THE GENESIS OF DISASTER

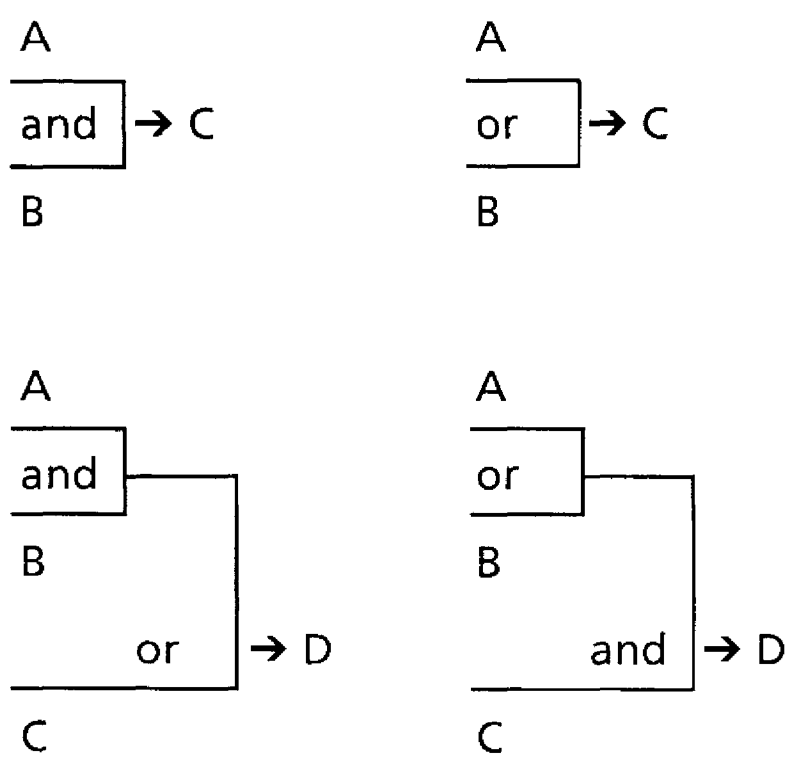
ACTORS are based on:

and gates — A and B → C

&

or gates — A or B → C

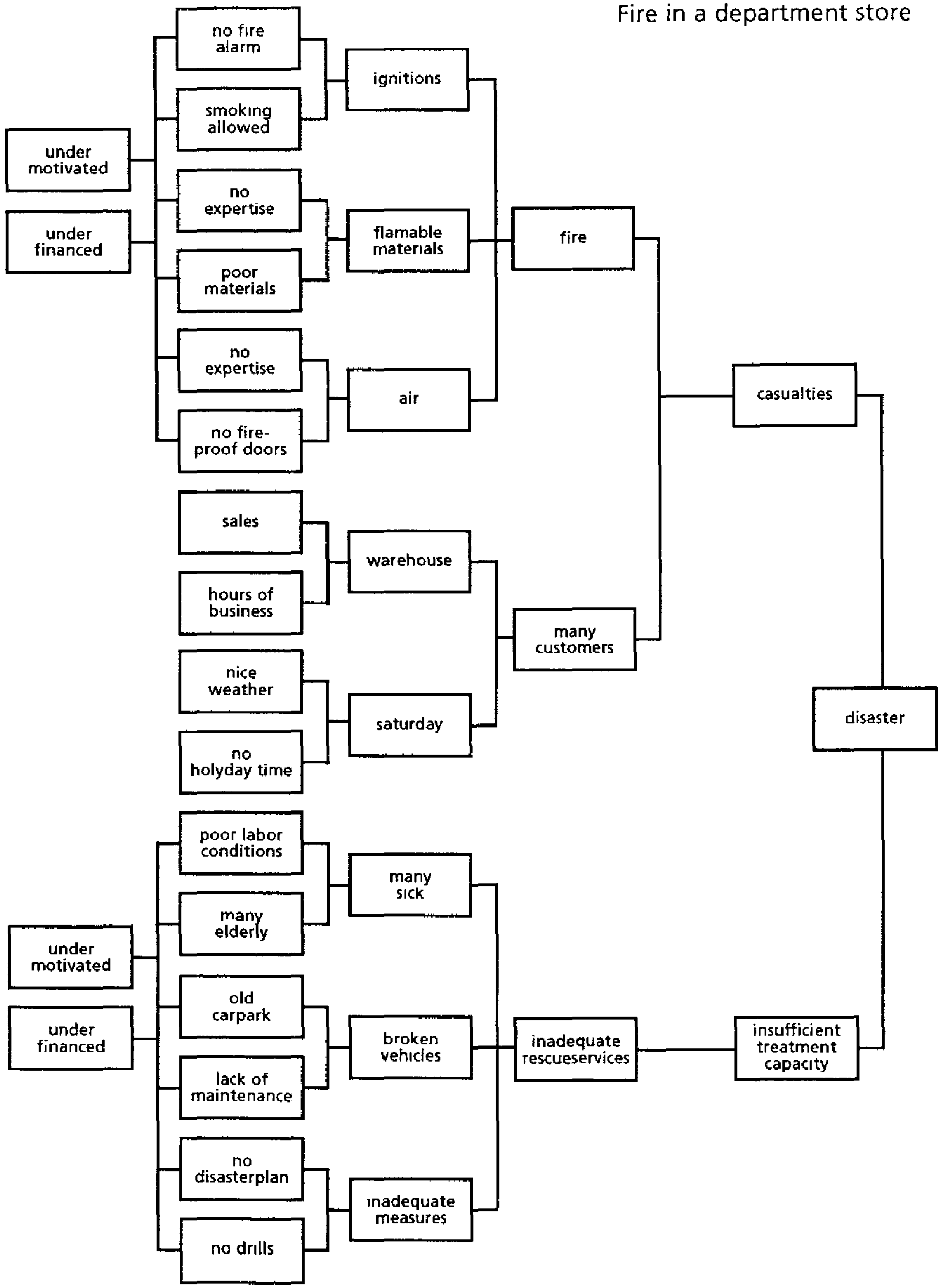
All kinds of combinations are possible:



Man has always been intrigued by disasters. For many centuries disasters were considered as dooms of God. Up till the industrial phase only naturally occurring disasters were the menace of mankind. Increasing technology based on more and more scientific discoveries created a transition from an agricultural phase to an industrial one in the history of man. The latter not only introduced the ability to gain more prosperity, but also to gain more destructive power. As a complication of both, man-made disasters were the consequence. Together with the explosion of world population this has led to mass casualty situations, varying from traffic accidents to world wars.
More than 200 million people were killed in the 20th century, a cruel age without an equal in the history of mankind.

Anyway, man-made or cultural disasters are open for analysis. Many, so called actors originating from the past could lead to this kind of disasters. Since the ferry "Harald of Free Enterprise" usually left the port of Zeebrugge with open cargodoors to rid the cardecks of exhaust fumes, this in itself was not the final cause of its capsizal. However, should these doors have been closed, this disaster would not have happened. Many actors from the past have played a role in this dramatic occurrence. All actors leading to a disaster could be traced back into the past which is probably only true for man-made disasters and not for naturally-occurring ones. These actors can act together or alone.

Fire in a department store



Let us consider a fire in a department store, which is shown in the graph. This graph should be read from the right to left! The combination of a fire (= destructive event) and many people has led to a sudden discrepancy between number of victims and their treatment capacity. Fire is a combination of heat, air and flamable material. Because of bargain sales and the right time of the day and week, the department store was crowded with people. On the other hand among the rescue personnel many were sick, which in itself was caused by bad labour conditons and relatively more elderly. Quite a number of cars of the ambulance services were out of order, because of, among other things, insufficient maintenance. Fire could have spread easily, because of lack of fire and smoke sensors, while smoking was not prohibited. Air could easily reach the fire, because the fire proof doors were malfunctioning. The common denominators for the fire and the inadequate mobilisation of medical rescue personnel were insufficient financial means and lack of motivation, and probably both are linked to one another.

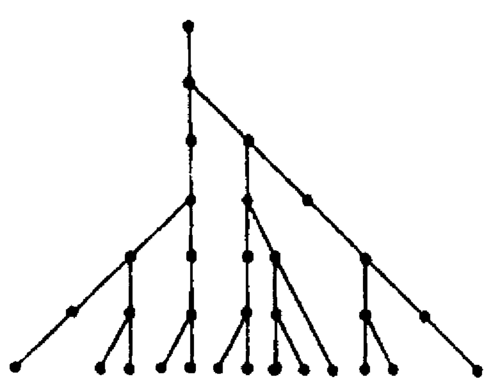
However with the birth of a new science, the mathematics of chaos, another new frontier for disaster medicine may be opened. This new science offers a way of seeing order and pattern where formerly only the random, the erratic, the unpredictable- in short the chaotic- had been observed. Research into this direction is initiated.

AN ALARM PROCEDURE*

* ADAPTED FROM AN ARTICLE IN THE
JOURNAL OF EMERGENCY MEDICINE (1985)

Growth of a rabbit colony

Months	Adult Pairs	Young Pairs	Total
1	1	1	2
2	1	2	3
3	2	3	5
4	3	5	8
5	5	8	13
6	8	13	21
7	13	21	34
8	21	34	55
9	34	55	89
10	55	89	144



n	an	Sn
1	1	1
2	1	2
3	2	4
4	3	7
5	5	12
6	8	20
7	13	33

If each person calls two other people (assuming that each call takes one minute), then for seven minutes the following scheme can be obtained:
a_n, calls per minutes (n); S_n, total numbers of calls.

Disaster procedures are initiated by an alarm scheme. This scheme alerts all the personnel who are involved directly or indirectly. The wide variety of schemes in existence are usually based on the features of locally prevailing situations. An alarm is normally raised by one person who calls various other people. These people in turn will call other people, and so on, according to prearranged plans. Certain mathematical principles can be applied to calculate the number of people who can be reached within a fixed period of time; or to calculate the time needed to alert a fixed number of people. The basics for these mathematical principles were mastered already bij Fibonacci in mediaeval times.

In 1202 Fibonacci raised and solved the following problem: Rabbits breed rapidly. It is assumed that a pair of adult rabbits produces a pair of young rabbits every month and that newborn rabbits become adults in two months and produce, at this time, another pair of rabbits. Starting with an adult pair, how big will a rabbit colony be after the first, second, third, etc. month?

During the first month a pair is born so that there are two couples present. During the second month the original pair has produced another pair. One month later both the original pair and the first born pair has produced new pairs so that two adults and three young pairs are present, etc.

Let a_n denote the number of adult pairs at the end of the n-th month. Thus we get the following sequence:

$a_1 = 1$, $a_2 = 1$, $a_3 = 2$, $a_4 = 3$, $a_5 = 5$, $a_6 = 8$,.....

This is the famous Fibonacci sequence. It has the following remarkable property:

$2 = 1 + 1$ or $a_3 = a_1 + a_2$,
$3 = 1 + 2$ or $a_4 = a_2 + a_3$,
$5 = 2 + 3$ or $a_5 = a_3 + a_4$, etc.

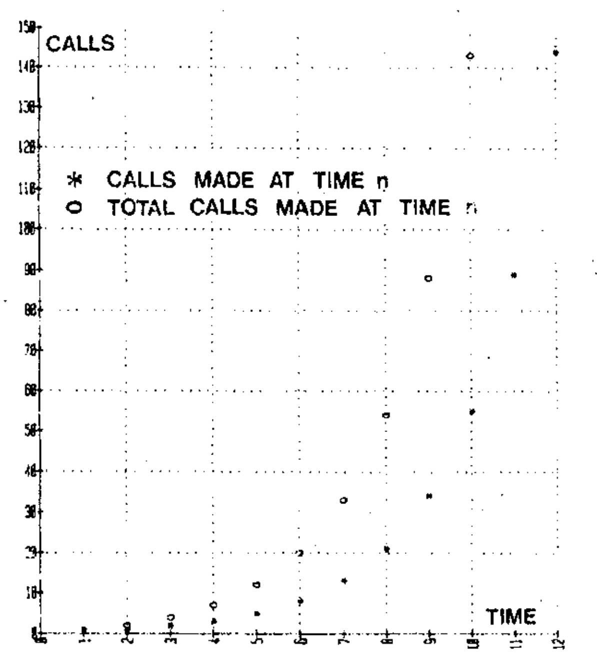
This sequence can also be applied to a certain alarm scheme. Providing that each person has to call two other people, the following scheme can be obtained, which in fact in a Fibonacci sequence. The number of people who can be called in each minute (assuming that each phone call takes one minute) is given by:

$$a_n = \frac{1}{\sqrt{5}} \bullet \left[\frac{1+\sqrt{5}}{2}\right]^n - \frac{1}{\sqrt{5}} \bullet \left[\frac{1-\sqrt{5}}{2}\right]^n$$

where n equals minutes.

Calls per minute and total numbers of calls after n minutes

Minutes (n)	Calls per minute (a_n)	Total number of calls (S_n)
1	1	1
2	1	2
3	2	4
4	3	7
5	5	12
6	8	20
7	13	33
8	21	54
9	34	88
10	55	143
11	89	232
12	144	376
13	233	609
14	377	986
15	610	1596
16	987	2583
17	1597	4180
18	2584	6764
19	4181	10945



Time versus calls
for the first 12 minutes

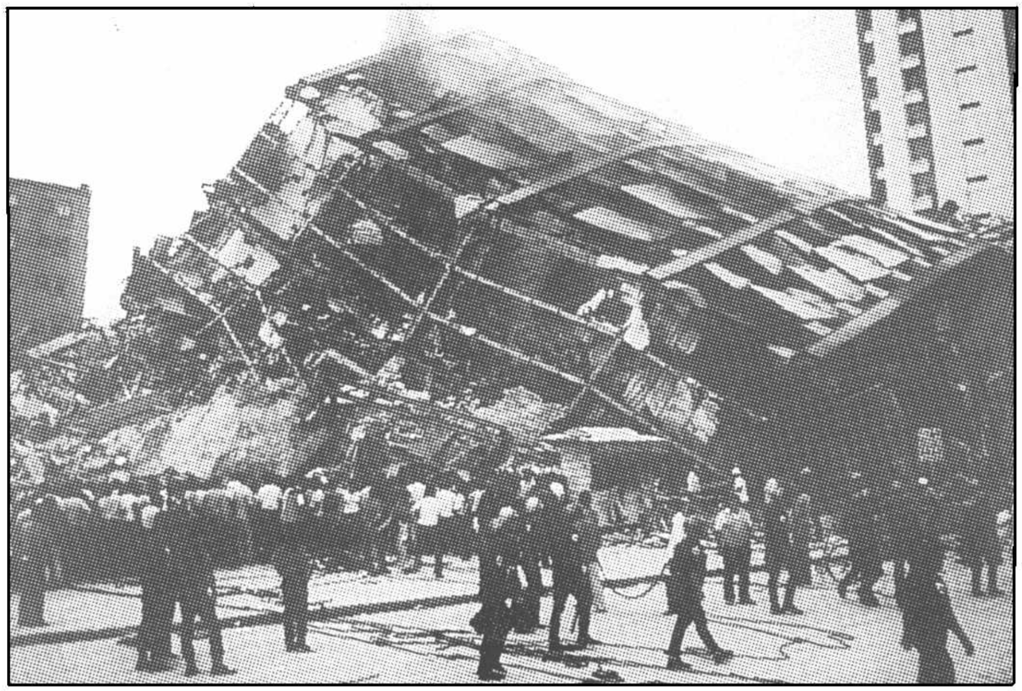
This equation looks rather complicated; however, with the pocket calculator it is easily calculated. For example, in the sixth minute (n=6) eight people are called; the total number of people called at that moment is, of course, the sum of the people called until that time and is given by:

$$S_n = a_{n+2} - 1$$

This implies that a table and a graph can be obtained of the total number of people alerted, the time required, and the calls per minute.
The advantage of this method is obvious, particularly if a large number of people have to be alerted; from a simple graph or table either the time or number of people required can be read. A formidable amount of people can be reached in a few minutes-in less than 20 minutes more than 10,000 people! Because each disaster procedure usually has its own alarm scheme some standardization of alarm procedures might be another advantage.
One disadvantage in the employment of this scheme, in which each individual calls two others, is that it may well be necessary, depending on the prevailing circumstances, to call one, or three, or even more. The second disadvantage is shown should any one person not answer the phone. In this case the caller should alert the two succeeding people of the missing person, which, of course, means that the graph or table no longer provides accurate figures.

DEFINITION, CLASSIFICATION AND SCORING OF DISASTERS*

* ADAPTED FROM AN ARTICLE IN THE JOURNAL OF EMERGENCY MEDICINE (1990)



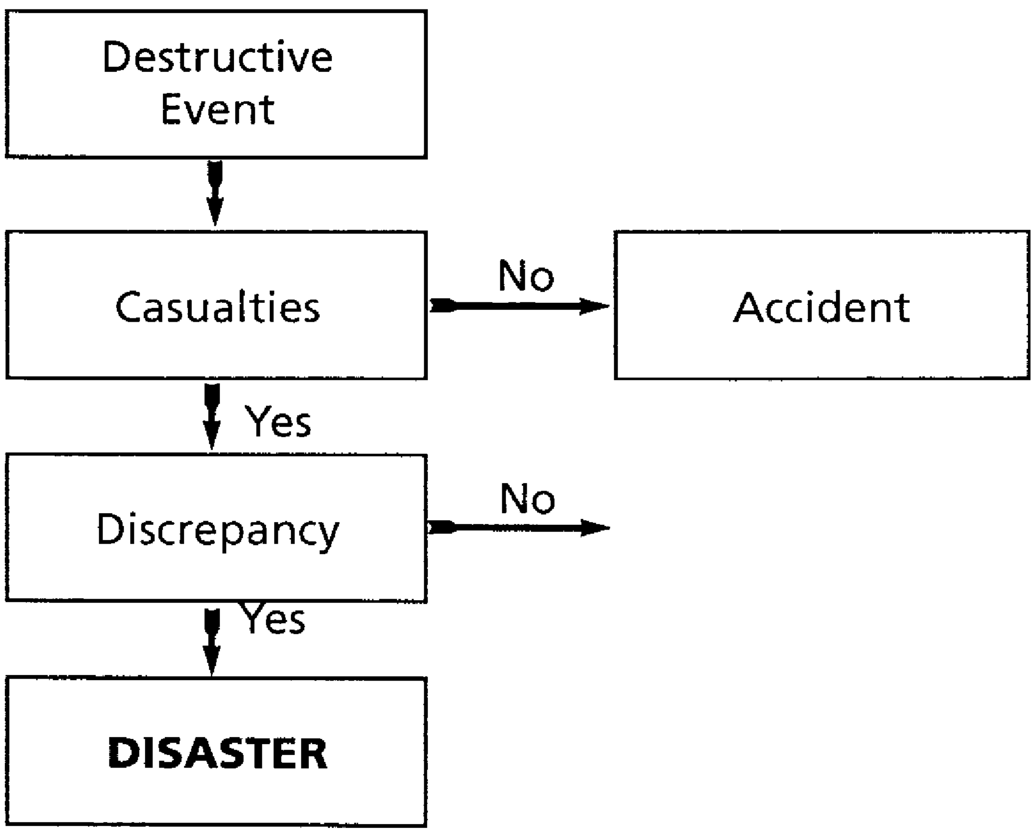
Man's experience down through the ages had frequently been attended by disasters of one kind or another. Our ancestors were tested by naturally-occurring disasters, whereas their modern descendants are also exposed to manmade hazards. In addition to loss of life and permanent disability of the victims, disasters produce considerable material damage.

It is difficult to evolve a meaningful definition of the word disaster. Most dictionaries identify this as a calamity or major accident and while this is correct, such a definition fails to reveal why a calamity or major accident should be a disaster. The word is applicable to everything from an event like an earthquake to occasions when two ladies turn up for a party wearing the same dress. From a medical point of view it is, therefore, of utmost importance to construct a simple definition for a disaster and, at the same time, to outline the criteria for its classification. Once such criteria have been determined, a scale can be evolved from which the gravity of the disaster can be assessed, which also allows the scientific comparison of various events.

Definition, classification, and measurement will create a foundation for that part of medicine called disaster medicine.

The first proposals for such a classification have come from William Rutherford. Later, an international working-party with representatives drawn from various countries and organizations continued his efforts and developed a meaningful definition. Simultaneously, a disaster severity scale was constructed. This chapter reviews these efforts and describes the methodology used.

A disaster can be defined as a destructive event that claims so many victims that a discrepancy arises between their number and the treatment capacity. A similar event without victims that does not cause this discrepancy would be called an accident.



Definitional algorithm following a destructive event

METHODOLOGY

Destruction of his hay shed by fire is a destructive event for the farmer, but not so for the neighbouring population. A serious traffic accident involving a bus with schoolchildren usually results in material damage with casualties and can be considered as a major accident for a town or village but hardly so for the region or province. These events can generally be dealt with adequately by the resources available locally (police, fire brigade, ambulance services, and hospitals). However, should the demands outstrip the potential of the resources, further aid can be obtained from neighbouring municipalities, and in this way the destructive event with casualties may acquire regional or even national proportion. This could be the case with floods or earthquakes. On the other hand, it is also conceivable that a country may be confronted with widespread destruction involving no threat to individuals or life.

From a medical point of view, a distinction should be made between destructive events with or without casualties and with or without extra mobilization of medical resources. A destructive event without casualties, but with extra mobilization of other than medical resources should be regarded as a calamity. A destructive event with casualties and without extra mobilization of medical resources should be considered as an accident, and with extra mobilization of medical resources as a disaster. Consequently, a disaster was defined as a destructive event that causes so many casualties that extra mobilization of medical resources in required. Detailed consideration of this definition, however, brought further interesting facets to light.

First, a destructive event: Civil disturbances may account for a large number of victims yet are not necessarily destructive in the sense that a great deal of material damage is caused.

1. THE EFFECT ON THE SURROUNDING COMMUNITY:

simple(1)———————————— compound (2)

2. DISASTERS CLASSIFIED ACCORDING TO ORIGIN

Man-Made (0)		**Naturally Occurring(1)**
Traffic		Fire
Explosion		Earthquake
Structure collapse		Hurricane, tornado
Fire		Volcanic eruption
Panic		Avalanche, mud slide, land slide
Civil disturbance		Meteoric collision
Nuclear accident		Drought
Poison gas		↓
Local wars →	(Refugees) →	Famine
		↓
		Epidemic

The majority of disasters give rise to victims with mechanical (including thermal) traumata: wounds, sprains, bleedings (internal/external), fractures, dislocations, concussions and organ damages. The minority of disasters results in chemical, nuclear and microbial lesions.

Second, the medical resources: These can also be defined and assessed, although the availability and stage of development of such services is not universally the same, they nevertheless exist.
Third, casualties: Although in fact the number of injured is known, the real concern is the relationship between the number of casualties and the potential of the resources available. Even a serious explosion or fire need not be a disaster in the presence of adequate facilities for rescue and treatment.
Since the medical resources could not only increase their treatment capacity by extra mobilization, but also by optimizing their own disaster preparedness, the definition was adapted later into: "A disaster is a destructive event that causes a discrepancy between the number of casualties and their treatment capacity". The breaking-point is indicated by the medical severity index and is described in the next chapter. The algorithm of the latest conception mentioned is shown in the figure.
From the above it would appear that disasters may be classified, and at the same time graded or scored, according to:

1 The effect on the surrounding community, with further differentiation into a simple effect and compound effect.
  In fact, the occurence of a disaster and the response thereto, in the form of initiation and coordination of the rescue services, are intimately associated with each other. In the case of a simple disaster, the integrity of the surrounding community remains intact, and the (extra) resources of the local and regional rescue services prove adequate to deal with the situation. Should a compound disaster occur, in which case the resources available locally and regionally are unable to cope alone, the involvement of national and international organizations is required. A rail-traffic accident involving a passenger train in a West-European country might be given as an example of a simple disaster whereas an earthquake in a densely populated region of North Africa could give rise to a compound disaster. A simple disaster is accorded a score of 1, whereas a compound disaster receives a score of 2.

2. The cause: In this case, a differentiation is drawn between naturally occurring and cultural (man-made) disasters. Man-made disasters are generally less complicated and more confined than natural disasters, for which reasons cultural disaster are accorded a score of 0 and the natural sort a score of 1. Of course, a major war could be an exception to this general rule.

3 The duration of the cause

< 1 hour (0)
1 - 24 hours (1)
> 24 hours (2)

4 The radius of the disaster area in which casualties have fallen.

< 1 km (0)
1 - 10 km (1)
> 10 km (2)

5 The number of casualties dead and wounded requiring medical treatment

< 100 (0)
100 - 1000 (1)
> 1000 (2)

6 Average severity of the injuries sustained:

$$S = \frac{T1 + T2}{T3}$$

0	1	2
$T1 + T2 \ll T3$	$T1 + T2 \approx T3$	$T1 + T2 \gg T3$

3. The duration of the cause of disaster: This can be short (less than 1 hour), relatively long (1-24 hours), or long (more than 24 hours). The majority of simple disasters occurs instantaneously, while compound disasters are usually characterized by a longer initiation time (eg, earthquakes, famines, epidemics). The subdivision into short, relatively long, and long is arbitrary and may have to be revised. The subdivisions are given scores of 0, 1 and 2 respectively.

4. The radius of the disaster area: This can be small (less than 1 km), relatively large(1-10 km), or large (more than 10 km).
   From a medical viewpoint, the disaster area implies that area in which casualties have fallen. It is not, therefore, that area characterized by damage, for example, broken glass. Scores of 0, 1 and 2 are accorded, respectively.

5. The number of casualties (N): An arbitrary division of the number of casualties is made as follows:
   minor: 25-100 casualties, dead and wounded, requiring medical treatment;
   moderate: 100-1000 casualties, dead and wounded, requiring medical treatment;
   major: more than 1000 casualties, dead and wounded requiring medical treatment;

   Even a few casualties may give rise to enormous problems to unprepared communities, whereas large numbers of injured may hardly exhaust resources that are adequate and well-organized. The casualties requiring admission to hospital form, from a medical point of view, the crucial group; the dead and slightly injured, who do not require inpatient treatment, are, in this respect, less important. The groups are graded with scores of 0, 1, and 2, respectively.

6. The average severity (S) of the injuries sustained by living victims: The usual distribution of injuries sustained is given as serious 10%, moderate 30% (both groups requiring hospitalization) and light 50% (10% dead). Should there be a relatively large number of slightly injured or sick, requiring no hospitalization, a score of 0 is accorded; otherwise, in the usual case a score of 1 is given. On the other hand, should the disaster result in a relatively large number of seriously injured or very ill a score of 2 is accorded.

7. The medical rescue time: rescue, primary treatment, transportation

< 6 hours (0)
6 - 24 hours (1)
> 24 hours (2)

DISASTER SEVERITY SCALE

Scale	Location	Cause	Date
12	Armenia (USSR)	Earthquake	1988
11	The Netherlands(NL)	Floods	1953
10	Bhopal (India)	Poisonous gas	1984
9	Mexico City (Mexico)	Earthquake	1981
8	Texas City (USA)	Explosion	1947
7	Tenerife (Spain)	Traffic	1977
6	Piper Alpha (UK)	Explosion	1988
5	Los Alfaques (Spain)	Explosion	1978
4	Zeebrugge (B)	Traffic	1987
3	Beek (NL)	Explosion	1975
2	Prinsenbeek (NL)	Traffic	1972

7. The time required by the rescue organizations for initiation of primary treatment,organization of transport facilities, and evacuation of the injured could be short (less than 4-6 hours), relatively long (6-24 hours) or long (more than 24 hours).

   In the case of a compound disaster in such an area, the primary treatment time will be that time required for the institution of the most urgent first-aid measures at the site, followed by definitive medical treament. The score allocation is therefore arbitrary and may require revision according to the particular circumstances. The subdivisions are graded with a score of 0, 1, and 2, respectively.

Thus, by attributing to the individual classification a grade of 0, 1 and 2, the score itself increasing with gravity, duration, number, or intensity, a figure is obtained which is the sum of the variously accorded scores and which lies between 1 and 13. This scale is called the Disaster Severity Scale (DSS). In order to avoid scale 0, the options of classification 1 were chosen as 1 and 2, instead of 0 and 1.
The DSS was tested by subjecting a number of disasters to a retrospective study. The table shows how assessment of these disasters in this way bore a reasonable similarity with the factual occurence. Two examples may explain the compilation of this table.
The Armenian earthquake in 1988 was a compound disaster (score 2), of natural origin (score 1), the duration of the cause was relatively long (score 1), the radius of the disaster was more than 10 km (score 2), the number of casualties amounted to 50,000 (score 2) with many seriously wounded victims (score 2), while the time required by the rescue organizations was long (score 2). Summation of the individual score resulted in scale of 12.
The Prinsenbeek disaster in 1972 on the other end of the scale was a simple one (score 1), of man-made origin (score 0), the duration of the cause was short (score 0), the radius of the disaster area was small (score 0), the number of casualties requiring hospitalization amounted to 100 (score 1), with a "normal" distribution of categories (score 1), while the time required by the rescue organization was short (score 0). Summation of the individual scores resulted in a scale of 3.

BASICS of DISASTER MEDICINE

Definition

Classification

1. simple ↔ compound
2. man-made ↔ God-made
3. duration of cause
4. radius of impact area
5. number of victims (N)
6. severity factor (S)
7. rescue, primary treatment and transport time

Scoring

disaster severity scale

Discussion

Disaster medicine studies the medical and organization problems of disasters. It is a young branch of medicine and confusion still occurs because people use terms in different ways. The foundation of any science is definition, classification and measurement, and if disaster medicine is to grow and progress, it also must have a consistent and recognized definition, classification, and measurement of disasters. By using the criteria "casualties" and "discrepancy between number and treatment capacity" a simple definition of a disaster has been formulated. The classification scheme is based on variables, which are directly related to disaster, either to its origin or to its effect. By quantifying or weighing these variables and summing the individual scores, a disaster severity scale can be constructed, which runs from 1 to 13. This approach could provide a firm foundation for the science of disaster medicine, on which basis further development can be confidently expected.

In the event of general international agreement on the definition, the classification, and the associated Disaster Severity Scale, it should be possible to assess more accurately the gravity of a given situation. However, the publication of exact figures exposes cooperating countries to the possibility of criticism. For this reason, there may be initial resistance on the part of certain countries to joining such a registry scheme. This reservation should be overcome if exact disaster registration is to be established. Additionally, more precise registration would allow scientific comparison of disasters and perhaps also provide an answer to the question of whether the incidence of disaster occurence is increasing with the growing world population and technology.

A limitation of the practical use of this scoring system is that it can only be applied retrospectively. For this reason the medical severity index had been introduced and will be discussed in the next chapter. This index not only indicates the breaking point between accident and disaster, but also quantifies the medical severity instantaneously.