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INJURIES IN EARTHQUAKES: CONSIDERATION OF LOCAL SOCIAL CHARACTERISTICS IN THE CONSTRUCTION OF ESTIMATION SCHEMES

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SUMMARY

Qualitative experimental equations in which local social indexes were used as predictor variables were derived to interpret the distribution of the injured in an area through which the severity of ground shaking was substantially uniform. It was indicated first that accidents are apt to occur in urbanized areas; and second that, in an urbanized area, accidents are apt to occur in the sections in which the average dwelling size is small and in which the population of the aged is large.

INTRODUCTION

The scattering of the plot in Fig. 1, showing the relationship between seismic intensity and injury rate for a municipality in an earthquake, suggests the necessity to use additional factors, beside seismic intensity, in estimating injuries.

The high injury rate for the city of Sendai in the 1978 Miyagiken-Oki earthquake indicates the significance of social characteristics of an affected area on the occurrence of injuries. Among the cities of which data were plotted in Fig. 1, Sendai is the only major city affected by a destructive earthquake. Urbanized circumstances in a major city, which is basically characterized by limited dwelling space due to its high polulation density, can be regarded as a probable indirect cause of injuries.

In this paper, we made an attempt to develop an estimation scheme for injuries in which local social characteristics were taken into account. We analyzed data collected for this particular purpose in a city affected by a recent earthquake. The data contains the following two kinds of information: (1) in which zone in the sruvey area each accident occurred; and (2) what the social characteristics of each zone were.

DATA

First, we conducted a mail survey addressed to the injured persons in Noshiro in the 1983 Nihonkai-Chube, Japan earthquake to investigate exactly where each person was injured. We asked an additional question about the cause of the accident to identify the casualties attributed to a tsunami and to exclude them from the examination here.

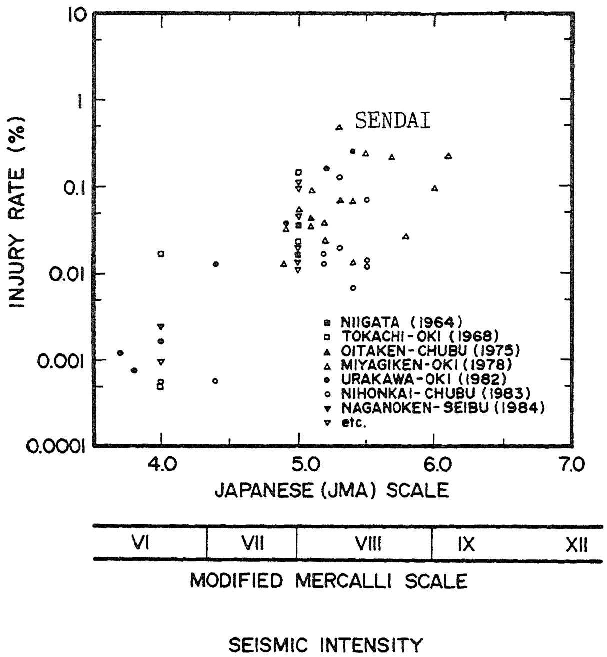

Fig. 1 Relationship between seismic intensity and injury rate.

It turned out that approximately 50 persons were injured by causes other than the tsunami. The data for 37 out of the approximately 50 people who were treated at medical facilities were finally collected.

We used all the data for the 37 persons in this study, irrespective of the seriousness of casualty. The seriousness of injuries experienced by those persons extended rather wide, as we sent out survey forms to all the persons who were treated at medical facilities. Among the 37 injured persons, 15 persons needed medical treatment longer than a month, and 7 persons were hospitalized.

Second, we collected the following local characteristics data for each zone in Noshiro: (1) building density, (2) population density, (3) average family size, which strongly correlates directly with dwelling size, (4) female/male ratio, (5) population density for infants (6 and under), and (6) population density for the aged (65 and over).

Data were collected for each of the 88 administrative zones in the city. Although the city, which had a population of approximately 60,000, was composed of 375 zones, only 88 zones were densly inhabited. In most cases, the size of a zone coincided with the size of a community within the city.

ANALYSIS

Maps Fig. 2 (a) shows the distribution of the zones in which at least one person, or more than 2.2 persons per square kilometer, was injured.

The zones in which ground shaking was relatively severe are indicated in Fig. 2 (b) in terms of seismic intensity and Fig. 2 (c) in terms of the damage

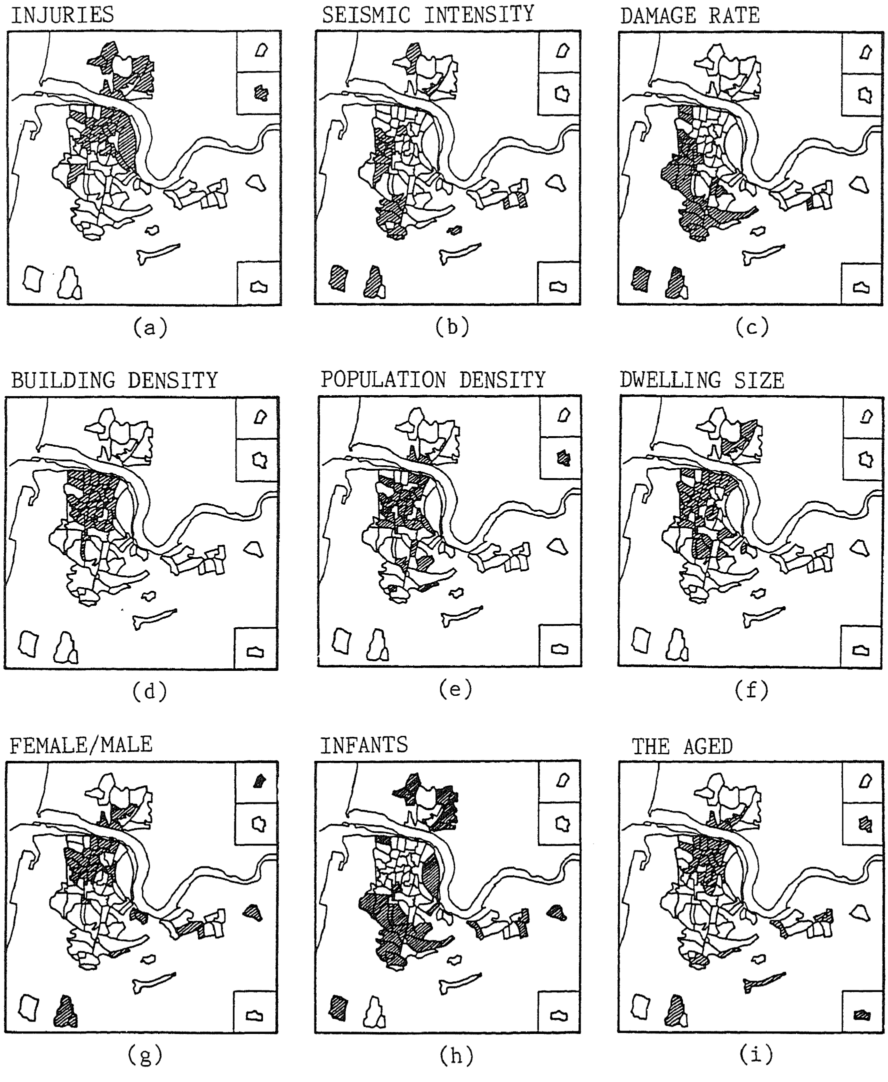

Fig. 2 Distribution of zones in which
(a) injuries occurred,
(b) seismic intensity was high,
(c) damage rate of wooden dwelling structures was high,
(d) building density was high,
(e) population density was high,
(f) dwelling size was small,
(g) female/male ratio was high,
(h) population density for infants (6 and under) was high,
(i) population density for the aged (65 and over) was high.

rate of wooden dwelling structures. The distribution of zones in which ground shaking was severe does not correspond to the distribution of the injured. In this particular case for Noshiro, since the severity of ground shaking varied within a limited range, its effect is hidden by the social factors.

Fig. 2 (d) through (i) are the indication of the zones in which (d) building density was relatively high, (e) population density was relatively high, (f) average dwelling size for a household was realtively small, (g) female/male ratio wss relatively high, (h) density for infants (6 and under) was relatively high, and (i) density for the aged (65 and over) was relatively high.

Distribution of the zones in which injuries occurred coincides, in general, with the distribution of the zones in which (1) building density was high, (2) population density was high, (3) average dwelling size was small, (4) female/male ratio was high, and (5) population density for the aged was high, respectively. This suggests that the residents who stayed in a limited space and who were physically less capable were apt to be injured. This tendency is consistent with the results of some of the recent studies in which the details of the environmental change and human responses were directly investigated.

Experimental Equations In the next step, we tried to derive experimental equations, using local characteristics data as predictor variables, to sort out zones in which injuries occurred. No earthquake engineering indexes which indicate the severity of ground shaking were used for this particular case for Noshiro, since the severity of ground shaking was uniform throughout the investigated area and had no significant effects on the distribution of the injured.

An experimental discriminant equation was derived as follows:
Injuries are likely
to occur in a zone, if score c is greater than Co
not to occur in a zone, if score c is less than Co

where,

$$c = \sum_{i} \left(c(i,1) \quad c(i,2) \quad c(i,3) \right) \cdot \begin{pmatrix} d(i,1) \\ d(i,2) \\ d(i,3) \end{pmatrix}$$

with Co being the score to discriminate the likelihood, whether or not injuries are likely to occur, and is determined in the multiple variable discriminant analysis; c(i,1), c(i,2), and c(i,3) are category weight coefficients that are determined in the mlutiple variable discriminat analysis; d(i,1), d(i,2), and d(i,3) are a set of dummy variables that are given as follows:

d(i,1)=1, d(i,2)=0, and d(i,3)=0,
when the value of a regional index is relatively high (one-third-higher),
d(i,1)=0, d(i,2)=1, and d(i,3)=0,
when the value of a regional index is intermediate, and
d(i,1)=0, d(i,2)=0, and d(i,3)=1,
when the value of a regional index is relatively low (one-third-lower);

i is the suffix to identity the regional index.

We established two regions, A and B, for which experimental equations were respectively derived. Region A, being composed of 88 zones, is characterized by the broad range of the degree to what extent a zone is urbanized; Region B, being composed of 45 most urbanized zones, is characterized by the limited range of the degree to what extent a zone is urbanized. The range of population density for region A and B is from 420 to 10,650 and from 2,130 to 10,650, respectively.

We derived experimental equations in which a combination of three of the following four regional indexes: (1) building density, (2) average dwelling size, (3) female/male ratio, and (4) population density for the aged.

The most efficient discriminant equation for region A was obtained as follows:

Injuries are likely
to occur in a zone, if score c is greater than -0.13
not to occur in a zone, if score c is less than -0.13

where,

$$
\begin{aligned}
c =& (\ 0.76\ \ -0.22\ \ -0.55)\cdot\begin{pmatrix} d(1,1) \\ d(1,2) \\ d(1,3) \end{pmatrix} \text{ building density} \\
&+(-0.33\ \ -0.16\ \ \ 0.49)\cdot\begin{pmatrix} d(2,1) \\ d(2,2) \\ d(2,3) \end{pmatrix} \text{ dwelling size} \\
&+(\ 0.53\ \ -0.11\ \ -0.44)\cdot\begin{pmatrix} d(3,1) \\ d(3,2) \\ d(3,3) \end{pmatrix} \text{ female/male ratio}
\end{aligned}
\qquad (1)
$$

Category weight coefficients are shown schematically in Fig. 3 (a). This experimental equation correctly discriminated, whether an area had the injured or not, 55 (62%) of the 88 zones.

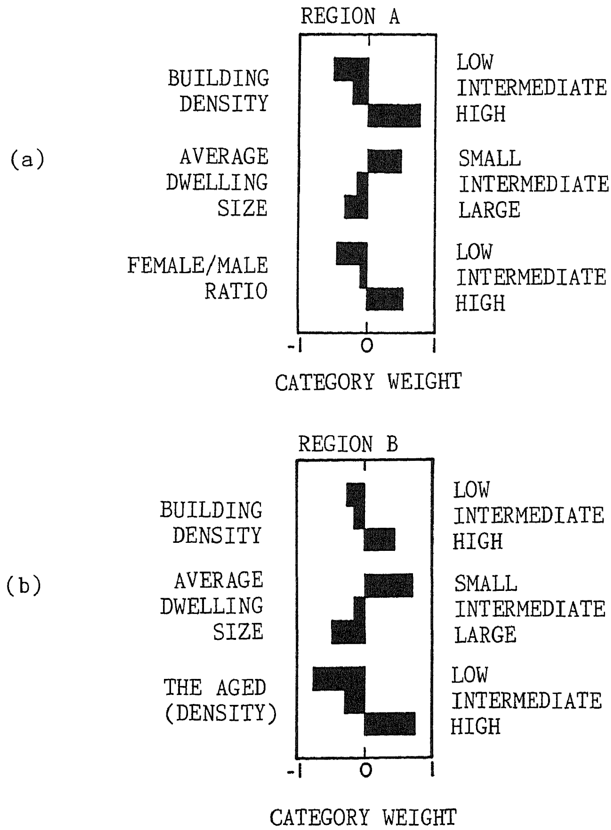

Fig. 3 Category weight coefficients for experimental discriminat equation.

The most efficient discriminant equation for region B was obtained as follows:

Injuries are likely
to occur in a zone, if score c is greater than 0.30
not to occur in a zone, if score c is less than 0.30

where,

$$
\begin{aligned}
c = &(0.46 \ -0.18 \ -0.27)\cdot\begin{pmatrix} d(1,1) \\ d(1,2) \\ d(1,3) \end{pmatrix} \text{ building density} \\
&+(-0.51 \ -0.16 \ \ 0.70)\cdot\begin{pmatrix} d(2,1) \\ d(2,2) \\ d(2,3) \end{pmatrix} \text{ dwelling size} \\
&+(0.76 \ -0.32 \ -0.77)\cdot\begin{pmatrix} d(3,1) \\ d(3,2) \\ d(3,3) \end{pmatrix} \text{ density for the aged}
\end{aligned} \qquad (2)
$$

Category weight coefficients are shown schematically in Fig. 3 (b). This set of weighting coefficients correctly sorted 35 (77%) of the 45 zones.

RESULTS

Fig. 3 (a) shows the building density, which generally represents the degree to what extent a zone is urbanized, was the most significant predictor variable in Eq.(1) for region A. It is pointed out that the likelihood of the occurrence of injuries is closely related to the level of urbanization itself for an area which is characterized by the broad range of the degree to what extent a zone is urbanized.

In contrast, in Eq.(2) for region B, the building density was less significant as a predictor variable than the population density for the aged and the average dwelling size of a zone (Fig.3 (b)). As region B did not contain such a significant area-to-area difference of the level of urbanization as region A, more specific information concerning residents and their dwellings were necessary so as to evaluate the likelihood of the occurrence of injuries.

CONCLUDING REMARKS

The importance of social characteristics data in the estimation of the injured was practically demonstrated through a case study. The distribution of the injured in a recent earthquake was interpreted in terms of several local indexes, such as average dwelling size, building density, population density for the aged in the affected area.

As the first step toward the construction of quantitative formulas, some qualitative experimental equations were derived to interpret the distribution of the injured. Although we derived only qualitative equations in this study because of the limitation in the amount of data, we can use a similar statistical technique to obtain a quantitative evaluation if data having appropriate size are collected in a future earthquake.

ACKNOWLEDGEMENTS

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