EARTHQUAKES IN TURKEY: RECONSTRUCTION PROBLEMS, DAMAGE PREDICTION, AND RECOVERY FORECASTING FOR EARTHEN STRUCTURES

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ABSTRACT

Field research after the Gediz, Lice, and Caldiran-Muradiye earthquakes in Turkey has revealed various problems dealing with the post-disaster restoration and reconstruction. Based on lessons learned from Turkish earthquakes, suggestions to improve reconstruction are offered. Further, research from Turkish disasters has led to the construction of two models. One predicts the number of houses destroyed based on earthquake magnitude and discriminates between housing types. The second model predicts recovery progress at any given time after the quake has occurred.

Since about four out of ten people in the world live in the over 30 countries which are located in active seismic zones, earthquakes provide a continual catastrophic threat.[1] The threat is very real for the Republic of Turkey.[2] Turkey is one of the approximately 30 countries that has historically experienced earthquakes, and it is located on one of the earth's two major seismic belts. Earthquakes in that country are very common occurrences.

This research was undertaken to identify problems in rural reconstruction following earthquake disasters in Turkey and to provide a model for authorities in predicting recovery times following disasters.[3] The model would link time to the way resources are expended in the reconstruction effort, and thus act as a guide for the insertion of appropriate amounts of money and material into the affected area through the reconstruction period. Such a model could be used to deal with any earthquake occurrence since it is based on a generalized data scheme which presents all data in a percentage format. The model can also perform a "rationality check" on the reasonableness of initial recovery estimates very early in the reconstruction phase.

The Earthquake Threat in Turkey

Earthquakes, one of the worst natural hazards, can cause catastrophic disasters.

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[1]For an understanding of the problem, see the Summary in Earthquake Engineering Research, A Report to the National Science Foundation (Washington, D.C.: National Academy of Sciences, 1979), particularly pages 1-7 and 19-20, Also, Thomas C. Nichols, Jr., "Global Summary of Human Response to Natural Hazards: Earthqakes," in Natural Hazards, Local, National, Global, edited by Gilbert White (New York: Oxford University Press, 1974), pp. 274-284, and Tapan Mukerjee, Economic Analysis of Natural Hazards: A Preliminary Study of Adjustments to Earthquakes and Their Costs. Natural Hazard Research Working Paper No. 17, Institute of Behavioral Science, University of Colorado, Boulder, Colorado, 1971.

[2]William A. Mitchell, "Reconstruction After Disaster: The Gediz Earthquake of 1970," Geographical Review, Vol. 66, No. 3, July 1976, pp. 297-298.

[3]The authors express their appreciation to Mr. Teoman Guzey, Executive Director, Turkish Ministry of Reconstruction and Resettlement; Mr. Oktay Ergunay, Head of the Turkish Earthquake Research Institute; Professor Erol Tumertekin, Head of the Geographical Institute, University of Istanbul, for assisting on the research, and to the Frank J. Seiler Research Laboratory, USAFA, and Dean of the Faculty for partial funding of the project.

They have the potential to release concentrated energy on the order of nuclear weapons.[4]

When an earthquake strikes, there are many independent variables that may influence the severity of the disaster. The actual impact of the natural event, or damage to humans, depends on physical characteristics of the event, and socioeconomic adaptations by the threatened community. The affected area can be very vast; in fact, a high magnitude earthquake can inflict widespread damage and casualties over a 50,000 square mile area.[5]

Severe and major earthquakes in densely populated areas can have catastrophic consequences. Why? In general, because the hazard damages and destroys man-made structures.[6]

Earthquakes occur because the earth's crust is dynamic, not static, and is not a single rigid shell but floats as ten major and minor plates on a body of hot plastic rock. When movement along these plates occurs suddenly, the result is an earthquake. Because of location on or near these plates, or faults, some countries are particularly vulnerable to earthquake disasters.[7] The Republic of Turkey is one such country.

Turkey was chosen as the study area for several reasons. The most obvious is that frequently both severe and major earthquakes occur there. The country is crossed by the Alpide seismo-tectonic belt, in which seventeen percent of the world's earthquakes occur. Destructive earthquakes have occurred there since the earliest days of recorded history. In very recent years, many Turks have been killed in earthquake disasters (Table 1). For example, 2,394 were killed in 1966 (Varto), 116 in 1967 (Adapazari and Pulumur), 1,143 in 1970 (Gediz and Burdur), 870 in 1971 (Bingol), 2,385 in 1975 (Lice), and 3,700 in 1976 (Muradiye).[8]

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[4]A classified study evaluating the similarities of damages caused by earthquakes and nuclear disasters has been completed using data from the People's Republic of China and the USSR. Timothy H. Miner, William A. Mitchell, and William J. Weida, Analyzing and Modelling Natural Disasters: Implications for Recovery from Nuclear Disasters (U), United States Air Force Academy Technical Report 79-3, DFEGM, USAFA, Colorado 80840, report classified Secret, February 1979.

[5]Harold C. Cochrane, Natural Hazards and Their Distributive Effect--A Research Assessment, University of Colorado Monograph NSFRAE 75003, 1975, p. 2.

[6]Weisbecker and others describe very well what earthquakes do. See Leo W. Weisbecker and others, Earthquake Prediction, Uncertainty, and Policies for the Future: A Technological Assessment of Earthquake Prediction, prepared for the National Science Foundation, Stanford Research Institute, Menlo Park, California, Final Report, January 1977, p. 7.

[7]See Robert Iacopi, Earthquake Country (Menlo Park, Calif.: Lane Books, 1976), pp. 26-27.

[8]Provided to Mitchell by the Earthquake Research Institute, Ministry of Reconstruction and Resettlement, Government of Turkey. Diacritical markings for Turkish place names are omitted in this paper.

TABLE 1

Major Earthquakes in Turkey (1925-1976)

Date	Location	Intensity I_o	Magnitude M	Deaths	Houses Destroyed
7 Aug 1925	Afyon-Dinar	IX	5.9	330	2,500
31 Mar 1928	Izmir Torbali	IX	7.0	170	2,600
18 May 1929	Sivas-Susehri	VIII	6.1	64	1,357
19 Jul 1933	Denizli-Civril	VIII	5.7	20	200
4 Jan 1935	Erdek	IX	6.7	5	600
19 Apr 1938	Kirsehir	IX	6.6	155	2,500
22 Sep 1939	Izmir-Dikili	IX	7.1	150	1,500
26 Dec 1939	Erzincan	X-XI	7.9	40,000	140,000
20 Feb 1940	Kayseri-Develi	VIII	6.7	40	500
10 Sep 1941	Van-Baskale	VIII	5.9	192	600
15 Nov 1942	Bigadic-Sindirgi	VIII	6.1	16	750
20 Dec 1942	Niksar-Erbaa	IX	7.0	3,000	32,000
20 Jun 1943	Adapazari-Hendek	IX	6.6	285	1,000
26 Nov 1943	Tosya-Ladik	IX-X	7.2	5,000	40,000
1 Feb 1944	Bolu-Gerede	IX-X	7.2	2,831	50,000
25 Jun 1944	Gediz-Usak	VIII	6.2	20	3,500
6 Oct 1944	Ayvalik-Edremit	IX	7.0	30	5,500
20 Mar 1945	Adana-Ceyhan	VIII	6.0	13	370
21 Feb 1946	Kadinhan-Ilgin	VIII	5.6	12	400
31 May 1946	Varto-Hiniz	VIII	5.7	650	3,000
23 Jul 1949	Karaburun-Izmir	IX	7.0	7	865
17 Aug 1949	Karliova	IX	7.0	450	3,500
13 Aug 1951	Kursunlu	IX	6.9	50	3,354
3 Jan 1952	Hasankale	VIII	5.8	94	1,570
18 Mar 1953	Yenice-Gonen	IX	7.4	265	1,750
7 Sep 1953	Kursunlu	VIII	6.4	22	430
16 Jul 1955	Soke-Aydin	IX	7.0	23	470
20 Feb 1956	Eskisehir	VIII	6.4	1	1,440
25 Apr 1957	Fethiye	IX	7.0	67	3,100
26 May 1957	Bolu-Abant	IX	7.1	66	5,200
25 Apr 1959	Koycegiz	VIII	5.7	3	630
18 Sep 1963	Cinarcik	VIII	6.3	1	230

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Date	Location	Intensity I_o	Magnitude M	Deaths	Houses Destroyed
14 Jun 1964	Malatya	VIII	6.0	8	678
6 Oct 1964	Manyas	IX	7.0	30	5,523
13 Jun 1965	Denizli-Honaz	VIII	5.7	14	468
7 Mar 1966	Varto	VIII	5.6	14	1,100
19 Aug 1966	Varto	IX	6.9	2,394	20,007
22 Jul 1967	Adapazari	IX	7.2	89	5,569
26 Jul 1967	Pulumur	VIII	6.2	97	1,282
3 Sep 1968	Amasra-Bartin	VIII	6.5	29	2,072
23 Mar 1969	Alasehir	VIII	6.9	41	3,700
28 Mar 1970	Gediz	IX	7.3	1,086	9,452
12 May 1970	Burdur	VIII	5.9	57	1,487
22 May 1971	Bingol	VIII	6.2	870	5,356
6 Sep 1975	Lice	VIII	6.9	2,385	8,165
24 Nov 1976	Caldiran-Muradiye	IX	7.1	3,840	9,232

Source: Earthquake Research Institute, Republic of Turkey, Ankara, June 1977.

There is every reason to believe that Turkey will continue to experience earthquakes! Hence, it is an excellent laboratory in which to model recovery.

Presently, adjustment to earthquakes is primarily in the form of distributing losses through emergency relief, since the hazard cannot be reduced and modification of vulnerability is not now practical. An ideal adjustment would be to have the people live only in safe areas. Turkey, however, is a country about the size of Texas, with a population of over 45 million people, of which over ninety percent is seismitically active (Figure 1). Consequently, there is insufficient space even if it were economically and culturally feasible to relocate the population.[9]

Dwellings in Turkey

There were approximately 6.5 million housing units in Turkey in 1970.[10] Three million, nine thousand dwellings were located in rural settlements with populations under 10,000. There were in 1970 about 65,000 villages containing approximately 61% of the population.

About 2.6 million dwellings were located in towns and cities with more than 10,000 inhabitants. These also included shanty town dwellings.

In terms of earthquake-resistent housing, there is a severe shortage in Turkey. The Turkish delegates to the "Intergovernmental Conference on the Assessment and Mitigation of Earthquake Risk" held in Paris in 1976 revealed that 30% of the rural dwellings require immediate structural repair and strengthening while 17% are in a condition beyond repair (Figure 2).[11]

Rural dwellings in Turkey are about 50% stone and brick masonry, about one-third adobe, and approximately 13% timber frame structures. About 11% are a mixed or hybrid types (Figures 3 and 4). Village houses are mostly one-story units (58%). The remainder are two story. The average house has less than 100 square meters of

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[9] An attempt to estimate casualties and damages within minutes after an earthquake occurs in Turkey was made by William A. Mitchell, Richard Wolniewicz, and John F. Kolars, "Predicting Casualties and Damages Caused by Earthquakes in Turkey: A Preliminary Report," United States Air Force Academy Technical Note 78-2, DFEGM, USAFA, Colorado 80840, March 1978.

[10] Housing data taken from Country Monograph of Turkey, UNESCO, Ankara, 1976, and from the Ministry of Reconstruction and Resettlement, Government of Turkey, Ankara, June 1977 and 1978.

[11] Country Monograph of Turkey, p. 27.

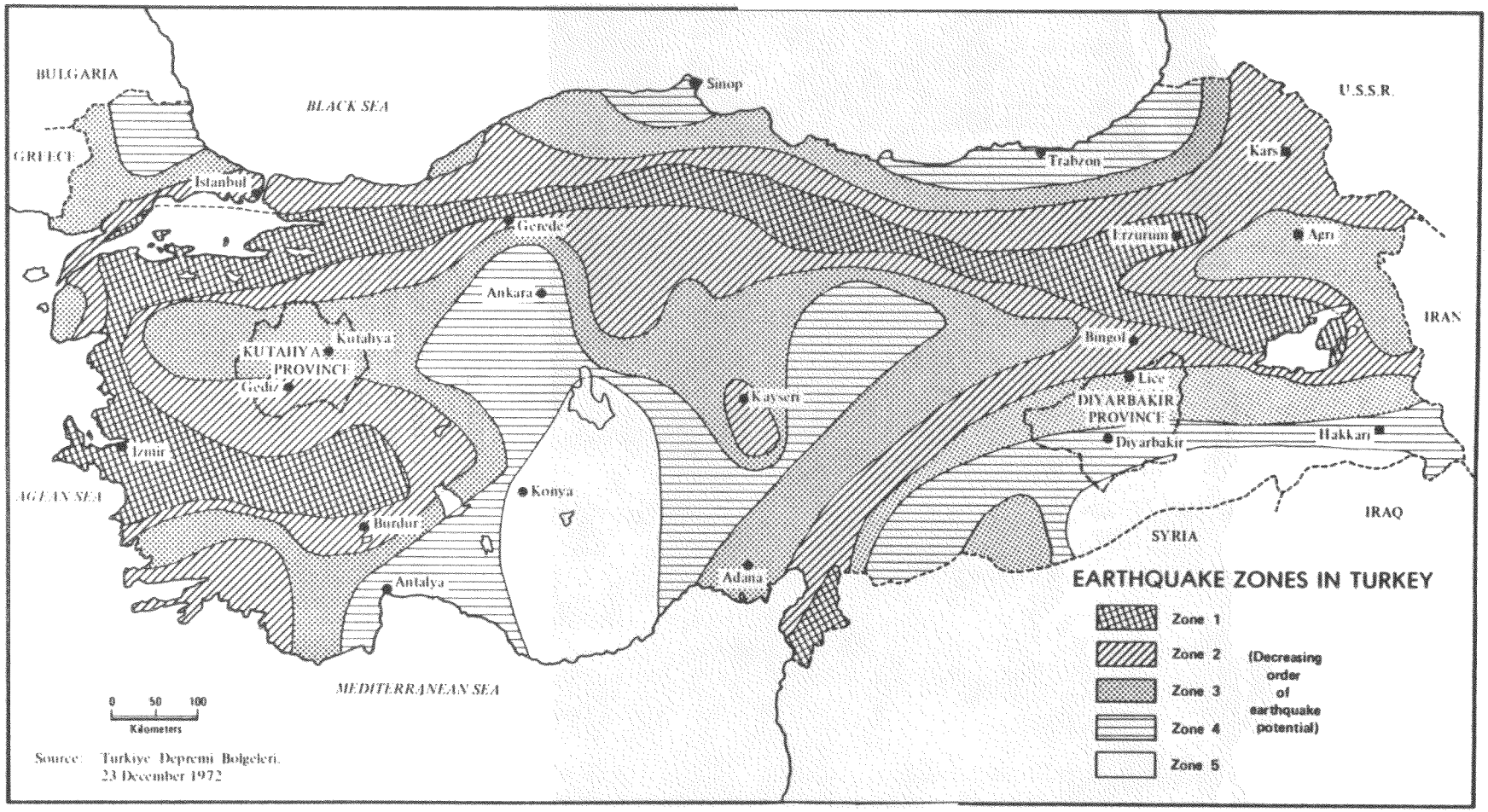
BULGARIA
BLACK SEA
GREECE
Sinop
U.S.S.R.
Trabzon
Kars
Istanbul
Gerede
Erzurum
Agri
Ankara
IRAN
KUTAHYA PROVINCE
Kutahya
Gediz
Bingol
Lice
DIYARBAKIR PROVINCE
Kayseri
Izmir
Diyarbakir
Hakkari
AGEAN SEA
Konya
IRAQ
Burdur
SYRIA
Antalya
Adana
EARTHQUAKE ZONES IN TURKEY
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
(Decreasing order of earthquake potential)
MEDITERRANEAN SEA
0 50 100
Kilometers
Source: Turkiye Depremi Bolgeleri. 23 December 1972

FIG. 1