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ASSESSING DISASTER MAGNITUDE: . A SOCIAL SCIENCE APPROACH

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ONE major impediment to rational disaster response is the inadequate definition and, therefore, the loose usage of the terms involved. To the United States Office of Emergency Preparedness *(1)*, disaster was the "occurrence or imminent threat of widespread or severe damage, injury, or loss of life or property resulting from any natural or man-made cause." Other authors have defined disaster more quantitatively. Sheehan and Hewitt *(2)*, for example, in their pilot survey of global natural disasters for the years 1947–1967, described a major disaster as an event satisfying one or more of the following criteria: it caused at least $1,000,000 in damage, or killed or injured at least 100 people. Michaelis *(3)* considered "accidents" as events in which one person but not more than 999 people were killed or placed in imminent danger of being killed whereas "disasters" similarly involved 1,000 up to 1,000,000 persons, and the term "catastrophe" was reserved for events killing or imminently endangering 1,000,000 or more individuals.

A major difficulty in defining disaster is the varying relationship between damage suffered and lives lost. This contrast is a key distinguishing factor in both the Developed and Developing Worlds. Dacy and Kunreuther *(4)* have recently demonstrated that fatalities caused by natural disasters are declining in the United States, although property losses are still escalating. This trend is repeated throughout the Developed World and, indeed, distinguishes it from the Developing World where death and injury totals caused by hazards remain extremely high. During the years examined by Sheehan and Hewitt, the average loss of life per disaster impact was 1065 in Africa and 1216 in Asia (excluding the USSR). In contrast, an average of only 37 fatalities occurred during each North American disaster. The situation is reversed when economic losses are considered, property damage being by far the greatest in the Developed World.

DISASTER MAGNITUDE. This dichotomy hinders realistic global comparisons of disaster and increases the need for a magnitude scale based on units which can be applied ubiquitously without assigning any unrealistic monetary values to lives lost or injuries sustained. Cognizance must clearly be taken of the many disparate parts to disaster—fatalities and injuries, financial losses, and societal disruption—in order adequately to assign some measure of magnitude to it. The problem of establishing disaster magnitude then can only be resolved satisfactorily by establishing some common unit of measurement to apply to such apparently incommensurable facets of disaster. One aspect, however, is common to all such discrete components of calamity: they evoke, or are associated with, some adaptive or coping behavior on the part of the affected individuals; that is they cause "stress."

The scaling of life-event and life-style items which cause stress is an aspect of psychophysics, the division of psychology that deals with man's ability to make subjective magnitude estimations about certain of his experiences *(5)*. Holmes and Rahe *(6)* have developed a social readjustment rating scale by questionnaire testing of a sample of convenience composed of 394 varied subjects. Each subject was asked to rate a series of 43 events, such as the death of a spouse, personal injury, change in work or sleeping habits, according to the relative degree of required adjustment. Each event was compared with marriage, which had been assigned an arbitrary value of 500 (later all scores were divided by 10). Although obviously individual differences occurred, Holmes and Rahe reported that consensus was high concerning the relative order and magnitude of the means of items. The social readjustment rating scale can be used to assign "life stress" values to those events commonly occurring during a disaster (Table 1). The validity of these values has since been confirmed by a variety of other studies *(7)*.

TABLE 1
ABRIDGED SOCIAL READJUSTMENT RATING SCALE
(After Holmes and Rahe)

Life Event	Mean Stress Value
Death of spouse	100
Death of close family member	63
Death of close friend	37
Personal injury or illness	53
Injury or illness of close family member	44
*Injury or illness of close friend	25
Loss of employment	47
Change in financial state	38
Revision of personal habits	24
Change in living conditions	25
Change in work hours or conditions	20
Change in residence	20
Change in schools	20
Change in recreation	19
Change in social activities	18

* Author's estimate.

It is this concept, the generation of "stress" by events, which is the basis for the disaster magnitude scale presented here. The first step in establishing the total stress associated with an adverse incident must be the assessment of that caused by deaths and injuries. Death differs from injury, of course, by more than simple magnitude. It does, in fact, represent a threshold, the significance of the crossing of which has been a matter of philosophical and religious debate for thousands of years. Since death apparently precludes adaptive behavior, it is impossible to assign a meaningful stress value to an individual killed during a disaster. In many cases death may be instantaneous, in others it may be a welcome respite from hours of suffering beneath the rubble of collapsed buildings. In the present study, in order to overcome the difficulty of assigning a meaningful stress value to an individual killed during a disaster, it is assumed that the stress associated with death in disaster is equal to that which would have been experienced had the individual lived and his or her spouse been killed. Additional stress is assigned to such a fatality if relatives or friends have been killed or injured, or his social environment disrupted. Naturally these assumptions are open to question but may be considered at least as valid as assigning a dollar value to the life lost, a more usual accounting mechanism *(8)*.

If this procedure is accepted, then an approximate value for the total stress caused by fatalities and casualties suffered during a disaster can be calculated. Such a value is obtained by summing the stress suffered by eight distinct groups: the dead, their spouses, close family members and friends, and the injured and those with similar relationships to them. Before such a value can be calculated, however, the average number of married victims and their total close family members and friends must first be established.

The percentage of the population that has entered into matrimony naturally varies from state to state and country to country and, therefore, so too does the proportion of disaster victims likely to be married. In North America, taken as exemplifying the Developed World, approximately 45 percent of the population is married *(9)*. In the Developing World such information may be less readily available; in India, for example, more than 85 percent of marriages are religious, yet most Hindu marriages have not been registered in any official sense. It is, therefore, extremely difficult to establish the percentage of the population that is married *(10)*. Since the large number of children below 15 years of age (42 percent in India), and the small number of old people (12 percent above 50 years of age in India), are also characteristic of the Developing World, the author suggests that some 43 percent of the population are perhaps typically married in such countries. This figure is adopted for developing areas because the unbalanced age structure of their populations is commonly counterbalanced by early marriage, which in effect reduces the length of childhood. Family size in the Developed World is generally smaller than in the Developing World. In North America the average family size is 3.2 whereas in India it is 5.0. If one includes close relatives not living in the household, the figures are, perhaps, more properly 4.5 and 7.5.

It is no less difficult to assign a value to the average number of close friends a disaster victim might be expected to have.

The nature of close and lasting friendships has been the subject of considerable study in the social sciences and stands at the core of a wide range of literature. F. McKinney *(11)* cites a study carried out at a Midwestern university where students claimed on average 53 friends; this large number apparently reflected an inability to distinguish true friends (those with whom a lasting, intimate and deep affection was shared) from acquaintances. McKinney views two or three staunch friends as a minimum personal requirement. Personal experience and discussion with others has led the author to adopt the latter figure, three, as being typical of the number of individuals who, as close friends, would suffer any appreciable stress on the death or injury of a disaster victim. This figure seems appropriate for use in both the Developed and Developing Worlds.

If we accept the preceding assumptions concerning the percentage of victims likely to be married, their family sizes and number of close friends, it becomes possible to assign a stress value to the deaths and injuries associated with disaster.

Disasters, however, also cause stress by their impact on the infrastructure and through the societal disruption that this precipitates. Ideally, to calculate accurately the stress each individual suffers as a result, details of his or her place of employment, financial investments, and recreational and religious habits should be considered. Clearly, such information is rarely, if ever, fully available, particularly during or after a disaster which typically results in large and permanent data losses.

To circumvent this difficulty an attempt has been made to provide mean stress values associated with such infrastructural disruption (Table 2). The mean stress values assigned to events of differing intensity are based on Holmes and Rahe's social readjustment rating scale, as well as on a search of the disaster literature, discussions with numerous individuals and personal experience. For example, to assign a total infrastructural stress value to an intensity XII disaster, such as the May 8, 1902, eruption of Mt. Pelée, which destroyed St. Pierre *(12)*, the stress value in Table 2 (200) is multiplied by the total population affected (in this case, 30,000). Although considerable care has been taken in assigning stress values to events of differing intensity, it should be clearly understood that these could be improved by introducing a wide range of disaster survivors to the social readjustment rating questionnaire. Indeed, the values presented in Table 2 should be viewed as provisional, subject to revision as additional data become available. The event intensity scale, which forms part of this table, is conceptually similar to the modified Mercalli scale (used to describe the intensity of earthquake impact); however, it differs from it in permitting intensities to be assigned to any event (natural or human) having environmental ramifications. This scale has been developed by the author. Its rationale is derived from the fact that, to a large degree, it is the effect, rather than the cause, which is of dominant significance in disaster. The event intensity scale is designed to allow the classification of phenomena on the basis of their impact; thus, for example, similar weight is given to the worst affected areas of St. Pierre in 1902 and Yungay in 1970. Since the physical and social consequences of these events were similar, although their causes were not, both would be assigned the maximum event intensity score of XII on the scale. Naturally, as with the modified Mercalli scale, intensity would normally decline with distance from the source of the disturbance, whether this be a river channel, volcanic crater or market for contaminated grain. A series of differing event intensities, diminishing from the "core," would normally be associated with any single disaster, from which stress values for the affected population could be calculated.

If the assumptions made during the preceding discussion are accepted, it now becomes possible to assign total stress values to any event. Two formulas appear to be required, however, because of differences in the social fabrics of the Developed and Developing Worlds. The basis of the first component is described in order to illustrate how the formulas were derived. The figure 445 was obtained by adding the stress value the deceased was considered to have suffered (100) to that experienced by the husbands or wives of the 45 percent of the fatalites that were married (45). Also totalled were the stress units experienced by close family members who were

TABLE 2
INFRASTRUCTURAL STRESS VALUES

Event Intensity	Designation	Characteristics	Stress Value
I	Very minor	Instrumental	0
II	Minor	Noticed only by sensitive people.	2
III	Significant	Noticed by most people including those indoors.	5
IV	Moderate	Everyone fully aware of event. Some inconvenience experienced, including transportation delays.	10
V	Rather pronounced	Widespread sorrow. Everyone greatly inconvenienced; normal routines disrupted. Minor damage to fittings and unstable objects. Some crop damage.	17
VI	Pronounced	Many people disturbed and some frightened. Minor damage to old or poorly constructed buildings. Transportation halted completely. Extensive crop damage.	25
VII	Very pronounced	Everyone disturbed; many frightened. Event remembered clearly for many years. Considerable damage to poorly built structures. Crops destroyed. High livestock losses. Most people suffer financial losses.	65
VIII	Destructive	Many injured. Some panic. Numerous normal buildings severely damaged. Heavy loss of livestock.	80
IX	Very destructive	Widespread initial disorganization. Area evacuated or left by refugees. Fatalities common. Routeways blocked. Agriculture adversely affected for many years.	100
X	Disastrous	Many fatalities. Masonry and frame structures collapse. Hazard-proofed buildings suffer considerable damage. Massive rebuilding necessary.	145
XI	Very disastrous	Major international media coverage. Worldwide appeals for aid. Majority of population killed or injured. Wide range of buildings destroyed. Agriculture may never be reestablished.	180
XII	Catastrophic	Future textbook example. All facilities completely destroyed; often little sign of wreckage. Surface elevation may be altered. Site often abandoned. Rare survivors become life-long curiosities.	200

neither the disaster victim nor married to the deceased (189) and those units suffered by friends (111). The death of one individual in the Developed World was then considered to generate 445 stress units. The first component in formula (2), 630, is larger since family size in the Developing World is greater. Casualty stress coefficients were derived in a similar manner. The third component in the formulas is an infrastructural stress value. It was calculated by assigning an event at least one intensity (Table 2) and, therefore, an associated stress value. For example, in an area experiencing intensity X, all members of the population were considered to suffer a stress value of 145. By multiplying this value by the total number of affected inhabitants, an infrastructural stress value, the third component, was derived. Where the event's intensity decline is with distance from a central core, as for example in an earthquake, infrastructural stress values should be calculated for each zone and then summed. The two formulas which follow were derived using these principles:

$$TS_{DD} = 445a + 280b + cd \quad (1)$$

and $$TS_{DG} = 630a + 410b + cd \quad (2)$$

where TS_{DD} = total stress caused during a calamity occurring in the Developed World

TABLE 3
EXAMPLES OF EVENT MAGNITUDE

Event	Location	Date	Magnitude
Plague (Black Death)	Europe/Asia	14th century	10.9
Spanish Armada	British coastal waters	July 21-29, 1588	7.2
Black Hole of Calcutta	Bengal, India	1756	5.0
Eruption of Mt. Pelée	Martinique	May 8, 1902	7.3
Landslide	Frank, Alberta, Canada	April 29, 1903	5.1
Titanic sunk by iceberg	South of Newfoundland Grand Banks	April 14–15, 1912	6.1
World War I	Europe	1914–1918	10.5
Munitions ship explosion	Halifax, Nova Scotia, Canada	1917	7.1
Train derailment in tunnel	Modane, France	Dec. 12, 1917	5.2
Great Purge	USSR	1936–1938	10.2
World War II	World	1939–1945	11.1
Atomic Bomb	Hiroshima, Japan	Aug. 6, 1945	8.2
Tsunami	Hawaiian Islands	April 1, 1946	5.8
USS Thresher lost	Off Cape Cod, Mass.	April 10, 1963	4.7
Glacier avalanche	Yungay, Peru	May 31, 1970	8.1
Mass poisoning from fungicide-treated grain	Iraq	1971	7.4
Flood	Rapid City, S. D.	June, 1972	6.6
Earthquake	Managua, Nicaragua	Dec. 23, 1972	7.9
Tornado	Xenia, Ohio	April 3, 1974	6.4
Cyclone (Tracy)	Darwin, Australia	Dec. 25, 1974	6.6
Bus skidded into lake	Japanese Alps	Jan. 1, 1975	4.1

TS_{DG} = total stress caused during a calamity occurring in the Developing World
a = number of fatalities
b = number of seriously injured
c = infrastructural stress value associated with an event of this intensity (Table 2)
d = total population affected.

The author appreciates that these formulas rest on numerous generalizations. It is assumed, for example, that death and injury caused by hazards will be spread evenly throughout the population, irrespective of age or sex. This is not typically the case because the young and old are usually most vulnerable. During the Bangladesh storm surge of November 12–13, 1970, the greatest loss of life was experienced in these two categories since neither group was able to cling to trees, an act which saved many others from drowning *(13)*. Nor do these formulas take into account second-generation disasters, such as famines, epidemics or revolutions which are frequently the ultimate result of an initial adverse event. Any social benefits associated with disaster are also neglected. A further weakness is that secondary economic losses, caused elsewhere by production disruption in the affected area, are neglected, as is stress caused among sympathetic members of the national or international community not directly involved. It should be pointed out, however, that stress caused by second-generation disasters, secondary economic losses and external sympathy can also be assigned an infrastructural value from Table 2 and calculated separately. Similarly, although some might argue that death and injury, being so common in the Developing World, cause less stress to those affected, Holmes and Rahe's data tend to negate this view. Secondary stress caused by disasters occurring in the Developed World is normally considerably greater,

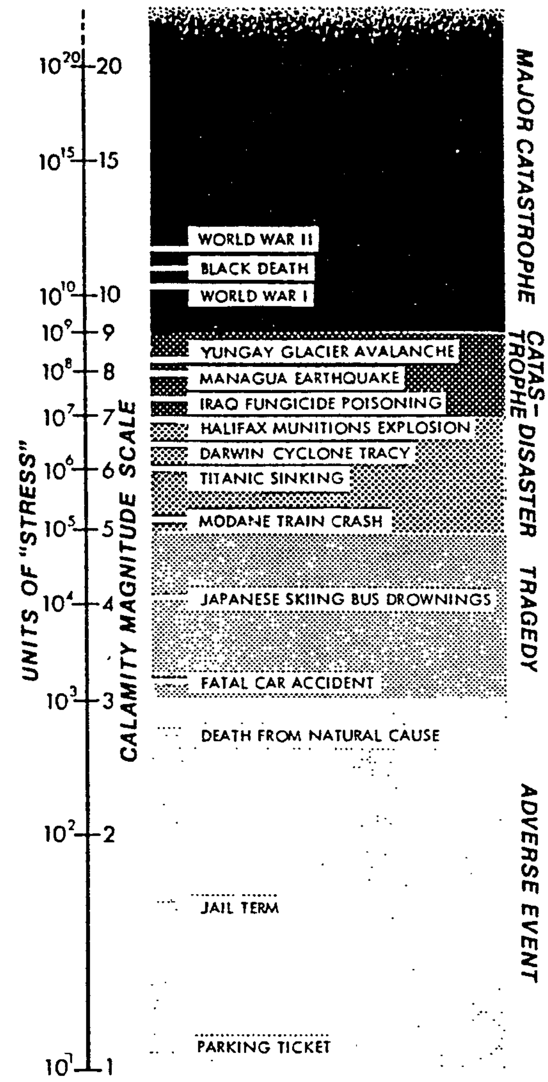

Figure 1. Calamity magnitude scale.

however, than in the Developing World. This is because news media coverage is extensive in the former and the population is highly literate. As a result, some relatively minor events, such as the sinking of the Titanic, have generated widespread international sympathy. That is, the news itself creates magnitude III-IV events elsewhere, thus increasing the stress associated with the original event. For example, the author has estimated that the sinking of the Titanic directly caused some 1,460,000 stress units, but generated over 2.5 billion stress units of public sympathy.

DISASTER SCALE. Applying the formulas already presented, the total stress associated with a wide range of events has been calculated (Table 3). The volcanic eruption of Mt. Pelée was determined to have caused 25,022,000 units of stress, for example, as compared with 120,200,000 stress units associated with the glacier avalanche which on May 31, 1970, destroyed Yungay, Peru. Other examples calculated included a two-car collision (*cd* in this case was taken to be a major financial loss to two car owners) in which two fatalities and three injuries were sustained and, therefore, 1806 units of stress generated, and the First World War which was responsible for approximately 53 billion stress units.

Once calamitous events have been quantified in this manner, it becomes possible to establish a magnitude scale by which significance is assigned according to the total stress generated. A logarithmic scale, developed by the author, is based on associated event stress (Figure 1). "Adverse events," such as a single death from natural causes, are considered to generate between 0 and 10^3 units of stress and to range in magnitude from 0 to 3 on the scale. "Tragedies," such as automobile accidents with several fatalities, and light aircraft crashes killing pilot and passengers, cause 10^3 to 10^5 units of stress. Such tragic events range from 3 to 5 on the scale. "Disasters," from 5 to 7 on the logarithmic scale, generate between 10^5 and 10^7 units of stress. Examples experienced have included the April 3, 1974, Xenia, Ohio tornado, 6.4; and the June, 1972, Rapid City, South Dakota floods, 6.6. On the proposed scale, "catastrophes" range in the total number of stress units generated from 10^7 to 10^9, and are considered to vary in magnitude from 7 to 9. Examples have included the Managua, Nicaragua earthquake of December 23, 1972, 7.9; and the 1971 mass poisonings experienced in Iraq from grain treated with mercury fungicide, 7.4. The scale reserves the definition "major catastrophe" for events causing more than 10^9 stress units. Included in this category have been the Black Death of 14th century Europe, 10.9, World Wars I, 10.5, and II, 11.1. The scale is, of course, open-ended, reflecting both the global population explosion and man's penchant for nuclear weapons.

CONCLUSIONS. In common with all attempts to generalize about the nature of society, the event magnitude scale presented here has obvious limitations. It does, however, also possess several features which, in the author's opinion, establish a case for its utility. Its use, for example, generates a single figure which characterizes a disruptive event, yet which reflects such disparate phenomena as death, injury, damage and societal disruption. By providing a common denominator, based on several components, the scale may enhance disaster comparison. The value of such a process to research is perhaps more obvious than to policy formulation.

In addition, this measure can be calculated extremely rapidly on the basis of casualty figures and a brief description of the damage alone, which allows rapid comparisons to be made with earlier events with which the information recipient may be far more familiar. Initial press reports of the December 25, 1974 cyclone damage experienced by Darwin, Australia, for example, allowed the author to place this event immediately at a magnitude of 6.6 on the scale, similar in size to the Rapid City floods.

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(13) See, for example, A. Sommer and W. H. Mosley in L. C. Chen, ed., *Disaster in Bangladesh: Health Crisis in a Developing Nation* (London: Oxford University Press, 1973).