

AN EVALUATION OF CHEMICALLY RELATED DISASTERS USING
THE BRADFORD DISASTER SCALE

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In order to compare disasters arising from different sources it is necessary to apply quantitative measures. A classification system, the Bradford Disaster Scale (BDS) is presented. The proposed scale is logarithmic in nature and is based on the number of fatalities involved in the occurrence of a disaster. It is shown that the method is useful for hazard identification and quantification and can be used as a tool for structured and strategic planning. As an example of this technique evaluations of disasters that have occurred in chemical and allied industries world-wide, in Europe and the UK over the period 1970-1987 are presented.

Keywords:- Bradford Disaster Scale, Chemical Disasters, Classification, Magnitude, Frequency.

INTRODUCTION

Hillsborough, Bhopal, Mexico City, the Armenian earthquake, Ethiopian famine and the Herald of Free Enterprise are some of the more notable disasters that have occurred over the past few years.

Studies based on historical data covering a range of major incidents can be found in the literature and those presented by Fernandes-Russell (1), Grist (2), Griffiths and Fryer (3, 4) and Kletz (5) are typical examples.

It has been suggested that a disaster may be defined as:

"an event which afflicts a community, the consequences of which are beyond the immediate financial, material or emotional resources of that community".

For the purpose of the present study a disaster is defined as:

"an event where ten or more fatalities result from one event over a relatively short period of time".

Disasters may involve man-made events such as rail or air crashes, fires and explosions, or may be natural occurrences such as earthquakes or violent storms. there may be a combination of man-made and natural factors such as a combination of an inadequate dam design and abnormal weather conditions resulting in the collapse of the dam.

the event again may be localised in place and time as in the Clapham Common rail disaster or it may involve a large part of a nation such as flooding in Bangladesh.

To compare disasters of like occurrence or similar fatality rate, requires that each disaster be quantified numerically before any such comparison is

made. The Bradford Disaster Scale and associated classification system provides a methodology for the quantification of disasters based on the number of fatalities involved. This allows disasters arising from different sources and causes to be directly compared.

PRIMARY CLASSIFICATION OF DISASTERS

Disasters may be categorised into three classes:

Natural Disasters

These are generally beyond the ability of man to produce, influence or prevent, e.g. earthquakes, volcanic eruptions, cyclones etc.. The scale of the loss of life from natural disasters can range from a few individuals to many millions.

Man-Made Disasters

These are disasters of anthropogenic origin. Examples are air and rail crashes fires and explosions, mining and marine disasters. The associated loss of life from this type of disaster seldom exceeds several hundred.

Hybrid Disasters

These arise from a concatenation of anthropogenic and natural events. Man and his associated activities can produce natural disasters that would not otherwise have occurred or may significantly aggravate the consequences of natural disasters. Examples of this form of disaster are the subsequent flooding of the delta areas in Bangladesh due to the removal of the Himalayan forests, the large scale deaths that occurred in the developed nations due to the production of smog from the burning of fossil fuels.

The loss of life from this type of disaster can be, and usually is, large.

For the purposes of this paper, disasters have been classified by type into seventeen categories and these are presented in Table 1 associated with the degree of man's involvement.

For the purposes of the present study some of the categories will be grouped together as they will otherwise present difficulties in classifying source data. The differentiation between fire and explosion, avalanche or landslide is not always possible. Similarly the effects of drought, famine, plague and epidemic are often so interrelated that it is not possible to identify the primary cause of death.

The query against Hybrid Climatic disasters is that although the activities of man can influence climatic effects no disaster that can be completely classified in this manner has yet been identified.

THE SCALE OF THE PROBLEM

Within the last century over 400,000 people have lost their lives in disasters that have occurred within Europe. Within the United Kingdom, during the same period, 31,500 have suffered a similar fate.

During the period 1970-1987 483 people perished within Europe due to disasters occurring within chemical and allied industries. During the same period 45 people similarly lost their lives in the U.K..

TABLE 1 - Disaster Classification and Predominant Agent

<u>Disaster Type</u>	<u>Natural</u>	<u>Man-Made</u>	<u>Hybrid</u>
Avalanche/Rockfall	Yes	No	Yes
Landslide/Mudslide	Yes	Yes	Yes
Air Transport	No	Yes	Yes
Climatic	Yes	No	?
Drought	Yes	Yes	Yes
Famine	Yes	Yes	Yes
Epidemic	Yes	No	Yes
Plague	Yes	Yes	Yes
Earthquake	Yes	No	No
Fire	Yes	Yes	Yes
Explosion	No	Yes	Yes
Flooding	Yes	No	Yes
Marine Transport	No	Yes	Yes
Mining	No	Yes	Yes
Rail Transport	No	Yes	Yes
Volcanic Activity	Yes	No	No
Miscellaneous	No	Yes	Yes

Figure 1 gives a frequency curve for the last 100 years in ten year intervals for disastrous incidents occurring within Europe from all classes of source. This shows that there was a gradual increase for the first eight ten year periods followed by a much more rapid increase over the last two ten year periods. Figure 2 gives the corresponding figures for the U.K.. The plot here is more erratic but shows a decline over the first five ten year periods followed by a general increase especially over the ten year period covering 1978-1988.

Figure 3 shows the cumulative total of incidents for chemical and allied industries for the period 1970-1987 in Europe. It is seen that there may be a slowing down in the rate of disaster occurrence in the latter part of the period.

FREQUENCY OF DISASTERS BY TYPE

The annual frequency of disasters that have occurred over the past one hundred years by type are shown in Figures 4 and 5 respectively for Europe and the U.K. (the frequency of chemical disasters has been derived for the period 1970-1987,

The major difference between the two sets of results is that the U.K. suffers fewer natural disasters than Europe.

With regard to chemical and allied industries, the U.K. has a frequency rate of 0.28 incidents per annum whereas the total for Europe is 1.95 incidents per annum. If these two incident rates are compared on a demographic basis they are seen not to be inconsistent.

Although man-made and hybrid disasters are more frequent than natural disasters the number of lives lost in Europe due to the latter is far greater, c.f. Figure 6 (the 1898-1908 and the 1908-1918 results are reduced by a factor of ten for both categories). The results for the U.K. are the reverse of those which occur in Europe as a whole in that man-made and hybrid disasters claim more lives than do natural disasters. This is due to the relatively few and minor natural disasters that have occurred in the U.K. c.f. Figure 7.

THE BRADFORD DISASTER SCALE AND CLASSIFICATION

Due to emotional and other factors, there is often difficulty in comparing one disaster with another. Magnitude of fatalities is obviously an important factor, and to a lesser extent the type and origin of the cause. Due to the large variation in numbers of fatalities that can occur in a disaster, ranging typically from 10 to 1,000,000, the human mind has often difficulty in the perception of the magnitude and scale of disasters.

For this reason the following Scale of Magnitude is proposed:

TABLE 2 - Bradford Disaster Scale

<u>No. of Fatalities</u>	<u>Magnitude</u>
1	0
10	1
100	2
1000	3
10000	4
100000	5
1000000	6

Intermediate values are simply given by the common logarithm (base 10) of the number of fatalities.

This scaling method based on common logarithms has been previously used by Richardson (7); also a reference to this method can be found in Marshall (8,9).

Complementary to Table 2 a classification scheme can be introduced such that:

TABLE 3 - Classification

<u>Fatalities</u>	<u>Class</u>
0 - 10	0
10 - 10 ²	1
10 ² - 10 ³	2
10 ³ - 10 ⁴	3
10 ⁴ - 10 ⁵	4
10 ⁵ - 10 ⁶	5
10 ⁶ - 10 ⁷	6

In Table 4 examples are presented using this classification system for some notable disasters:

TABLE 4 - Notable Disasters by BDS: Magnitude and Classification

<u>Disaster</u>	<u>Fatalities</u>	<u>Magnitude</u>	<u>Class</u>
Flixborough	28	1.45	1
Clapham Common	36	1.56	1
Hillsborough	95	1.98	1
Piper Alpha	166	2.22	2
Bhopal	2000	3.00	3
Armenia	24000	4.38	4

Using the Bradford Disaster Scale and Classification System the frequency of disasters that have occurred in Europe and the U.K. over the past one hundred years can now be analysed as follows:

TABLE 5 - Frequency of Disasters by BDS Class (1888-1988)

<u>BDS Class</u>	<u>Europe</u>	<u>U.K.</u>
1	901	235
2	217	44
3	19	1
4	4	1
5	1	0

A similar analysis can be performed for disasters occurring in chemical and allied industries for the period 1970-1987:

TABLE 6 - BDS Classification of Chemical and Allied Industries Disasters (1970-1987)

<u>BDS Class</u>	<u>World</u>	<u>Europe</u>	<u>U.K.</u>	
0	93	18	3	
1	75	15	2	For chemical and allied industries an additional Class 0 has been introduced with fatalities 5-10.
2	5	2	0	
3	1	0	0	

Comparing Tables 5 and 6 the most notable feature is that the difference between Class 1 and 2 disasters is approximately a factor of five in frequency for total disasters but for chemically related disasters the factor rises to between seven and fifteen.

PROBABILITY OF OCCURRENCE

For emergency planning purposes it would be useful to know not only the probability of a disaster occurring within a given time period but also the likely magnitude of that disaster.

Within Europe as a whole, the probability that there will be no Class 1 disasters in any given year is very small. The most likely scenario is that within any given year Europe will experience between 5 and 11 Class 1 disasters. For Class 2 disasters the most likely probability is that Europe will experience at least two such incidents each year with the loss of between 200 and 2000 lives.

Class 1 disasters can be expected to occur within the U.K. twice every year, with a reasonable probability of the total rising to four, and for Class 2 disasters there is a reasonable probability of one such disaster occurring every three to four years.

The probability of up to, and including, Class 1 chemical and allied industries disasters occurring within Europe within any given year is high with a strong likelihood of two such events occurring per annum. For Class 2 disasters the probability of any such event occurring in any given year is lower and the expected frequency is one such event every ten years.

Chemical and allied industries within the U.K. can be expected to be responsible for one Class 0 incident (1 - 10 deaths) every six years and one Class 1 incident (10 - 100 deaths) every nine years.

The period of analysis for chemical and allied industries disasters has been divided into two distinct periods, i.e. 1970-1979 and 1980-1987 and the frequency rates calculated for each period.

TABLE 7 - Frequency of Chemically Related Disasters for the Periods 1970-1979 and 1980-1987 World and European Frequency Rates

<u>BDS Class</u>	<u>Frequency per annum</u>			
	0	1	2	3
<u>Period/Area</u>				
World				
1970-1979	5.3	4.5	0.3	0.0
World				
1980-1987	5.0	3.8	0.25	0.13
Europe				
1970-1979	1.2	1.0	0.2	0.0
Europe				
1980-1987	0.75	0.63	0.0	0.0

From the Table above it can be seen that there appears to be a small decrease in the frequency rate for all Classes on a world-wide basis, that is apart from the very major incident, the Class 3 disaster at Bhopal. The situation within Europe appears to show a more defined decrease in the frequency rates but this may be due in part to incomplete collection of data.

The most notable change within Europe which could explain this apparent drop is the introduction of the Seveso Directive Legislation of the European Commission in the late 1970s under which there is a greater degree of awareness of hazards and control of major chemical sites by the appropriate statutory authorities.

DISCUSSION

The problem of classification of disasters to allow comparisons between different types has been studied and some key factors identified. These key factors are number of fatalities, type of disaster and degree of man-involvement.

Within Europe there is a high expectation that between 5 and 11 Class 1 disasters will occur each year. Each of these Class 1 disasters will produce between 20 and 50 fatalities. One of these Class 1 disasters will recur in the chemical and allied industries. These industries will also be responsible for one incident per year which will produce between 5 and 9 fatalities, i.e. Class 0.

For the United Kingdom it is anticipated that two Class 1 disasters will occur each year with a strong probability that this could rise to five in any one year. Again in the UK one Class 2 disaster can be expected to occur every three years, although in the two years 1986-1988 in the U.K. there were in fact three Class 2 disasters. Pure statistical analysis at present is unable to establish whether the higher number of Class 2 disasters which have occurred within the past two years are random rare events or are the beginning of an toward trend arising from some societal change such as undermanning.

As regards overall planning strategies the present study suggests that emergency planning could perhaps concentrate on preparing for disasters of man-made origin and in which fatalities are between 20 and 50 with up to 100 survivors with severe injuries requiring immediate medical treatment. These estimates are of necessity of a very approximate nature.

However, it is believed that the present study does provide a methodology and a classification system for analysing disasters so that planning on a regional or national basis regarding provision of necessary and relatively scarce resources can be made on a quantitative judgemental basis.

CONCLUSIONS

1. A quantifiable system of classification has been demonstrated.
2. There has been an increase in the U.K. in the number of disasters over the past ten years of over 30%.
3. There is a high probability that a U.K. disaster will be either of transportation or fire origin.
4. The likelihood of a major natural disaster occurring within the U.K. is small.
5. The majority of disasters occurring within the U.K. are of anthropogenic origin and in principle are preventable.
6. There appears to be a decrease in the number of disasters arising from chemical and allied industries during the period 1980-1987. This may be due to the introduction of new legislation or poor data collection.

RECOMMENDATIONS

1. That the usefulness of the method be evaluated for emergency planning purposes.
2. That the method be extended to include incidents that could have resulted in potential disasters.
3. That the method be used for initial hazard identification and risk evaluation and as a tool for strategic planning.
4. That the scale when combined with the probability of occurrence be developed as a tool for resource allocation and level of response planning.
5. That the research be extended to include factors in the scale other than fatalities, e.g. injuries, economic factors, environmental effects etc..

REFERENCES

1. Fernandes-Russell, D., 1988, "Societal risk estimates from historical data for UK and worldwide events", Environmental Risk Assessment Unit, Research Report No. 3, University of East Anglia.
2. Grist, D. R., 1978, "Individual risk. A compilation of recent British data", UKAEA, HMSO, SRD R125.

EUROPEAN CHEMICAL DISASTERS

CUMULATIVE TOTALS (1970-1987)

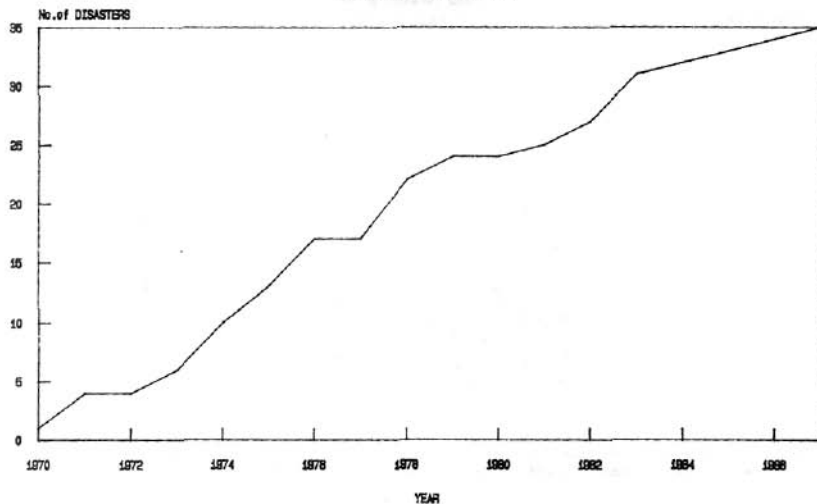


FIGURE 3

EUROPEAN DISASTERS

ANNUAL FREQUENCY BY TYPE
(1888-1988)

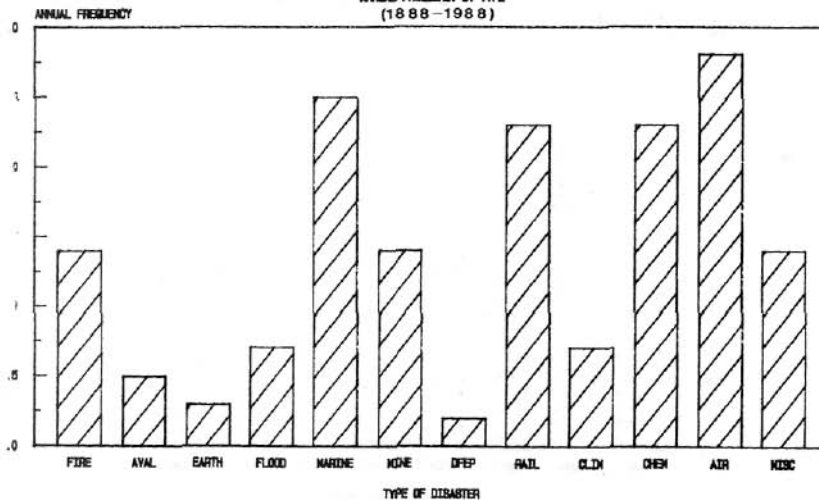


FIGURE 4

EUROPEAN DISASTERS
10 YEAR PERIOD ANALYSIS

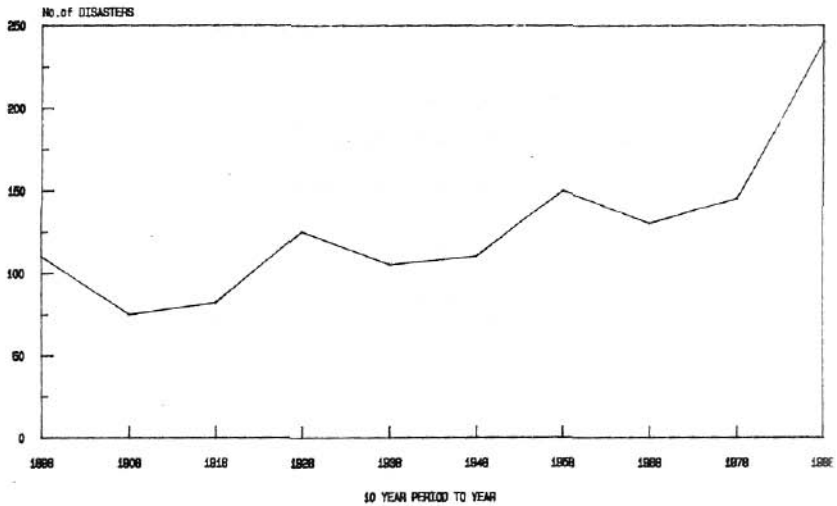


FIGURE 1

UNITED KINGDOM DISASTERS
10 YEAR PERIOD ANALYSIS

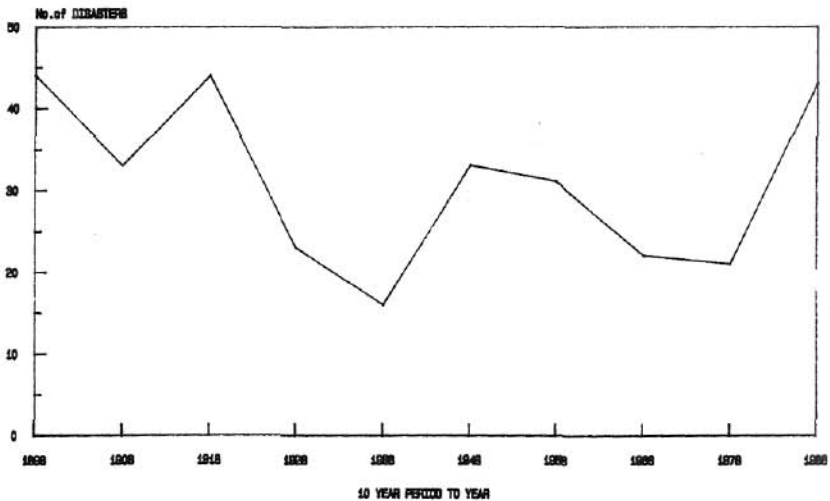


FIGURE 2

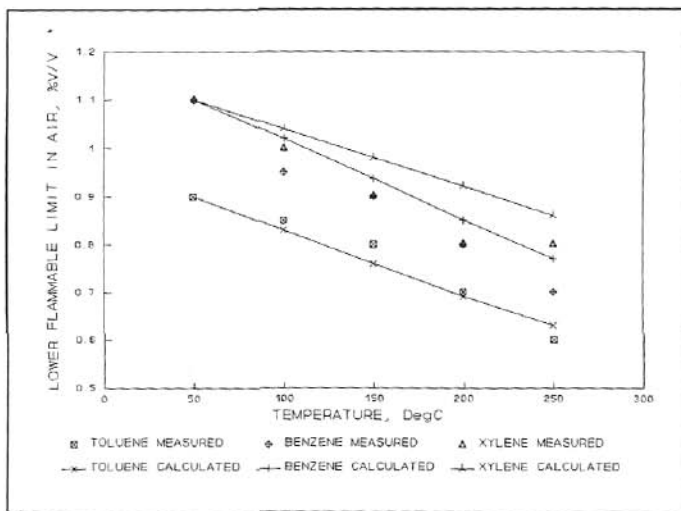


Figure 1 COMPARISON OF MEASURED LFL DATA FOR AROMATICS WITH PREDICTED VALUES

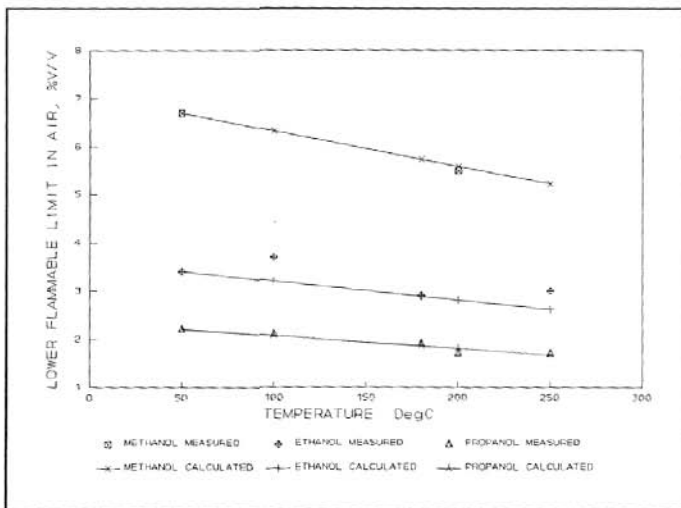


Figure 2 COMPARISON OF EXISTING LFL DATA FOR ALCOHOLS WITH PREDICTED VALUES

UNITED KINGDOM DISASTERS

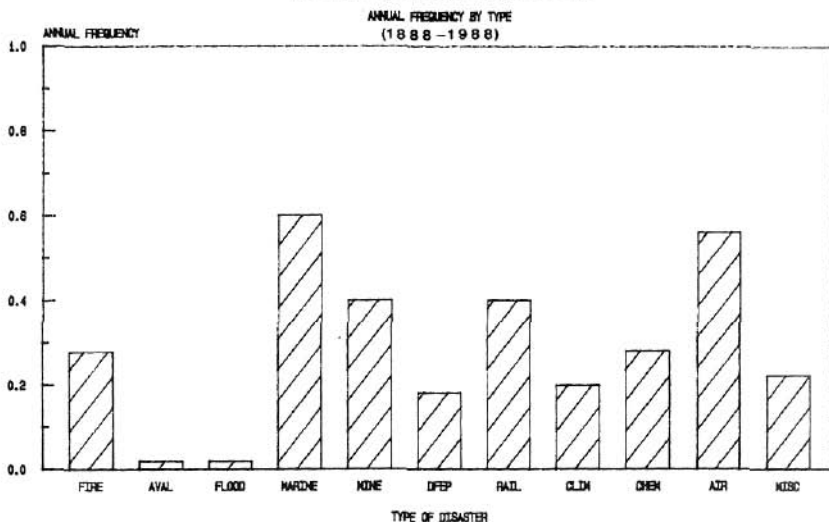


FIGURE 5

EUROPEAN DISASTER FATALITIES (1888-1988)

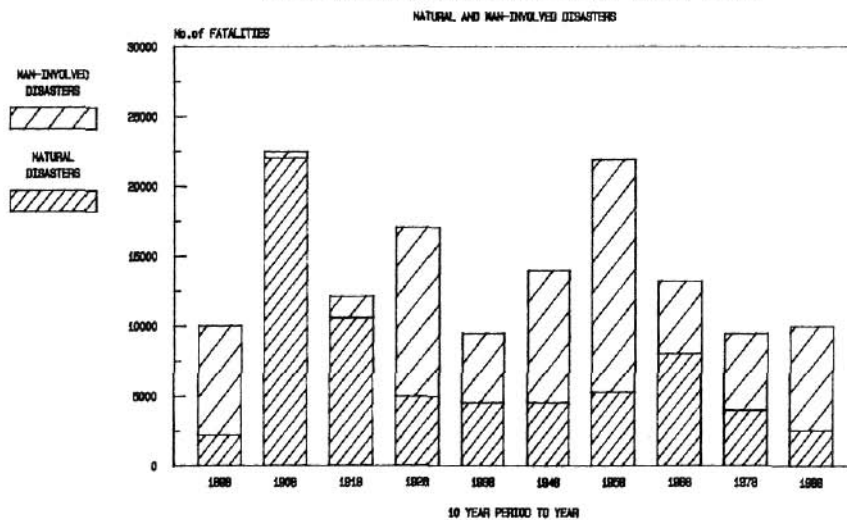


FIGURE 6

U.K. DISASTER FATALITIES (1888-1988)

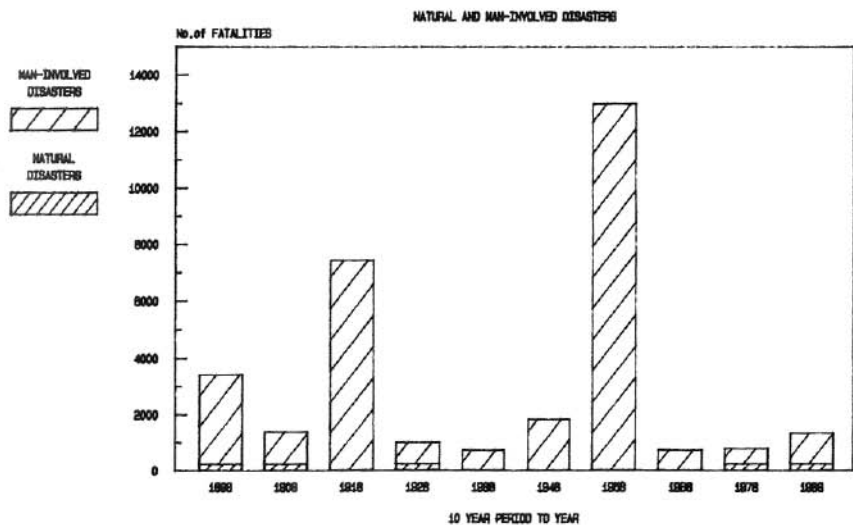


FIGURE 7