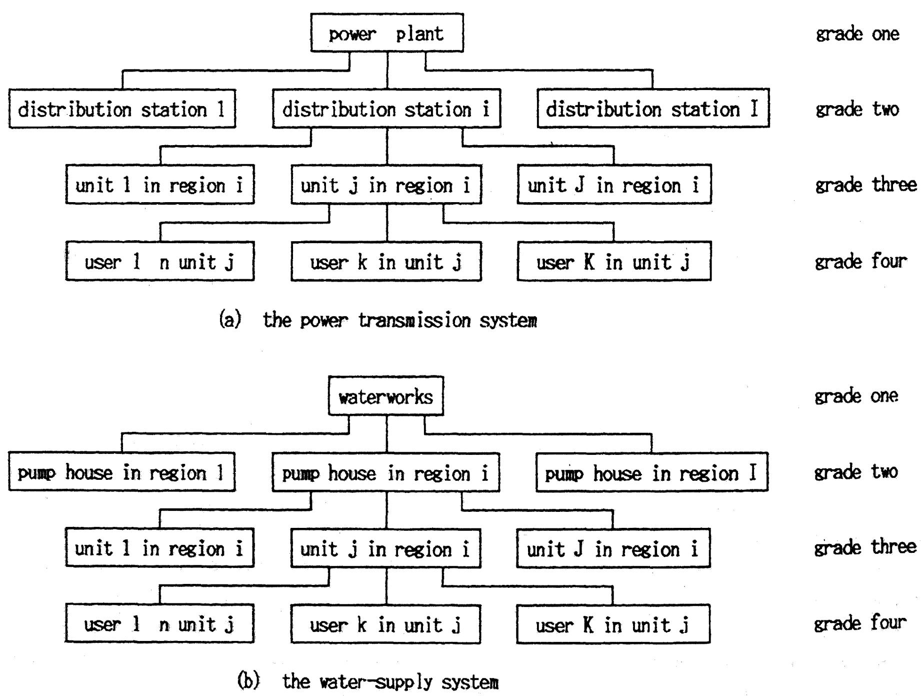


Fig. 1 The gradation graph of the urban engineering system

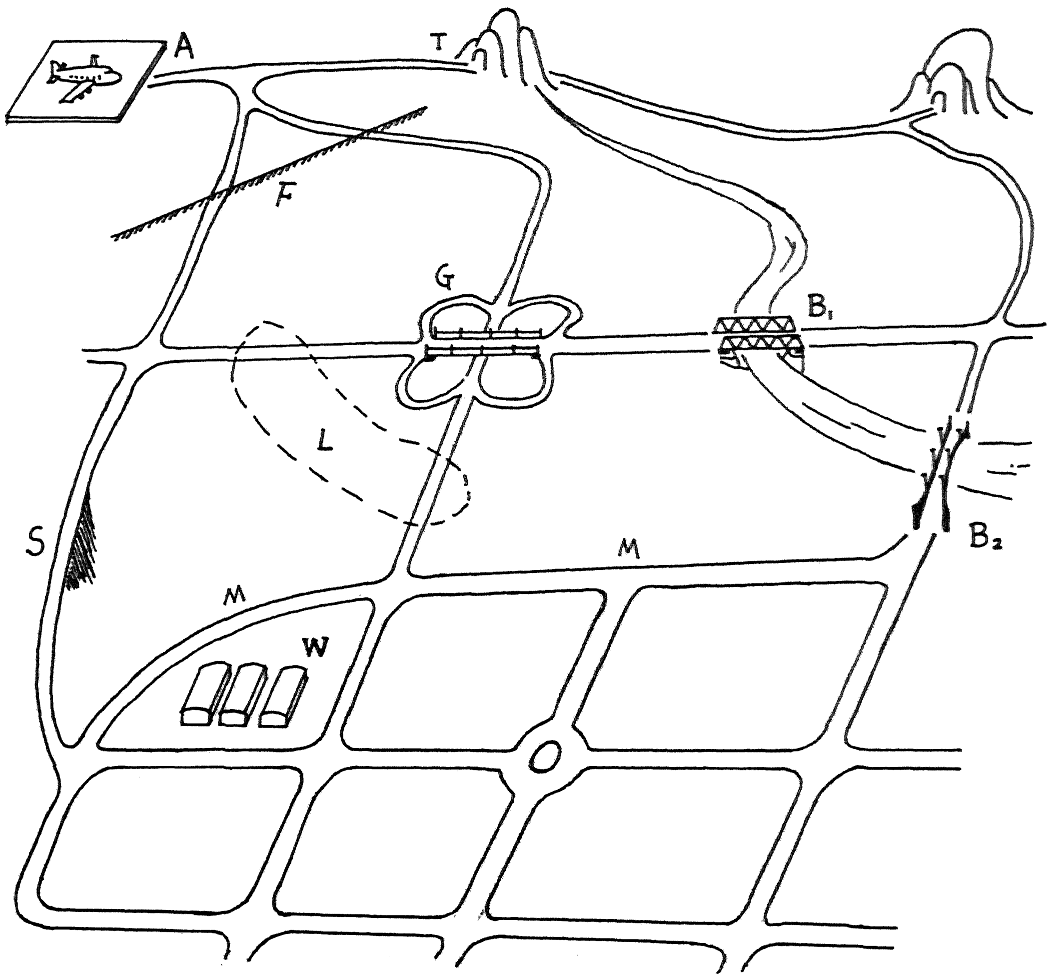
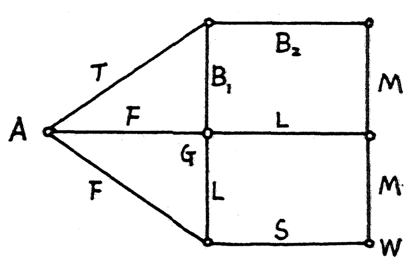


Fig. 2 the transportation system of a region of a city



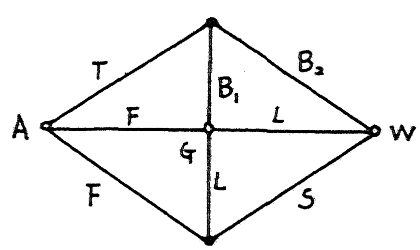


Fig. 3 the network moldel of Fig. 2 Fig. 4 the general weighted network Gl is ease to treatthis problem at the step searching the minimum path sets.

The calculating steps are given out as the follows:

Step one: use the common program calculating the minimum path sets of the edge weighted network to calculate the minimum path sets of the G1 which include only the edge weights. The results are:

F,S; F,L,L; F,L,S;
F,L; F,B1,B2; F,L,B1,B2;
T,B2; T,B1,L; T,B1,L,S;

Step two: consider the weights of the vertexes of the general weighted network. Bring the weighted vertexes into related paths, the minimum path sets of G1 including the vertex weights could be lined up as:

A,F,S,W; A,F,L,C,L,W; A,F,C,L,S,W;
A,F,C,L,W; A,F,C,B1,B2,W;
A,F,L,C,B1,B2,W; A,T,B2,W;
A,T,B1,C,L,W; A,T,B1,C,L,S,W;

Step three: consider the correlation of the failure events. According to the absorbing rule of the set theory:

$$A \cup AB = A \qquad (2)$$

and the definition of the minimum path, the minimum path sets of the general weighted network G1 could be obtained as follows:

A,F,S,W; A,F,C,L,W; A,F,C,B1,B2,W;
A,T,B2,W; A,T,B1,C,L,W;

Step four: Search the uncross sum of the minimum path sets. The uncross sum of the minimum path sets of G1 is

$$AFSW + AFSCLW + AFSCLB1B2W + AFSCTB2W + AFSCLB1TB2W + AFTB2W + AFTB2B1CLW$$

Step five: Calculate the connective probability of the network. Note the reliabilities of the line segments or buildingstructures as:

$$R(i) = 1 - P(i) \quad (i = A,T,G,\dots) \quad (3)$$

The connective probability R for airport A to warehouse W is:

$$\begin{aligned} R = R(A)R(W)\ (&R(F)R(S) \\ &+ R(F)P(S)R(C)R(L) \\ &+ R(F)P(S)R(C)P(L)R(B1)R(B2) \\ &+ R(F)P(S)P(C)R(T)R(B2) \\ &+ R(F)P(S)R(C)P(L)P(B1)R(T)R(B2) \\ &+ P(F)R(T)R(B2) \\ &+ P(F)R(T)P(B2)R(B1)R(C)R(L)\ ) \end{aligned}$$

4 CONCLUSIONS

4.1 The general weighted network (including or part including edge weights as well as vertex weights) could be used to estimate the earthquake damage of the lifeline as well as the building structure systematically.

4.2 The failure correlation of the events could be considered at the step calculating the minimum path sets of the network.

4.3 The gradation method could be applied to deal with the problems of estimating the damage of the large city.

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