NBSIR 80-2070

Second International Seminar on Human Behavior in Fire Emergencies: October 29 - November 1, 1978 Proceedings of Seminar

B.M. Levin and R.L. Paulsen, Editors

Issued June 1980

Sponsored by:
Center for Fire Research
National Engineering Laboratory
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U.S. DEPARTMENT OF COMMERCE, Philip M. Klutznick, *Secretary*

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The conduct of the Seminar and the production of this report were part of a Fire/Life Safety Program jointly sponsored by the National Bureau of Standards' Center for Fire Research and the Department of Health, Education, and Welfare.

The program was a five year activity initiated in 1975, consisting of projects in the areas of: decision analysis, fire and smoke detection, smoke movement and control, automatic extinguishment, and behavior of institutional and other populations in fire situations.

Foreword

The safety of building occupants in fire emergencies depends on both the fire protection features of the building and the actions of the occupants. In designing buildings and in developing fire safety requirements for buildings, there has been available for use a large body of technical information regarding the characteristics and effectiveness of the various fire protection features, and research is underway to provide more needed information. However, there has been little technical information regarding human behavior in fire that can be used in designing buildings, in developing fire safety requirements for buildings, or for training occupants to properly respond to fire emergencies.

Fortunately, over the last few years, a number of research projects have been started to provide the needed information. In the Spring of 1977, Dr. David Canter invited a group of scientists to discuss their work and their interests in the field at the First International Seminar on Behaviour in Fire. This Seminar was specially designed to give the investigators in the field an opportunity to meet each other, to discuss methodological problems, and to be brought up to date on each other's research activities. The technical program consisted mainly of descriptions of programs and informal discussions. Most of the technical progress reported at that meeting will be published in a book edited by Dr. Canter entitled "Human Behaviour and Fires".

The Second International Seminar on Behaviour in Fire was held at the National Bureau of Standards. The Seminar had a larger attendance partly reflecting the growth of technical activities in the field. The technical program consisted mainly of formal presentations of technical papers and panel discussions. The schedule and the arrangements were again designed to give the participants ample opportunity to meet with each other and have informal discussions.

These Proceedings contain the papers presented at the Seminar. In some cases, the full paper has been published elsewhere and only the abstract is printed here.

The field of human behavior in fire is still a new and small technical discipline. It is making a limited but increasing impact in the broader field of fire protection. There is no professional society or journal that properly services this field of inquiry. This series of International Seminars on Behaviour in Fires and Proceedings helps fill this void. We are pleased to have been able to organize and host the Seminar and to have edited these Proceedings.

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Abstract

The safety of building occupants in fire emergencies depends on both the fire protection features of the building and the actions of the occupants. Until recently fire protection experts have relied mainly on experience and intuition regarding the capabilities and actions of building occupants in the development of fire protection systems and training programs. Research projects underway can assist the fire protection experts by providing them with needed information to supplement their experience and intuition. This report contains summaries of some of the recent research in this field as reported at an international seminar on the subject. It also contains the invited papers presented at the seminar on the topic of panic.

A SUGGESTED METHODOLOGY FOR APPROACHING FIRE SAFETY AND ITS RELATION TO FAULT-TREE ANALYSIS.

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Fire may be regarded as an aspect of the working of an entire system. That is, fire represents a failure of a system. In order to fully understand the situation, it is necessary to be aware of the dynamism and 'wholeness' within things. The very way in which we think needs to show this consciousness. Before one can carry out a study from this point of view, an appropriate methodology or guiding structure is required. The methodology should not be 'static' and mechanical but should be 'active' and continuing. A study of this kind is never really 'finished'. A possible methodology is tentatively suggested. Within such a framework many different techniques and tools may be employed. Each of these tools will have specific and limited aims. One such technique is fault-tree analysis. Up to now, fault tree analysis has been applied to 'hard' engineering systems where the parts and the relationships between the parts may be well defined and quantified. There are numerous problems involved in using fault-tree analysis in fire safety considerations and these problems need to be overcome in a general way. Factors involved cover material properties, geometry and people's behaviour. In the short term a relatively simple, although crude, way in which fault-tree analysis may be used is described.

Key words: System; systemic; dynamic; failure; fire safety; methodology; fault-tree; sensitivity; imprecision; estimate type.

1. Introduction

It is desirable to have an approach to fire safety which considers all the factors involved as parts of an integrated whole and does not regard things in a fragmentary way. The elements which contribute to fire safety (or the lack of it) do not vary independently of each other; they interact to produce the behaviour of an entire system. In order to understand the full nature of the risk in a particular situation, it is necessary to attempt to consider all the relevant factors and the relationships between them. Only with a systemic approach can a deep and comprehensive understanding come about.

The word 'system' has been used in many different ways and it is suitable here to adopt the broad definition that a system is any entity, conceptual or physical, which consists of interdependent parts. A closed system is such that no interaction takes place with elements outside the system. Ultimately there is only one closed system, i.e. the Universe. Smaller systems will be open to a greater or lesser extent.

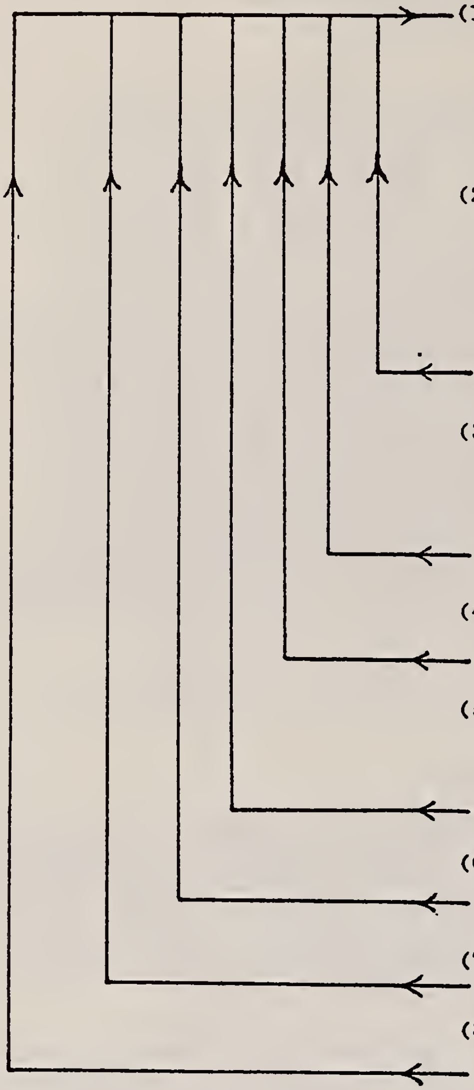
2. Methodology

When carrying out a systemic study, it is necessary to have an idea of the objectives of the study and an appropriate methodology. Which methodology is suitable depends upon the study objectives and the nature of the systems involved.

It is useful to consider systems as either 'hard' or 'soft'. A 'hard' system is one in which the parts and relationships can be well defined and quantified (such as an engineering system). A 'soft' system is one in which the parts and relationships are not easily defined and quantified. All systems in which human beings play a large part are essentially 'soft'. Also, it may not be possible to give exact expression to the objectives of a study of a soft system, at least at the beginning.

When considering the problem of fire safety in hospitals, the objective might be rather tentatively stated as: "How to increase fire safety in hospitals". However, the exact statement of the 'problem' would almost certainly change as the study progressed.

A possible appropriate methodology for the systemic study of fire safety might be:



(1) Formulation of 'the problem'. Description of the problem. Parts involved and relationships between the parts. Systems involved. 'Objectives' of the study.

(2) Development of models with respect to the systems involved. 'Objectives' associated with the systems. Structures; processes; flows; constraints; forces. Models may be verbal, mathematical, physical. Broad qualitative models and quantitative (e.g. fault tree) models may be employed.

(3) Examination of specific past failure situations. Each failure should itself be examined from a systemic point of view. 'Near miss' situations. Statistics and other information.

(4) Select areas for further research or investigation.

(5) Consideration of 'the problem' in the light of the earlier stages of the study. Generation of ideas on how to tackle the 'problem'.

(6) Evaluation of possible courses of action and consequences.

(7) Carrying out action.

(8) Appraisal. Assess the position and keep cycling round; things are never 'closed'.

(This methodology is considered more fully in an article entitled "Towards a Rational Approach to Fire Safety", which is due to appear in the Journal "Fire Prevention Science and Technology", No 22, during the second half of 1979.)

Although this methodology is written as a series of steps, it should not be regarded as a "sausage machine" which, when completed, produces a "correct answer". The need will probably arise to return to earlier steps and cycle round. It may be necessary to return to the stage "formulation of the problem" more than once. For example, it might increase fire safety to reduce the number of electrical appliances in a hospital, but then the absence of a particular electrical instrument might have a very damaging effect with respect to some other aspect of the system. The methodology should be regarded as dynamic and not static. The 'problem' may become very complex and there cannot be a single 'solution'.

However, the methodology does provide a guiding structure for tackling the situation. Within the structure, techniques may be used which may be 'sausage machines' to a greater or lesser degree. One of the techniques which might be used at the second stage is fault tree analysis.

3. Fault Tree Analysis

This is a method by which failures that can contribute to an undesired event are organised logically. The resulting arrangement is a tree-like structure with information flow from the branch tips, the single most undesired event being at the convergence of the branches. The logical connections are expressed through AND gates and OR gates. The AND gate is such that an output event occurs if, and only if, all the input events occur. For the OR gate, the output event occurs if one or more of the inputs occur. Such trees have been used, for example, in the nuclear power industry, as a way of considering the protection system in a reactor. The basic roots in the nuclear power tree are events such as the failure of a power supply and probability or frequency values are associated with these. For example, a particular event may be represented by the probability of a failure occurring per month. Figure 1 shows a small segment of a fault tree for the automatic protection system of a nuclear power station. If the pressure within the core becomes dangerously high, then one or more sensors should detect this and transmit signals through the elements of the protection system to cause the control rods to drop. The reactor should then go into a safe state. The 'undesired event' which could take place is that the control rods would not drop when they should do. This is represented on the tree as 'no trip'.

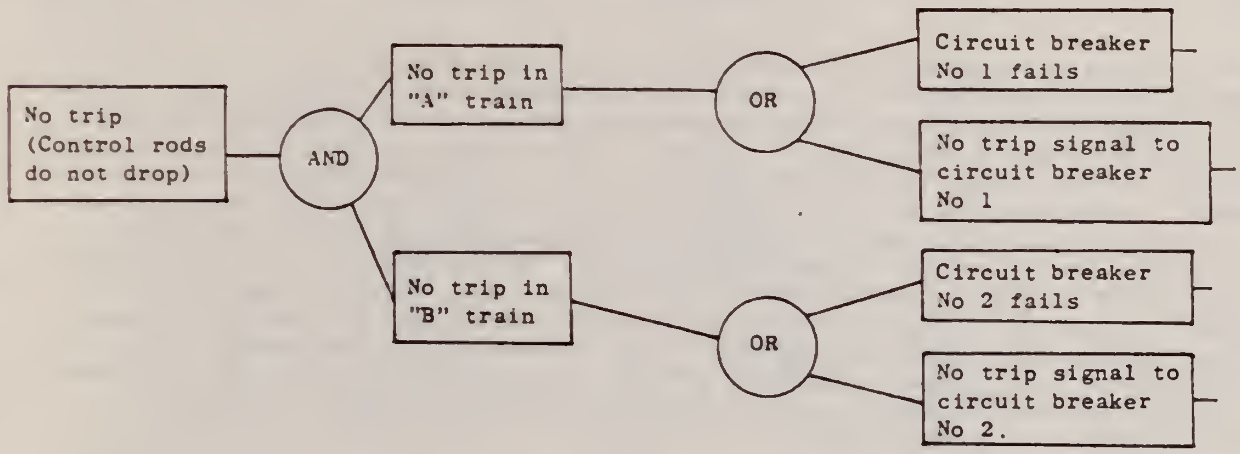


Figure 1. A Small Segment of a Fault Tree for the Protection System of a Nuclear Power Station.

When one attempts to apply such a method in the case of fire, however, it is found that it is by no means straightforward. One of the essential differences between a system such as a power station protection system and a fire situation is that the latter represents a system which has a time development. The parts of a fire development tree cannot be connected in a simple logical way, as was possible in the nuclear case, because the logical connections depend upon time in a very complex way and this considerably complicates the modelling. In addition, there are a very large number of elements to be taken account of, involving material properties, geometry and people's behaviour. Further, it will very often be the case that the basic knowledge, in terms of the dynamics and data associated with these elements, will not be known.

The problem needs to be tackled in a general theoretical manner before a fault-tree type of approach can be applied in other than a very crude way. Nevertheless, it might be instructive to ask what could possibly be gained at the present time from a study of a particular fire from a fault-tree point of view. To this end a consideration of the fire which occurred in Coldharbour Hospital in July 1972 has been carried out. A brief sketch of the events connected with the fire is necessary. For further details the reader is advised to refer to the "Report of the Committee of Inquiry into the Fire at Coldharbour Hospital". (Cmnd. 5170, HMSO).

4. The Coldharbour Fire

The fire took place in Winfrith Ward on the night of 4/5 July 1972. The hospital had been built in 1940/41 and Winfrith Villa had been originally designed as 'barrack room' accommodation. Just before the fire, the ward had been upgraded to make it 'more homely'. Large spaces had been split up by partitioning. The fire brigade had recommended that the partitions conform to Class 'O' with respect to surface spread of flame properties, but, in the event, the partitions installed were found to conform only to Class 2 and Class 4. Thirty-four patients, most of whom were mentally handicapped, were housed in the villa. There were two doors to the open air from the ward, one on the north side and one on the east side. Both of these doors were locked. A corridor from the ward on the south side led to the bathroom, WC, and, further away and through a set of fire doors, the kitchen. The nurses' desk was in the ward, just opposite the exit to the corridor. There was one nurse on duty in the ward throughout the night.

Just after 2.20 am, the nurse left the ward with the charge nurse and went to the kitchen to make a cup of tea. The fire is thought to have started at approximately 2.30 am. A cry or shout from the dormitory was heard by the nurses at about 2.50 am and the nurse ran straight to the ward to find a serious fire in progress. He turned round and smashed a break glass alarm, after which he returned to the dormitory, taking with him an automatic hose from a reel. However, he found that he could not get into the dormitory because of the smoke which had reached the entrance by then.

After a while, the north door was opened from the outside and some of the patients rescued. However, at about 3.01 am, almost certainly due to the opening of the north door, flashover took place, which put an end to further entries into the ward by anyone but the fire brigade. The brigade arrived at 3.10 am and flaming was finished by about 3.19 am. Thirty patients had died.

To consider one specific sequence of events such as this is of limited value. It is true that making a change such that one of the vital causal elements could not occur again would remove the possibility of that exact chain of events recurring, as well as other chains in which that element played a crucial part. However, to an extent every fire is unique and such a measure may well lessen the probability of a similar fire occurring again by only a small amount. Looking at the specific course of events, though, may be more useful if an attempt is made to extend the number of possible fire sequences which we are prepared to consider and which might lead to a similar catastrophe. We know that with the system such as it was in Winfrith, a fire undiscovered by staff between 2.30 am and 2.50 am led to thirty deaths. This may be used as a dynamic basis for attempting to increase the number of possible fire sequences under consideration. The problem of time dependence in the general fault-tree theory is here translated crudely into this fundamental piece of information. Bearing in mind that this approach is very approximate, a fault-tree may be constructed along the lines of Figure 2.

The diagram represents a number of different fire sequences which could possibly result in a disaster similar in magnitude to the one that occurred at Coldharbour. Each box is associated with a probability. The possibility of a fire being initiated by the contact of a lighted match or lighted cigarette with bedlinen has been considered to be of particular importance. In general, other ways in which the fire could start should be considered separately as well. An attempt has been made to consider various circumstances in which the nurse might be unaware of the existence of the fire between approximately 2.30 am and 2.50 am. In principle, the effect of the combustibility properties of the partitions, walls, floors, furnishings, etc. has been included. Also, whether or not an automatic detector system exists has been put into the model.

The final box, P_s, is the probability of a fire starting at about 2.30 am and being sufficient to kill approximately thirty people within about thirty minutes. Different situations will be reflected in different probabilities. We shall consider first of all

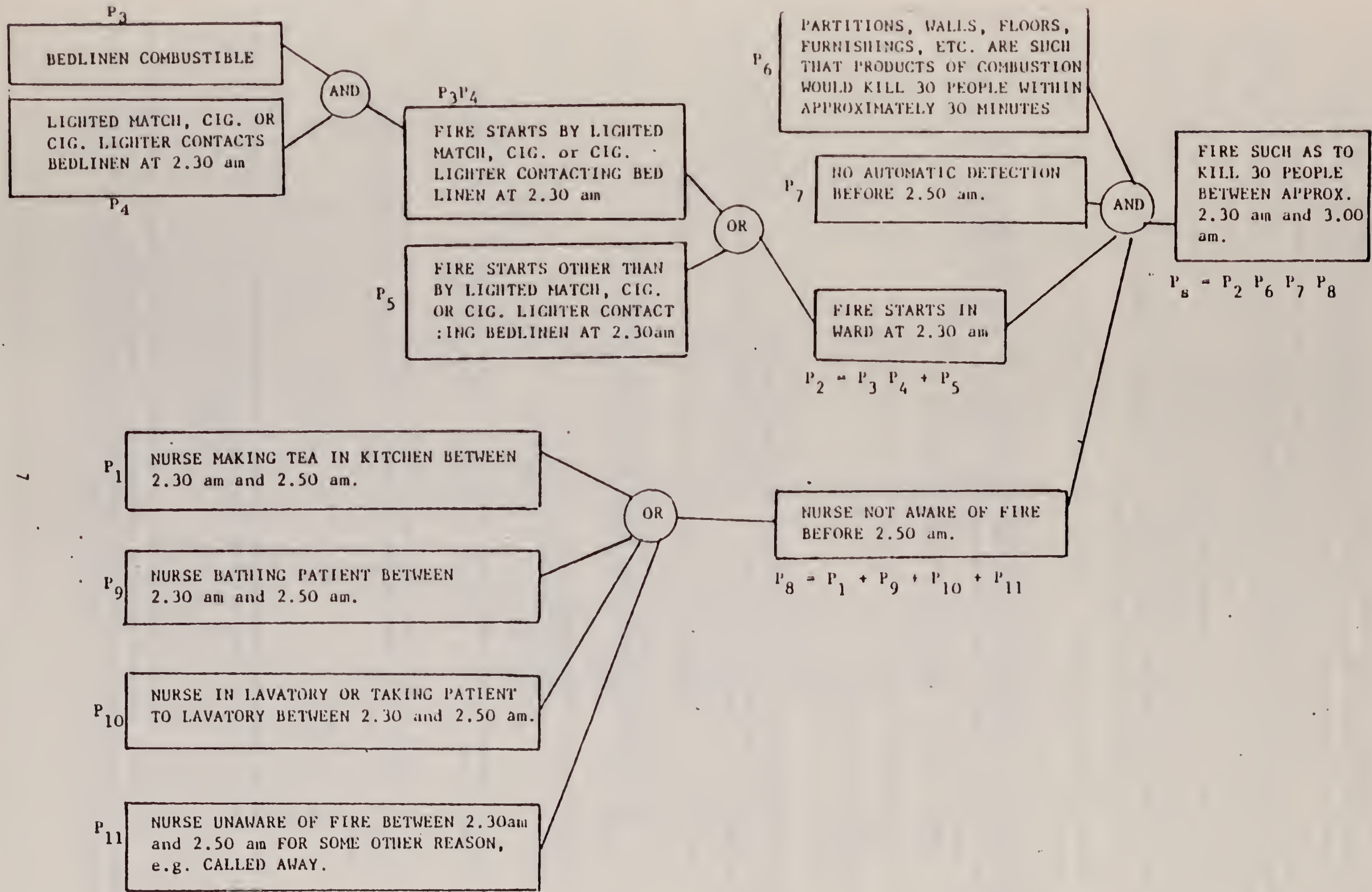


Figure 2: Fault tree for the probability, P_s, of a fire occurring in Winfrith Villa such as to kill about thirty people between 2.30 am and 3.00 am.

the system as it existed at Coldharbour (System 1) and then go on to consider other possible systems which would represent a few fire safety measures which could be taken. 'System 1' refers to the entirety of interacting parts which produced fatalities in the Coldharbour fire. The possible changes to this original system considered here are:-

(a) All bed-linen non-combustible. Making this change to System 1, then call the result System 2.

(b) Partitions of Class '0' rather than Class 2 or Class 4. Making this change to System 1, then call the result System 3.

(c) Nurses' station (with tea-making facility) in ward. Making this change to System 1, then call the result System 4.

(d) Automatic detector system. Making this change to System 1, then call the result System 5.

Each of these systems is considered in relation to System 1. P_s for System i (where i stands for 1,2,3,4 or 5) is written as P_{si} and the ratio P_{si}/P_{s1} determined in each case. For example, if P_{s2}/P_{s1} is 0.5, then if we make the change indicated in System 2, we would expect the probability of a fire similar to the one which occurred to be reduced by half. (The ratio P_{si}/P_{s1} might be called the 'reduction factor').

The basic relations are:-

$$P_s = P_2\ P_6\ P_7\ P_8$$
$$P_2 = P_3\ P_4 + P_5$$
$$P_8 = P_1 + P_9 + P_{10} + P_{11}$$

(The events characterised by P_1, P_9, P_{10}, P_{11}, have been taken to be mutually exclusive, although this is not a necessary condition). Further details on the logic of AND and OR gates may be found in references 1, 2 and 3.

System 1: The system as it existed in Coldharbour hospital just before the fire.
Then $P_6 = 1$; $P_7 = 1$; $P_3 = 1$
$P_2 = P_3P_4 + P_5$, which, in this case, becomes $P_2 = P_4 + P_5$.
P_s for system 1 is P_{s1} and likewise for other systems.
$P_{s1} = (P_4 + P_5)P_8$.

System 2: Same as system 1 but bed-linen non-combustible.
Then $P_3 = 0$. Also, estimate that $P_5 = \frac{2}{3}\ P_4$
Then $P_{s1} = 1.67\ P_4P_8$; $P_{s2} = P_5P_8 = 0.667\ P_4P_8$. $\dfrac{P_{s2}}{P_{s1}} = \dfrac{0.667}{1.67} = 0.4$

System 3: Same as system 1, but partitions of Class '0' rather than Class 2 and Class 4.
Estimate that $P_6 = 0.2$. Then $P_{s3} = 0.2\ (P_4 + P_5)P_8$ and $\dfrac{P_{s3}}{P_{s1}} = 0.2$

System 4: Same as system 1, but have a nurses' station (with tea making facility) in the ward. Then $P_1 = 0$; also we need to make an estimate of each of the probabilities P_9, P_{10}, and P_{11}. Let P_1 under system 1 be of magnitude p, and estimate that:

$$P_9 = 0.25p \qquad P_{s1} = (P_4 + P_5)1.31p \qquad \frac{P_{s4}}{P_{s1}} = \frac{0.31}{1.31} = 0.236$$
$$P_{10} = 0.05p \qquad P_{s4} = (P_4 + P_5)0.31p$$
$$P_{11} = 0.01p$$

System 5: Same as for system 1, but with an automatic detector system. Estimate that $P_7 = 0.1$; $P_{s5} = (P_4 + P_5)\ 0.1\ P_8$, and $\dfrac{P_{s5}}{P_{s1}} = 0.1$

Systems 2 to 5 represent four possible changes which could be made to increase the level of fire safety. We may now consider possible combinations of these changes. The system incorporating the changes made in both system i and system j will be written as System i/j, and the appropriate P_s as P_{sij}. A similar notation is used for more than two changes.

For example, the system with all four alterations is System 2/3/4/5, and the appropriate P_s is written P_{s2345}. The results are summarised in Table 1. All the estimates made in the consideration of each system are listed.

There are represented here a total of fifteen possible fire safety alterations to the original system, based on four separate changes. Clearly this is by no means exhaustive; these are not the only changes which should be considered in attempting to improve the fire safety level. The point here, however, is to illustrate the use of the method rather than to propose definite measures in a particular situation.

(NB. In Table 1, 'Ratio P_{si}/P_{s1}' refers to all the systems in which two, three or four changes to the original system have been made. This is for the sake of simplicity).

,Table 1

System	Estimates made	Ratio P_{si}/P_{s1}
2/3	$P_5 = \frac{2}{3} P_4$ $P_6 = 0.2$	$\frac{P_{s23}}{P_{s1}} = 0.08$
2/4	$P_5 = \frac{2}{3} P_4$ $P_9 = 0.25p$ $P_{10} = 0.05p$ $P_{11} = 0.01p$	$\frac{P_{s24}}{P_{s1}} = 0.095$
2/5	$P_5 = \frac{2}{3} P_4$ $P_7 = 0.1$	$\frac{P_{s25}}{P_{s1}} = 0.04$
3/4	$P_6 = 0.2$ $P_9 = 0.25p$ $P_{10} = 0.05p$ $P_{11} = 0.01p$	$\frac{P_{s34}}{P_{s1}} = 0.0473$
3/5	$P_6 = 0.2$ $P_7 = 0.1$	$\frac{P_{s35}}{P_{s1}} = 0.02$
4/5	$P_7 = 0.1$ $P_9 = 0.25p$ $P_{10} = 0.05p$ $P_{11} = 0.01p$	$\frac{P_{s45}}{P_{s1}} = 0.0236$
2/3/4	$P_6 = 0.2$ $P_5 = \frac{2}{3} P_4$ $P_9 = 0.25p$ $P_{10} = 0.05p$ $P_{11} = 0.01p$	$\frac{P_{s234}}{P_{s1}} = 0.0189$
2/3/5	$P_6 = 0.2$ $P_5 = \frac{2}{3} P_4$ $P_7 = 0.1$	$\frac{P_{s235}}{P_{s1}} = 0.008$
2/4/5	$P_5 = \frac{2}{3} P_4$ $P_9 = 0.25p$ $P_{10} = 0.05p$ $P_{11} = 0.01p$ $P_7 = 0.1$	$\frac{P_{s245}}{P_{s1}} = 0.0095$
3/4/5	$P_6 = 0.2$ $P_7 = 0.1$ $P_9 = 0.25p$ $P_{10} = 0.05p$ $P_{11} = 0.01p$	$\frac{P_{s345}}{P_{s1}} = 0.00473$
2/3/4/5	$P_5 = \frac{2}{3} P_4$ $P_6 = 0.2$ $P_9 = 0.25p$ $P_{10} = 0.05p$ $P_{11} = 0.01p$ $P_7 = 0.1$	$\frac{P_{s2345}}{P_{s1}} = 0.00189$

It has been necessary to estimate some of the probabilities involved. Each of the fifteen possible alternative systems contains one or more estimates. The final system, containing all four changes (i.e. System 2/3/4/5) involves a total of six such quantities. Wherever possible, each of the estimates has been guided by information. For some of the probabilities, more well-founded values could be obtained by carrying out appropriate studies. (As for example in the cases of P_9, P_{10}, P_{11}). Other quantities, such as P_6 in the present case, are much more difficult to estimate.

There are a number of different types of estimate which may be made in a study of this kind.

These may range from 'judgement' (or 'guesswork') which is not consciously based on any definite information, to values which are very well grounded in data. A classification of types of estimate and the relationship to the present study is considered in the appendix.

However, as has been said, the present intention is to illustrate the kind of technique rather than to suggest concrete measures. According to this model, with the values put in, if all the four changes were made, the probability of a similar major loss of life due to fire at Winfrith Villa would be reduced by a factor of about 0.00189. That is, if P_{S1} is the probability of thirty fatalities occurring between 2.30 am and 3.00 am in the original system (System 1) then the probability of a similar catastrophe happening in a system incorporating all the changes (System 2/3/4/5) is $P_{S2345} = 0.00189 \ P_{S1}$.

This raises the question of how sensitive the final result is to the values of the quantities injected. How dependent the final ratios are upon a particular value is a function of both the logic of the model (i.e. the parts and the way the parts are connected) as well as the magnitudes of all the quantities put in. To obtain some idea of the effects of changes, each of the six estimated probabilities will be considered in turn. The alteration in the final result brought about by reducing the estimate for each guessed value by 50 per cent has been determined.

1. P_5 : This is considered with respect to System 2. Taking $P_5 = \frac{2}{3}P_4$ gives $P_{S2}/P_{S1}=0.4$. Taking $P_5 = \frac{1}{3} P_4$ gives $P_{S2}/P_{S1} = 0.25$. That is, reducing the estimate for P_5 by 50 per cent reduces the ratio P_{S2}/P_{S1} by 38 per cent.

2. P_6 : Reducing P_6 by any percentage reduces the final ratio by the same percentage.

3. P_9 : This is considered with respect to System 4. Reducing P_9 by 50 per cent reduces P_{S4}/P_{S1} by 34 per cent.

4. P_{10} : This is considered with respect to System 4. Reducing P_{10} by 50 per cent reduces P_{S4}/P_{S1} by 6.8 per cent.

5. P_{11} : This is considered with respect to System 4. Reducing P_{11} by 50 per cent reduces P_{S4}/P_{S1} by 0.85 per cent.

6. P_7 : As with P_6, reducing P_7 by any percentage reduces the final result by the same percentage.

We see that the final result is very sensitive to the estimates of P_6 and P_7. Also, for the particular magnitudes chosen of all the quantities involved, the final ratios are highly dependent upon the values of P_9 and P_5, but much less so upon the values of P_{10} and P_{11}. In general, one must be very careful that the estimates put in are based on as solid foundations as possible. It is important not to attach an unjustified significance to numbers which result from any model. All models have limitations and it is essential to be aware of what those limitations are. One must be conscious of the assumptions, both explicit and implicit, contained within a model. Any output must be seen in full awareness of the assumptions made. Further, the imprecision of the input and what this means for the output needs to be clearly realised. The whole question of imprecision of the input is a vital one for all models involving complex systems.

5. Conclusion

As stated earlier, the particular model presented here is by no means all embracing. There are many important factors which have not been mentioned. A multitude of changes could be made in order to increase fire safety, from a consideration of a small item of furniture to a change in overall design or organisation. Also, the probability P_5 should be broken down further to consider other specific ways in which a fire could start. For the Coldharbour fire in particular, one could mention that the north and east doors were locked and that in fact the "brigade could only force their way into the east door with difficulty". Co-ordinated and constructive action by the people involved is crucial; for example the Report mentions that "there was no organised effort to open the locked doors". More generally we have to understand much more about the behaviour of people in a fire situation.

Further, at Coldharbour the fire brigade did not arrive as soon as it should have done because of a failure in the 'alerter system'. This delay in calling out the local brigade may have had little effect upon the result of the fire but in other circumstances it could be of crucial importance.

This brings us back full circle to the points made at the beginning of this article. The total situation is complex and clear cut 'solutions' are rarely, if at all, possible. Given this, an attempt must be made to consider all relevant factors and how they affect each other. The problem of fire safety needs to be examined from a systemic point of view and not in a disjointed or narrow fashion. Within such a study, both qualitative and quantitative models should help in the conceptualisation. In particular, models of the fault-tree type may be developed and used in the tackling of problems. To this end it is desirable to construct a conceptual fault-tree model which is adequate from the point of view of understanding of the elements involved and the way they interact. Specifically, the difficulty of the time dependence has been mentioned and all of these problems will have to be overcome in a general way. In the immediate term, this paper has attempted to show how a study of a particular fire may help, albeit in a very crude and limited manner, in the overall understanding of the situation.

Appendix

Types of Estimate

A categorisation of estimates has been made in chapter 2 of the report "Canvey" (see ref 4). A coding taken from this work may be listed as:

(a) A scientifically based figure to which, if necessary, a standard deviation could be attached.

(b) Based on statistics but some 'judgement' has been used. Could be made more definite if more time and trouble were taken.

(c) Have attempted to relate an operation under consideration to some other operation which has previously been analysed in some other context and for which fault tree assessments have been made.

(d) A 'judgement' has been used but the prospects are poor for ever reducing the uncertainty.

(f) Based on a fault tree.

To this classification might be added type (e) and type (cl):

(e) A 'judgement' has been used but the prospects are good for reducing the uncertainty.

(cl) Have attempted to relate an operation to some other operation which has been analysed but for which fault tree assessments have not been carried out.

Further, the comment should be made that when a fault tree is referred to the nature of the probabilities injected into the tree should be clearly stated. The values put into a tree may range from guesses to well-grounded figures.

We may now consider the estimates made in this paper in the light of this typology:

P_5 : Has been arrived at after looking at a report (personal communication) based on official statistics. (DHSS, London). It would be estimate type (b).

P_7 : Arrived at after consulting ref 5. This could also be considered estimate type (b).

P_9, P_{10}, P_{11} : These would be type (e). More well-founded probabilities could be obtained by carrying out appropriate studies.

P_6 : This is much more difficult to estimate. P_6 should itself be broken down into a fault tree which would embrace such elements as toxicity properties, fire resistive and surface spread of flame characteristics, geometry, as well as others. Work carried out by Rogowski (ref 6) suggests that Class 'O' partitions might be expected to make a substantial difference to the probabilities involved. The value 0.2 has been assumed and this would correspond to type (e).

Acknowledgements

I would like to thank Dr E W Marchant and Professor D J Rasbash, both of the Department of Fire Safety Engineering, University of Edinburgh, for their useful comments during the preparation of this article. This work was carried out with financial support from the Department of Health and Social Security.

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A MODELING PROCEDURE FOR ANALYZING THE EFFECT OF DESIGN ON EMERGENCY ESCAPE POTENTIAL

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A technique for calculating the number of directed escape routes is presented. The technique can be used to describe the changing opportunities for safe escape due to the spread of flame and accumulation of combustion products. The layout of the Beverly Hills Supper Club is used to illustrate the application of this technique which provides the architect, building engineer, code official and fire specialist with a tool for objectively and quickly analyzing the effects of design on escape potential.

Key Words: Egress; evacuation; fire incident.

While the design of a building must attempt to facilitate the activities of its occupants by making it easy for a customer to find their offices and for the businesses to perform their various functions, the effect of the design on emergency escape potential should not be overlooked. Is the best design for normal daily activities in conflict with a design that enables all occupants to reach locations of safety easily and quickly?

The NFPA Life Safety Code states that "every building . . . shall be provided with exits sufficient to permit the prompt escape of occupants in case of fire or other emergency." The code provides, in a prescriptive manner, design specifications for providing the level of firesafety intended by the code writers; however, it does not define in a performance sense what it means to have a sufficient number of exits or how much time and physical stamina are required for safe escape.

While the model described in this paper will not address all these questions, it does attempt to provide the architect and building engineer with a tool for objectively obtaining a measure of escape potential based on minimal data. Of primary concern is the ability of the occupants to escape once a fire has been detected. This paper describes a technique for describing a measure of escape potential by calculating the number of directed routes from any room to a location of safety. Here, a route is defined to be a sequence of connected rooms ending with a designated location of safety. A tunnel, another fire compartment, or the outdoors can serve as a location of safety depending on the dwelling type. Floor plans for a

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The model was developed as part of a project to study firesafety in residential occupancies, being funded by the Department of Housing and Urban Development (Project H-2316).

single-family dwelling and the more intricate Beverly Hills Supper Club that was recently destroyed by fire are used to illustrate the application of this technique.

The possibility of escape from involved areas of the building is an important factor in assessing the hazards of fire. Leaving the building is the surest way of minimizing injuries due to fire and structural failure. Describing the escape potential is the first step toward assessing other aspects of exiting and occupant survival.

Related Work

A number of other modeling approaches have been proposed for determining escape potential. Based on a formulation similar to the Maxwell-Boltzman gas model, Henderson (1971) attempted to simulate human crowd movement. Stall (1975) has developed a random movement simulation of people movement which is being enhanced to bias occupant movement in response to various warning signals. The NFPA (1977) has described a state-transition simulation for modeling the probabilistic response of fire growth in terms of a few general criteria for escape.

The approach described in this paper is similar to methods for analyzing the reliability of networks in general. However, the definition of an escape route that has been adopted for this study limits the extent that the concepts of reliability can be applied.

Escape Potential

In contrast to the several stochastic models, the calculation of escape potential is approached here as a deterministic, combinatorial problem on a mixed graph. The graph of nodes and arcs describes the connectivity of rooms and locations of safety. Nodes are used to represent all physically "defined" rooms, portions of large areas, and the locations of safety. Arcs are used to indicate the connectivity of these areas and the possible directions of travel.

Figure 1 shows the escape graph for the accompanying single-family dwelling. For example, nodes "K" and "H" in Figure 1 represent the kitchen and hallway, respectively. An undirected arc connects these two areas since it is possible to travel between these rooms in either direction. However, a single directed arc is used to represent one or more exits from the kitchen to the outside since it is unnecessary to model travel back into the dwelling. The number and type of exits from a room are not distinguished as long as a connection exists.

During an emergency evacuation, someone may take a path that is the shortest route to a location of safety or the most round-about route imaginable. For planning purposes, a reasonable description of the opportunities available to the occupant may be sufficient for an initial assessment of escape potential. Here "reasonable" is used to describe certain assumptions regarding the level of perception, human behavior, and extent of crowdedness. For instance, as the level of perception and perhaps the number of people increases, the number of duplicate arcs comprising escape routes may decrease so that there are absolutely no retracings and the variation in node length may decrease from a weighted average of distances to all possible exits to the length of the shortest path to the nearest exit. Consideration must also be given to the fact that the routes used for escape may vary over time as the occupants locate the nearby exits and establish free-moving flow patterns without even accounting for changes in the escape graph due to the spread of the fire and combustion products.

While one might consider all the distinct routes to be designated locations of safety, a slightly more restrictive definition is used here

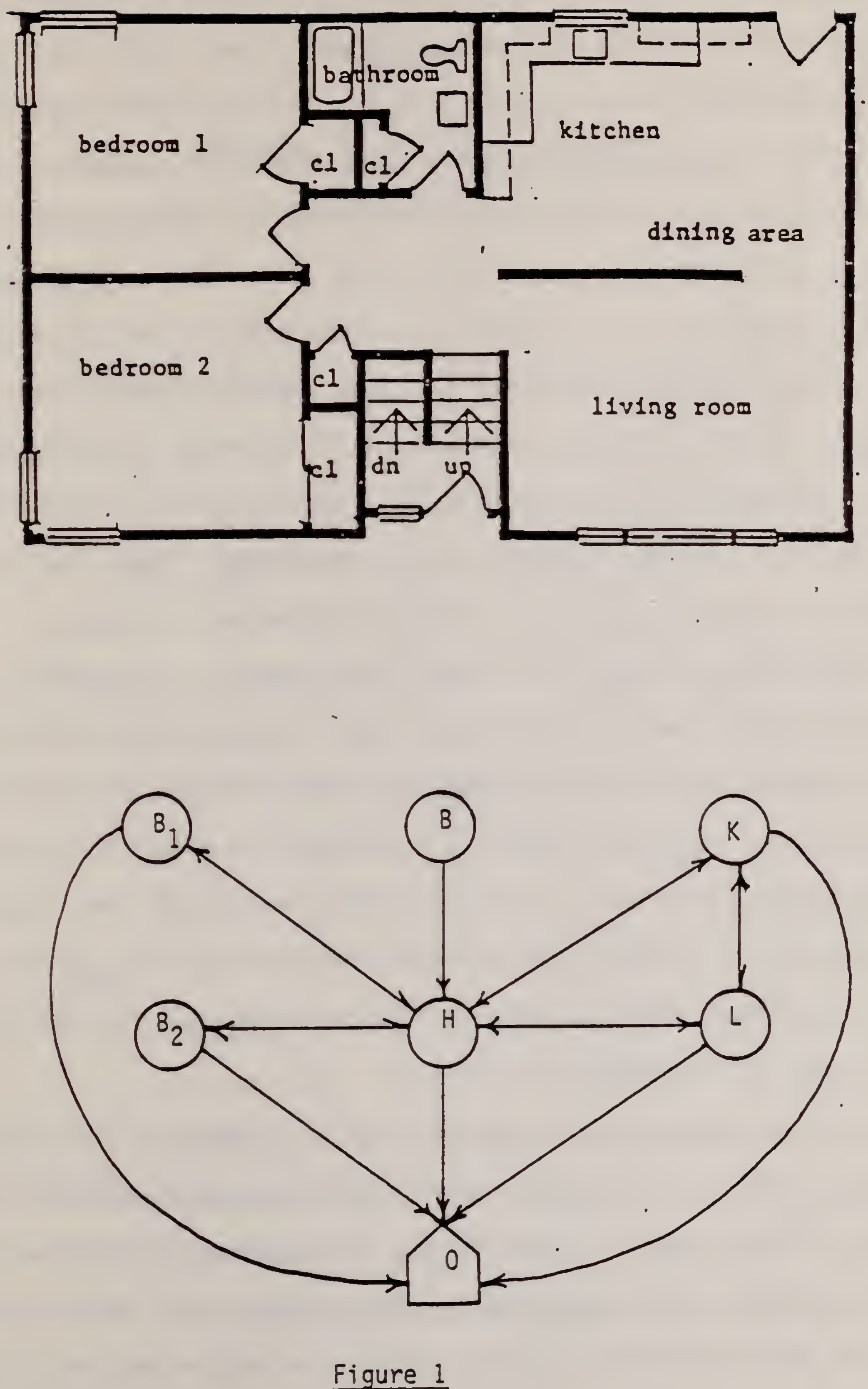


Figure 1

Floor Plan and Escape Graph for a
Single-Family Dwelling

to characterize valid escape routes. It is assumed that the extension of a route is always directed toward a designated location of safety and that opposing movement through a room is prohibited. Table 1 indicates the number of escape routes from the kitchen and hallway in the single-family dwelling.

This definition of an escape route does not allow for "backtracking" or "circling." Backtracking is the situation in which occupants will enter a room or start down a hallway before they realize that they should not continue, and hence, turn around and retrace their steps. Circling describes a situation that is similar to backtracking in that the occupant passes through the same room more than once; the difference in this case being that the occupant takes another path in returning to a previous location. Excepting for the room of origin, travel through a room directly connected to a location of safety is also prohibited. Thus, the location of safety represents an "escape sink" as illustrated in Figure 2.

Disallowing circling also prevents the movement of occupants in different directions through one or more rooms. While the prohibition of circling may imply an assumption that all occupants are familiar with the building which is rarely true, occupants attempting to escape from a particular area will likely communicate verbally or observe others leaving the same location so that they will not normally circle back toward their initial origin. However, connected rooms on different routes can be used to extend alternative paths as illustrated in Figure 3.

While the existence of an escape route is a basis for analyzing the necessary conditions for egress, other factors must be considered in an analysis of life safety. In particular, the model does not address the difficulty that a person has in traversing a route. This difficulty may depend on the individual's physical capabilities and perception of risk,

TABLE 1

POTENTIAL ESCAPE ROUTES FROM THE KITCHEN AND HALLWAY

Routes from Kitchen	Routes from Hallway
K → 0	H → 0
K → L → 0	H → K → 0
K → H → 0	H → L → 0
	H → B_1 → 0
	H → B_2 → 0

Key:

K = Kitchen

L = Living Room

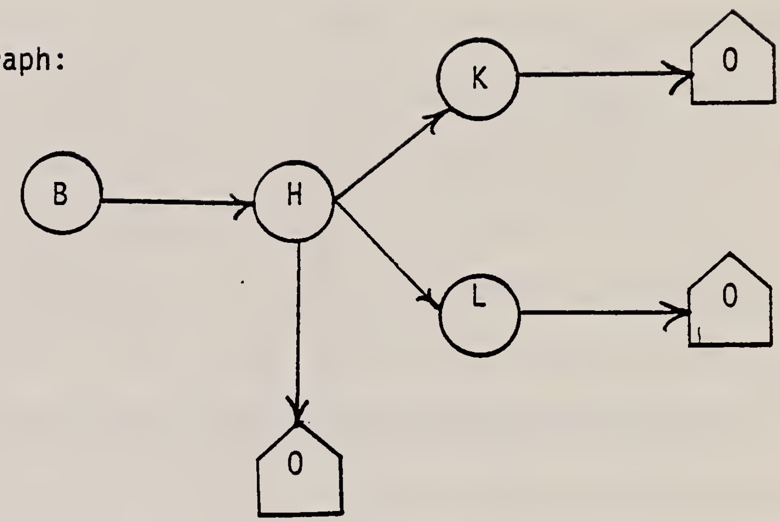
H = Hallway

B_1 = Bedroom

B_2 = Bedroom

0 = Outside (Location of Safety)

Partial Escape Graph:



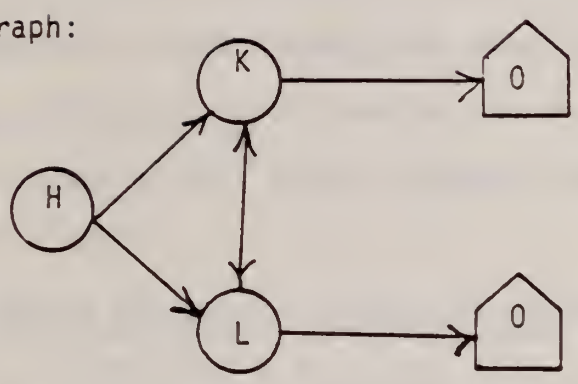
Single Valid Directed Escape Route:

B → H → 0

<u>Figure 2</u>

Locations of Safety as an Escape Sink

Partial Escape Graph:



Valid Directed Escape Routes:

H → K → 0

H → L → 0

H → K → L → 0

H → L → K → 0

Figure 3

Connected Areas for Route Exchange

the type and amount of combustion products, the number of persons using the same route, and the structural characteristics of the escape route itself.

Nevertheless, the number of escape routes does provide an indicator of an individual's chances of eventually selecting a path to a location of safety and an objective measure of the differences in building designs. The techniques for determining these routes focuses attention on the escape potential from each room as well as from the entire building. By identifying actual or hypothetical fire scenarios in which various rooms become impassable, it is possible to investigate the susceptibility of routes to blockage by different types of fires in terms of the length of time that routes are available for an occupant to escape safely. Of particular importance will be the time when routes from a room no longer exist.

Algorithm for Determining the Number of Directed Escape Routes

The technique for determining the number of directed escape routes is an iterative scheme that selectively searches adjacent nodes until all possible branches have been investigated. In this application where no distinction is made regarding the travel between or through rooms, only the existence of an eligible branch is relevant. Starting at a specified location, the technique begins by identifying adjacent locations. For each one of these locations, the number of paths through it is the same as the number through the preceding location. Then, all arcs connected to these locations are removed from consideration in order to prevent backtracking and circling. Because the number of branches is likely to increase as additional locations are considered, the total number of directed routes from the starting location would also continue to increase.

To describe this algorithm in mathematical notation, it is necessary to define the following variables and sets.

Let:

k = specified starting location,

s = specified location of safety,

R_k = number of directed routes from location k,

N = set of nodes,

E = set of nodes directly connected to a location of safety,

A_j = set of nodes that can be reached directly from node j, and

c_i = number of routes through node i.

Then, the algorithm is as follows:

1. Initialization

$R_k = 0$

$c_i = \begin{cases} 0 \text{ for all } i \in N,\ i \neq k \\ 1 \text{ for } i = k \end{cases}$

$J = \{k\}$

$A_j = \{s\}$ for all $j \in E$ and $j \neq k$

2. Adjacent Node Idenfification and Counter

$\hat{c}_j = c_j + c_i$ for all connected combinations of nodes $i \in J$ such that $i \notin E$.

3. Arc Removal

Remove nodes $j \in J$ from A_i for all nodes $i \in N$.

4. Termination Check

If $|J| = 0$, stop. Otherwise, set $\hat{J}=J$, $J=\emptyset$, and $C_i=\text{Max}\ \{c_i, \hat{c}_i\}$ for all $i \in N$ and proceed to the next step.

5. For each node $j \in \hat{J}$ and then for all $i \in A_j$

(a) $c_i=c_i + c_j$

(b) $J = J \cup \{i\}$

(c) $R_k = R_k + c_j$ and set $c_j = 0$ if $j \in E$

6. Return to Step 2.

This algorithm always terminates since the number of arcs is finite and each one is considered no more than once.

Modeling Escape Potential During a Fire

As a fire and the associated combustion products spread throughout a building, rooms become impassable. Melinek and Booth (1975), and Birky (1977) review the hazard characteristics of the combustion products in fires. When a room becomes impassable, all arcs associated with that room are removed. Table 2 illustrates the effects of blocking either the kitchen or hallway. As might be expected, the consequences of blocking a central location such as the hallway is worse than the blockage of a remote location such as the kitchen.

Usually, the number of potential escape routes decreases as the number of impassable rooms increases. However, blocking certain rooms can actually lead to an increase in the number of escape routes because of decreased interference among routes converging on particular rooms. Blocking certain exits also can allow for the construction of longer routes which, in turn, may increase the number of routes that are calculated. However, these

TABLE 2

EFFECT OF BLOCKED ROOMS ON THE NUMBER OF
ESCAPE ROUTES IN A TYPICAL SINGLE
FAMILY DWELLING

Number of Directed Escape Routes

Location	All Rooms Passable	Kitchen Blocked	Hallway Blocked
Kitchen	3	x	2
Hallway	5	4	x
Living Room	3	2	2
Bathroom	1	1	0
Bedroom 1	2	2	1
Bedroom 2	2	2	1
TOTAL	16	11	6

NOTE: An "x" indicates a room that is considered to be impassable.

additional routes may be much more susceptible to blockage because of their longer length. Therefore, it is essential to investigate the effects of different fire scenarios on the escape potential before assessing the overall safety of a building design.

Analysis of Escape Potential

This model is used in several ways to describe the effects of a building design on escape potential. The various ways of describing the dimensions of escape potential are motivated by the factors that an occupant might consider in assessing his chances for escape and that the fire service considers in planning its rescue and suppression actions. An analysis of the Beverly Hills Supper Club in Southgate, Kentucky, was undertaken to demonstrate the uses of the escape potential model. Figure 4 illustrates the layout of the Supper Club in which 165 individuals died as a result of a fire on May 28, 1977 (NFPA, 1977). Figure 5 illustrates the associated escape graph.

Table 3 presents the number of directed escape routes for the pre-fire situation and three different times during the fire. The "pre-fire" condition describes the escape routes that were available immediately before the fire. The remaining three situations describe the effects of the spreading fire and combustion products. In reviewing the results in Table 3, it can be observed that (1) the range in the number of potential escape routes before the fire varied from 2 to 40; (2) the kitchen, which is considered to be a hazardous area, had the largest number of "pre-fire" routes, and (3) the rate that the number of escape routes diminished varied from one room to another.

These observations emphasize the fact that pre-fire potential for escape can be very misleading if a central area such as a hallway or atrium becomes impassable. Furthermore, this tragic fire points out that the distance from a fire may be of minor importance in predicting the hazards of a fire.

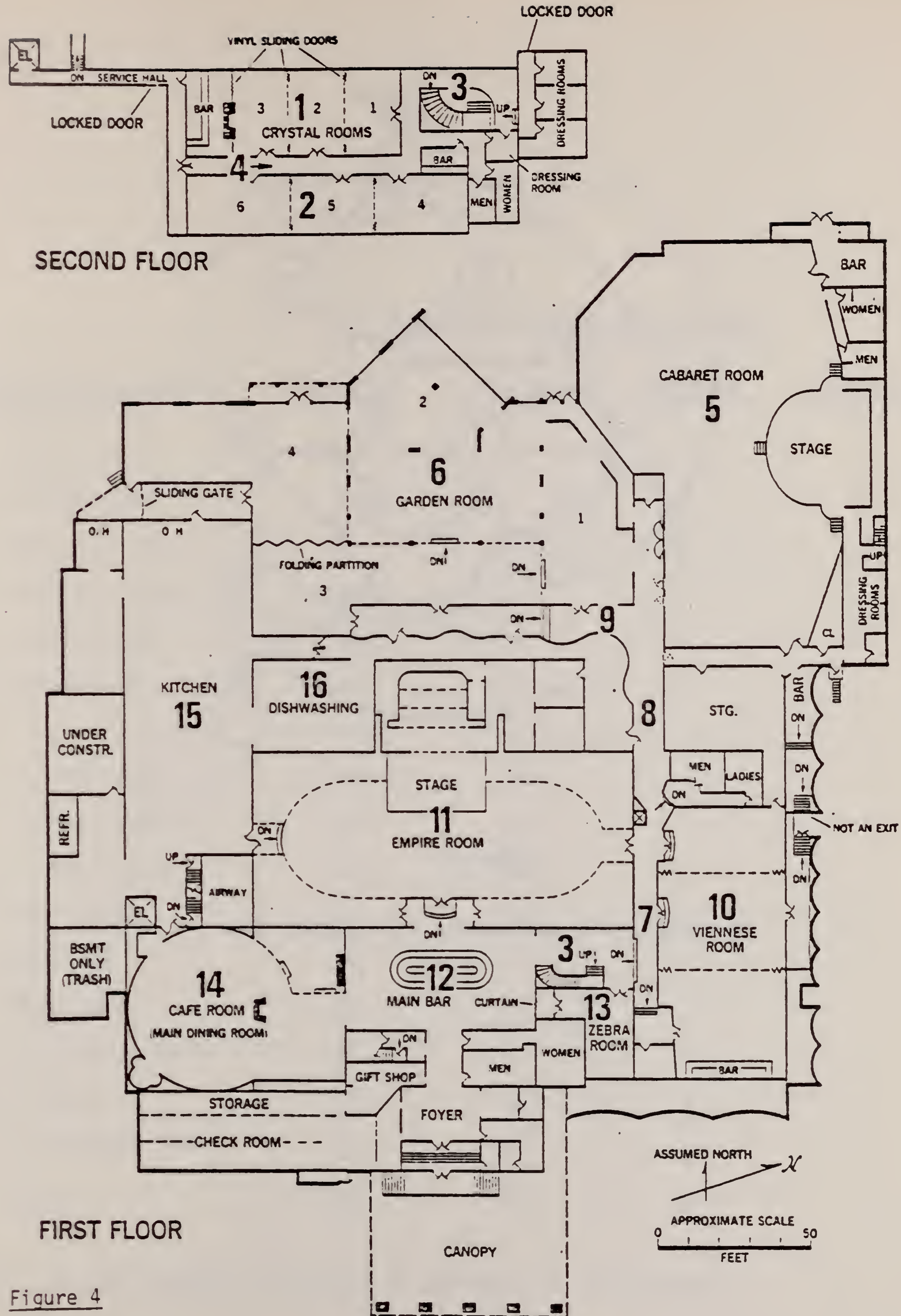


Figure 4

ROOM DEFINITIONS FOR EXIT ANALYSIS

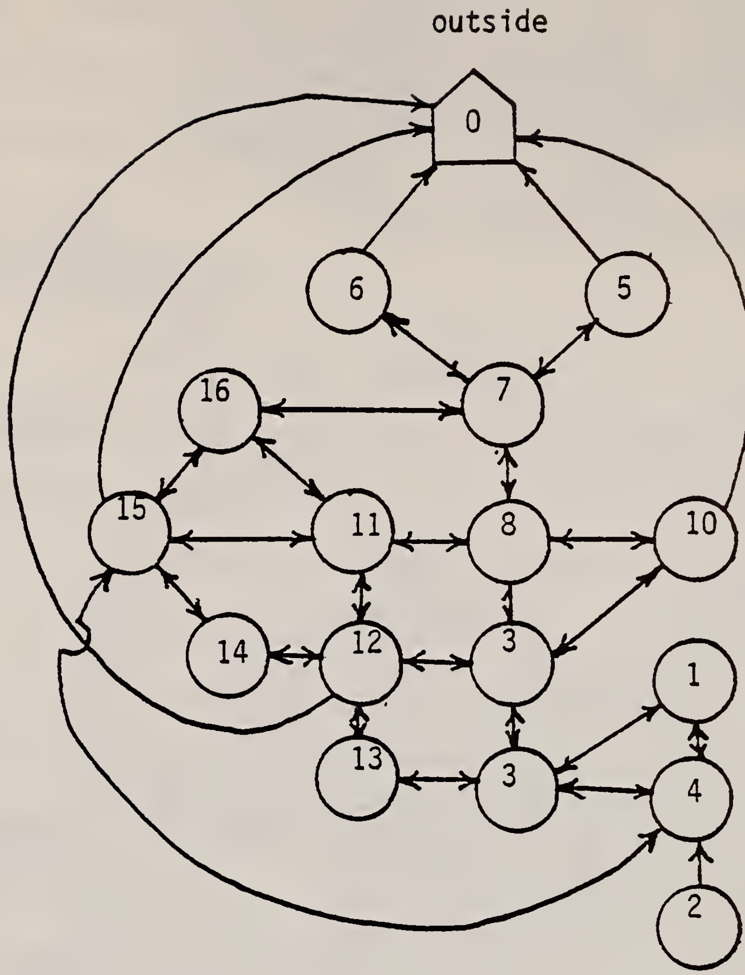


Figure 5

Escape Graph for the Beverly Hills Supper Club

Table 3

Number of Directed Escape Routes
During Actual Fire Scenario

Originating Location	Pre-fire	8:45-8:50	8:55-9:00	9:00-9:05
	Number of Directed Escape Routes			
1. Crystal Room	40	1	x	x
2. Crystal Room	39	1	x	x
3. Main Staircase	21	x	x	x
4. Upstairs Hallway	39	1	x	x
5. Cabaret Room	24	10	4	x
6. Garden Room	25	11	5	x
7. Corridor Section	21	x	x	x
8. Corridor Section	21	13	x	x
9. Corridor Section	24	10	4	x
10. Viennese Room	39	13	x	x
11. Empire Room	24	13	4	2
12. Main Bar	35	x	x	x
13. Zebra Room	21	x	x	x
14. Main Dining Room	2	1	x	x
15. Kitchen	35	20	6	1
16. Dishwashing Room	31	13	4	2
TOTAL	441	107	27	5

NOTE: An "x" indicates a room that is considered to be impassable.

From the occupant's perspective, the exits from a room may seem to be more indicative of his perception of the number of escape routes. However, this apparent opportunity for movement may be misleading. A room may have four doors; one on each side leading into different rooms. While it may seem that there are four escape routes, these routes may eventually include exiting through a lobby. In a sense, an occupant is "funnelled" into the lobby that, when blocked, eliminates all escape routes.

A Funnel Number is used to describe the myopic assessment of escape potential as well as to reflect the holistic aspects of valid escape routes.

Definition - A funnel number for a room is the smallest number of other rooms that, when blocked, will eliminate all directed escape routes through the building.

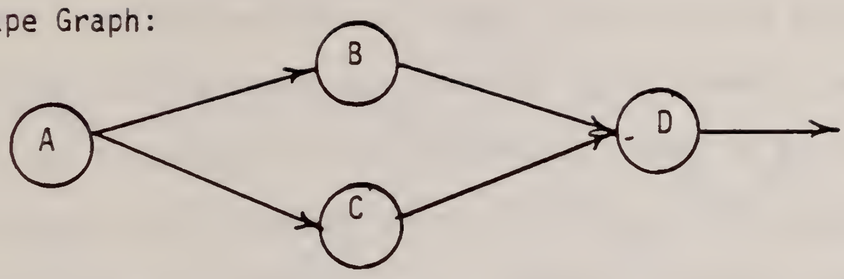
To focus attention on the occupant's perspective from a single room and his opportunities for escape, two distinct "funnel numbers" are calculated:

(1) Local Funnel Number - signifies the funnel number when considering only those rooms connected to the originating location.

(2) Remote Funnel Number - signifies the funnel number when considering all rooms.

In both cases, an exit to the location of safety from the originating room is not considered. The distinction between local and remote funnel numbers is illustrated in Figure 6. Thus, the remote funnel number describes the actual number of non-overlapping (or remote) escape routes while the local funnel number only provides an upper limit.

Partial Escape Graph:



Local Funnel Number: F_e (A) =2

Remote Funnel Number: F_r (A) =1

Figure 6

Local and Remote Funnel Numbers

The two funnel numbers may involve different degrees of effort to calculate. The local funnel number F_e for room j is as follows:

$$F(j) = \begin{cases} |A_j| - 1 & \text{if } j \in E \\ |A_j| & \text{otherwise} \end{cases}$$

The remote funnel number F_r can be determined by a trial procedure or by using a maximal flow algorithm on an expanded escape graph. First, it is observed that for any node j,

$$F_r(j) \leq \min F_e(j) \leq \lambda \text{ where } \lambda = \begin{cases} |E| - 1 & \text{if } j \in E \\ |E| & \text{otherwise} \end{cases}$$

The restructuring of the escape graph involves the addition of directed arcs to represent each room. Also, all arcs associated with a room are divided into directed arcs so that all incoming arcs are to one of the room nodes while all outgoing arcs are from the other nodes as illustrated in Figure 7. Furthermore, all arcs are assigned a flow capacity of one. Table 4 indicates the funnel numbers for the Beverly Hills Supper Club. The situations where the remote funnel number is less than the local funnel number are circled.

In an attempt to describe the durability of the directed escape routes during a fire, an analysis was undertaken of the impact of blocking rooms. This analysis involved first blocking one room at a time, then pairs of connected rooms, and finally, connected room triplets. In identifying only combinations of connected rooms, it is assumed that the fire and combustion products are more likely to spread through open doorways than burn through walls. Table 5 illustrates the consequences of blocking a single room.

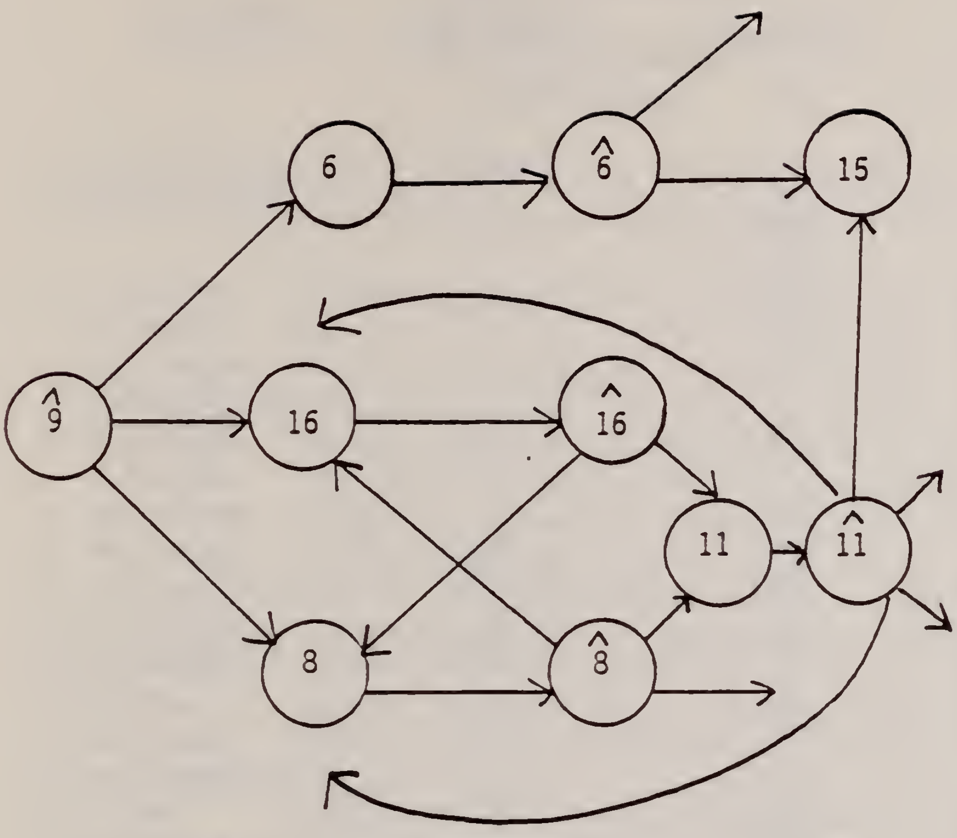


Figure 7

Partial Expansion of Escape Graph

Table 4

Funnel Numbers for the Beverly Hills Supper Club

Originating Location		Local/Remote Funnel Numbers*	
	Pre-fire	8:45-8:50	8:55-9:00
1. Crystal Room	2/2	1/1	x
2. Crystal Room	1/1	1/1	x
3. Main Staircase	5/3	x	x
4. Upstairs Hallway	3/2	1/1	x
5. Cabaret Room	1/1	1/1	1/1
6. Garden Room	2/2	2/2	2/2
7. Corridor Section	3/3	x	x
8. Corridor Section	5/4	4/3	x
9. Corridor Section	4/4	4/4	3/3
10. Viennese Room	2/2	1/1	x
11. Empire Room	4/4	3/3	2/2
12. Main Bar	4/3	x	x
13. Zebra Room	2/2	x	x
14. Main Dining Room	2/2	1/1	x
15. Kitchen	4/4	3/3	3/2
16. Dishwashing Room	4/4	4/3	3/2

NOTES: (1) An "x" indicates a room that is considered to be impassable.

(2) Circled numbers indicate a situation in which the remote number is less than the local funnel number.

*Does not include the direct exit to a location of safety.

Table 5

Single Room Blockage Effect

Number of Directed Escape Routes

Blocked Areas

Originating Location	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Crystal Room	x	40	1	19	34	34	6	8	22	36	22	30	38	40	26	18
2. Crystal Room	20	x	1	0	33	33	5	7	21	35	21	29	37	39	26	17
3. Main Staircase	20	21	x	19	18	18	4	5	12	19	12	16	20	21	13	10
4. Upstairs Hallway	20	39	1	x	33	33	5	7	21	35	21	29	37	39	26	17
5. Cabaret Room	22	24	16	20	x	23	14	5	1	20	16	16	22	24	14	10
6. Garden Room	23	25	17	21	24	x	15	6	2	21	17	17	23	25	14	11
7. Main Corridor	20	21	17	19	18	18	x	5	12	19	12	16	20	21	13	10
8. Main Corridor	20	21	17	19	18	18	16	x	12	19	12	16	20	21	13	10
9. Main Corridor	22	24	16	20	23	23	14	5	x	20	16	16	22	24	14	10
10. Vienniese Room	37	39	31	35	33	33	16	5	21	x	21	29	37	39	23	17
11. Empire Room	22	24	16	20	20	20	14	5	16	20	x	19	22	24	17	10
12. Main Bar	33	35	17	31	27	27	19	12	19	27	22	x	26	34	25	19
13. Zebra Room	20	21	1	19	18	18	4	5	12	19	12	16	x	21	13	10
14. Main Dining Room	2	2	2	2	2	2	2	2	2	2	2	1	2	x	1	2
15. Kitchen	32	35	29	41	29	28	27	15	19	21	17	28	33	34	x	14
16. Dishwashing Room	28	31	19	25	28	28	16	5	17	25	17	22	28	31	21	x
TOTAL	341	402	201	310	358	356	177	97	209	338	240	300	387	437	259	185
RATIO	.77	.91	.46	.70	.81	.81	.40	.22	.47	.77	.54	.68	.88	.99	.58	.42

Definition. The blockage effect is the ratio of the number of routes remaining when a room is blocked to the total number of directed escape routes.

For example, the blockage effect when the kitchen (room 15) is blocked, B_{15}, is calculated as follows:

$$B_{15} = \frac{259}{441} = 0.59$$

As illustrated in Table 5, the values of the blockage effect range from 22% for the corridor section to 99% for the main dining room. It can be observed that blocking room 8, 7, 16, 3, or 9 is more critical than blocking other rooms; and conversely, it is more important to keep these rooms passable. Figure 8 illustrates the average blockage effect over all rooms for all combinations of one, two and three connected rooms.

The susceptibility of a route to blockage increases as the route lengthens. Generally, shorter routes not only are less susceptible to blockage but also decrease the exposure of the occupants to any level of the combustion products, thus increasing their chances of escape. Table 6 illustrates the range and average values for the directed escape routes from each room.

A ratio involving the average number of rooms in a directed escape route is used to describe route length. This ratio, referred to as the susceptability ratio, is defined for location i as follows:

$$S_i = \frac{\sum_{j=1}^{N_i} r_{ij}}{N_{iR}}$$

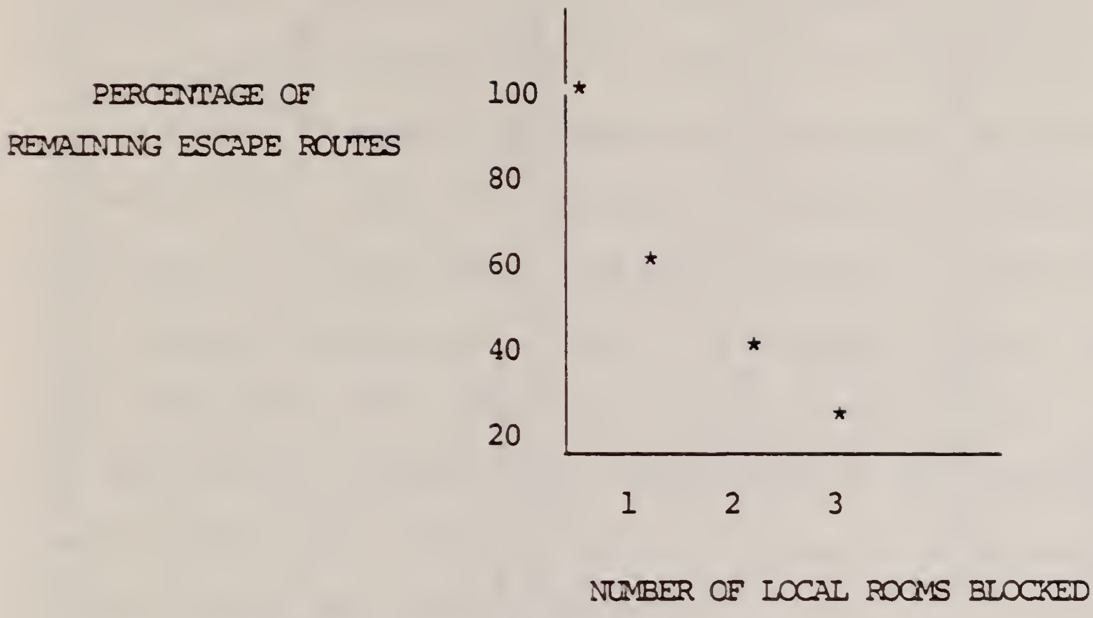


Figure 8

Effect of Fire Spread on Escape Potential

Table 6

Analysis of Route Length

Originating Location	Number of Directed Escape Routes	Number of Rooms in a Route* Shortest	Average	Longest	Susceptibility Ratio
1. Crystal Room	40	3	6.7	9	.42
2. Crystal Room	39	3	7.7	10	.48
3. Main Staircase	21	2	5.1	7	.32
4. Upstairs Hallway	39	2	6.7	8	.42
5. Cabaret Room	24	3	5.9	8	.37
6. Garden Room	25	2	5.5	8	.34
7. Corridor Section	21	2	4.5	6	.28
8. Corridor Section	21	2	4.0	6	.25
9. Corridor Section	24	2	4.8	8	.30
10. Viennese Room	39	4	5.3	7	.33
11. Empire Room	24	2	4.8	8	.30
12. Main Bar	35	3	5.4	8	.34
13. Zebra Room	21	2	6.1	8	.38
14. Main Dining Room	2	2	2.0	2	.13
15. Kitchen	35	2	4.8	7	.30
16. Dishwashing Room	31	2	5.0	8	.31

*Routes representing a direct exit from the originating location to the outside are not considered.

where N_i = number of interior directed escape routes indexed by j,

r_{ij} = length of route j from location i, and

R = number of rooms.

Smaller values of the susceptibility ratio indicate shorter routes. As illustrated in Table 6, values for the susceptability ratio ranged from 0.13 for the Main Dining Room to 0.48 for one of the Crystal Rooms.

Figure 9 illustrates a comparison of the number and length of the directed escape routes. The quadrant is arbitrarily divided into four sections at the mid-points of the positive scale. It might be argued that the best design would provide a large number of short routes while the worst design would have a small number of long routes. The numbering of the sections indicates that a large number of long routes might be a bit better than a small number of short routes when considering occupant loading and the use of early warning devices.

<u>Summary</u>

The technique is useful for both planning and communication. Requiring minimal data, it provides the architect with a means of quickly reviewing the escape potential during the preliminary stage of design. Furthermore, it provides a mechanism for the architect, code official, and fire service representative to critique the plans for a new building or the renovation of an existing building. Here, the analysis has not assumed any knowledge that could differentiate among the likely rooms where ignition might take place and probable fire spread scenarios. This type of information could be used to weigh the various results to more accurately summarize the escape potential based on the proposed activity within the particular building.

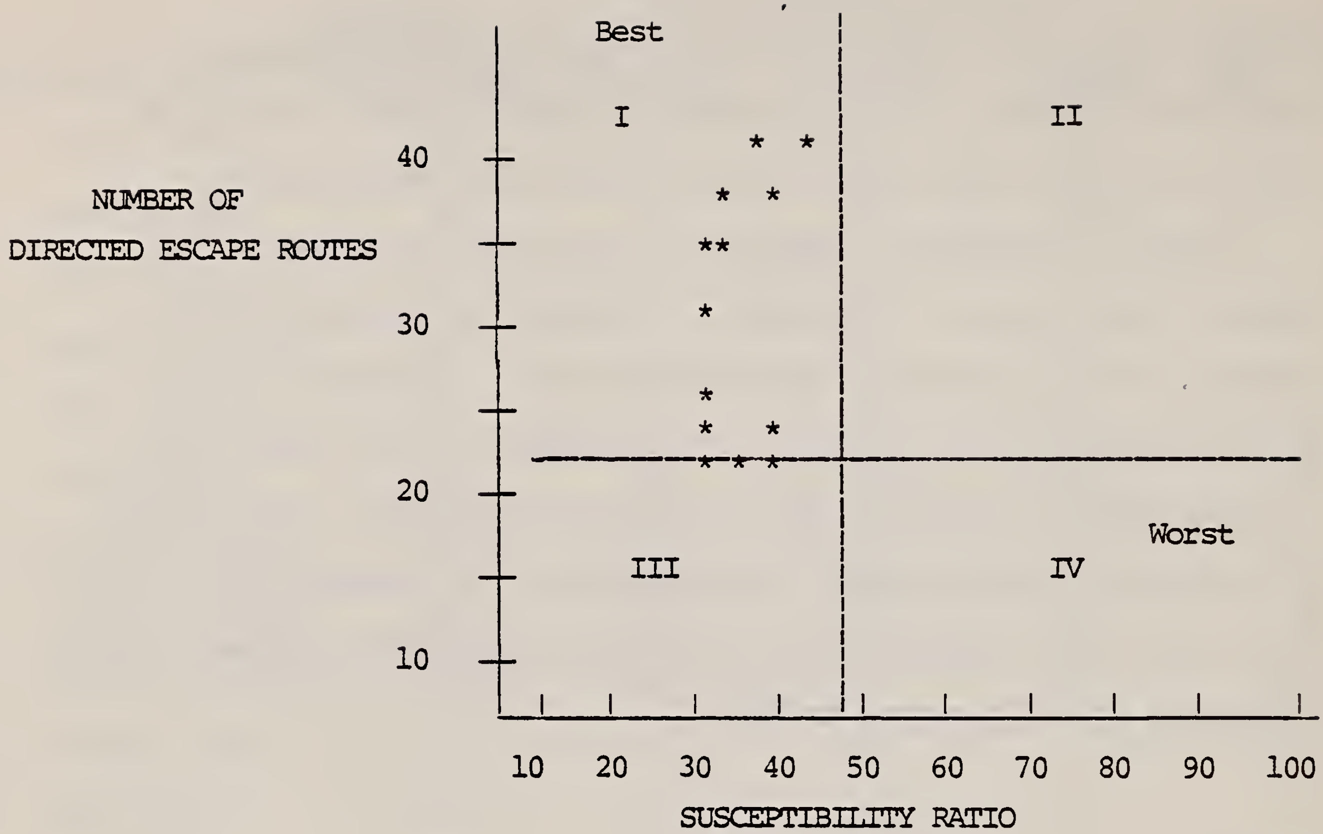


Figure 9

Comparison of Route Length and Number

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*HUMAN BEHAVIOR ASPECTS OF THE ST. JOSEPH'S HOSPITAL FIRE

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The fire incident at St. Joseph's Hospital on August 10, 1977 was detected by the nursing staff at approximately 8:45 p.m., at which time the fire had obtained a post flashover development in the area of origin, a bathroom on the second floor. The 130 year old, four-story building of ordinary construction had 171 patients. The fire extended from the second floor to the ceiling of the third floor through a pipe chase and the wall stud spaces.

The fire department was notified automatically with the activation of the local fire alarm system within the facility at 8:48 p.m. through an auxiliary system arrangement with the public fire alarm system. The seven nursing staff assigned to the area of fire origin evacuated a total of thirty-four patients in a period of 6 to 7 minutes, with twenty-two of these patients being evacuated in less than 3 minutes. At the time of fire department arrival on the fire floor, all the patients had been evacuated from the fire area with the exception of 2 male patients. The fire department personnel using breathing apparatus removed both patients. One patient could not be revived, while the other died approximately one week later.

Total evacuation of the hospital was accomplished by the staff, fire and police department personnel, with assistance from some citizens. The 171 patients were evacuated in a time period from 16 to 19 minutes.

*Only the abstract of the complete report is printed here. The complete reference is:

John Bryan and Philip J. DiNenno "An Examination and Analysis of the Dynamics of the Human Behavior in the Fire Incident at St. Joseph's Hospital, Philadelphia, Pa. on August 10, 1977." University of Maryland. National Bureau of Standards Report No. NBS-GCR-78-140. May 1978.

THE RIGHT TO RISK - NORMALIZATION

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Risk is part of life and the right to take risks should not be denied any sector of the community. A contemporary trend toward normalization of the lives of the handicapped involves allowing them to take the kinds of risk we all accept as part of normal life. In the nineteenth, and well into the twentieth century, institutional care, although often enlightened in itself, segregated the handicapped from the rest of society and often reached after them even after they were returned to their homes. But today we are de-institutionalizing our approach to the handicapped, who are being encouraged to participate in all activities of normal life. For this to happen, the built environment has to be free of physical barriers, and provision made to provide protection from unacceptable levels of risk, while not inhibiting freedom to move and grow. Architects and environmental designers are key professionals in the task of making it possible for the handicapped to enter schools, homes, offices, public buildings and even hospitals, just like anyone else. To the code writing bodies falls the task of understanding the developmental capabilities of disabled people and interpreting this in building codes that encourage upward mobility for a too long restricted sector of our community.

Key Words: Acceptable risk; barrier-free; building codes; built environment; de-institutionalization; developmentally disabled; environmental design; handicapped; normalization; overprotection; upward mobility.

We are all born with some intelligence but little knowledge. Knowledge is gained through experience, which is often very painful. Experimentation is not new. When man first decided to walk on two feet instead of crawling, he immediately subjected himself to one of the greatest risks in our society, that of falls. It is well to remember that Senator John Glenn from Ohio who was one of the first men in history to orbit the earth in a satellite, suffered a concussion when he slipped and fell in his bathtub. All new learning experiences, and many if not most, recreational experiences are accompanied by varying degrees of risk. The right to take such risks should not be denied to any sector of our society, including the handicapped.

We have endeavored, through education and legislation, to permit the handicapped to live in a "normal" environment, i.e., to be permitted to live in a "normal" house in a "normal" community; to be gainfully employed; to be permitted to go to theaters, parks, museums, and do all of the things that "normal" people do.

Here is a partial account of some past activities on behalf of the handicapped:

In 1958, the President's Committee on Employment of the Handicapped assisted by the Veterans Administration and the Department of Labor printed a guide on facilities needed to make buildings accessible to the handicapped. The ANSI Standard 117.1 entitled "Making Buildings and Facilities Accessible to and Usable by the Physically Handicapped" was promulgated and is adopted by most states for public buildings.

In 1968, Congress passed Public Law 90-480, the Architectural Barriers Act, which provided that all federally funded buildings must be accessible to and usable by the handicapped. Since that time many states and local communities, as well as the federal government, have passed legislation granting the right to handicapped people to use and enjoy the built environment.

Recently, a new federal law has begun to change the methods of educating handicapped children in public schools. It emphasized "normalization" which is to integrate the handicapped into the mainstream of the educational process; not in separate classrooms but in the same classrooms as those students who are not disabled. The "Education of All Handicapped Childrens Act" requires that all disabled students be given individual evaluation and placed in the least restrictive environment possible.

In the nineteenth, and well into the twentieth century, it appeared that government or charitable institutions were the best and only way to serve the needs of the handicapped. During this period these institutions housed, cared for and protected those who were rejected from society such as the lame, the blind, the mentally impaired, the deaf, etc. Many of these institutions did a remarkable job and should be complimented for their compassionate work.

This emphasis on institutionalization, however, caused the segregation of the handicapped from the mainstream of society. The primary result of institutional care and special education has been separation and isolation. The prevalent belief that only the experts were qualified to deal with the handicapped, inhibited, if not prevented a normal life.

Throughout the country today there is a trend to de-institutionalize even the severely handicapped and return them to the normal community. The community must, therefore, accept a moral obligation by accommodating certain of the specialized needs of those who are generally handicapped as well as for those with developmental disabilities. When speaking of de-institutionalization, we are not advocating the removal of handicapped individuals from larger institutions by placing them in smaller institutions; rather, it is our sincerest desire that they be allowed to function in normal community settings in the real world. If special needs and different requirements for handicapped persons are not as necessary or as substantive as we once believed, then facilities with minor modifications can be used to accommodate all people.

Architects and other environmental designers are among the key professionals with obligations to see that such facilities modifications are achieved. Such an obligation means designing buildings free of barriers -- without barriers in the way, spaces are created and connected in hardware specifications, in controls and lighting, and access to and from buildings including measures regarding life safety from fire.

There will probably always be a need for some special programs and institutions designed to rehabilitate the severely disabled. But the primary challenge of society is to assist the "Quiet Revolution" of the handicapped in claiming their rights to the normal use and enjoyment of the built environment. They need more than ramps and curb cuts, they need to be understood as complete human beings. They want equal education, equal employment opportunities, equal risk, health care, recreation and transportation. The wish to be assimilated into the mainstream rather than be isolated- included rather than excluded --"for their own good." Their challenge demands that we overcome our fears, change our attitudes, remove barriers that inhibit their free use of facilities and especially that we treat them as normal human beings. We must also learn not to overprotect them. We must encourage them to do things for themselves, even if it takes them a long time and involves the taking of risks.

Very often, society's zeal to "help" those who need "help" to help themselves, has denied the handicapped basic learning experiences by creating overprotective environments or relationships.

The existence of overprotective relationships between parents and handicapped children, between grandparents and handicapped children, between adults and their handicapped friends have long been recognized by professionals in the field of rehabilitation. The present decade brought the recognition that established private and governmental agencies organized to help the handicapped,and many professionals employed to direct the programs of the agencies were also very often overprotective and paternalistic. It is only very recently that there has been any recognition that the environments which were being created by these agencies and professionals to provide opportunities for handicapped persons were themselves inhibiting positive developmental processes.

All programs for persons with developmental disabilities and other handicaps should be based on the developmental concept; that is, programs should provide opportunities for the participant to learn increasingly complex skills which will lead to more control over himself and his environment.

If all elements of risk are denied persons with developmental disabilities and other handicapping conditions, essential developmental opportunities are therefore also denied.

Indeed, not being able to subject oneself to risk prevents an essential learning process. It is an accepted adage that one learns from one's mistakes. In addition, risks, taking chances, enhances one's decision-making ability, and therefore lessen dependency. Further, to discourage risk limits activity and experiences, and therefore measurably inhibits growth, humanization and freedom.

Therefore, codes and standards which are promulgated nationally, statewide, or in local communities in regard to facilities promoting opportunities for persons with developmental disabilities and other handicapping conditions should seek to enhance the developmental and experimental processes.

This should not be construed to mean that there is not a need for a barrier-free environment or for special adaptive equipment or necessary codes and standards to provide basic safety and protection. But such codes and standards should reflect modern concepts in regard to providing opportunities for persons with developmental disabilities and other handicapping conditions.

Our society, perhaps, has to take what it may consider risks so that some of its members may be provided with necessary opportunities. By taking such risks, society, including members who need special opportunities, will grow.

Overprotection not only prevents one from taking learning-educational risks, but in many instances can lead to the denial of basic rights and freedoms. A handicapped person can be denied access to a building, an aircraft or other means of transportation for "his own good" as it would be difficult to evacuate him.

Put in simple terms, it would be possible to assure any person, handicapped or not, that they will not perish in an automobile accident. However, in order to eliminate the risk, that individual would not be permitted to set foot into an automobile or any vehicle; indeed he would not be permitted within 100 meters of any highway. People, including the handicapped, should have the right to choose between normal risk taking and self denial.

Another facet of overprotection is the outreach of the institution into the normalities of life. In other words, when the handicapped person leaves the institution, then the institution (or part of it) follows him into the community. The institution will apply the same sanctions and demands of the "residence facility" occupied by the handicapped as it did of the rehabilitation center, hospital, nursing home, etc., from which he was discharged. This is not only extremely costly, and inhibits normalization, but the ambience of the institution in all its aspects is still present.

Communication is not entirely written and spoken. Body language is an example of a different and often more effective method. The demands or sanctions of an environment are part of still another method of communication. The decoding of the message given by our surroundings is not greatly dependent upon high intelligence. Almost anyone feels the difference between the lobby of the Regency Hyatt House Hotel and that of Sing-Sing Prison. A different behavior pattern for occupants is at once understood. Living design literally shouts messages of expectation to the occupant.

Multi-bedded rooms say you are not an individual, you exist only as part of a group. Carpetless floors say we expect you to soil them and you are unworthy of being trained not to. Concrete walls, wired glass windows in steel frames, obvious fire protection systems, say you are not capable of normal judgement in case of a fire emergency. Baths, showers, and toilets with little or no privacy say you have no right to dignity. The message of the design will come through to the occupant loud and clear. What is more, the public by the same insidious osmosis will gear their own behavior and expectations to the language of the environment. They too will treat the occupants of a halfway house, a day care center, or other institution as somewhat less than human.

I do not advocate that we invite the disabled to integrate into the community without making any changes to accommodate them. It is obvious that barriers must be eliminated in order that the handicapped may have the free use and enjoyment of the built environment. It is equally obvious that they should not have to endure more or increased risks than a normal person and that some special provisions will have to be made for them. It was to this end that as Chairman of the Committee on Safety to Life, I appointed a sub-committee to prepare special provisions for the handicapped to be placed in all occupancies sections of the 1980 Life Safety Code, NFPA-101. It is also why I am pleased to serve on the Advisory Board of the Task Force on Life Safety and the Handicapped.

We must first decide what measures are absolutely essential, cost effective and not overly restrictive. Code writing bodies will have to be educated to understand that developmentally disabled persons are capable of living a normal life and that it is the goal of all sectors of the community to promote this philosophy. The prevailing attitudes of society that, because a person is handicapped he is not able to take care of himself and must therefore be identified and labeled as requiring institutional care, must be changed.

Very costly facilities, devices, alterations, etc., will simply not be achieved because of the economic impact on the community, including the handicapped. Therefore, they will be forced to stay on in the institutional environment unless some compromise is reached.

The goal should be to promulgate the family group living concept of normalized existence for the handicapped so that they can live in a residential environment. It will require a massive educational program amongst the code writing bodies, the building officials that interpret the codes at the local level, the licensing bodies that issue licenses and planning and zoning officials that are overly protective of other existing residential communities. A plan must be developed to successfully mount this obstacle to reach the intended goal.

We must all make a concerted effort to test whether or not any proposed or existing requirement, rule, standard, law, regulation, etc., is truly productive, cost effective, and that its final result will help the handicapped and not harm them. I was told an anecdote at the President's Committee on Mental Retardation that I believe bears retelling:

> "A young lady using long leg braces and crutches, was climbing the stairs out of a subway in New York City. In order to climb the stairs, she placed both crutches under one arm, put one hand on a banister and hopped up backwards, one step at a time. She reached an intermittent landing and stopped to rest, still of course, facing down the stairs. A young, compassionate, well built man, wanting to help, without saying a word, placed a strong arm around the young lady's waist, and carried her down the stairs."

Codes and standards concerning facilities providing opportunities for persons with developmental disabilities and other handicaps should help society to make certain that it is building the kind of environment which enhances upward movement for disabled individuals and does not, inadvertently or otherwise, take them down.

FIRES AND HUMAN BEHAVIOUR:
EMERGING ISSUES

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A range of questions and issues within the study of behaviour and fires, which have not been fully explored are briefly presented. These draw upon a five stage model of human behaviour and fires and it is argued that a great deal has yet to be learnt in relation to each of these stages. Links to general concerns in social psychology from these issues are made.

The various questions and approaches to answering them are illustrated from a number of studies carried out by the Fire Research Unit at the University of Surrey, under the author's direction. These include statistical analyses of the effects of the firemen's strike, a study of emergency "999" calls and a content analysis of media reporting of fires.

In conclusion it is argued that behavioural studies of fires hold the potential for a radical impact on fire prevention and fire safety.

Key Words: Fire fighter; fire prevention; human behavior; media reporting.

ACKNOWLEDGEMENT:

I am grateful to the Fire Research Station of the Building Research Establishment for their continuing support of our research and to my colleagues John Breaux and Jonathan Sime. This is a revision of a paper originally presented to the Washington, 1978, Conference on Behaviour and Fires.

INTRODUCTION - A GENERAL MODEL

The purpose of this paper is to map out the emerging directions of fire-oriented behaviour research and to try and give some indications of those questions and issues which have not been fully addressed over recent years. This is an attempt to take stock and see what is being tackled and what is being ignored. The overview will be illustrated by reference to a number of small scale studies which have been conducted at the University of Surrey, but which have not been previously published. A brief attempt will also be made to relate fire research to other areas of social science research. Many of the problems of fires and behaviour do have counterparts in other areas of social science.

In order to put this map together it is necessary to present a summary structure of the issues of concern. Such a structure can be derived from the set of papers which I have edited, Fires and Human Behaviour*, being published by Wiley in 1980.

It has the following components:

a) Preparation before a fire happens

b) Recognition of a fire once it occurs

c) Actions in the fire

d) Escape from the fire

e) The after effects of the fire experience

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* This book also covers most of the material to which reference would be made for this paper. No formal references are therefore given.

These five broad headings seem to emerge in most discussion of behaviour in fires. Nonetheless, it should be recognised that this simple five stage model is very different from conventional decision making models, put forward by Engineers and Operational Research Consultants. It is also distinct from risk oriented models, or those that attempt to build the whole decision making process about fires around costs and benefits. Each of those decision models which attempt to set up processes to facilitate the selection of particular hardware systems, or even educational strategies, may be thought of as cross-sectional to the five-fold list above. The costs and benefits of particular actions could be identified in relation to each of the five areas indicated.

It is important to establish this link to other approaches to modelling and structuring of decision making about fires, both in order to clarify the way in which a behavioural orientation towards fires is different and in order to illustrate the way in which the behavioural approach is likely to bring together a wide range of other (engineering related) issues. It certainly serves to illustrate the way in which any particular engineering procedure, say focusing on means of escape, or on modes of prevention, may only achieve a sub-optimal solution if it does not take into account the whole process of human reactions to fires which tie different aspects together.

a) PREPARATION

One of the most direct examples of the relevance of considering how prepared people are for fires can be drawn rather directly from what might be considered as a field experiment, carried out during the winter of 1977/78. This was the firemen's strike. All full-time British firemen went on strike from the 14th November 1977 until the 15th January 1978. Because the Fire Research Unit at the University of Surrey was in operation during this period and had access to the incidence figures for the Surrey Region, it was possible to get figures for fires during the period of the strike and to get figures for the period immediately before the strike. It was also possible to get parallel figures for the previous year.

Table One presents the broad frequency figures for the number of fire incidents that were reported to the authorities. In that table are also indicated a breakdown of the incidents in relation to malicious fires, domestic fires, and false alarms with good intent. Figures are also available for the number of outside fires.

A number of comparisons can be made from these figures. Either the frequency of fires immediately before the strike can be compared with the same time period from the previous year or the incidence of fires which occurred during the strike can be compared with a similar period in the previous year. One further comparison, which is more difficult to validate, but which is nonetheless interesting, is to look at the number of fires in the period during the strike with those of the period immediately before it.

All these comparisons show quite clearly that during the period of the strike there were fewer fires than might have been anticipated. There is even a tendency in the figures to suggest that more fires occurred immediately before the strike than might have been expected. It almost looks as if there is an attempt by people to get their fires over with, whilst there is still a full fire brigade!

TABLE ONE

Frequency of fire incidents in Surrey in relation to the Firemen's strike of 14th November 1977 to 15th January 1978

		12 Sept. to 14 Nov.	15th Nov. to 15th Jan.
TOTAL NUMBER	76/77	817	911
OF INCIDENTS	77/78	1114	651 *
% Change		36	-29
MALICIOUS	76/77	83	58
CALL	77/78	104	68 *
% Change		25	17
DOMESTIC	76/77	55	96
FIRES	77/78	92	70 *
% Change		67	-27
FALSE ALARMS	76/77	138	114
WITH GOOD INTENT	77/78	122	86 *
% Change		-12	-25
OUTSIDE	76/77	60	45
FIRES	77/78	85	32 *
% Change		42	-29

* Frequency for period of strike

It is important to realize that during the period of the strike an alternative fire service was provided by the British Army, using equipment which was generally agreed to be outdated. The Police acted as the operations room and called in the military fire brigade to deal with fires of which they received notification. There was, as a consequence, a rather different calling system, record system, and certainly a different attendance time for getting to fires. This does make comparisons of figures for the different periods problematic, but nontheless it is very difficult to argue with the point that there were actually fewer fires occurring during the period of the firemen's strike, although of course, the amount of damage which resulted from any particular fire was typically much greater. The reasons for the fewer reported fires were no doubt due to many circumstances, not least, the likely reluctance of people to call the brigade during the strike and the consequent possibility of a great increase in the number of attempts to cope with fires by residents themselves.

That people were more reluctant to call the fire services around the time of the strike is perhaps best shown by the fact that the figures for false alarms with good intent was down for both the period before the strike and during the strike. The malicious false alarm frequency increased for both these periods. This suggests that one could argue that this reluctance to call the brigades does not account for the very radical difference in the number of incidents. The fact that the proportional change during the strike for domestic fires, false alarms with good intent, and outside fires were all of the same scale does suggest that people were either more careful, or more prepared to deal with a fire once it had occurred. There is still, however, one curious consistency in the figures that has been alluded to above, but which requires serious consideration.

This is the fact that the relative change in the number of incidents increased for all categories of fires, <u>prior</u> to the firemen's strike, when compared with the change during the firemen's strike.

These figures, then, suggest that there is some sort of social control over fire incidence. This raises the question of whether or not there is a sense in which many fires are only partially accidental. When it is recognised that most Western, developed societies put considerable resources into making people aware of fires and reducing the likelihood, then it seems possible that it is almost necessary to make a positive act against these controls before a fire will occur. It is also well-known that there are a great number of fires which are malicious, although there is no direct evidence of arson for them. This therefore raises a very important question as to whether or not, in relation to the whole issue of preparation, there are consistent patterns of behaviour which, possibly below the level of awareness of participants, do lead to the occurrence of many fires. To dismiss these as negligence or malice is not really to explore the problem directly. It is only necessary to relate this question to that of vandalism in general in order to be aware that there are many similarities between the two social problems. Many aspects of vandalism have been recognised as being meaningless, almost random events, relating to a particular lifestyle. Indeed, the argument that the person who creates the facilities which inspire vandalism may be considered as much a vandal as the person who destroys that facility, may well have many parallels to the issues underlying what we might call "pseudo-arson".

An important point here, is that dramatic changes in the incidence of fires, or at least in the frequency in which the fire services are called upon, can be related to the general preparedness of the population. A 29% reduction in total fire incidents, as shown in Table One, is a substantial figure indeed, and certainly not one to be dismissed as less significant than that which can be achieved with new forms of fire alarm or engineering systems.

DEMOGRAPHIC ASPECTS OF PREPARATION

There are many figures available which show that the people who get killed in fires tend to be the very old or the very young. There is also accumulating evidence that they fall into certain socio-economic groups. Data explored jointly by the Fire Research Station and the Fire Research Unit at the University of Surrey recently, shows that there are quite strong relationships between the frequency of fires occurring and the general standard of living of the areas in which those fires occurred. In other words, there is growing evidence that the pattern of risk of potential fire is not at all evenly distributed throughout the community. Fire research activities, at present, however, are not oriented towards this uneven distribution. The move towards studies of nurses' homes or of major institutions relates more to the fears of policy makers of public outcry if there were to be a major disaster in those areas, than to the overall frequency of incidents. It is also a matter of the current processes of control. It is much easier for policy makers to legislate for the control of centrally organised institutions. In order to influence and change patterns of behaviour across a broad set of domestic situations quite different processes of legislation and control are necessary. These processes would rely much more heavily upon education than they would upon codes of practice and legislation, because they would need to reach each of the individuals or families concerned directly, rather than giving instructions to the superior authority responsible for the institution.

It is probably because of these difficulties that demographic questions have tended to be ignored by researchers. The further political anxiety that the areas in which fire incidents are greater are also areas of other under-privelege, and thus may fuel the outrage of minority groups is probably also at the back of many politician's minds.

THE REPRESENTATION OF FIRES AND FIRE BEHAVIOUR

One of the important ways in which people learn about fires and thus are influenced in relation to their preparation for them is by means of what might be called social representation, i.e. the way in which fires are represented to the population at large, notably through newspaper and media reporting. In one study, carried out at Surrey, content analyses were carried out of newspaper stories of fires. It is clear from this that fires are represented as either disasters or great heroic rescue ventures.

This research showed that half a dozen words typically feature in many newspaper headlines about fires. "Hero rescues child in fire drama" is a very standard set of words that would make up most headlines. The way in which newspapers and media in general turn fires into a heroic event or disaster with a beginning, middle and end, including heroes or tragic victims is possibly one reason why so many people are interested in fires. Such a structure certainly influences Government decision makers in the way in which they think of fires and of research support for studies of behaviour in fires. It is also part of the point referred to above, that decision makers are more concerned with avoiding major disasters than stopping whole series of minor disasters, because the major disaster captures newspaper headlines and is a much more explicitly sensitive issue.

A further aspect of the newspaper reporting is that of "panic". The media use the term panic as a description of what occurs in fires on many occasions.

Thus they both draw upon a stereotype of the social representation of what happens in fires and at the same time add further evidence to this belief. Other reports produced by our team at Surrey have explored this issue more directly, but the source of belief in panic within the media does require careful consideration.

OTHER MODES OF COMMUNICATION

Given the power of media reporting of fires, it is important to find other ways of representing what goes on in fires in order to enable people to become aware of what is involved. Unravelling this sequence of events in particular case studies is clearly of value for this. At Surrey this was taken further and a "Firebox" was built, which represented the details of a hotel fire in such a way that people could make choices as to which decisions they would take. The "game" provides information on what the likely outcome of such decisions are. It is remarkable how wide ranging the interest has been in this simple "game". Since building it, a more elaborate version has now been developed, using a small desk-top computer and this has found its way into various exhibitions. Such interactive games, built around actual events, do go a long way towards changing people's awareness. We even have anecdotal evidence that they may change people's behaviour in actual fire events.

RECOGNITION

Before behavioural scientists started looking at fires, the way of thinking about them was closely related to the view of those people who are concerned with a fire once it has started, notably fire fighting agencies. This gave rise to the classic, machine-oriented view of a fire event. The metaphor might be put forward that we had only information of fires as if the cameras recording them had started rolling once the fire had been ignited. What has emerged from a number of studies is that the early stages of awareness and recognition are very important--the situation when residents think there may be a fire of some danger in existence.

This relates to the issue of fire alarms. At Surrey this has become a particular focus for research. The existing studies do indicate that there may be many other ways in which alarm systems can be used than at present. Perhaps more attention needs to be directed to the pay-offs which people find it necessary to establish in the early stages of a fire. This has been discussed before, but the argument is that the mistake of making the wrong assumption that a fire exists carries social consequences. Clearly the mistake of assuming that a fire does not exist when it does also carries consequences. In the early stages of a fire where the cues are typically ambiguous, the individual has to decide whether the pay-off matrix is in one direction or another. There have been many social psychological studies of the way in which these balances are achieved, but it is clear from the fire situation that people will try to establish the exact nature of the cost and benefits to themselves by attempting to get further information. At the present time fire-alarms really do not provide unambiguous information and research is now in motion to explore how that can be changed.

A related point, here, is the one of the role which a person has in the situation in which a fire occurs. The pattern of activities which a person undertakes when a fire occurs does seem to relate very directly to what his role is in that situation and the rules which he believes are appropriate. Thus in the early stages of a fire there is a sense in which an individual is trying to define what his role is. He needs to get information not only on the course of the fire but also on the behaviour of others in order to establish this. It seems quite likely that the current social and psychological studies of the definition of situations are particularly relevant to elaborating what cues people draw on in order to decide on the most appropriate behaviour for themselves. This is information which is most readily obtained from detailed case studies and is one of the reasons why we can never have too many detailed examples of exactly what has happened in any given fire event. Furthermore, it is not a far step from thinking about the particular role which an individual may have to realising that the role structure of different organisations will lead to different potentialities in any given fire. This is recognised to some extent in the fire grading of buildings, but perhaps the organizational issues ought to be much more clearly identified in the future. This is particularly true if we are to relate fire alarm systems to the organizational structure which the buildings house.

ACTION

Once a fire has been recognised,one of the early stages of importance is the calling of the fire services. The use of special call systems such as the British 999 system has not been looked at by many researchers. However, in one study at Surrey it was possible to examine closely the patterns of conversations between operators and people calling in. The first point that emerged was that there was a great variation in the time it can take to get the address through to the operator. Given how crucial time is, and the great resources which are put into the fire brigades to decrease their attendance time, then any saving at this crucial stage would be of importance. Indeed the evidence collected in the small study at Surrey, suggested that there could be occasions in which whether the brigade gets there in time to save someone or not, could be a function of the efficiency of the call system. There is the further issue of whether or not malicious calls can be recognised in these early stages, on which this study threw some light. Beyond this is the question of what happened in those situations in which no telephone is available. This comes back to the demographic questions that was raised earlier, but again the fire services sometimes seem to rely on the wide availability of telephones. Yet they are not totally available in most countries.

One of the issues that emerged in looking at alarm calls was the way in which children making telephone calls led to many difficulties. This opens up the question of children in fires. If the greater docility and difficulty of responding and understanding the complex situation which a fire is, is put together with the other difficulties of role definition and use of the resources available, then it becomes clear that children do present a very special group. The fact that they are often in institutional settings, serves further to open up the question as to whether or not we should be looking particularly at children in fires and their special requirements.

EQUIPMENT

Research at Surrey has consistently demonstrated how rare it is for people to use fire extinguishers that are available, and the difficulty they have had even with the extinguishers which they tried to use. It is possible that these statistics are a bit misleading in that the minor fires to which brigades are not called may well be precisely those fires in which extinguishers are used effectively. Nonetheless the provision of extinguishers and other forms of fire-fighting hardware presupposes that people can and do use this equipment. It is likely that the manufacturers of this equipment will keep relatively quiet on any weaknesses that might be revealed in the use of the equipment. Here again is an area which has been ignored by researchers. All the indications point to the fact that the existing first-aid fire fighting equipment is frequently either inappropriate or ineffective. It is necessary to get much more detailed information before people can act on these general indications.

ESCAPE

The particular point to be emphasised here is that the modelling of sequences of activities in complex and varied situations is exceptionally difficult. Social scientists have not really been able to develop a rich set of procedures for handling these sorts of problems. From work by the Fire Research Unit it has been possible to demonstrate that, using multi-dimensional scalogram procedures, unique patterns of behaviour can be readily identified. These unique patterns do seem to relate to unusual roles within the fire situation, most notably that of the arsonist. But they also serve to show that consistencies in the sequences can be identified and that a classification scheme may be derived which could be related to the outcome and intensity of the fire. It is absolutely essential to identify what the most appropriate sequences are which do occur in fires, in order to provide the appropriate guide lines for fire training. The fact that there are so many differences and confusions in the training guidance given serves to illustrate how complex the problems are. Here again is an area where social science research of behaviour in fires would also contribute much to our understanding of sequences and patterns of behaviour generally.

THE AFTER-EFFECTS OF FIRE

Few researchers seem to have looked at post-fire trauma, the after-effects of fire. In current attempts by the Fire Research Unit to develop a national survey of what happens in fires, using a postal questionnaire, it has become clear that a large proportion of people move from the address of the fire. Current figures suggest that as many as two-thirds of people who have been involved in major fires found the necessity to move on. Whether this is for directly functional reasons in that their house is inhabitable, or whether it is for more psychological reasons, of wishing to get away from the tragic scene, is difficult to determine. Whatever the reason there are clearly a large number of people displaced by fires, far larger than might have been guessed by figures for loss of buildings. The general implications of even the social consequences of post-fire trauma and the loads that are put upon any social or welfare services have not been explored. This is another area where future research which looked at both the psychological and the social consequences of being involved in fire, may throw important light upon the roles which fires play in the community as a whole.

CONCLUDING QUESTIONS

By way of summarising this informed overview of issues which have not been fully studied yet, four questions can be asked for future research.

1) Are fires ever completely accidental?

There are implications in answering this question in terms of a yes, a no, a qualified yes, or a qualified no.

2) What are the actual type and number of fires which occur?

This may seem like a surprising question given the plethora of national statistics. Nonetheless there are many doubts both about the accuracy of these figures and the proportion of fires which occur which are actually reported. Estimates vary that between 10% and 20% of all fires are actually reported. When this is put against the demographic questions as to <u>where</u> fires occur, then it is clear that we do need much fuller sets of information. This is information simply about the occurrence of fires, where and when.

3) How dangerous are the current warning systems?

There are many criticisms of alarm systems and there has been little examination of "natural alarm systems" e.g. telephones, people shouting and the like. Does the reliance upon bells and other forms of hardware really act as a hindrance rather than a help? This is part of the very general question as to what dangers and hindrances to ordinary usage are provided by current fire protection practices. There well may be more people injured by smoke doors or badly designed fire escapes, than are ever saved by existing ones in the case of fires. This is certainly a cost benefit relationship which needs further exploration.

4) What are the appropriate escape actions in fires and how can they be planned for?

It is quite clear that each fire situation has its own qualities. It is also clear that there are patterns of behaviour which naturally occur, some of which may be successful and some not. What are appropriate sequences?

If these four questions can begin to be answered and the other issues referred to in this paper can be resolved, or at least a stab made at resolving them, then it is likely that the social orientation towards behaviour in fires could have a more dramatic effect on fire precaution and fire practice than social research has had on any other area of human endeavour. The goals, then, indicated in this paper are not simply to dot the "I"s and cross the "T"s of engineering practice, but to provide a full and firm basis for a radically new approach to fire prevention and fire precaution.

PANIC - FLIGHT - EVACUATION

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This paper presents the results of numerous studies on the phenomenon of panic. It defines, analyzes and relates the components of panic; considers the concept of individual predisposition for the inadaptive behaviors of panic; and presents observations on evacuations.

Key Words: Evacuation; factor analysis; fire drills; firefighters; human behavior; panic.

INTRODUCTION

As I speak English with some difficulties, I think that the best way to communicate our research to you is through the presentation of slides. Diagrams are indeed an international language.

The first topic was "panic and fire." But since flight is often seen as the main component of panic, we have had to observe evacuations either as exercises or after a real warning.

It can be also supposed that there is an individual background for inadaptive behaviors observed in panic.

Fire, panic, attitudes and evacuation are the four points I will show you in 17 figures*.

Figure 1 - Evolution of Fires in the Region of Paris

The military batallion of firemen of Paris was created by Napoleon in 1811, the regiment in 1867 and the brigade in 1967. The number of inhabitants protected by the corps has increased a lot but the number of fires has increased very much faster: for 1 million inhabitants, this number was 22 times the number in 1811. We don't know exactly why. It seems that the change of batallion to regiment and to brigade had no effect on the increase in fires.

We can see on the diagram when the area under consideration was not Paris itself but Paris and surroundings there is a break of the general regression curve given by the equation:

$$x = 124.46\ e^{.015t}$$

The equation for the curve best fitting the data prior to the break is

$$x = 126.40\ e^{.016t}$$

which is not significantly different.

The equation for the curve best fitting the data after the break is

$$x = 7.65\ e^{.033t}$$

In this case the exponential growth rate coefficient increases by a factor of two. This can perhaps be explained by the fact that many factories were built during this period in the area surrounding Paris.

*The figures are labelled in French. However, English subtitles are provided.

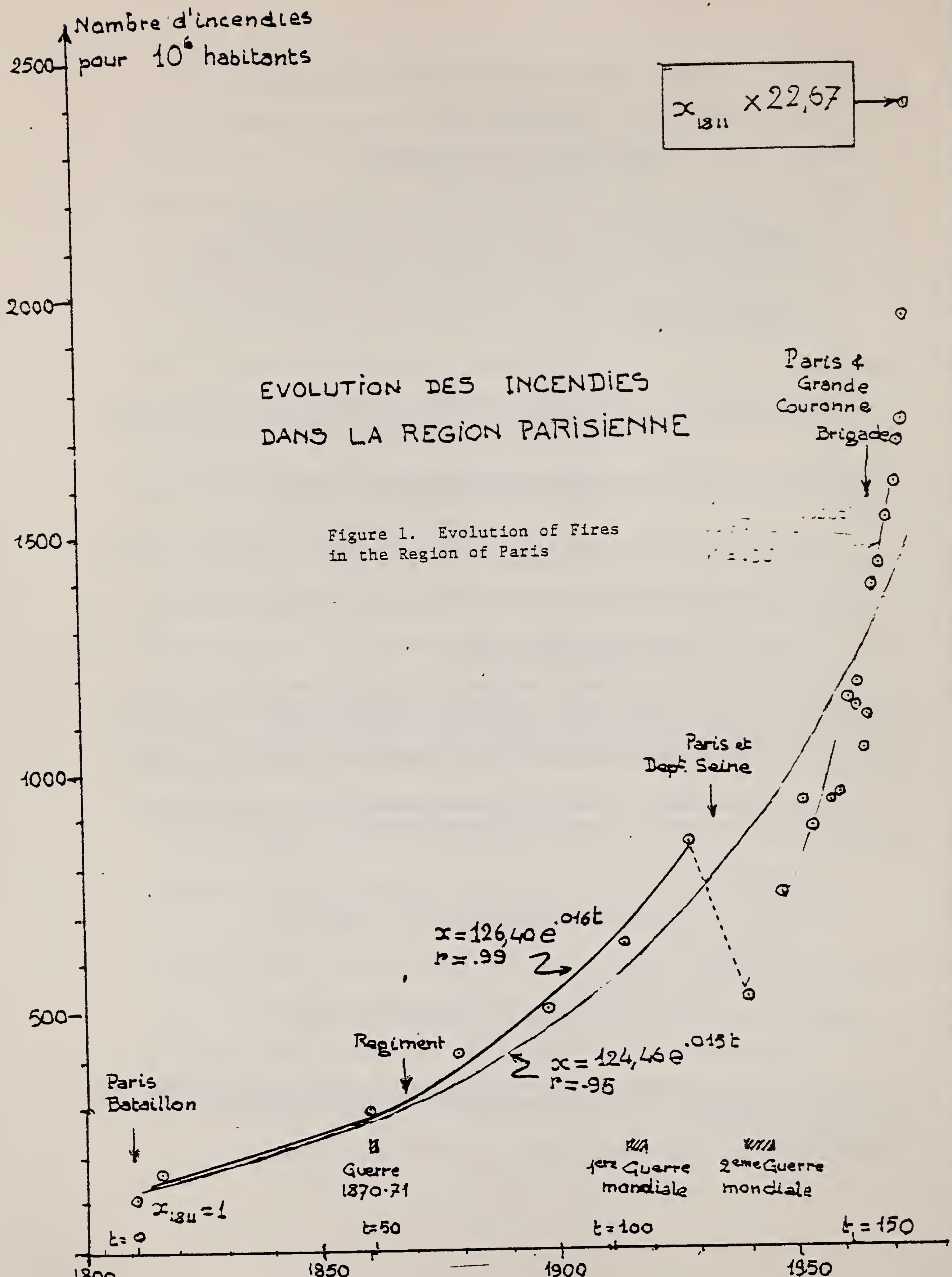


Figure 1. Evolution of Fires in the Region of Paris

France is not a country which is regularly threatened by natural hazards like earthquakes, volcanos or floods; fire is indeed the most frequent disaster. For this reason, our studies are mostly focused on fires.

Figure 2 - Panic in the Press

For the purpose of organizing observations on "panic" in the field it was necessary to understand what this word means.

Firemen warn about panic when one person tries to jump out of a window because of a fire.

The point of view of the top administration for security is given in a red book: "Regulations for protection against risks of fire and panic in institutions admitting public." This regulation seems to be oriented toward collective flight; but this interpretation can be seen as a very subjective one.

More objective is our analysis of newspapers: In 4700 articles about disasters, only 328 are concerned with panic (7%). Of the 328, 67% quote characteristics; 73% use the word; 41% use both the word and quote characteristics.

These characteristics are grouped as:

Feelings (Terror, fear, anxiety...)
Vocal reactions (screaming, crying, calling for help, weeping...)
Physical reactions (fleeing, jumping in the void, trembling...)
Outcomes (rush, trampling, suffocation...)

In an inquiry of a sample of Parisian residents, the same characteristics were found with some differences in percentages (see Figure 2).

Figure 3 - Hypothetical Structure of Panic

Another source of suggestions for structuring the observations on the field are the books and papers of specialists of behavioral science. I'm indebted to Professor Quarantelli for his deep analysis and personal remarks.

We derived from the model of panic in the book by Martha Wolfenstein, "Disaster", the basis for our diagram. Wolfenstein's 6 components are shown on the diagram by rectangles. But these 6 components must be discussed and don't seem to be sufficient. We added:

(1) Nine other components, as inputs or outputs;
(2) Connections between the components of the set.

Thus was built a provisional model of the system.

As we shall see egocentrism and agressivity are very infrequent.

Terror can take place on a two dimensional space: (1) rational uncertainty vs. intense emotion on one hand, (2) objective fear vs. anxiety without an object on the other. Fear is indeed a source of confusion and is believed to be contagious.

Confusion is the mental disorder characterized by: (1) slowness of perceptions and identification; (2) impossibility of attention, thinking and judgement; (3) uncertainty in regard to space and time; (4) slowness and incompleteness of responses; and (5) inability to recall information. Because of confusion, decision-making is difficult and decisions are seldom implemented. Confusion is produced not only by terror itself but also by belief in the urgency of a response when we are far from solving the problem.

Finally contagion must be discussed with the next diagram.

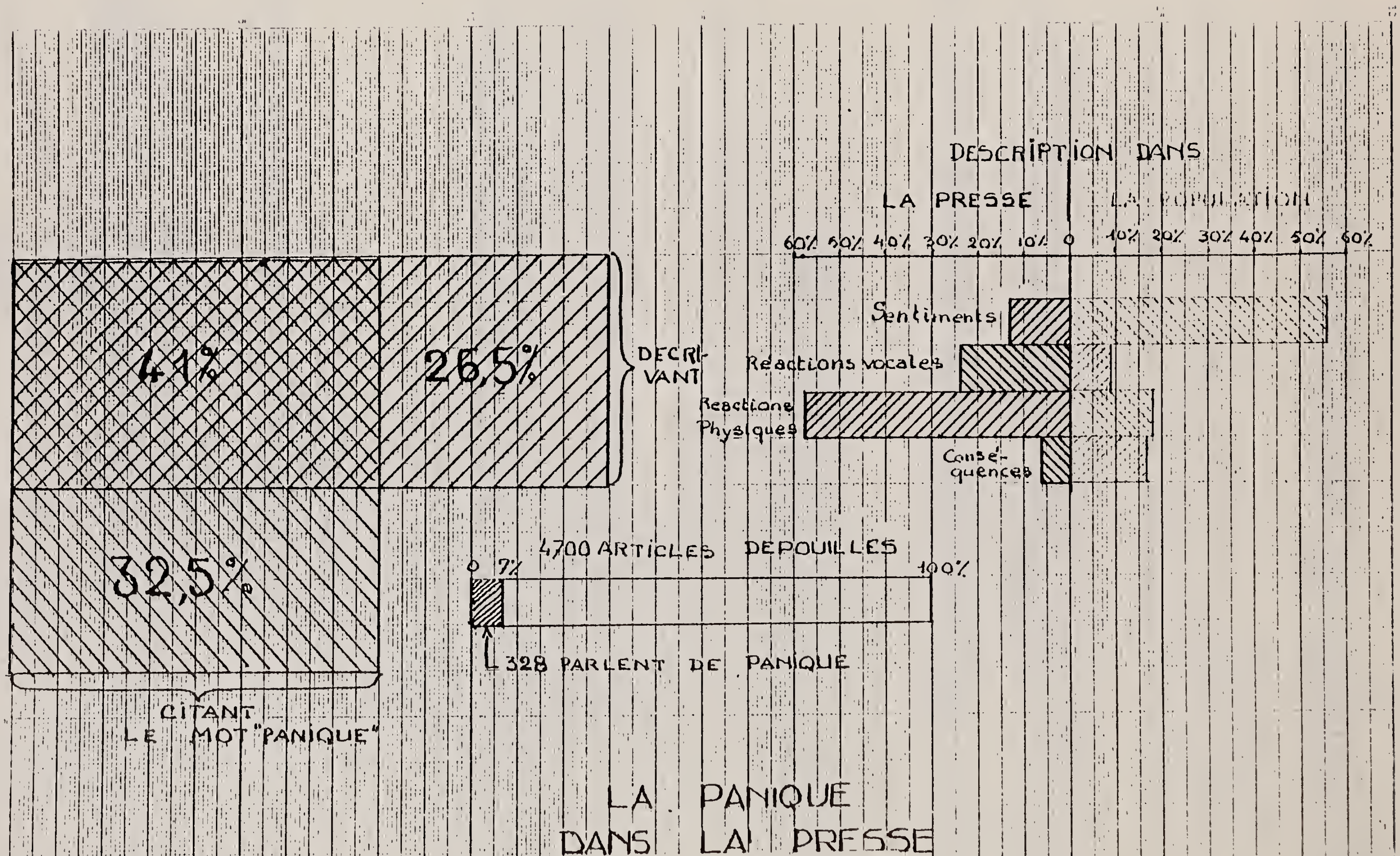


Figure 2. Panic in the Press

STRUCTURE HYPOTHETIQUE DE LA PANIQUE

Figure 3. Hypothetical Structure of Panic

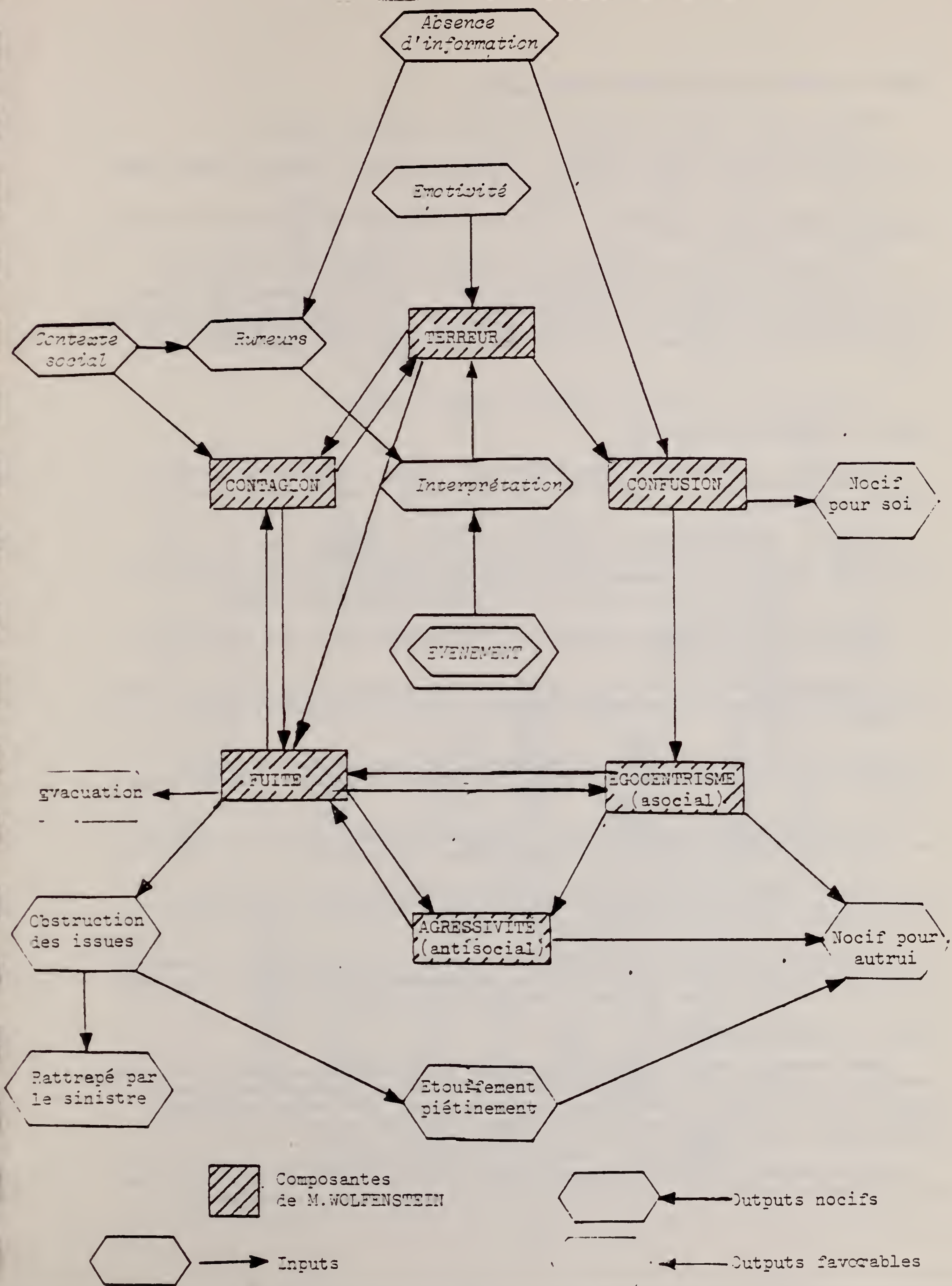


Figure 4 - Panic in the Lima Stadium (May 25, 1964)

Contagion may be discussed either with reference to flight or terror.

We must first eliminate the contagion of flight by rubbing or pushing in a dense crowd. This is frequent and not specific of panic.

This diagram is drawn according to a photograph of the panic in the stadium of Lima in which nearly 300 persons died.

On the diagram we can infer the direction of movement from the direction of faces: full face, back-view, side or three quarter face left or right. Each person is not shown but only zones where persons move in the same direction. The diagram shows: (1) the vicinity of persons moving left and right; (2) persons not moving toward exits and looking at the photographer; persons like these are in close vicinity to back-viewed persons moving toward exits.

We can infer that if flight is contagious it is very local.

Figure 5 - Contagion and Imitation

The question of contagion is a very complex one. We must turn ourselves toward the last source of hypothesis: the simulation of panic by computer and by experimentation on animals, namely mice.

Simulation, comparing rationality and distance to exits with contagion, shows that variance of rate of size of evacuated population against initial size is accounted for 14% by contagion alone and 21% in combination with distance and 13% in combination with rationality. So contagion appears insufficient to explain the danger of flight.

Experiments with mice show no contagion of terror or flight but a need for shelter or for close contact with others.

One question regarding contagion is this: is it the effect of crowd behavior as a whole; or the sum of the effects of individuals one on each other with, eventually, positive feed-back?

The first alternative gives rise to many models from Lebon and Tarde to the more elaborate one of French mathematician Kreveras. The second alternative is depicted in the diagram.

The perceived flight of somebody can be understood, by another, either as a model of response in a doubtful situation or as a sign of danger to do likewise.

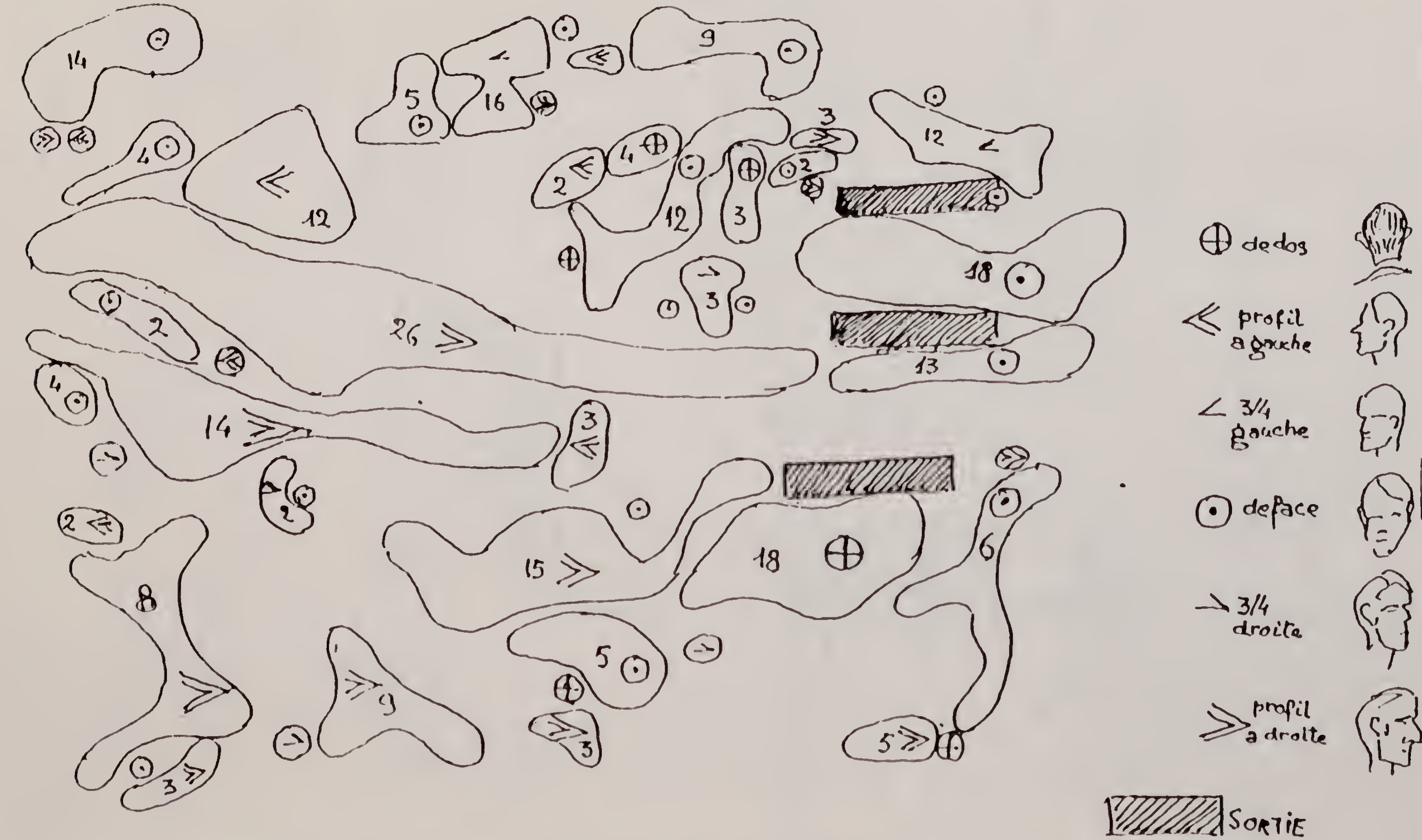
Another point of view is that there is an "identification" of one subject with a terrorized one. This can be studied as a psychoanalytical mechanism. It seems that a previous analogy is needed for identification to emerge.

We have indeed, at least three non-exclusive hypotheses. Because we did not proceed to in-depth interviews we cannot provide additional enlightenment on this topic: for us, the question of the structure and mechanism of contagion remains open.

Figure 6 - On-site Observations

A more systematic set of data was obtained under very favorable conditions. The general commanding the Firemen Brigade allowed our assistant to stay at the station and to get a place in the first vehicle to leave after the warning signal. The average time elapsed between signal and arrival on the site was 5 minutes. That was the best opportunity to observe panic if there was any.

The six components of Martha Wolfenstein were used and they are labelled M to S. Five other components were added for a better picture of the event: they are labelled A to E.



PANIQUE AU STADE DE LIMA (25 Mai 1964)

Figure 4. Panic in the Lima Stadium (May 25, 1964)

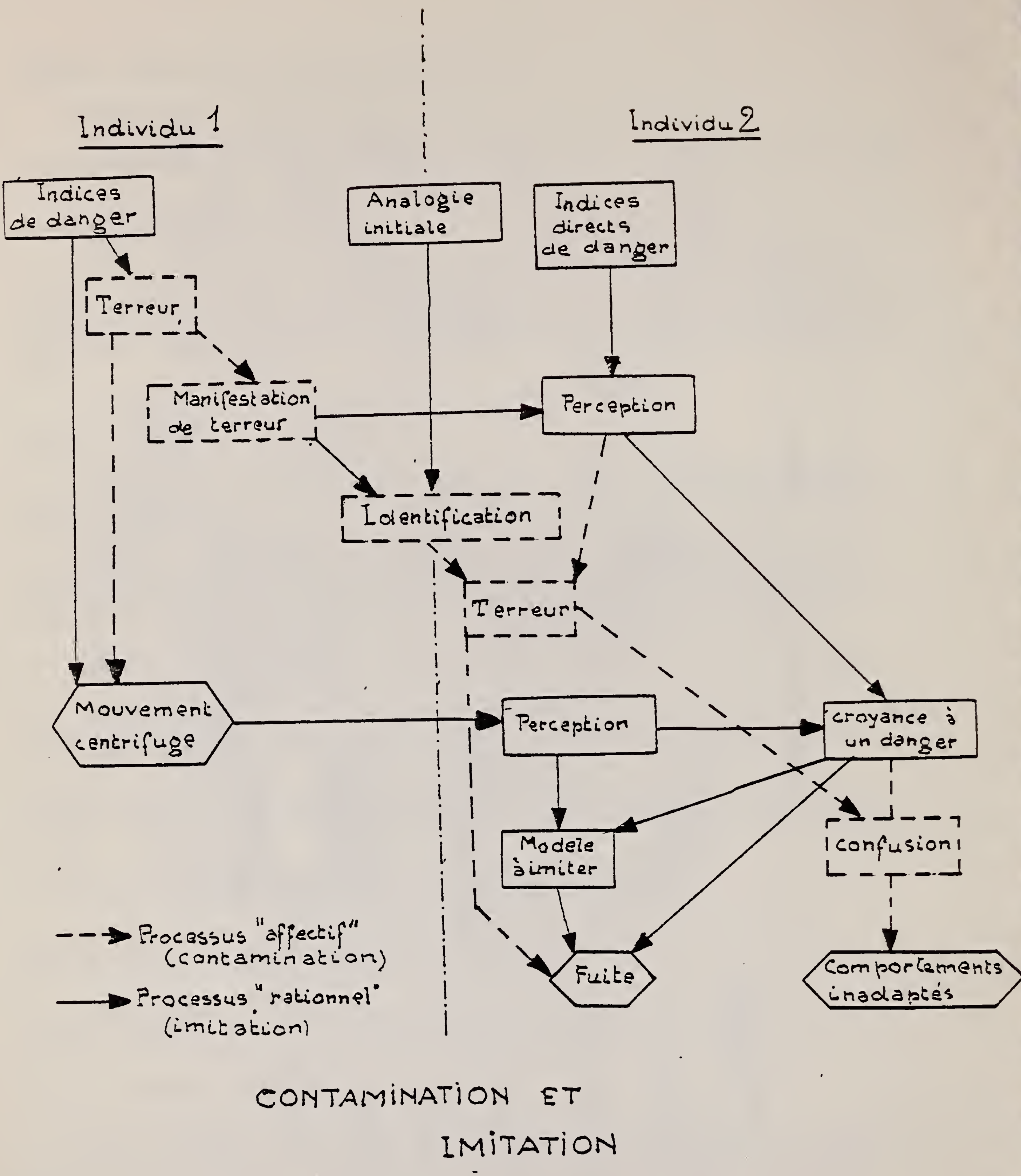
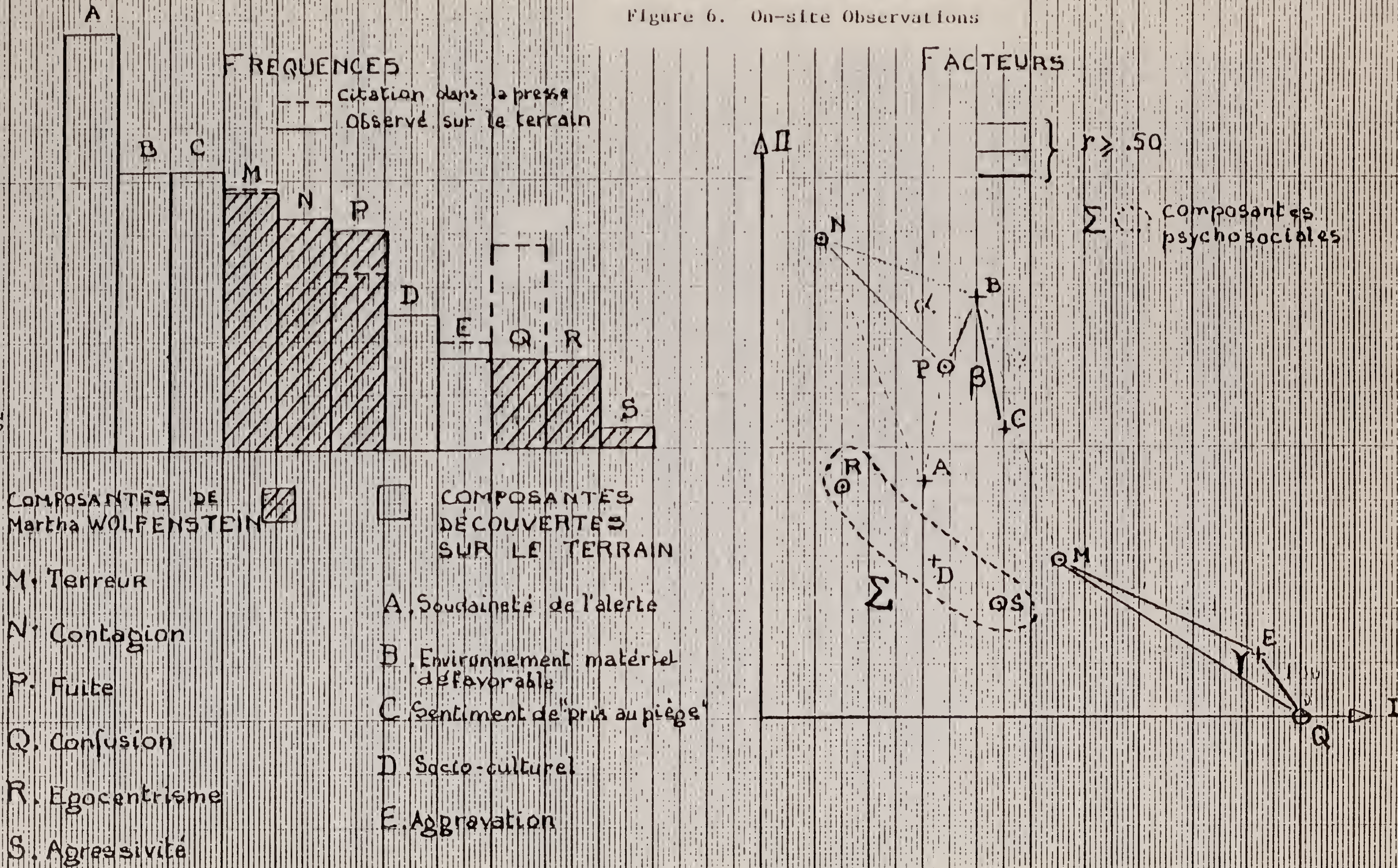


Figure 5. Contagion and Imitation

OBSERVATIONS SUR LE TERRAIN

Figure 6. On-site Observations



The most frequently observed component is suddenness of alarm and the least frequent agressivity. The frequency of M-terror, P-flight, E-increasing the danger is the same as in newspapers. Q-Confusion is more often quoted in newspapers. Only at one event were all six of Wolfenstein's components observed.

Connection between two components was measured by correlation. This coefficient is not an index of causal connection, as supposed with earlier hypotheses, but it indicates only coexistence. The correlations among all components were explained through factorial analysis. Two factors were extracted:

I - explaining fully confusion
II - explaining the major part of contagion.

Each component is plotted on a two-dimensional map, with two axes corresponding to the two factors.

Except for three of them, the components are plotted nearly on a straight line, that is, they are explained by a linear combination of the two factors. "Social components" are outside this straight line. They are aggressiveness, selfishness and low cultural level. If we draw a line between two points each time there is a correlation greater than or equal to .50, between the corresponding components, then we split the previous diagram into three clusters: (α) N-contagion, P-flight, B-unfavorable environment; (β) B-unfavorable material environment, C-feeling of being entrapped; (γ) Q-confusion, E-increasing danger, M-terror. This shows that contagion is more associated with flight than with terror.

INQUIRIES IN THE FIELD

We have had an opportunity to obtain observations in the field to obtain data and information regarding these hypotheses.

We can split our observations into two parts: (1) special case studies: they are labelled "clinical cases" even if data were collected or analyzed with formal procedures; (2) standardized inquiries.

Clinical Cases

For each clinical case I will give you a short specification of the event and the main outcome of the study.

1. We were invited by the National Security Administration, to study an individual case: the death of Mrs. Dyna Gray and of her four children, burned when leaving her home in a motor-car because of a forest fire. Had she "panicked"? The witness of her husband and all her neighbors allows us to say "No". Here the personality of Mrs. Gray was the determining factor of this judgment.

2. A very little fire, but with heavy smoke, occurred in a building with 18 floors. A woman tried to jump from the 8th floor. The panicked woman said "Fire! Fire! A broken leg is better!" The next morning we inquired in the whole building. The inquiry shows:

   (a) This woman had a low level of culture: the myth of fire was determining her behavior.

   (b) Another woman mastered her stress because she felt an important duty not to manifest her own fear before her defective son; but at the cost of subsequent psychosomatic diseases.

   (c) The lack of knowledge of the effective presence of firemen on the site increased anxiety.

   (d) Associating with neighbors reduces anxiety. This is the same as with mice, and, if I have understood correctly, in a recent report Mr. Mawson has the same conclusions.

3. After a fire in a hotel in Neederland, where more than ten persons died, a physician told us that he had been able to escape because he customarily explores all possible exits in a new residence.

4. In two stores, warnings of fire (false alarms) and a bomb alert was followed by resistance against evacuation. The same resistance to evacuation was found in a third store that had only the false alarms. This resistance extended, in some cases, to the top manager.

5. A fire developed during a performance at the Music Hall "Folies Bergères". Since the public was well informed, evacuation was performed with great calm. But afterward, there were requests for reimbursement of ticket charges.

6. A fire on the roof of the Athenée Royal, a school of Bruxelles, led to the evacuation of 600 children from 6 to 16 years old with the very greatest calm, because of a well transmitted warning and good supervision of the children.

7. The fire with the most impact that we have had to study is the fire at a dance in the little town of Saint Laurent du Pont: 144 boys and girls died, poisoned by smoke and burned. Only 20 could escape, and 12 of these were interviewed as intensively as possible in consideration of the remaining stress. From these interviews, it appears that the fire was terrible, but there was no panic in the sense that there was no agressivity and no selfishness, with the boys always allowing the girls to flee first. The rush toward exits was normal given the speed of the fire. The smoke was very toxic and caused rapid death.

Figure 7 - Revision of Structural Hypothesis

Now, we draw these links on the diagram of Figure 6 showing the hypothetical structure of panic according to the views of Martha Wolfenstein. Most of the anticipated links disappear. If we bring together clusters α and β, the graph is now disconnected and split in three parts (1) α and β, (2) γ, (3) the "social components" without correlations. Panic appears, with this analysis, to overlap three distinct phenomena: flight (and contagion), terror (and confusion), and social. These three may be combined.

Figure 8 - Observed Structure of Panic

Since this graph is topological and not metric, the former, like other graphs, may be reorganized without loss of its characteristics. This diagram shows the connections of the map of factors but with a shape which lets emerge some interesting properties. The first are the three clusters; a second property is this: if we take as the threshold of acceptance .40 correlation instead of .50, and draw the corresponding dotted lines, it appears that the diagram becomes more connected and has a main direction from A-suddenness of alarm to E-aggravation of danger; the components of Martha Wolfenstein lie in an intermediate place between the two; and the three "social components" remain outside without any connection with each other, other than the proximity on the factorial map.

As a conclusion we can say that panic, as often said, has many aspects. An illustration of this can be given by extracting all the sub-graphs from this full graph. Having 11 elements, there are $2^{11} = 2048$ parts of the set, each one giving a type of panic! But that is only a figure!

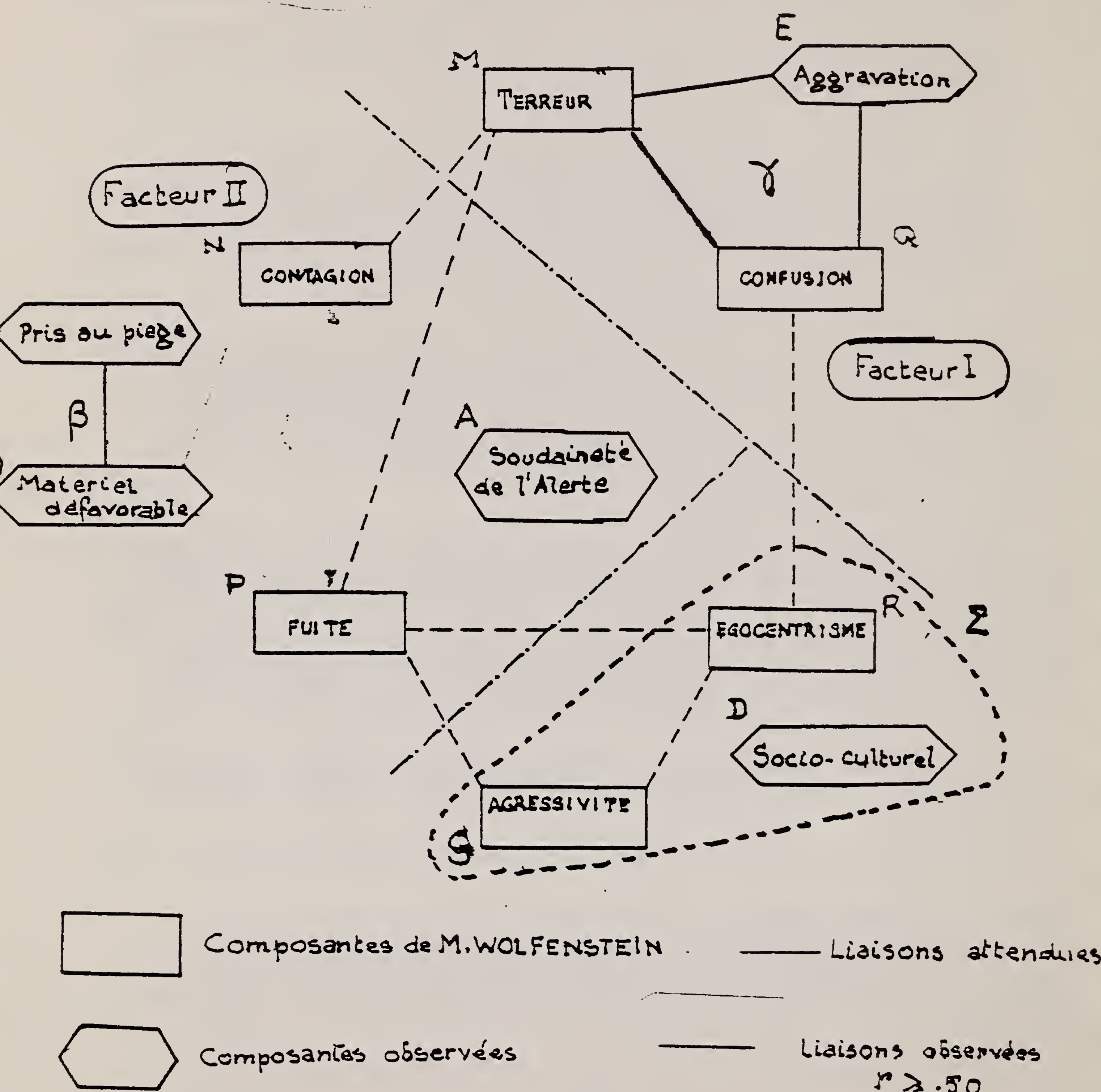
It is important to notice that the model is structural and static and not at all dynamic and causal.

Figure 9 - Proneness to Disasters

It is a natural hypothesis that there are some predispositions for panic within the individual and the environment. This is easier to investigate than behavior during a disaster since the latter happens at random, while a study of the former can be scheduled as one wishes.

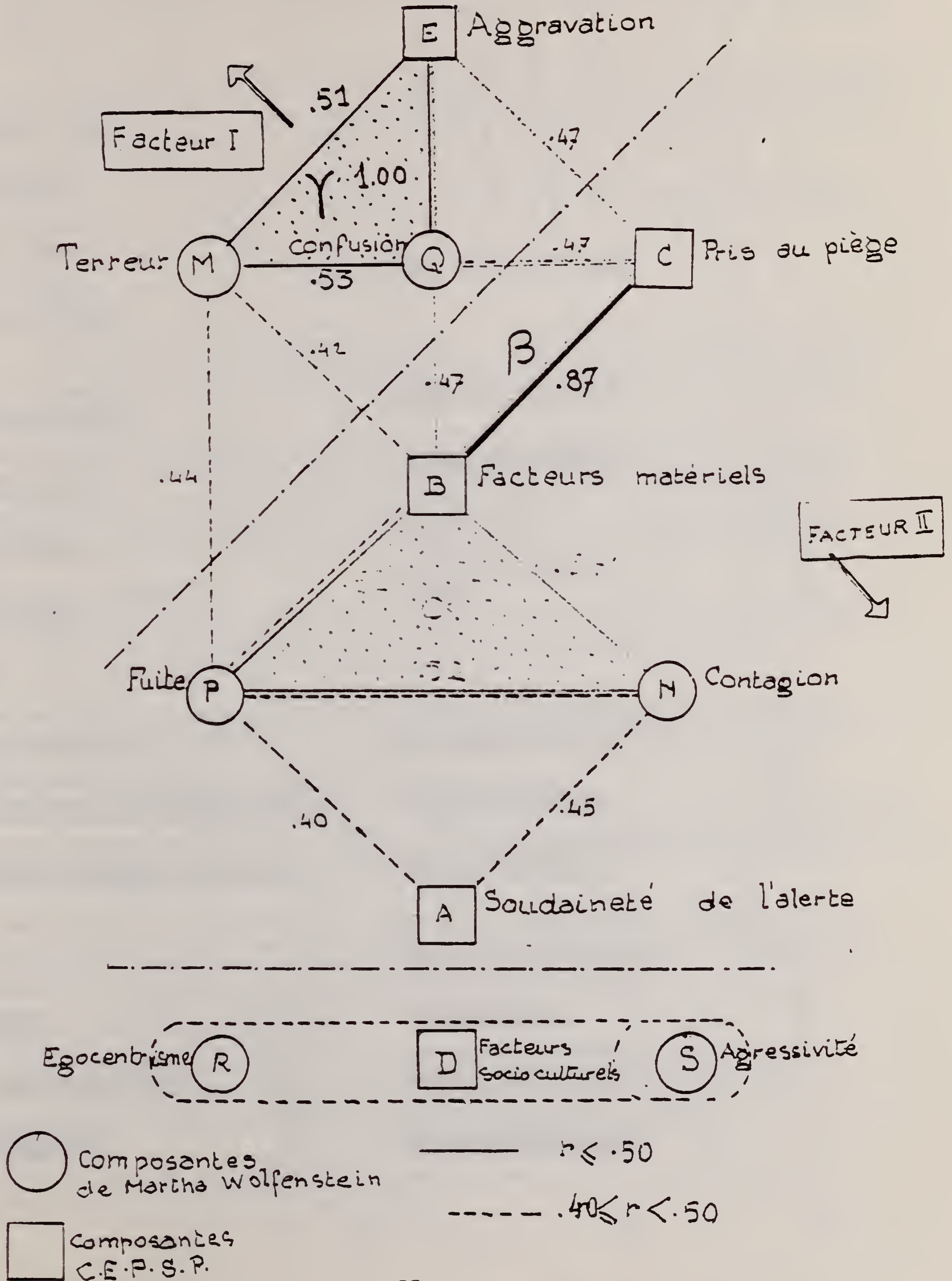
REVISION DES HYPOTHESES DE STRUCTURE

Figure 7. Revision of Structural Hypotheses



STRUCTURE OBSERVEE
DE LA PANIQUE

Figure 8. Observed Structure of Panic



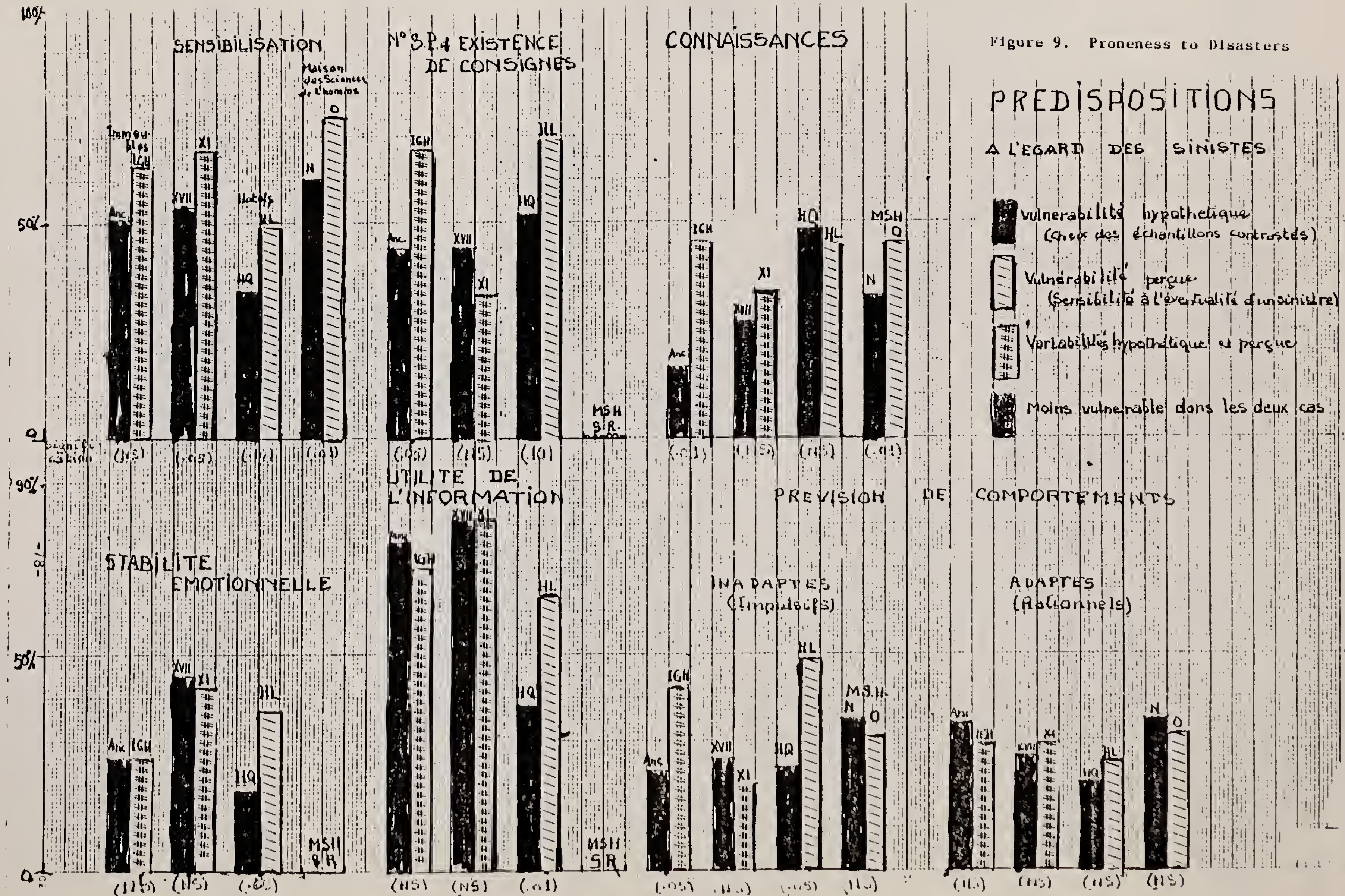


Figure 9. Proneness to Disasters

A first inquiry was performed in Paris with a random sample of 354 persons. The outlook of either rational or impulsive behavior was matched with an index of "fragility". This index was built in part with some items given in a questionnaire on anxiety by Eysenck, with questions about dreams of disasters and uneasiness in situations like being underground in a crowd, etc.

The correlation between fragility and extreme prospects is .46, but there is an important set of "mixed" people displaying rationality and impulsivity together. They were not taken into consideration for the correlation's computation. For this reason the number .46 is only indicative that there exists some connection between fragility and predisposition to panic as given by self-rating.

From this inquiry, questions were chosen for constructing a standardized questionnaire. It was used four times and each time two samples of opposite "vulnerability" were matched:

1 - Less than 6 floor building vs. 30 floor building
2 - Middle class district vs. special district of cabinet-makers.
3 - Hotels with less than 100 rooms vs. hotel with 1000 rooms.
4 - The same institution was used twice, the "Maison des Sciences de l'Homme" (MSH) at two years interval. In this case, the second sample shows two different populations, one having been interviewed the first time and the other not. The responses of the latter were similar to the original responses of the repeat group. It was grouped with the first sample. This result shows that an inquiry had an educative effect.

The "vulnerability" used for the choice of samples was a mere assumption of the research team. It is a very complex notion taking into account materials and shapes of buildings, activities of people, safety devices, ways of exiting. It is very hard to have an objective measure of it and it is beyond the capabilities of psychologists focused on behavior. Vulnerability is only one of the conditioning variables to be taken into account. For this reason it was subjectively appreciated and we shall see that it was not as good as we thought.

For purpose of clarity and shortness of presentation, the 20 questions were grouped into 7 topics: (1) Sensitizing, (2) Existence of specific regulations, (3) Knowledge in matters of security, (4) Emotional stability, (5) Feeling of information's utility, (6) Forcasting of adaptive, or (7) Inadaptive behavior.

The vulnerability assumed by the research team is not always felt by the subjects, based on the answers to the question: "Have you thought that a disaster can happen here?" So we must consider as an intervening variable the "perceived vulnerability" instead of "assumed vulnerability".

As assumed, the feeling is greater where there is hypothetic and perceived vulnerability together. In hotels and "Maison des Sciences de l'Homme" the feeling is greater with perceived vulnerability. It seems that in these cases the feeling is greater when people are more informed by the display of security devices or by a previous inquiry, as in MSH.

The diagram shows the influence of vulnerability on other sets of responses. But we need to go further, for instance to understand if the response "to go out fast" means "impulsive flight" or "obeying the evacuation order without loitering." Before doing this we must look at the real effect of vulnerability.

Figure 10 - Attitudes toward Disasters

If we consider the forecast of self-inadaptive behavior, we see that differences in percentages are statistically significant, often at .01 level, only when "perceived vulnerability" is concerned (comparison provided by the five boxes across the center of the chart) but not when "assumed vulnerability" alone is concerned.

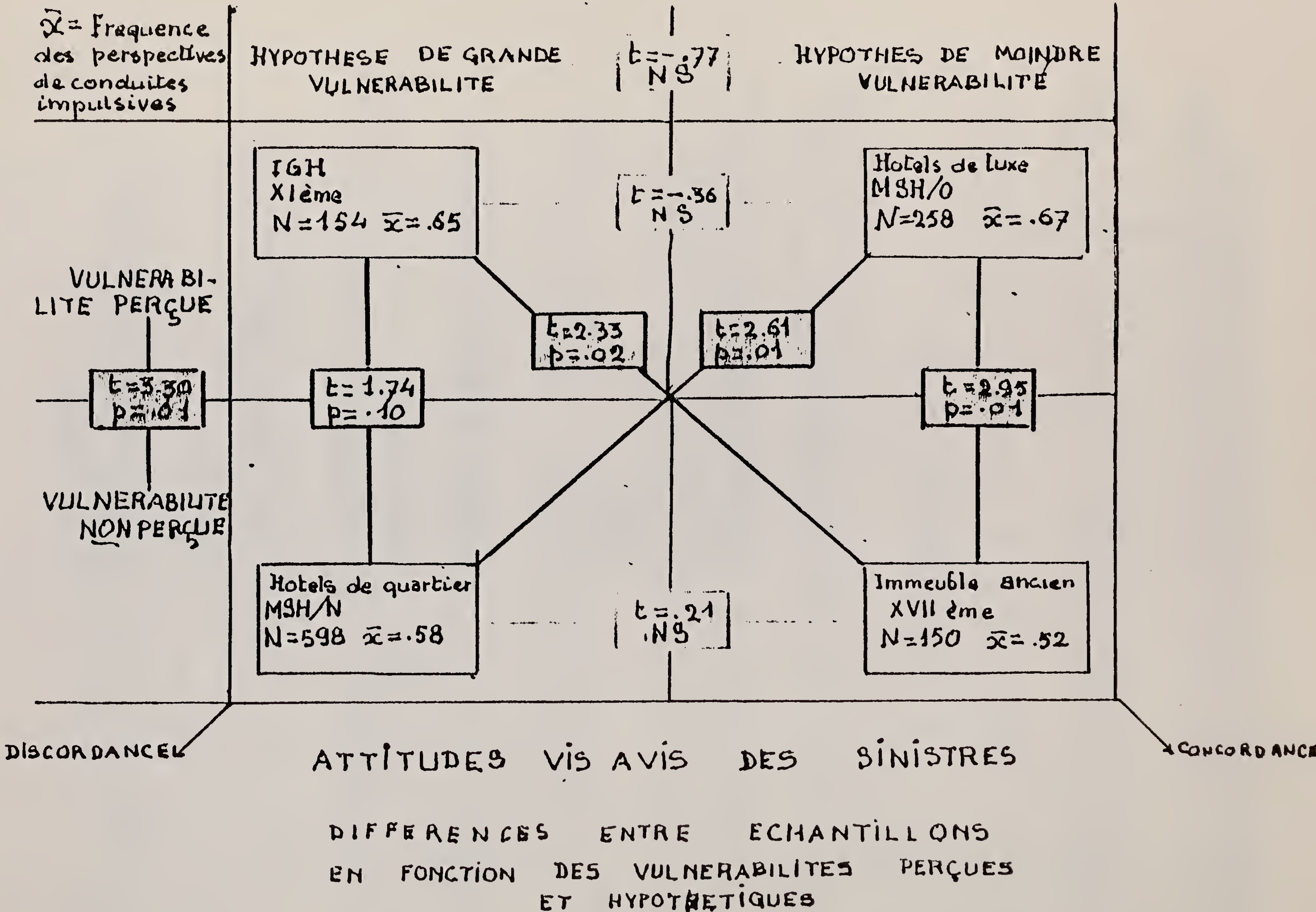


Figure 10. Attitudes towards Disasters

Figure 11 - Factor Analysis of Individual Attitudes

Correlations are computed between all pairs of characteristics in the legend. Correlations are computed between percentages, at the level of samples, and not between individual responses. Three factors were computed by factor analysis, namely:

I - regulations
II - action behavior
III - inhibition as opposed to impulsive behavior

Six clusters arise on the diagram:

- submission to safety team
- operational sphere
- affective sphere
- social
- technical knowledge
- knowledge of regulations
- impulsive behavior

Figure 12 - Resumé of Factors of Attitudes

This diagram shows the relative positions of the seven clusters, represented by their centers of gravity. One, submission, is on one axis, five upon the horizontal plane, and the seventh (the impulsive behavior) is below this plane.

Figure 13 - Evacuation - Crowding at Exits

One of the dangers of panic is crowding near exits, as it seems from the official regulations I have talked about. Even without panic, this phenomenon can occur as it is shown in a simulation of an evacuation of a store. The map and the density of people were given by the General Commanding Firemen of Paris. The 400 pieces were moved by hand one after the other following the judgement of the two operators, that is, as rationally as possible.

A "phase" of the simulation is completed when each piece takes one step forward. The phase is labelled "t". The simulation is over when all pieces went out through the three exits. It lasted 32 phases.

The diagram exhibits the configuration of people near the three exits at three phases: (1) at the beginning of the operations, (2) at phase 16, (3) at the last phase. The maximum of crowding appears exactly at the middle of the duration of the simulation.

Figure 14 - Net Time of Evacuation in Terms of Number of Occupants

We had an opportunity to observe 22 evacuations either as exercises or after a bomb alert, with very different buildings and people.

The direct observation of behavior showed nothing. But two points required attention: the duration of evacuation and the opinion of participants after evacuation.

For duration we must consider:

1. The net duration, that is, the time elapsed between the first person and the last going out of the building; it depends obviously on the number of persons to be evacuated and on the size of exits.

2. The latency time, lag between the evacuation signal and the first individual appearing at an exit.

The latency time is much more difficult to analyze. It includes inertia in first moving and travelling through the building. The evacuation signal is not always heard by observers and the time of beginning is not known.

Figure 11. Factor Analysis of Individual Attitudes

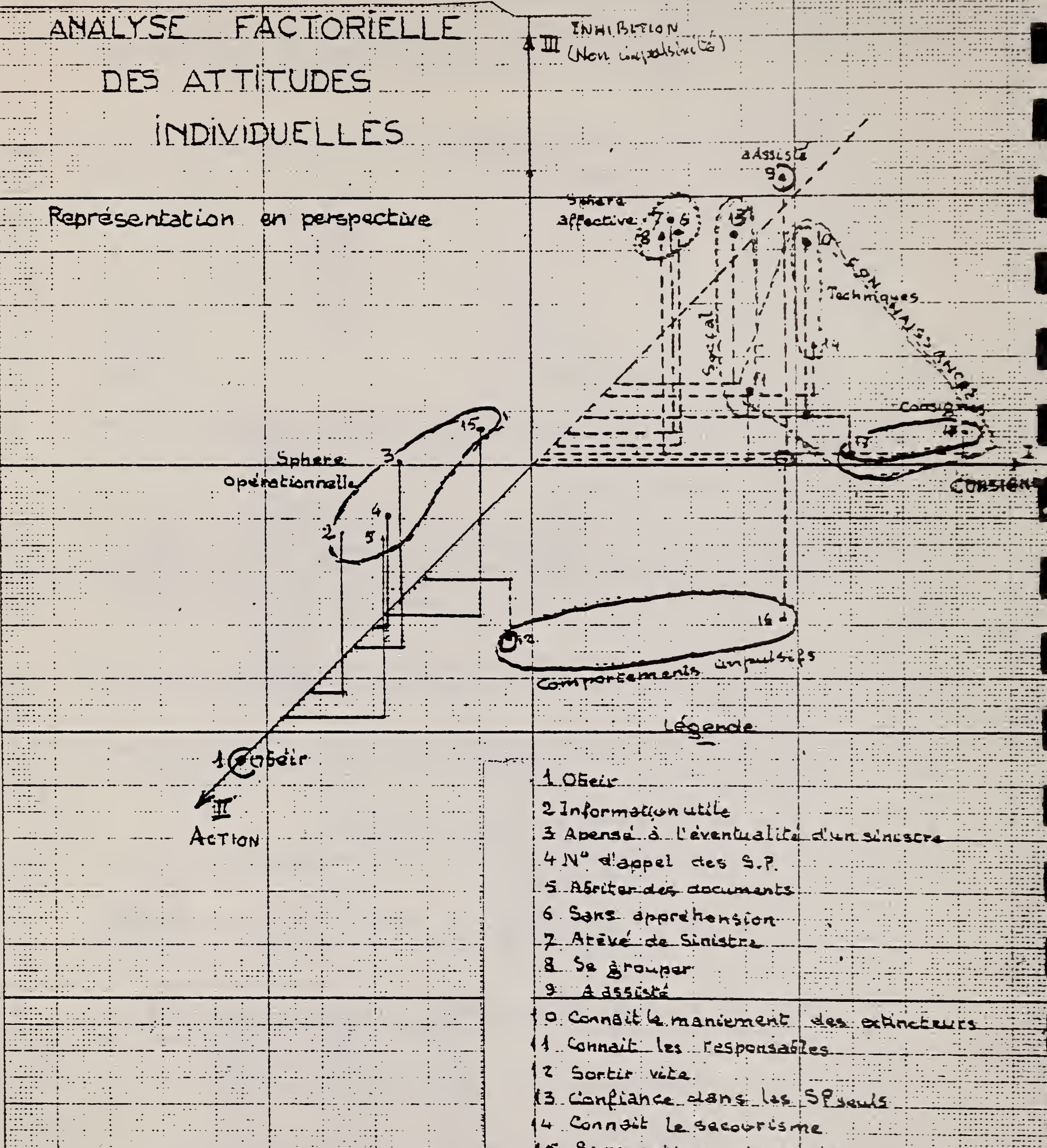
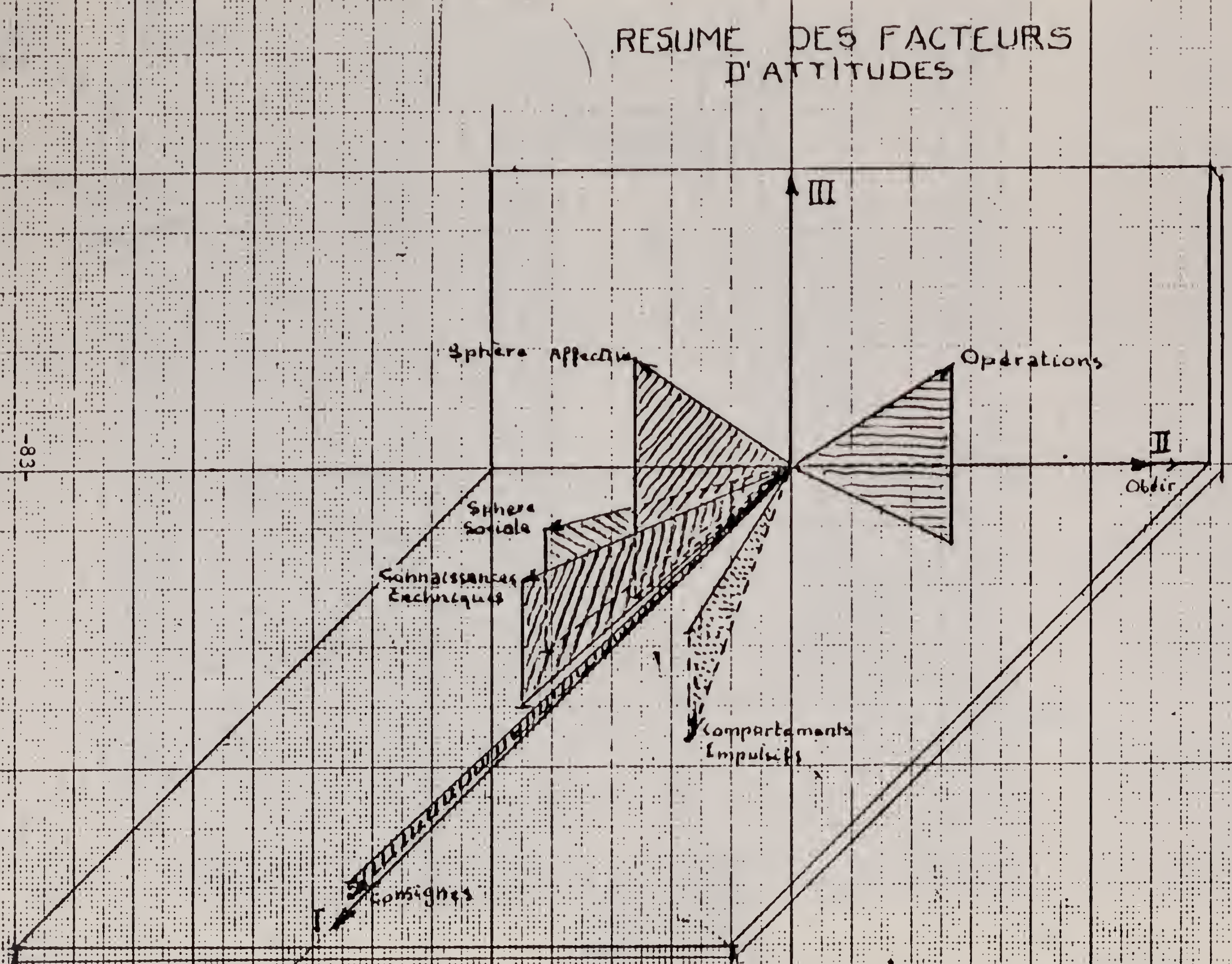


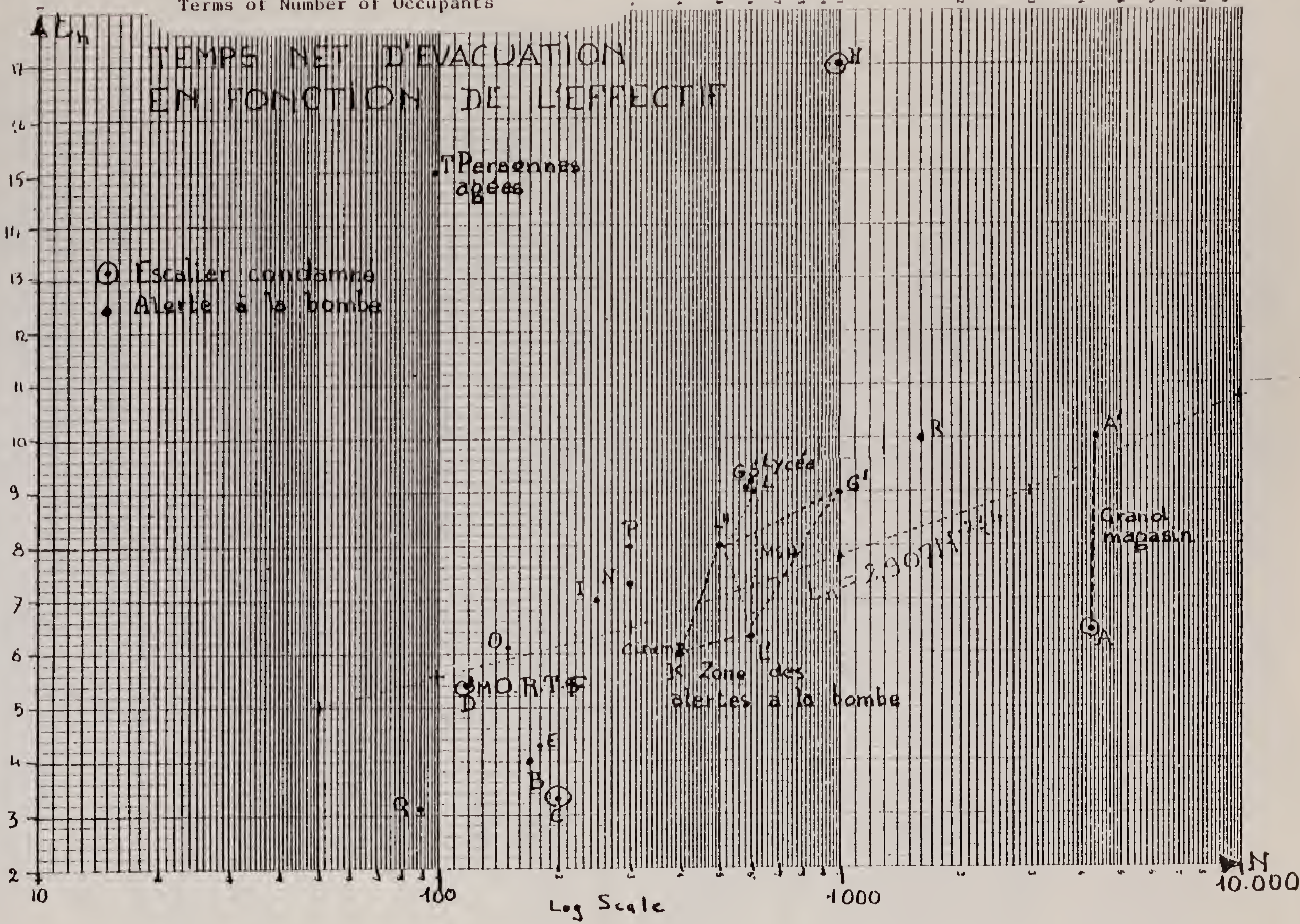
Figure 12. Resume of Attitude Factors



EVACUATION- AGGLUTINATION AUX PORTES

Figure 13. Evacuation--Crowding at Exits

Figure 14. Net Time of Evacuation in Terms of Number of Occupants



Another factor regarding the beginning point should be taken into account: the instant of the first indication of possible danger is perceived; then there can be a lag between this indication and the decision of evacuation; this was the case in four bomb alerts.

The diagram shows that net duration, t_n, can be approximated by the regression equation:

$$t_n = 2{,}907\ N^{.234}$$

This estimation is better than a linear one and is quite different from the well known "Japanese" formula. N is the number of persons evacuated; it varies between N = 50 for a home for the aged to N = 4000 for occupants of a store.

The representative points are very dispersed around the regression line. This can be partly explained by people's responses to questionnaires as we shall explain later. Organization of the exercise, regulation of the establishment, perception of alarm signal and knowledge about security are the main variables on which the performance of the evacuation depends.

<u>Figure 15</u> - <u>Reaction Time and Net Time of Evacuation</u>

On the diagram are plotted the <u>latency time</u> and the net duration. These two are correlated at .54. We do not yet have explanations for this.

In the upper right quarter are the worst evacuations; the worst of all is a big administration building containing 1000 persons. The best lies in the lower left quarter. All the real bomb alerts are characterized by long latency time: the alarm is, in this case, given by a phone call from outside and is not to be confused with the signal of evacuation. It is always shown that the lag was caused by the hesitation of top managers to give the order of evacuation.

<u>Figure 16</u> - <u>Questionnaire after the Evacuation Exercise</u> *

For a more in-depth evaluation of the previous evacuations, an 18 item questionnaire was filled out by participants after each evacuation. The items can be divided into five groups concerned with:

1. <u>Regulations</u> - knowledge about them, perceived importance, and how well they are displayed.

2. <u>The conditions of the exercise</u> - suddenness, amount of light, etc.

3. <u>Expected effects of evacuation exercises.</u>

4. <u>Evacuations performance</u> - forecasting of exercise and perception of signal.

5. <u>Number of firemen or size of security team.</u>

As it can be seen, there is a great dispersion of responses either between samples for each question or the mean responses (connecting line) in the same group.

Between samples dispersion is explained by modality of warning, display and knowledge of regulations, and anticipation of exercises.

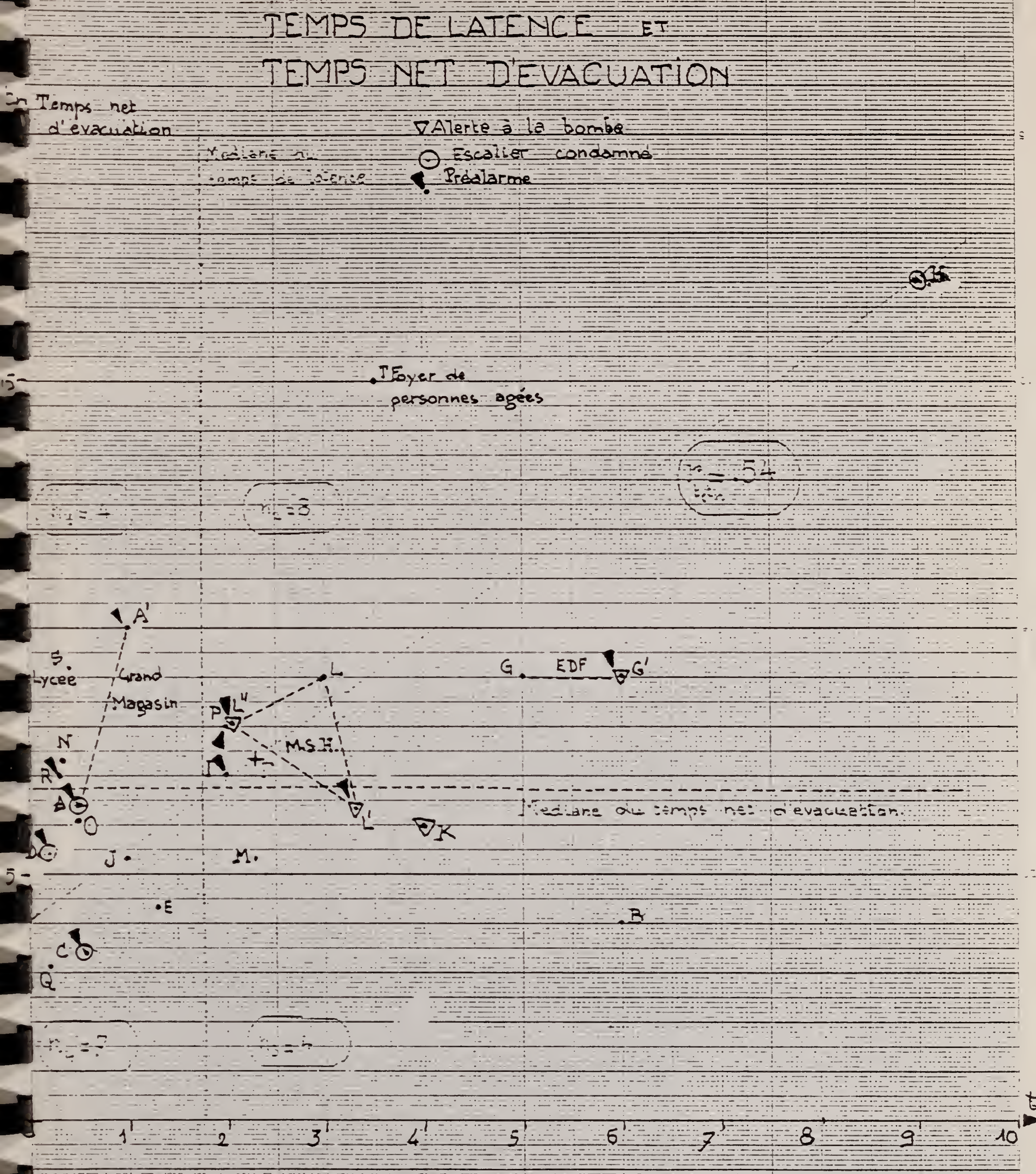
<u>Figure 17</u> - <u>Factor Analysis of the Questionnaire</u>

Correlations were again computed and a factor analysis was performed. Three factors were found:

I - Reality as appearing in regulations vs. hoped modalities of exercises;
II - Performing of exercises;
III - Exercises organizing.

*For reasons of duration of speech, this part was not given during the lecture. It is given here as an important part of evacuation studies.

Figure 15. Reaction Time and Net Time of Evacuation



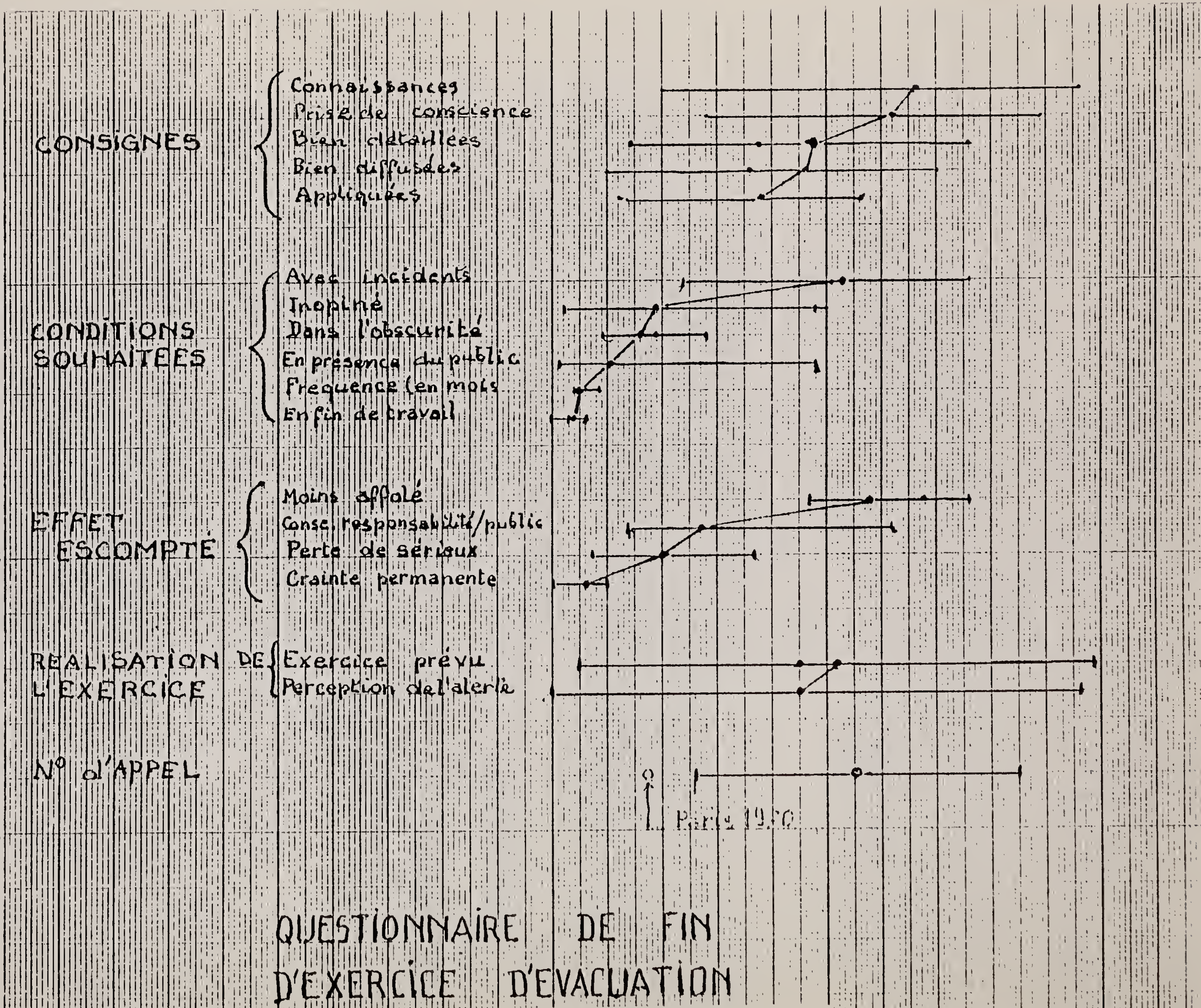


Figure 16. Questionnaire after the Evacuation Exercise

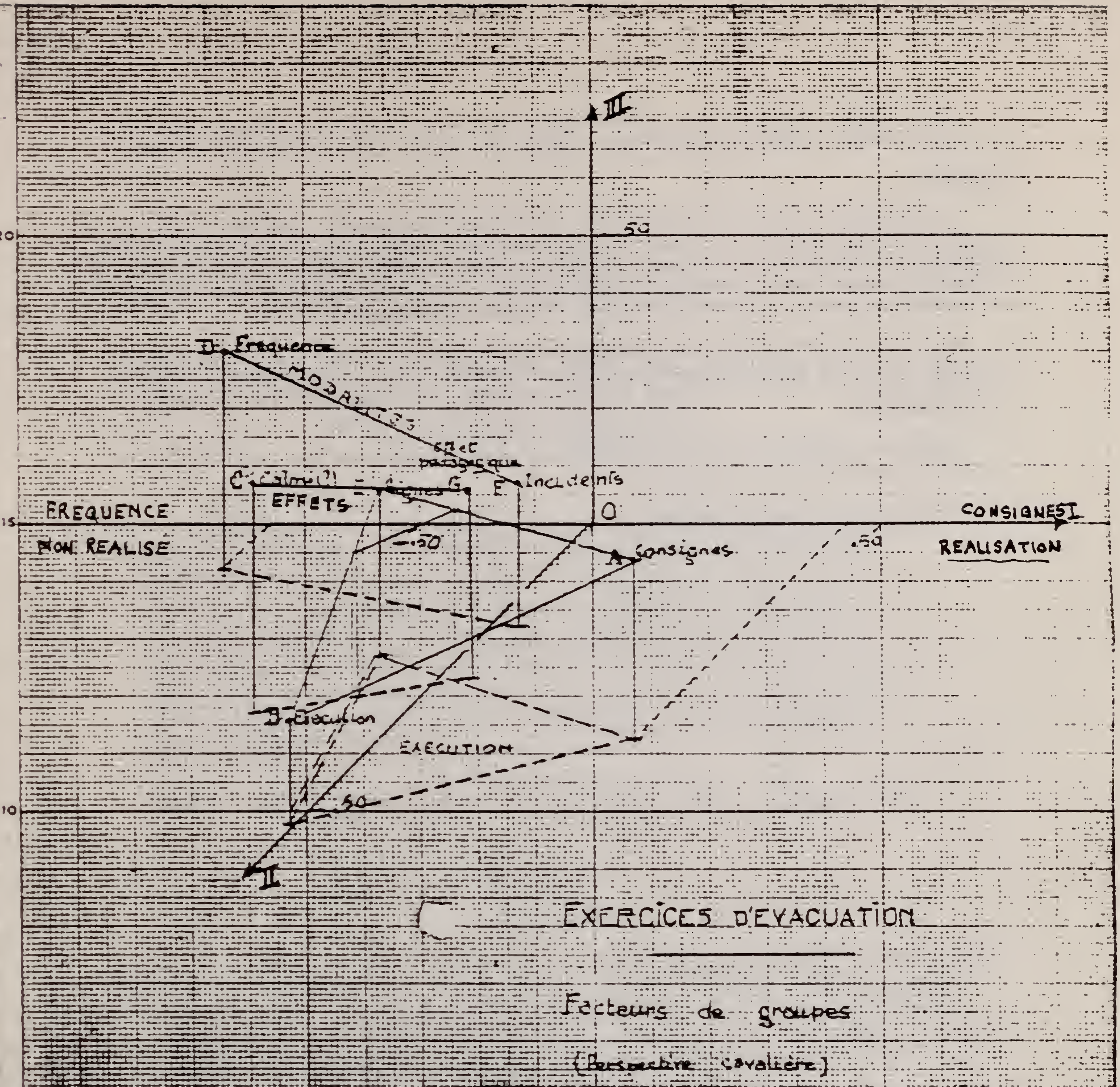


Figure 17. Factor Analysis of the Questionnaire

Three clusters appear namely, performance (execution), modalities and expected effects; the latter being between the two formers, shows that it is likely conditioned by them.

CONCLUSION

In conclusion, we can say that panic is a manifold phenomenon consisting of two main independent components: one involving the suddenness of alarm, and the other one involving confusion and aggravation of danger. Perhaps a weaker observed component can be added, a psychosociological one. Paroxysmal characteristics of behavior and collective behavior were not taken into account since they were not observed but they should be.

If, as it appears, people deny danger; information, education and training must be provided and, given the differences between populations, such actions should be based on accurate data collected in the field using well-established procedures and followed by careful analysis.

Objective analysis of evacuation exercises should provide fruitful information for developing specific local regulations.

I thank you for your attention.

EVALUATION OF SAFETY SYMBOLS

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The increasing use of symbols to convey fire safety information non-verbally is described. In addition the trend toward international standardization of symbols is discussed for transportation and other systems. The need for further research on symbols is discussed in terms of the advantages and disadvantages of symbol use. Advantages include rapid and accurate communication without the barriers of verbal language. Disadvantages include the too rapid proliferation of different symbols and inappropriate or misleading application. Furthermore, the failure to evaluate the understandability of each symbol is cited as a major problem. A case study which documents some of the advantages and disadvantages of a set of proposed fire-safety symbols is presented. Finally, areas for further research on symbol evaluation are discussed.

Keywords: Communication; evaluation methods; fire safety; hazard warnings; pictograms; safety information; standardization; symbols.

1. Introduction

1.1 Background

Information to guide, protect, or inform building users has traditionally been provided by written signs in buildings in the United States. Recently in Europe, however, there has been a tremendous growth in the use of symbols, or pictograms, to convey such information. This effort began with the development of standardized traffic symbols in Europe in the early 1900's. Now there are international standards for symbols for worker safety, hazardous materials transport, and health-care facilities, while still other standards are under consideration for fire safety alerting.

The desire to communicate information among all people everywhere through the use of symbols was most forcibly voiced by Margaret Mead and subsequently by Henry Dreyfuss [1][1]. Mead [2] felt that the development of a coherent set of pictograms would be the basis of an international language. She believed that this language could solve the problems of misunderstanding and semantic confusion which exist internationally.

The current efforts aimed at the development of symbols and standards for symbol use. are less ambitious, but they are still intended to reduce confusion and speed communication. At this point, there is an increasing use of symbols within the United States for transportation systems, hazard warnings, worker safety, and fire safety, as well as for public

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[1] Figures in brackets indicate the literature references at the end of this paper.

information. For example, the Department of Transportation (DoT) has successfully sponsored the implementation of standardized symbols for motorists, and has proposed other symbols for public information in transportation facilities. Increased concern for worker safety, consumer protection, and other key issues has sparked awareness in the U.S. of the concept of symbols as a viable means of communicating essential information.

Further evidence of the increasing interest in symbol use can be seen from the various national and international groups that are developing standards for symbols. At the national level, the American National Standards Institute (ANSI) has recently chartered the Z 535 Committee on Safety Colors, Signs and Symbols, while the National Fire Protection Association (NFPA) has sponsored a subcommittee on Visual Alerting Signs and Symbols. Both of these committees are working toward the development of voluntary standards for worker safety and fire safety symbols. The Society of Automotive Engineers (SAE) has also sponsored the development of a set of standard automotive symbols. In the international realm, the United Nations (UN) has developed signs and symbols for labelling hazardous materials for transport. Finally the International Standards Organization (ISO) has three committees dealing with standards for symbols. These include the Technical Committee (TC) 21 on Equipment for Fire Protection and Fire Fighting; TC 80 on Safety Colors and Signs; and TC 145 on Graphic Symbols. Again, each of these committees is concerned with the development of standard symbols.

1.2 Advantages of Symbols

Symbols can provide emergency, directional, and instructional information concerning buildings, products, and transportation systems to a wide variety of people. As noted earlier, a major impetus for the use of symbols has been the need to communicate essential information without the use of words [3, 4]. For example, symbols have been widely used in Europe because international travel is commonplace and language barriers are widespread. In the United States, moreover, the percentage of the population whose native tongue is not English, but Spanish, French, Vietnamese, etc. is increasing. For these people, as well as for illiterate or verbally handicapped persons, symbols can communicate information without the use of written words.

Symbols can also be an extraordinary medium for communicating a visual message rapidly and accurately [5, 6]. Symbols are recognized more rapidly and accurately, in some cases, than the same message in words [7, 8, 9]. For example, Janda and Volk [10] found that the reaction time for highway information was shorter for a symbol on any shape sign than for any combination of words and symbols, or for words alone. Thus the use of a directional arrow was found to be more effective than the words "turn here" or "road curves here." In fact the arrows were recognized more rapidly than the conventional and more familiar "STOP" sign. In addition, Walker, Nicolay, and Stearns [7] found that symbolic road signs were recognized significantly more accurately than word signs alone. They also determined that their subjects could remember the meaning of a previously unfamiliar set of symbols with 100% accuracy after an interval of 24 hours. Smith and Weir [6] suggested that symbols for road traffic signs are superior to verbal messages in terms of more rapid response time and recognition distance. Symbols can be also used to minimize confusion among alternative choices, moreover [11]. Smillie [12] found response times to be faster for symbols when stress was introduced as a variable. Accuracy, however, decreased for both printed words and symbols. Finally at least one researcher, King, [8] has suggested that symbols could be more effective than words under interference conditions. King [8] also determined that symbols were recognized more accurately than word signs under short display conditions (1/18 sec) while King and Tierney [13] found that symbols were more effective than words in conveying a desired meaning. These data indicate that symbols can convey information both accurately and rapidly. Under many conditions they can be more effective than words in communicating a small amount of information. These experiments did not even assess the most likely advantage of symbols over words; namely, that symbols can successfully communicate a particular message to people who do not all speak the same language.

1.3 Problems Connected with the Use of Symbols

Despite the potential effectiveness of symbols, there are some difficulties connected with their development and use. These problems relate primarily to the application of symbols, rather than to the intrinsic ability of symbols in general to convey information. One of the most critical areas concerns the lack of standardization. Each person, agency, industry, etc. who feels the need for a symbol develops one, often without consultation with any other group. There is little, if any, coordination on the kinds of information which should be symbolized, or agreement on which particular sets of symbols should be used. While there have been attempts to compile listings of symbols [1, 14] these are not complete, as new symbols have been generated subsequently in response to specific needs. In addition, while various international organizations such as the International Standards Organization (ISO), the Common Market (EEC), and the United Nations (UN), have attempted to standardize sets of safety symbols, most of these standards are not yet in force in the U.S.

For example, the Department of Transportation (DoT) commissioned the development of a set of 34 public information symbols to be used in transportation facilities such as airline, bus, and train terminals. While these symbols are intended to be used in such facilities, there is no guarantee that they will be used in other places where public information is provided; nor is the set complete, as it excludes fire and hazard alerting. The unfortunate possibility exists that building owners and the like will continue to use their own sets of symbols, since the DoT work is strictly oriented toward voluntary application. Thus the lack of standardization of symbols within the U.S. means that several different symbols may be used to convey a particular meaning.

A related problem connected with the application of symbols is the tendency for a symbol which has been used successfully in one application to be used in a quite different set of circumstances. For example, the "no entry" symbol (see Figure 1), originally intended for vehicular traffic, is now being considered for pedestrian traffic. Granted, there is a large measure of information transfer in that many pedestrians are also licensed drivers; nevertheless, the symbol may not be entirely appropriate, or understandable for pedestrian users. Furthermore, the "no entry" symbol may be intended only for vehicular traffic in some instances, and for all traffic in other situations.

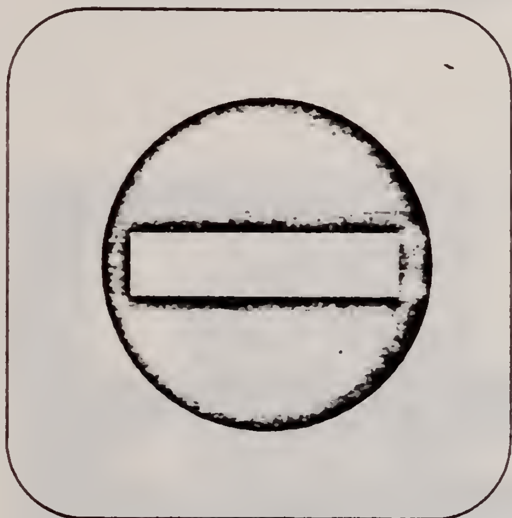


Figure 1. No Entry Symbol

Still another problem has arisen in which a particular situation is represented by several unique symbols. Thus, there are at least five proposed symbols for "exit" (see Figure 2), each with a very different representation of this idea. Needless to say, the potential for serious confusion is high.

Finally and most importantly, because symbols are typically developed and implemented in response to an individual and specific need, their effectiveness in communicating information to a larger audience is rarely evaluated. Although the creator of the symbol may understand its message perfectly, this message may not be communicated to anyone else. A prime example is a fire-safety symbol proposed by ISO TC 21 which means "no exit" (see Figure 3). In some instances, in fact, a symbol (and this is one) may communicate a meaning that is opposite from that which is intended. Apparently, this symbol can convey the meaning

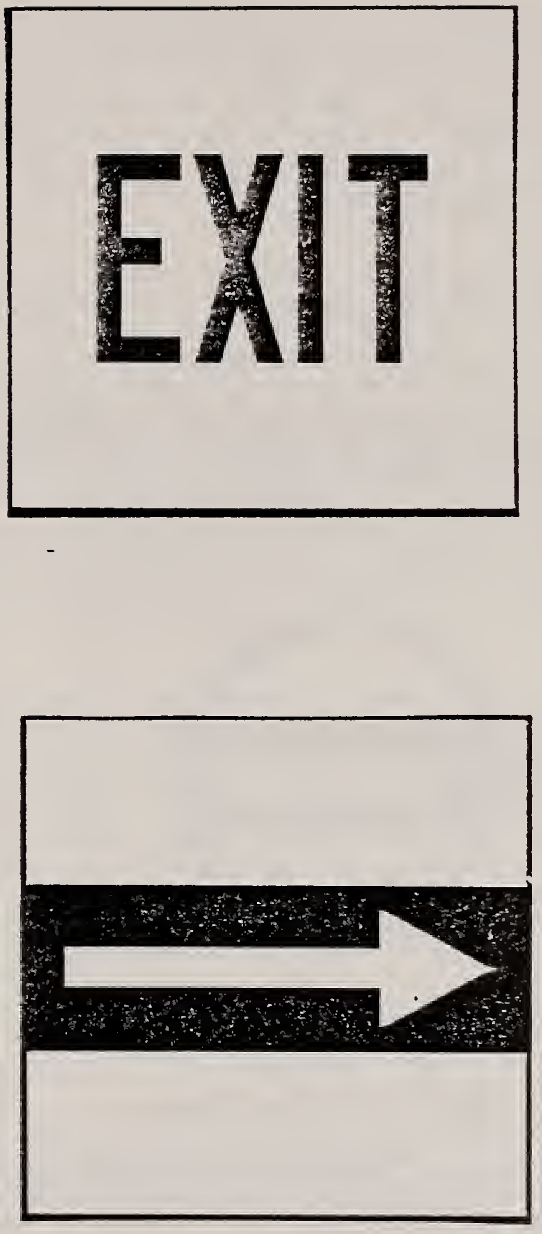


Figure 2. Examples of Proposed Exit
Signs and Symbols

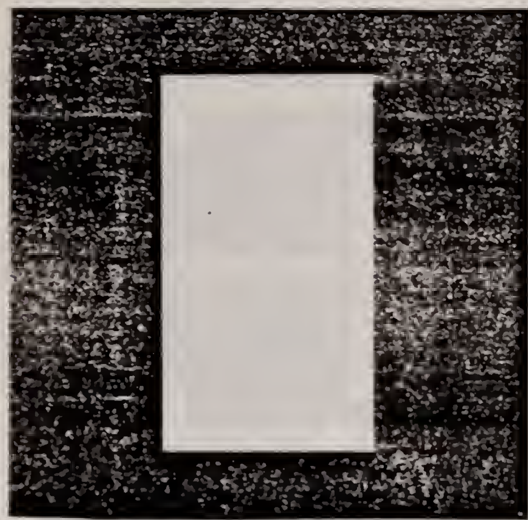


Figure 2 - Continued

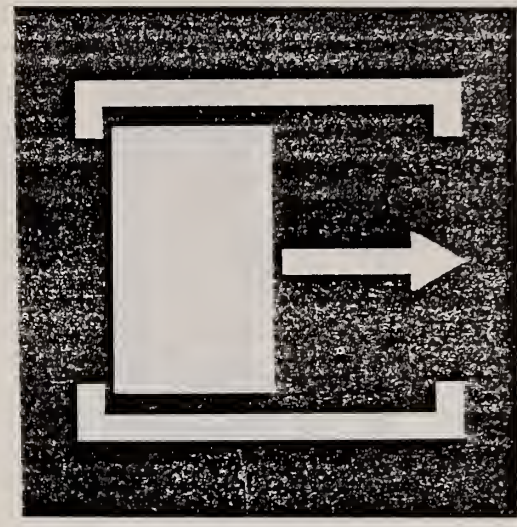


Figure 2 - Continued

Figure 3. No Exit Symbol Proposed by ISO

of "safe refuge" to some people. Failure to evaluate the effectiveness of a particular symbol is perhaps the most serious issue in the application of symbols and the development of national and international standards.

In the preceeding paragraphs, issues related to the effectiveness of symbols for communicating specific information have been raised. In addition, various problems relating to the application of symbols were discussed. These include a lack of agreement upon which situations need to be symbolized; the proliferation of symbols and symbol-producing groups; the development of confusing and contradictory symbols; and, most importantly, the failure to evaluate each symbol's ability to communicate a particular message to a given audience. These problems can seriously hamper the transmission of essential safety information.

Yet these problems can be resolved through evaluation and testing, and through the development of (voluntary) standards for symbol use. The issues raised here primarily concern the application of symbols and should not detract from the documented effectiveness of a carefully developed and researched symbol to convey urgent information accurately and rapidly. (See Section 1.2).

2. Case Study

In the second portion of this report, we will present a case study which illustrates many of the issues associated with symbol use. The symbols in question are a set of fire safety symbols now being considered as a draft international standard by the ISO TC 21 subcommittee on Fire Safety Symbols.

Input from the United States as one of the 84 members of ISO was required for the preparation of an ISO TC 21 standard on Fire Safety Symbols. Yet a preliminary inspection of these symbols suggested that a number of them might not be readily understood by people in the U.S. Furthermore, this set of symbols had never been evaluated or tested for its effectiveness in communicating the specific information intended. Consequently, there were no data that indicated whether these symbols did convey the desired safety information accurately.

2.1 Procedure

Under sponsorship of the NFPA subcommittee on visual signs and symbols, 22 fire safety symbols were evaluated for their accuracy and ability to convey fire safety alerting information. In this effort, 143 subjects, in a total of ten groups, were questioned about their understanding of these symbols. Although subjects were volunteers from a college community, a retirement home and several fire stations, no attempt was made to ensure that the subject selection process was at all random or representative.

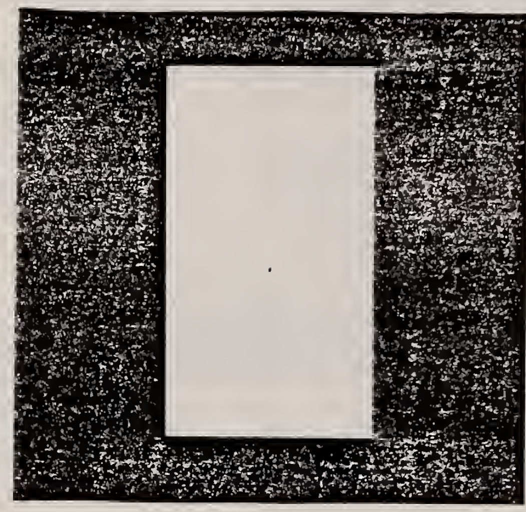
The symbols were presented one by one, as placards (.3 m x .3 m or 1' x 1') at a distance of no greater than 9.1 m or 30' from the subjects. See Appendix A for a picture of each symbol. Subjects were asked to write down a short definition of each symbol immediately after it was presented. They were allowed the option of "I don't know" as a response. The entire experiment including instructions lasted for about 45 minutes.

The responses were assessed by three judges who matched the answers against a predetermined meaning given by ISO for each symbol. The symbols were rated as "correct", "incorrect", or "no response". Agreement between two of the three judges was required for each final rating. The frequency of each type of rated response was recorded for each symbol. The percentage of subjects responding in each of the three ways was calculated for each symbol. In addition, where subjects responded incorrectly, the number and kind of alternate meanings were also tallied. Pictures of selected symbols which caused definite understandability problems are presented in Figure 4.

2.2 Results and Discussion

Table 1 presents the percentage of subjects (N=143) who responded correctly to six of the proposed ISO Fire Safety Symbols. These symbols were selected for this table to show the extremes of response. Thus, the symbol for telephone and the conventional EXIT sign were recognized by almost all of the subjects. (In fact, the only people who missed these signs were several persons from a retirement home who may not have understood the instructions, although many of the retired people performed well.) On the other hand, almost no one understood the blind alley symbol. Similarly, the ISO exit symbol, the "break glass" symbol, and the "do not block" symbol were recognized by only 20-25% of the 143 subjects. Pictures of all the symbols tested are provided in Appendix A, along with the percentage of correct recognition.

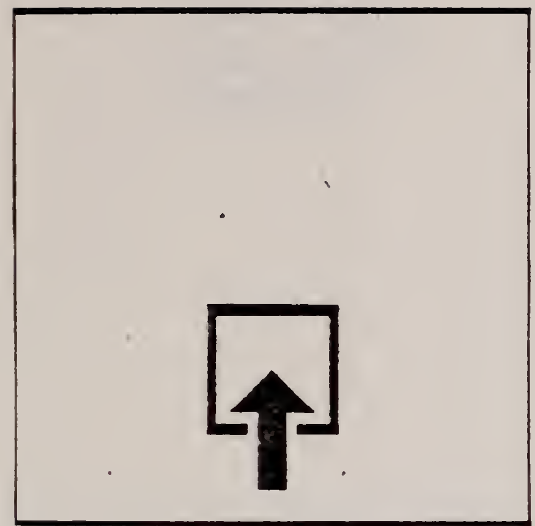
The results indicate that there are are serious drawbacks to the immediate use of some of the proposed ISO Fire Safety symbols in the U.S. At least several of the symbols were not understood by a large majority of subjects (under these testing conditions). These include the "exit," "no exit," "fire ladder," "break glass" and "do not block" symbols.



ISO EXIT

BREAK GLASS TO OBTAIN ACCESS

Figure 4. Symbols Responded to Incorrectly

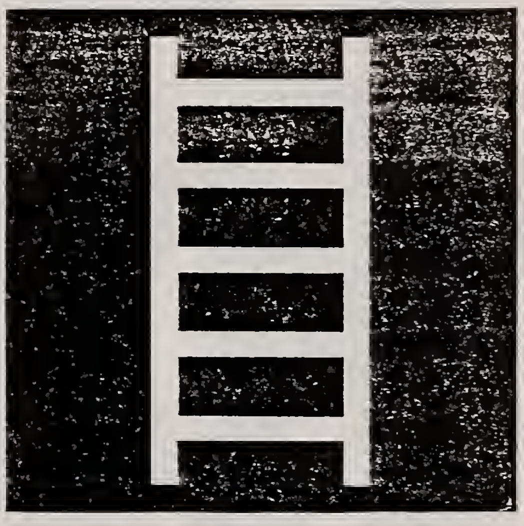


BLIND ALLEY—NO EXIT

DO NOT BLOCK—KEEP PASSAGEWAY CLEAR

Figure 4 - Continued

Figure 4 - Continued



FIRE LADDER

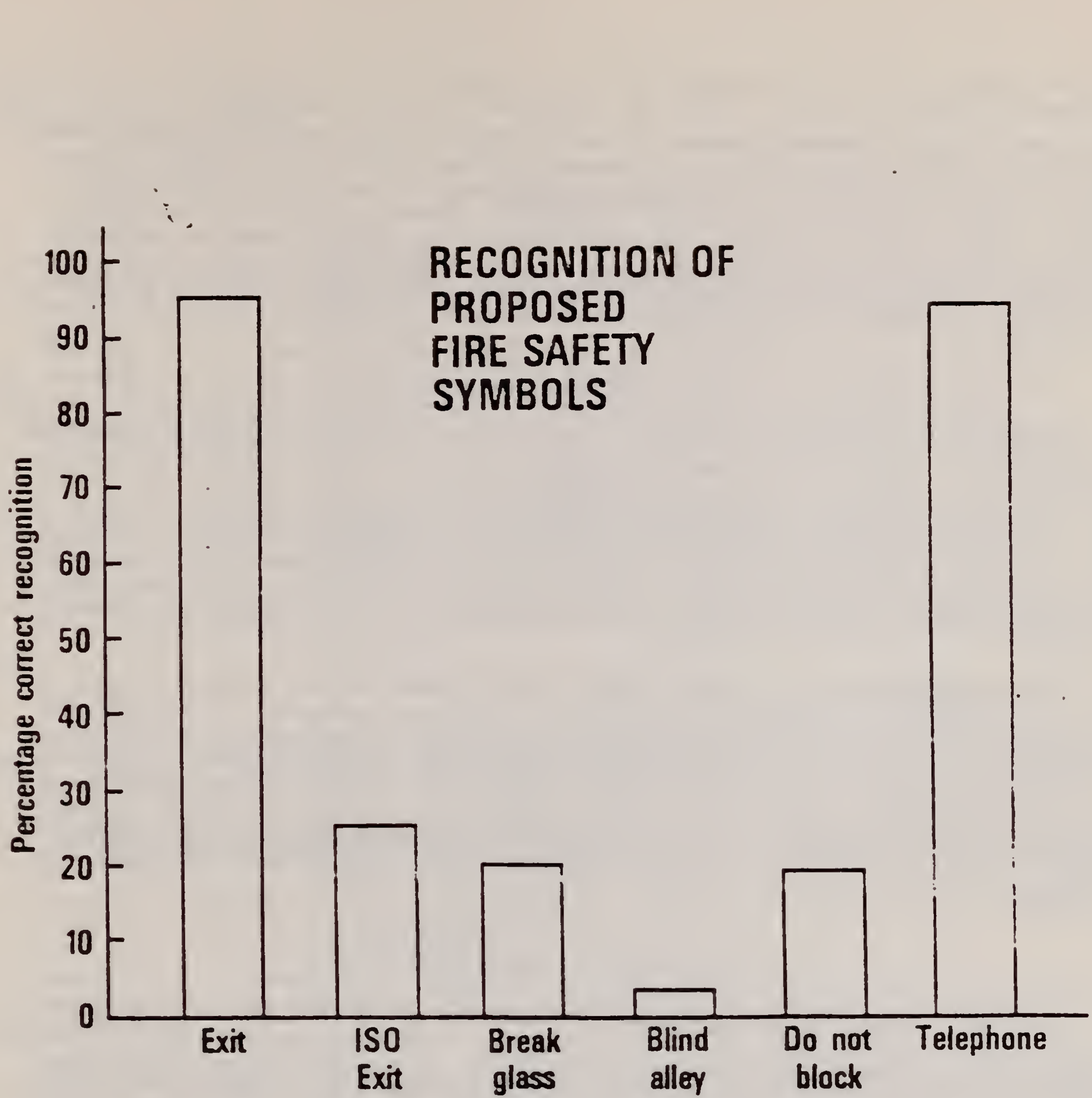


Table 1. Percentage of Subjects who Responded Correctly to Six of the Proposed ISO Fire Safety Symbols. See Appendix A for Pictures of the Six Symbols.

In addition, not only were several symbols incorrectly identified, in some cases they were given a meaning opposite to that which was intended. Thus, the "no exit" sign was interpreted as exit or safe area by almost 70% of the 69 subjects who identified this symbol incorrectly. It should be noted that about 140 of the 143 subjects either misidentified or did not respond to this particular symbol. Yet it should also be noted that 95% of the subjects were able to identify the "telephone" and "no smoking" symbols correctly, as well as the word "EXIT." This recognition rate is well above the 75% recognition rate set by Heard [15] as required for adoption of automotive symbols.

The results reported here are very preliminary, and are given only to provide an indication of the range of effectiveness which may be expected when symbols are used the sole means of conveying information. Thus, several of the symbols were accurately understood by the majority of the subjects. Other symbols were either not known, or, more seriously, were identified with a meaning opposite to that intended. While a fairly large number of people from a variety of backgrounds were tested, this was by no means a random or representative sample of subjects. Consequently, these results do not apply for all people in the U.S., and are not intended to provide a definitive answer to the fire safety symbols problem. They do indicate, however, the urgent need to evaluate the understandability of each symbol before it is used for a hazard warning. If a symbol does poorly during the evaluation, then redrafting should seriously be considered. If the symbol cannot be redrafted, then an intensive educational effort must be implemented.

3. General Discussion

An instance in which a symbol is given a meaning opposite to that intended illustrates the most serious problem with the use of symbols. Yet, this type of situation can arise when symbols are neither developed nor evaluated consistently. The potential for serious harm in a case such as the "no exit" symbol which was interpreted as "safe haven" is very great. Consequently, before symbols are adopted, particularly ones which relate to emergency situations, their effectiveness in communicating the desired safety information to the intended audience must be evaluated. Ideally, the evaluation process should occur during the initial drafting stages, and again before implementation to eliminate serious misidentifications.

An evaluation program for proposed safety symbols should provide evidence of each symbol's effectiveness for conveying information to a particular audience. If the symbol is not deemed effective, then one of two courses of action can be implemented. The first is to institute an intensive education program to teach people the meaning of the symbol, after which its effectiveness should be reevaluated. The second is to use information gained during the evaluation program (such as misidentification) to modify and improve the symbol. Again, the modified symbol must be evaluated before it is implemented. It is especially critical to evaluate <u>new</u> symbols and sets of symbols before they are used to convey safety information.

4. Research Program at NBS

As a result of the need to implement more effective symbols, NBS has begun a research program in which safety symbol use will be evaluated. Five major questions will be addressed in this program. These include: (1) which situations, or groups of situations, require symbols, (2) how do users evaluate specific symbols, (3) what are the methods and criteria for evaluating symbol effectiveness for these situations, (4) what are the characteristics of an effective symbol, and (5) what conditions affect the usefulness of symbols? A specific focus will be the testing and evaluation of safety symbols in the workplace and under emergency conditions--with the ultimate goal being technical input into the development of standards for symbol use and evaluation.

During the symbol research program at NBS, we will develop and implement a variety of test procedures for evaluating safety symbols. As Cahill [16] noted, the empirical validation of a symbol's effectiveness is an essential element of symbol development. Validation is a key step in determining whether a symbol accurately communicates the desired information and can affect the subsequent actions of the intended audience. Thus, Freedman, Berkowitz and Gallagher [17] tested public information symbols by determining if these symbols were successful in guiding people through a museum. Heard [15] assessed the effectiveness of automotive symbols by having subjects touch each control as the corresponding symbol was presented, while Easterby and Zwaga [18] asked a wide variety of subjects to define the meaning of each of six public information symbols.

The preceding examples are presented to indicate some of the situations in which symbols have been evaluated for their effectiveness. This knowledge can then be used to improve the symbol, implement an education program, or empirically support a symbol's widespread use. In conclusion, knowledge of the understandability of a given symbol, particularly a safety symbol, is essential before it is used. The development of standard evaluation procedures is seen as a critical factor in this process. The NBS research program will provide information on the use of different evaluation techniques, as well as data on the understandability of specific safety symbols.

5. Acknowledgments

While the authors of this report take full responsibility for its contents, we wish to mention all those who provided invaluable assistance during its preparation.

We would like to thank Mr. Robert Andrews and Mr. Samuel Beach, both members of the NFPA Subcommittee on Visual Alerting Signs and Symbols, for their assistance with the collection of information on the fire-safety symbols. We would also like to thank Dr. Robert Glass and Mr. Fred Stahl for their helpful comments during the review process.

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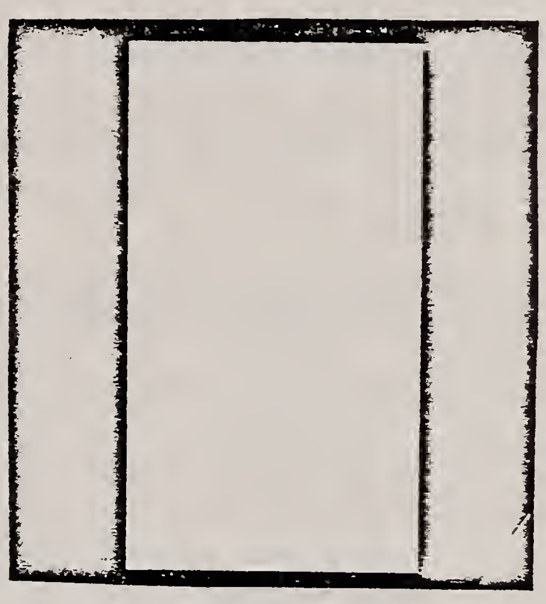
Appendix A

In the following section 21 photographs of the 22 fire-safety symbols used in this experiment are given. (The EXIT sign which was presented in both red and green type is only shown once.)

Under each photograph is presented the percentage of subjects (N=143) who responded correctly with an accurate definition of the symbol.

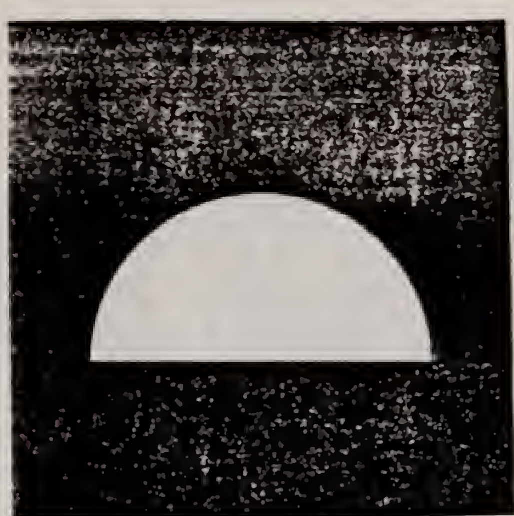


1. Emergency Exit

25% correct

2. Fire Extinguisher

93% correct



3. Fire-Fighters Equipment
1% correct

4. Do Not Lock

59% correct

5. Do Not Block - Keep Passageway Clear

19% correct

6. Fire Alarm Call Point

8% correct

7. Do Not Use Water

63% correct

8. No Smoking

93% correct

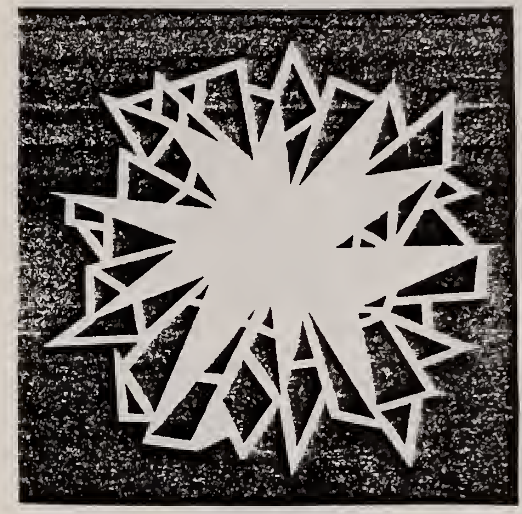
9. No Open Flame

78% correct

10. Telephone Emergency
red
65% correct

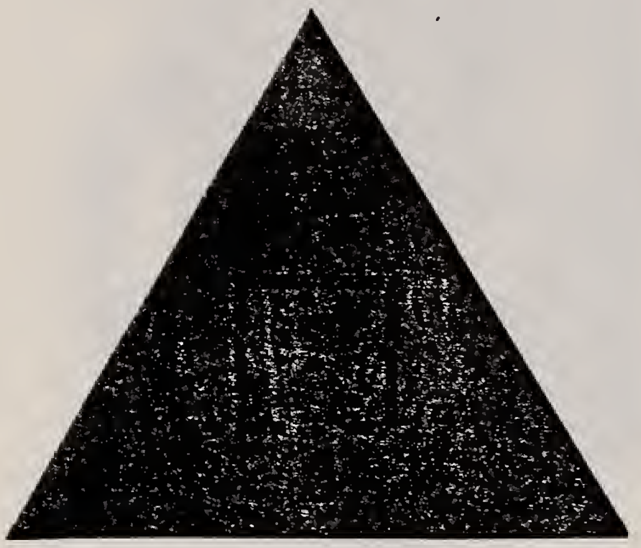
11. General - Blue - General

94% correct



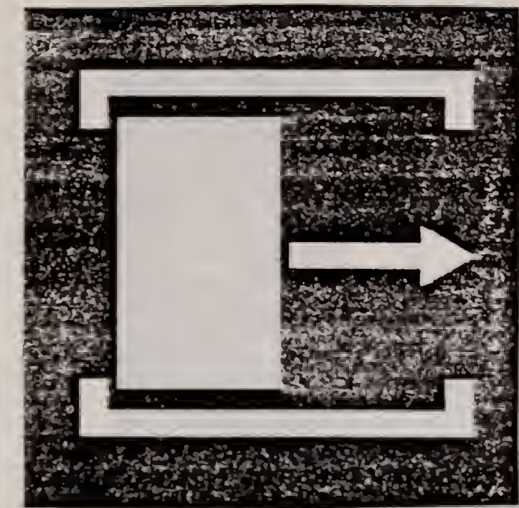
12. Break Glass to Obtain Access

30% correct

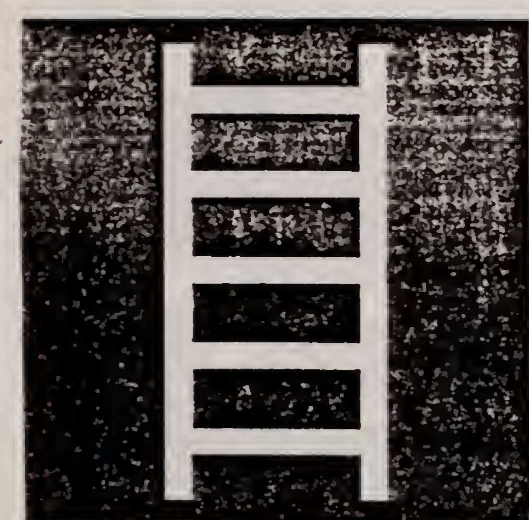


13. Blind Alley

3% correct

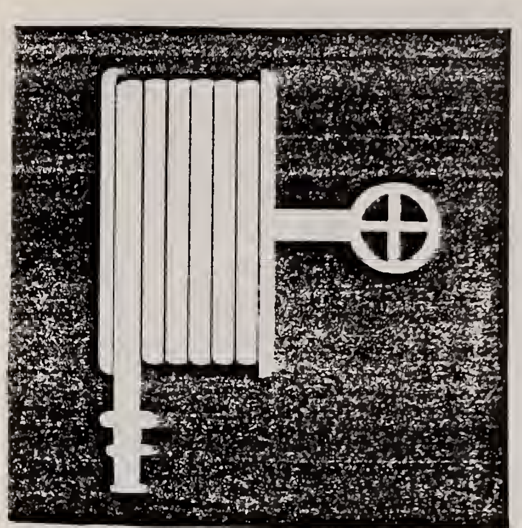


14. Slide Door to Right to Open
23% correct



15. Fire Ladder

57% correct



16. Standpipe (Hose and Reel)

84% correct

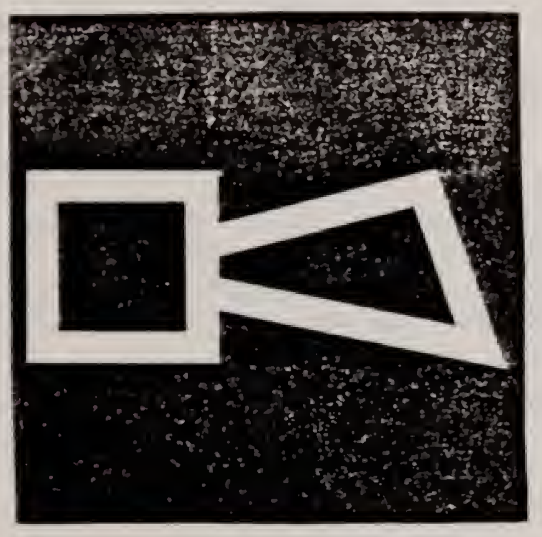
17. Direction to Fire-Fighting Equipment

17% correct

18. Fire Bucket Location

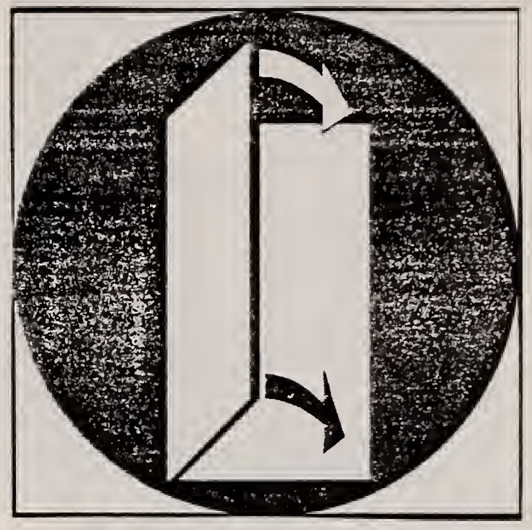
64% correct

19. Exit (in words) - both Red and Green
95% and 92% correct



20. Fire Alarm Horn

16% correct



21. Fire Door - Keep Shut

20% correct

HOSPITAL FIRE SAFETY
NON-ATTENDANCE AND PATIENT MOBILITY

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In hospital emergencies, the availability of staff to help patients is critical for their safety. The paper shows that in a post-natal ward some spaces used by patients can be unstaffed for periods much longer then 5 minutes. This is the interval for non-attendance proposed as the decision point for the installation of smoke detection systems. Spaces associated with, or adjacent to, patient spaces, from which a fire could threaten patient occupied spaces directly, were found to be unstaffed for periods up to 72 hours. The second part of this paper presents a simple technique to establish the relative mobility of nine different types of patient. Here the objective was to establish the number of staff required to prepare patients for evacuation and the number required to maintain evacuation movement.

It is proposed that a Patient Mobility Factor could be a key factor in the fire safety analysis of any hospital as it could help to make decisions about escape route provision and the virtue of concepts such as "defend-in-place."

Key words: Escape; fire; hospitals; patient mobility; rescue; staff availability.

Introduction

Hospitals are complex organisations dealing with many types of patient and using the skills of staff at various levels of expertise in many disciplines. Naturally, the prime concern of all staff is the care, treatment and general well being of the patients. In any emergency situation, an additional responsibility is given to staff, which is that of patient protection -- protection from the new threat(s) to life which may occur during the emergency. In the particular type of emergency - fire - discussed in this contribution, protection could include attacking the fire, removing the patients and many other actions, but an emphasis is placed on two related aspects of patient-staff relationships: (1) the amount of time that a patient-occupied space may be unattended by staff, and (2) the staff help needed by various types of patient to make a safe evacuation from a threatened space.

It is assumed that the emergency communications system and evacuation techniques are known and understood by staff members and that they all have an adequate knowledge of the layout, safety facilities and form of the buildings, to enable any life saving action to be taken without delay.

The information presented and the conclusions drawn on both the non-attendance and the patient mobility problems are based on preliminary observations carried out in some hospitals around Edinburgh. The results should be regarded as those of preliminary investigations into components of the hospital fire safety problem but may serve also as a starting point for more detailed appraisals of the problems of patient safety.

Other aspects of the hospital fire safety problem are being investigated at Edinburgh and they include a smoke load survey and the development of a simple fire safety evaluation technique for hospital buildings. In addition, a major research project is being pursued on the development of systematic techniques for the analysis and evaluation of fire safety in hospitals so that the various components of fire safety can be balanced to give a definable level of safety.

(1) NON-ATTENDANCE STUDY

All emergency situations have a strong dependence on time. The elapsed time during a fire emergency can be regarded as two time sequences developing in parallel. One sequence traces the development and increase in the threat that a fire will give to the people involved. The other is that time sequence which begins with the detection of a fire and ends with the people involved being safe, or dead. The former state occurs when they have either reached safety before untenable conditions were developed, or the fire was unable to develop to a dangerous size due to manual or automatic fire fighting, or perhaps because of a lack of fuel or combustion air. The latter state, death or injury, can be achieved easily if the people threatened are not able to move, or the time required for the detection of a fire is too long.

The most responsive and versatile fire detector is probably the alert human being and in hospitals lacking automatic detection systems, the availability of staff members becomes an important safety factor.

In general, the growth of a fire will follow an exponential increase in size with a ten-fold increase in intensity at the end of each 13 minute period after ignition. The production of smoke may follow a similar pattern but would make the environmental conditions untenable in the affected space much sooner than the attainment of unacceptable temperatures. In either case, early discovery of a fire is essential for any evacuation, or patient protection, plan to be successful.

The time available for effective evacuation will vary with respect to many factors and these include the type of materials burning, the size of the patient occupied volume, the volume rate of smoke production, and the type of patients under treatment. It is possible to calculate the time available before conditions become too smoky but this is quite a difficult process at present and a reasonable estimate of available time may be given by N/8 minutes, where N is the number of patients who could be threatened by smoke and/or toxic gases and who share the same volume. For example, a 20 bed ward would need to be evacuated in 2½ minutes and a 4-bed ward (or sub-ward) in 30 seconds, assuming, in both examples, that the fire was in the ward and its development not hindered. Such times may indicate the maximum time for periods of non-attendance providing that no automatic fire detection system was installed.[a] It is interesting also to recall part of the report of the official Inquiry into the fatal fire at Coldharbour Psychiatric Hospital (1) "...if the (management) system cannot ensure that the unattended period is limited to five or six minutes, then we are forced to recommend the provision of universal automatic fire detection by smoke detectors...." Since the Coldharbour Report, some studies have been carried out on the appropriateness and selection of detection systems (2).

It is therefore evident that patient occupied spaces left unattended for more than a few minutes could cause a serious reduction in fire safety. In addition, fires in other spaces, adjacent to or connected to the patient area spatially, could produce a serious threat if discovery of a fire was long delayed.

(a) Naturally, when exposed to a fire threat, the lower the mobility potential of patients the greater is the risk to their lives, and this would be another important factor in deciding on acceptable non-attendance times.

Method of Measurement

The non-attendance study had the objective of measuring the non-attendance times in various wards although only one ward type (post natal) is presented here. The times were measured by personal observation and at least nine periods of observation were undertaken so that a knowledge could be gained of the variation in staffing patterns with the time of day and the day in the week. For each period in the 24-hour day, three observations were made and the results presented in the diagrams are the average time periods over the three observations. There was found to be no significant difference between the days of the week. Some of the results presented will be unique to post-natal wards (e.g. the nursery) but other spaces such as the day room and the treatment room, may have similar functions in other types of ward. In these latter cases similar non-attendance times could result.

Patient sleeping areas were assumed to be non-attended during the night-time period (23.00-06.00) because of the difficulty of identifying which patients were asleep and which were awake. A definition of non-attendance for patient areas is: all patients asleep and no-staff present. In other areas the non-attendance time was defined as the time when no staff member was present. However, sub-ward areas were included, these containing one, two or three beds only.

For each activity space in the ward, a histogram is presented (Figures 1-16). The vertical axis represents the frequency of non-attendance, with respect to three basic time periods (5, 15 and 30 minutes) and the hour of the day along the horizontal axis.

In each of the diagrams the clear part of the bar indicates the periods of 5 minutes that the space is empty; the hatching shows the periods of 15 minutes and those parts "crossed" indicate the periods of 30 minutes in each hour that the area is empty.

Figure 1 shows the non-attendance pattern for the four sub-ward areas. Although these areas are well used by alert people, there are two or three periods throughout the day time when the unattended period is at least fifteen minutes. When compared with other areas this would seem acceptable unless any patient has a tendency to arson (a problem not uncommon in some hospitals).

Figure 2 indicates the periods when the patients' sittingroom is empty. As would be expected, this space is unused between 1.00 am and 6.00 am. If there is no automatic detection system, this could be an area where an ignition source could develop into a small fire unnoticed. A reference to Figure 17 shows that only four or five staff members would be available during this part of the day.

The kitchen (Figure 3) is fairly well used throughout the day but there are periods when a hazardous situation could occur unnoticed. Naturally, such an occurrence would depend on the probability of ignition for each of the power using appliances in the kitchen, but this is beyond the scope of the present paper.

In contrast, the various stores, Figures 4-7, tend to be visited infrequently and if any store is adjacent to a patient area, then a careful assessment of the possible ignition sources must be made in addition to the evaluation of the properties of the materials stored. Some spaces in the total ward area are unoccupied for much longer periods, up to 60 hours. These include laboratories in which continuous experiments are carried out. Any ignition in such spaces would be most harmful in the hours of low staffing levels, 5.00 pm to 7.00 am. (Figure 17).

Figure 8 shows that almost constant surveillance is possible in the nursery but the baby bathroom (Figure 9) is used for some part of each hour only. The bathroom and toilets are in fairly regular use throughout a large part of the day and if they are fitted with traditional equipment, are likely to be places of low fire hazards.

However, damp paper and cotton towels could present a smoke hazard if ignited (accidentally) during the night. Similar comments would apply to the sluice and treatment rooms (Figures 11 and 12). This group of spaces were occupied as dictated by the routine of the hospital.

The Sisters' Room (Figure 13) was unused from 10 pm to 7 am as most of the available staff were involved with baby care.

The histograms for the cloakroom, office and telephone (Figures 14, 15 and 16) show expected usage patterns.

Discussion

In all the activity spaces in this post-natal ward, periods of non-attendance exceeding five minutes were observed. This has serious implications for fire safety planning as the chance of not observing a fire in its initial stages becomes greater, especially as some of the areas had non-attendance periods much longer than might have been expected. This observation, however, does not mean that changes in nursing operations are required, or that smoke detectors should be installed in all spaces, but that the risk should be estimated and compared to the acceptable risk for the particular type of hospital. For example, the "additional risk" of the observed periods of non-attendance could be mitigated by the inherent fire safety of the occupied spaces.

In the design of new, and the decisions about alterations to existing hospitals, the "non-attended" spaces could be grouped to share some form of early fire detection, perhaps a smoke sampling system.

One aspect of fire safety which occurs after the detection of fire, is the preparation for and maintenance of movement for the patients threatened by a fire so that they may reach a place of relative, or absolute, safety. In some types of ward, the patient will be much more dependent on staff than in others. In all cases the effectiveness of an evacuation to safety will depend upon the ratio between staff available and staff required. Figure 17 is a record of actual staff number variation against time. It may be likely that the other wards may have given the same pattern of staff distribution throughout the day, although their patient : staff ratio may be different.

The next part of this contribution deals with the numbers of staff required to help various types of patient.

(2) PATIENT MOBILITY

The importance of considering both fire development and the reaction of people to the fire threat as a sequence of time, has been emphasised. The "degree" of non-attendance by alert people in various parts of a ward was considered as a factor in the time available for an ignition to be discovered. This part deals with two subsequent parts of the time, or event, sequence for the people involved - the problems of preparation for movement when under fire threat and the maintenance of movement to reach a place of safety. In this study an emphasis was placed on the availability of staff, or the number of staff required, to help a group of patients to reach safety. In the selected sample of nine ward-types, the need for staff help varied markedly as did the proportion of patients able to move without assistance.

Investigation Technique

After discussions with members of the nursing staff at various hospitals, it was agreed that the most realistic approach to the investigation was to ask the Sister, or Charge Nurse, a set of questions on a personal visit to any particular ward. The questions (see Appendix 1) were designed to give the investigator some information on the possibility of patient awareness to potential danger, the number of staff required to prepare the patient for evacuation, the number of helpers required to maintain movement towards safety and how the patient was to be moved.

As this study is a preliminary investigation, the types of ward chosen may not be representative of the total variation of ward types to be found in UK hospitals. They were selected to give a wide variation of patient types so that any significant evacuation problems could be identified. The ward types are listed below.

Table 1: Ward Types Selected

Ward Type	Number of Patients	Mobile Patients***
1. Ante-Natal	66*(4)**	95.5%
2. Post-Natal	88 (5)	80.7%
3. Surgical (Female)	58 (4)	24.1%
4. Young Chronic Sick	22 (1)	13.6%
5. General Medical	86 (5)	28.0%
6. Geriatric (Male)	46 (2)	0 %
7. Orthopaedic (Female)	91 (4)	5.5%
8. Acute head and spinal injury	54 (4)	3.7%
9. Assisted ventilation	7 (3)	0 %

* These numbers are the total number of patients investigated i.e. the total for all visits.

** The numbers in parenthesis indicate the number of visits made to each ward.

*** Mobile patients are those not requiring any help and able to move at least 90m.

Those wards with a regular turnover of patients were visited more times than long-stay wards in an attempt to gain a reasonable representation of the mobility distribution for each ward.

Results and Discussion

Table 1 above shows the proportion of patients who did not require help to evacuate. The overall percentage is 33.6% of patients in this category. This is in reasonable agreement with the accepted proportion of 40% but the distribution of mobile patients is far from uniform. From the Table it is clear that some groups require guidance only. It is important to note that the 40% figure cannot be applied to all groups of patient and if fire safety can be included in the emergency plan for staff members, then an understanding of the uneven distribution of non-mobile patients must be included in their training. The Tables in Appendix 2 give the compiled results for each of the nine wards. Using the responses to Questions 8 and 9, and assuming that each patient was in bed initially, a Patient Mobility Factor was calculated for each type of patient. It is expected that the problems created by the use of drugs, (e.g. sedatives), mental instability and defects in sensory response were included intuitively in the answers to questions 8 and 9 obtained from the nursing staff.

The calculation of the Patient Mobility Factor (PMF) is best described by an example. Taking data from Table 5 Appendix 2 (Male Geriatric Ward), thirty-four from forty-six patients required two staff members to prepare for evacuation, and twelve patients required one helper (Question 8). Similarly, for continuing movement, forty-two patients needed one helper and four only from forty-six could move alone. These numbers can then be assembled as follows:-

$$\text{PMF} = \frac{\text{Total number of staff actions required}}{\text{Number of patients}}$$

$$\text{Staff actions (A)} = (34 \times 2) + (12 \times 1) = 80$$

$$\text{Staff actions (B)} = (42 \times 1) + (4 \times 0) = 42$$

$$\text{PMF} = \frac{80 + 42}{46} = 2.65$$

(A) are the actions required to prepare for evacuation, and
(B) are the actions required to maintain evacuation movement.

The following table lists the PMF values for each of the nine wards. The third column of the table is a set of values which relate the degree of difficulty of moving patients taking ante-natal patients as unity. After further analysis, it may be possible to use such a rank order as part of a fire safety appraisal scheme for hospitals.

Table 2: Patient Mobility Factor (PMF)

Ward Type	PMF	Relative values
1. Ante-natal	0.17	1.0
2. Post-natal	0.65	3.8
3. Female Surgical	1.69	9.9
4. Young Chronic Sick	1.95	11.5
5. Mixed General Medical	2.15	12.6
6. Male Geriatrics	2.65	15.6
7. Female Orthopaedic	3.29	19.4
8. Acute Head and Spinal Injury	3.50	20.6
9. Assisted Ventilation	5.67	33.4

The PMF values may be helpful in comparing the difficulty of handling different types of patient. It should be noted also that simultaneous action is assumed in the calculations, a situation unlikely to occur because of the number of staff required for the preparation phase. Considering the geriatric ward, here a total of 40 staff would be required to prepare patients for simultaneous evacuation, but only 21 staff members to maintain evacuation. Taking the simple expression $\frac{N}{8}$ minutes, which gives the time available for evacuation (N being the number of patients), then the 40 staff would need to be assembled and evacuation completed within 3 minutes after ignition. This assumes the actual ward being under direct fire threat. In most hospitals the assembly of 40, or even 21 staff members in such a short time would not be a practicable proposition, but it is evident that the longer the time required before evacuation is completed, the greater the chance of a multiple fatality. Similarly, the post-natal ward would have no problems as 4 staff members would be required and Figure 17 shows that at least 4 people were available for 22 hours in every 24 hours.

PMF values may be useful in the assessment of the fire emergency needs of various types of patient as they concentrate on the number of able people required to help in particular ward types. Although the calculations described give some common measure, the patient handling problems in ward types containing specialised treatment areas (e.g. intensive care, and assisted ventilation) which have a high staff : patient ratio ordinarily, should have few problems as sufficient staff members could be assembled easily.

In some treatment areas and operating theatres, the patient may be in such a critical state that the fire safety designer should practice the concept of "defend-in-place", so that the patient and immediate staff do not need to leave the patient.

After the patients have begun to evacuate, other factors will influence their continued safety. For example the quality and quantity of escape paths whose adequacy will depend on the evacuation technique possible and the degree of protection available to the escape route.

Closing Remarks

The two studies described here represent preliminary investigations into two components of life safety - the amount of time that various spaces are unattended and the demands that patient mobility could create in an emergency. In the first part it was shown that non-attendance times could be excessive for some spaces within a ward, even when the ward area has up to five staff at night. Non-attendance times could be combined with fire incidence information for each existing hospital to help decide on the type, size and location of automatic detection and communication systems. For proposed buildings, non-attendance times for various spaces could give some guidance on the real need for some spaces, the 2- and 3- dimensional grouping of spaces for safety and surveillance reasons as well as information on the required performance of detection and communication systems.

The second part, on the emergency help required for various types of patient, develops the concept of Patient Mobility Factor. This gives a relative measure of the movement problems associated with different physical states of patients. The numbers of staff that would be required for simultaneous evacuation in some wards could never be made available and it is clear also that the total population in multi-bed wards where the patients are heavily dependent on staff care could never be evacuated in an emergency. The trial evacuations organised by DHSS at Hackney General Hospital (3) showed that the timely evacuation of geriatric patients by normal staffing using traditional techniques is not possible. Although analytical studies should be undertaken using all sizes of ward and levels of staffing, it is likely to be shown that there is a critical combination of ward size and staff required beyond which any fire would become a fatal fire. For all such situations, the fire safety emphasis could be better placed on surveillance (automatic or manual) to discover an ignition early coupled with effective fire suppression techniques (again automatic or manual).

Finally, in hospital fire safety, no single recommendation will be appropriate for all hospitals. It is essential, therefore, to analyse each situation and balance the fire and patient risk factors against the fire safety factors given by the staff available, the building and the installed fire safety equipment.

ACKNOWLEDGEMENTS

The invesgitations reported in this paper are part of a larger project on the systematic appraisal of fire safety problems in health buildings. The project is sponsored by the Engineering Division of the Department of Health and Social Security.

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APPENDIX 1

PATIENT MOBILITY INVESTIGATION

Set of Questions

General questions

1. Type of ward.

2. Number of beds in ward.

3. (a) Average patient age; range of age. (b) Ailment; (c) Average length of stay; range of length of stay.

4. At what time of day is patient sedated, if at all?

5. Are there any side effects from medication given?

6. Can the patient (a) see; (b) hear; and (c) react rationally to stimuli?

7. Is the patient in bed for most of the day?

8. How many people are required to prepare to move the patient to safety in an emergency?

9. How many people are required to move the patient to safety in an emergency, after preparation?

10. What method of movement would be used?

11. How quickly could the patient move/be moved, i.e. very slow, slow, normal?

12. How far could the patient move, or be moved, i.e. less than 10m, 30m, 90m?

13. Would the patient be in danger of dying if moved elsewhere in an emergency, i.e. could drips etc. be set up elsewhere afterwards?

APPENDIX 2

This appendix is a set of nine tables which correspond to the wards surveyed in the Patient Mobility Investigation and the information in the tables are responses to the numerous questions listed in Appendix 1.

Table 2-1 Ante-Natal Ward (4 visits)

3. (a) 27 years (20-39 years) (b) pregnancy (c) 8 days (0-29 days).

4.	52/66*	No sedation given
	10/66	Sedated all day
	4/66	Sedated at night
5.		Sedation only makes patients drowsy but able to be woken at night.
6.	66/66	No sensory decrement
7.	23/66	In bed for most of day
8.	63/66	Require no help to prepare to move to safety
	3/66	Require one staff member to help
9.	58/66	Require no help to move to safety
	8/66	Require one staff member.
10.	58/66	Walk to safety
	8/66	Use wheelchair
11.	62/66	Normal speed of movement
	4/66	Slow speed
12.	66/66	Able to move 90m or more
13.	1/66	Danger to life if moved.

These numbers throughout these tables refer to: in the denominator - the total number of patients observed for all visits; and in the numerator - the total number of patients observed for all visits who relate to the particular response.

Table 2-2 Post-Natal Ward (4 visits)

3. (a) Age 25 years (15-35 years) (b) After childbirth (c) 3.3 days (0-13 days)

8/74 Cesarian section patients.

4.	2/74	Sedated all day
	72/74	No sedation

5. Effect of sedation - makes patient drowsy but able to be roused.

6.	74/74	No significant sensory decrement.
7.	15/74	In bed for most of day.
8.	2/74	Two staff required to prepare patient.
	10/74	One staff required.
	52/74	No help required
9.	1/74	Two staff required to move patient to safety.
	11/74	One staff required.
	62/74	No help required.
10.	1/74	Stretcher to safety
	4/74	Use wheelchair
	69/74	Walk to safety.
11.	65/74	Normal speed of movement.
	9/74	Slow speed.
12.	74/74	Able to move 90m or more.
13.	74/74	No danger to life.

NB: Babies to be moved by additional help.

Table 2-3 Surgical Ward (Female) (5 visits)

3. (a) Age 49 years (17-84 years) (b) 45/72 post operative patients 59/72 abdominal trouble (c) 2.4 days (0-15 days)

4.	19/72	Sedated all day
	53/72	No sedation.
5.	Post operative anaesthetic effects render patient unconscious for about 10 hours.	
6.	62/72	No significant sensory decrement.
	5/72	Reactions suspect.
	5/72	One sense lacking.
7.	39/72	In bed for most of day.
8.	21/72	Two staff required to prepare patient.
	28/72	One staff required.
	23/72	No help required.
9.	17/72	Two staff required to move patient.
	18/72	One staff required.
	37/72	No help required.
10.	17/72	Bed used to move patient.
	9/72	Wheelchair
	46/72	Walk to safety.
11.	20/72	Normal speed of movement
	45/72	Slow
	7/72	Very slow.
12.	72/72	Able to move 90m or more.
13.	5/72	Danger to life if moved.

Table 2-4 Young Chronic Sick Ward (2 visits)

3.	(a) Age 46 years (28-66 years)	(b) 16/44 Waist down paralysed	(c) 42 months (0-72 months)

4.	16/44	Sedated at night
	28/44	No sedation
5.	Able to be roused from sedation.	
6.	42/44	Sensory response all right
	2/44	Poor sight.
7.	2/44	In bed for most of day.
	42/44	Mostly in wheelchairs.
8.	2/44	Four staff required to prepare patient.
	24/44	Two staff required.
	12/44	One staff required.
	6/44	No help required.
9.	18/44	One person required to move patient.
	26/44	No help required.
10.	42/44	Wheelchair used to move patient.
	2/44	Walk.
11.	18/44	Normal speed of movement.
	24/44	Slow speed.
	2/44	Very slow.
12.	44/44	Able to move at least 30m.
	18/44	Move 90m or more.
13.	44/44	No danger to life.

Table 2-5: Geriatric Ward (Male)(2 visits)

3.	(a) Age 73 years (51-89)	(b) 20/46 One side paralysed 10/46 Senile dementia 8/46 Total paralysis	(c) 77 days (0-96 days)

4.	12/46	Sedated all day
	30/46	No sedation.
5.	Able to rouse from sedation: 4/46 very drowsy continuously.	
6.	34/46	Sensory response all right
	12/46	Poor vision and speech, and irrational behaviour.
7.	10/46	In bed most of day.
	36/46	In wheelchairs
8.	34/46	Two staff required to prepare patients
	12/46	One staff required.
9.	42/46	One staff required to move patient.
	4/46	No help required.
10.	42/46	Wheelchair used to move patient.
	2/46	Trolley used.
	2/46	Walk.
11.	38/46	Normal speed of movement.
	6/46	Slow speed
	2/46	Very slow.
12.	46/46	Able to move at least 90m or more.
13.	46/46	No danger to life if moved.

Table 2-6. General Medical Ward (5 Visits)

3. (a) Age 72 years (50-93) (b) 23/86 heart complaint (c) 10.7 days (0-53 days)

4.	10/86	Sedated all day.
	38/86	Sedated at night
	38/86	No sedation.
5.	Sedation causes patient to be drowsy.	
6.	47/86	Faculties all right
	18/86	Reactions suspect.
	21/86	One sense deficient.
7.	19/86	In bed for most of day.
8.	2/86	Three staff required to prepare patient.
	33/86	Two staff required.
	27/86	One staff required.
	24/86	No help required.
9.	29/86	Two staff required to move patient.
	28/86	One staff required.
	29/86	No help required.
10.	5/86	Move in bed to safety.
	16/86	Wheelchair.
	65/86	Walk to safety.
11.	23/86	Normal speed of movement.
	48/86	Slow speed.
	15/86	Very slow.
12.	86/86	Able to move 30m.
	71/86	Able to move 90m or more.
13.	5/86	Danger to life if moved.

Table 2-6: Orthopaedic Ward (Female) (4 visits)

3.	(a) Age 61 years (14-87 years)	(b) 69/91 damage to hip or leg.	(c) 29.8 days (0-73 days)

4.	9/91	Sedated all day
	16/91	Sedated at night.
	2/91	Sedated when required.
	64/91	No sedation.
5.	Effect of sedation to make patient drowsy but able to be roused.	
6.	60/91	Sensory response all right.
	23/91	Reactions confused.
	8/91	Blind and deaf.
7.	59/91	In bed for most of day.
8.	74/91	Two staff required to prepare patient.
	12/91	One staff required.
	5/91	No help required.
9.	54/91	Two staff required to move patient.
	31/91	One staff required.
	6/91	No help required.
10.	54/91	Move in bed to safety.
	21/91	Wheelchair.
	14/91	Walk to safety.
	2/91	Use crutches.
11.	26/91	Normal speed of movement.
	56/91	Slow speed.
	9/91	Very slow.
12.	91/91	Able to move 30m.
	86/91	Above to move 90m or more.
13.	91/91	No danger to life.

Table 2-8: Acute Head and Spinal Injury Ward (4 visits)

3.	(a) Age 48 years (3-83 years)	(b) 27/54 severe head injury 9/54 spinal injury	(c) 8.8 weeks (0-35 weeks)

4.	54/54	No sedation.
5.	10/54	Unconscious.
6.	14/54	No reactions.
	16/54	Sensory response all right.
	24/54	Slow or confused reactions.
7.	24/54	In bed for most of day.
8.	44/54	Two staff required to prepare patient.
	8/54	One staff required.
	2/54	No help required.
9.	40/54	Two staff required to move patient.
	13/54	One staff required.
	1/54	No help required.
10.	40/54	Move in bed to safety.
	7/54	Wheelchair.
	7/54	Walk to safety.
11.	43/54	Normal speed of movement.
	11/54	Slow speed.
12.	54/54	Able to move 90m or more.
13.	2/54	Danger to life if moved.

Table 2-9: Assisted Ventilation Ward (3 visits)

3.	(a) Age 44 years (25-62 years)	(b) 6/6 Crushed chest	(c) 1 day (0-3 days)

4.	5/6	Sedated all day.
	1/6	No sedation.
5.	4/6	No reactions due to drugs or being unconscious.
	2/6	Drowsy during day.
6.	2/6	Sensory response all right.
	4/6	No reactions.
7.	6/6	In bed for most of day.
8.	5/6	Three staff required to prepare patient.
	1/6	Two staff required.
9.	5/6	Three staff required to move patient.
	1/6	Two staff required.
10.	6/6	Move in bed.
11.	1/6	Normal speed of movement.
	5/6	Slow speed.
12.	6/6	Able to move 90m or more.
13.	6/6	No danger to life if moved.

Figure 1a
Sub-Ward A
(1 Patient)

Figure 1b
Sub-Ward B
(1 Patient)

Figure 1c
Sub-Ward C
(2 Patients)

Figure 1d
Sub-Ward D
(3 Patients)

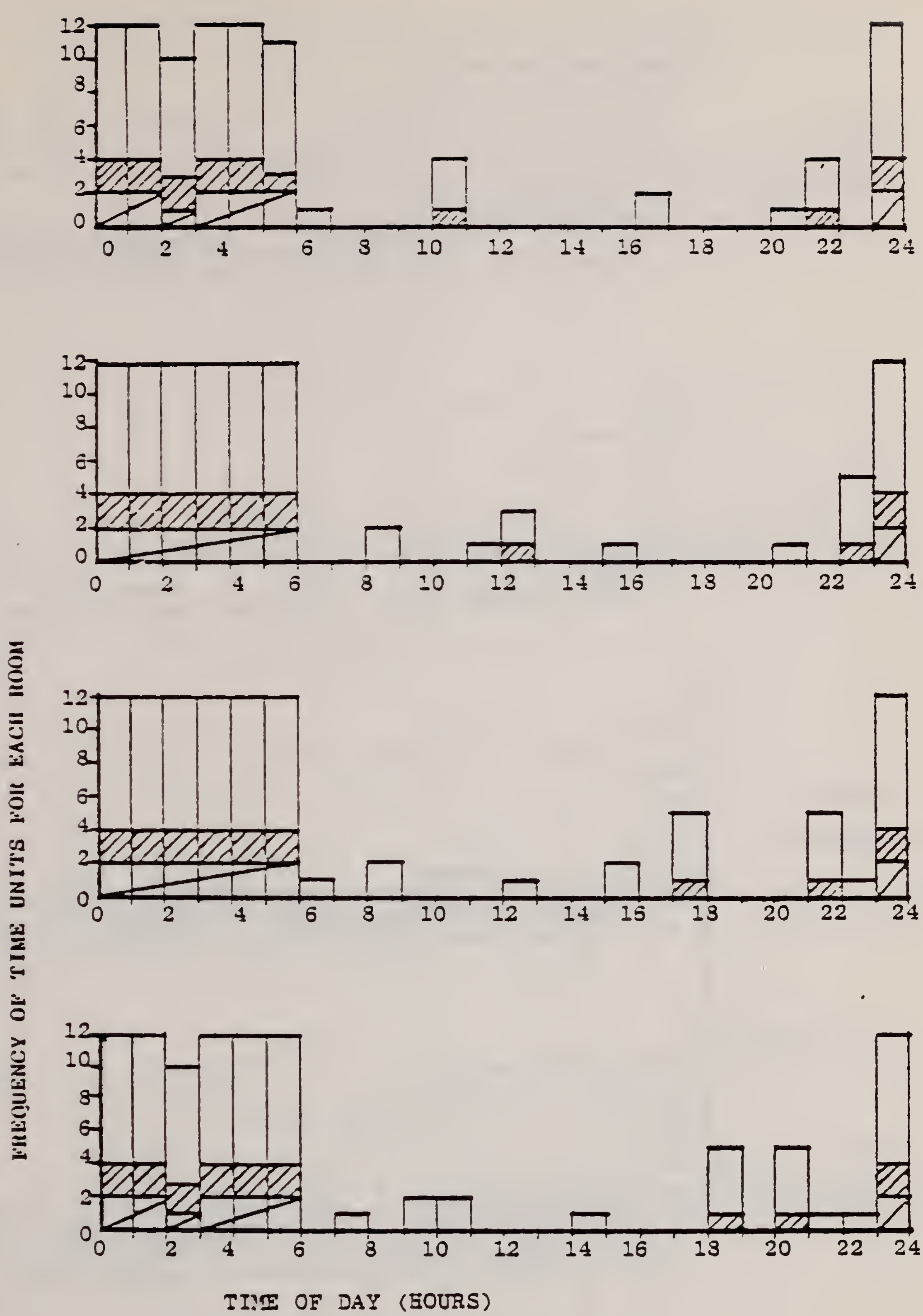


FIGURE 1: NON-ATTENDANCE TIMES FOR SUB-WARD AREAS.

FIGURE 2
PATIENTS' SITTINGROOM

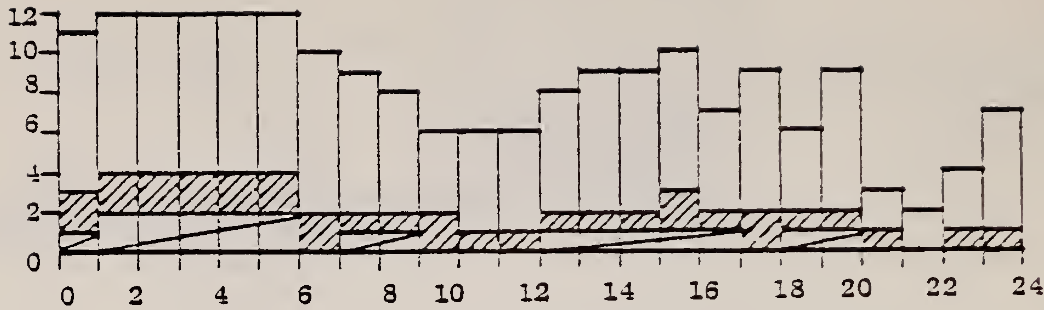


FIGURE 3
WARD KITCHEN

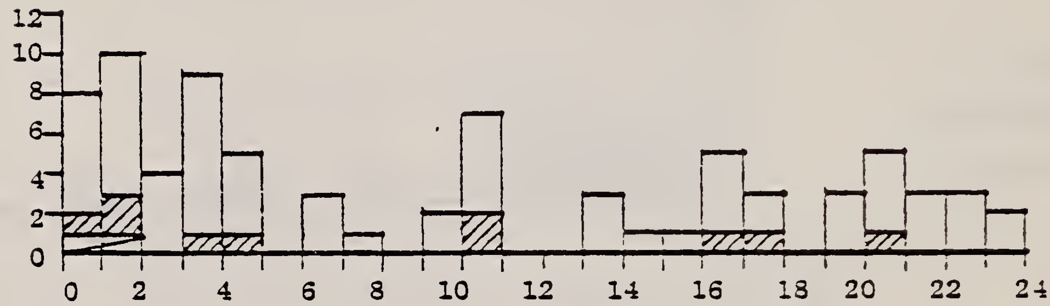


FIGURE 4
STOREROOM A

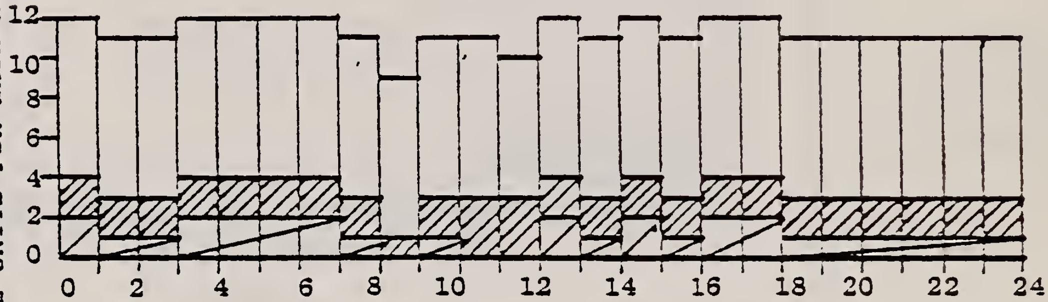
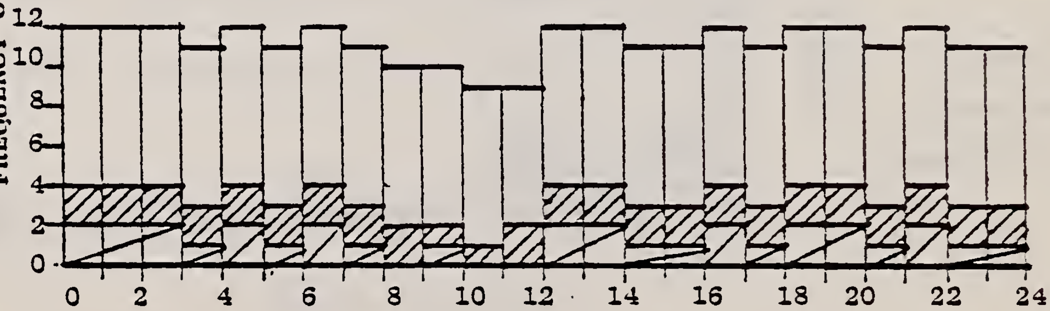


FIGURE 5
STOREROOM B



FREQUENCY OF TIME UNITS FOR EACH ROOM

TIME OF DAY (HOURS)

FIGURE 6
STOREROOM C

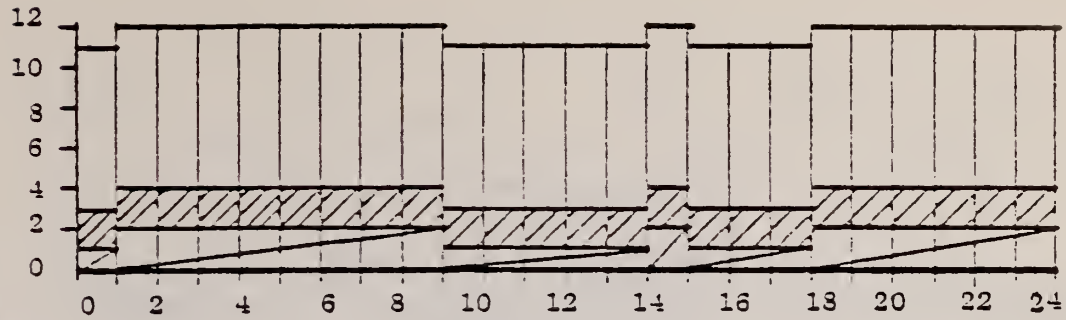
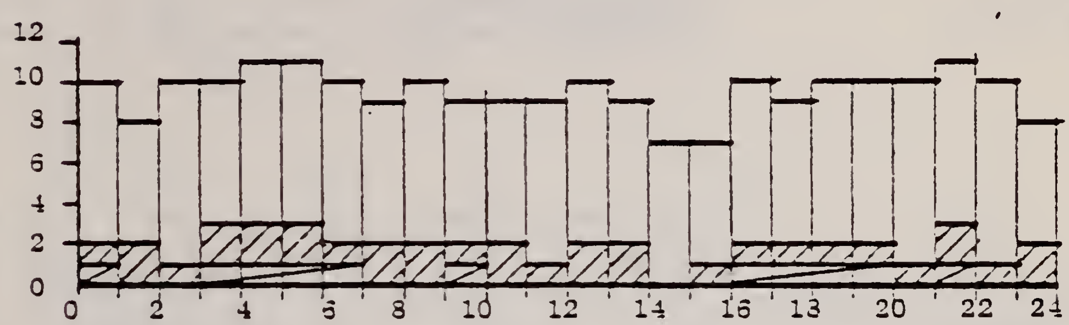


FIGURE 7
MILK STORE



FREQUENCY OF TIME UNITS FOR EACH ROOM

FIGURE 8
NURSERY

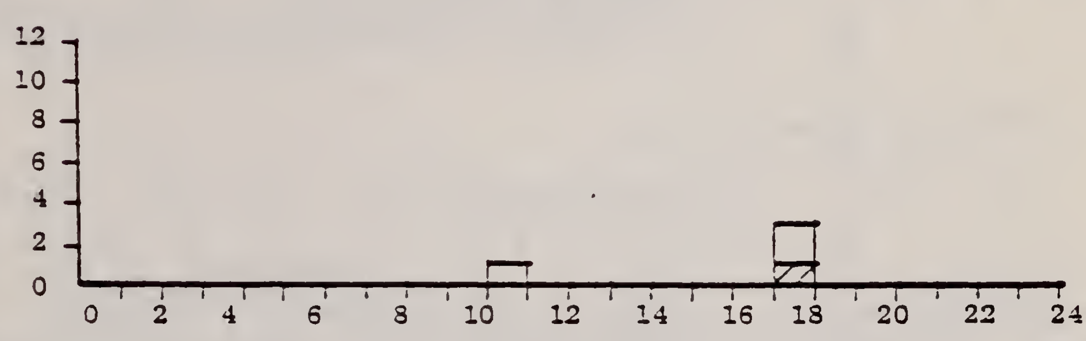
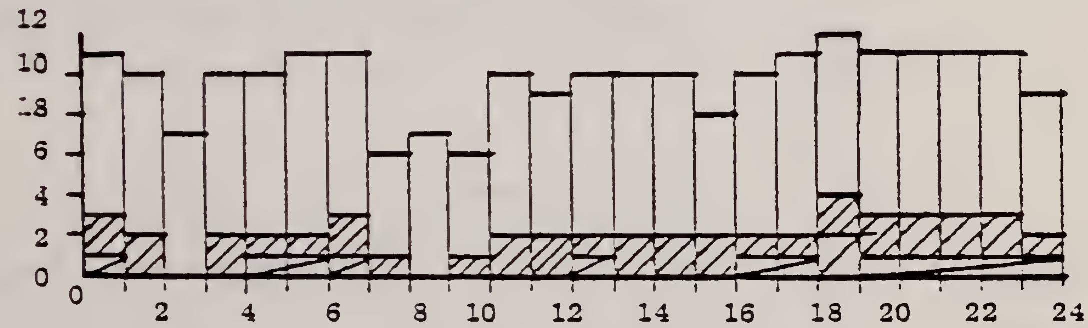


FIGURE 9
BABY BATHROOM



TIME OF DAY (HOURS)

FIGURE 10

BATHROOM AND TOILET

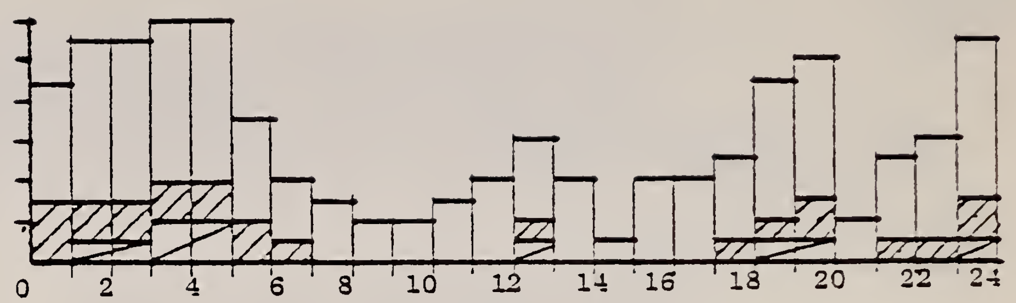
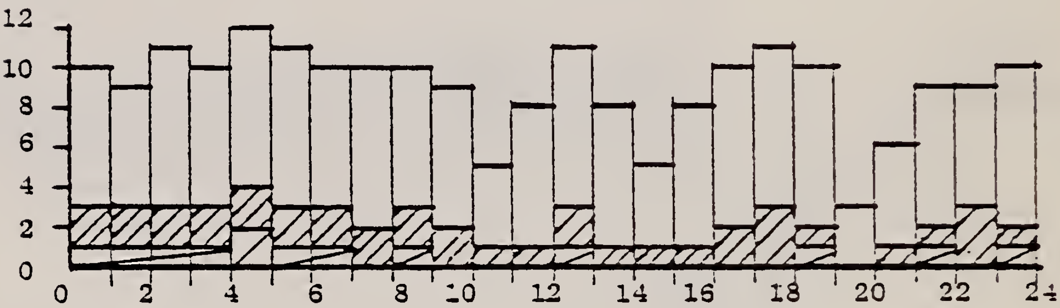


FIGURE 11

SLUICE ROOM



FREQUENCY OF TIME UNITS FOR EACH ROOM

FIGURE 12

TREATMENT ROOM

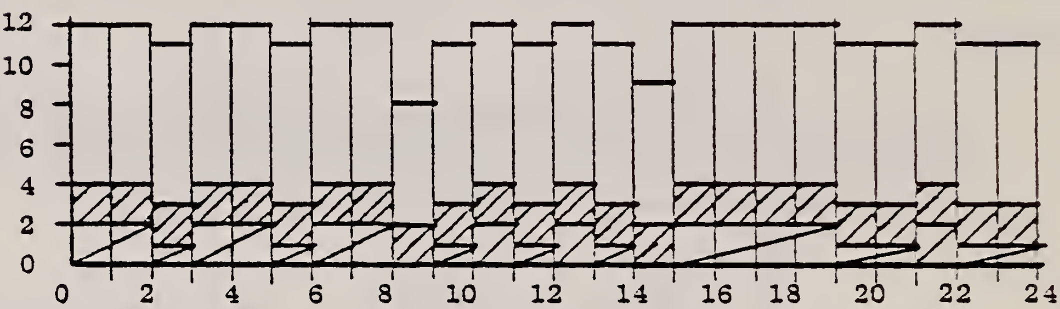
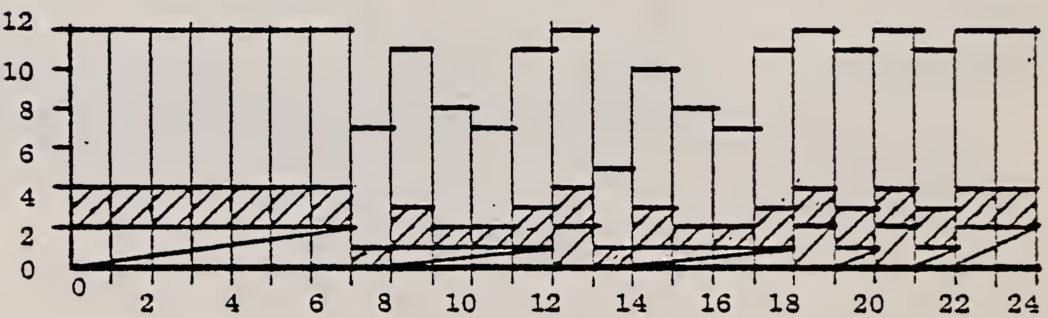


FIGURE 13

SISTER'S ROOM



TIME OF DAY (HOURS)

FIGURE 14

NURSES' CLOAKROOM

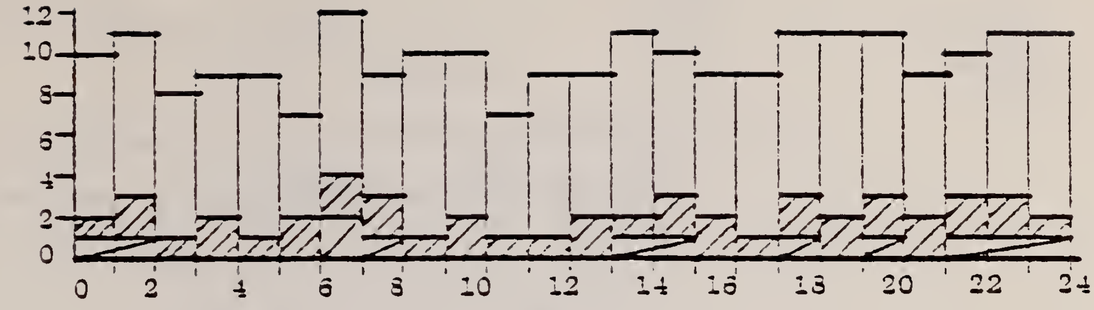


FIGURE 15

NURSING OFFICE

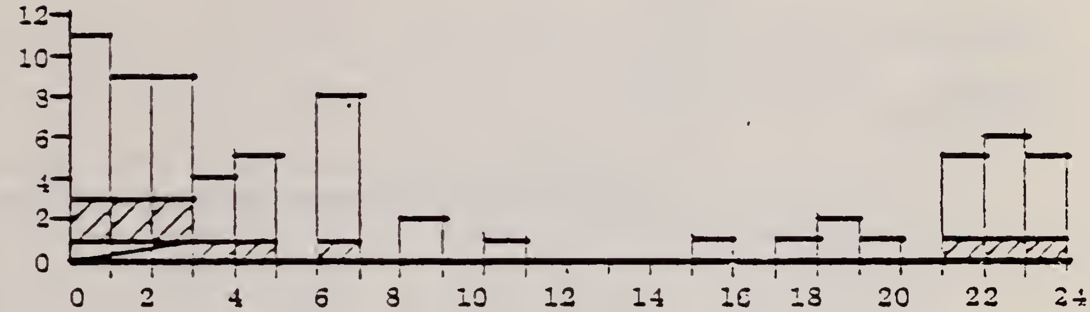
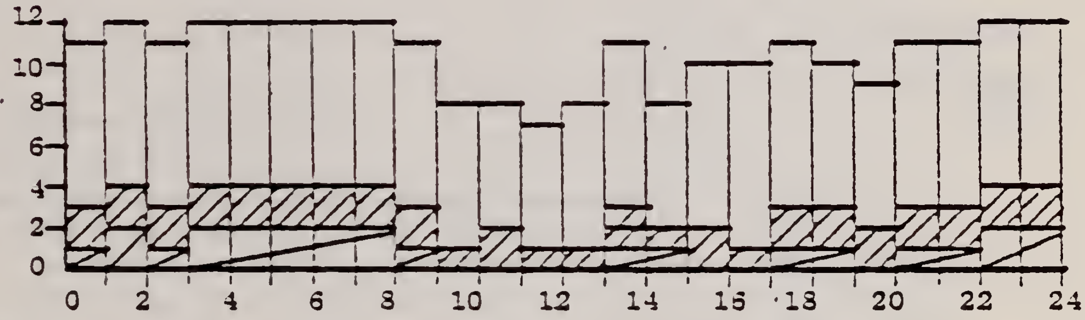


FIGURE 16

TELEPHONE CUBICLE



FREQUENCY OF TIME UNITS FOR EACH ROOM

TIME OF DAY (HOURS)

FIGURE 17a

NURSING STAFF

FIGURE 17b

NURSING AUXILIARIES

FIGURE 17c

DOMESTIC STAFF

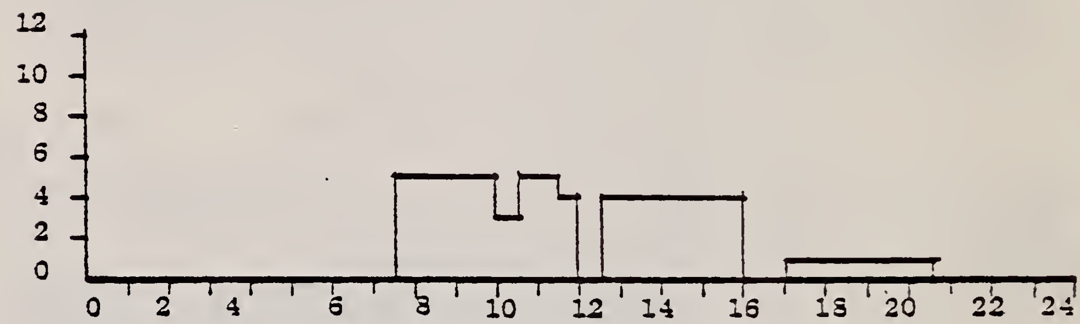
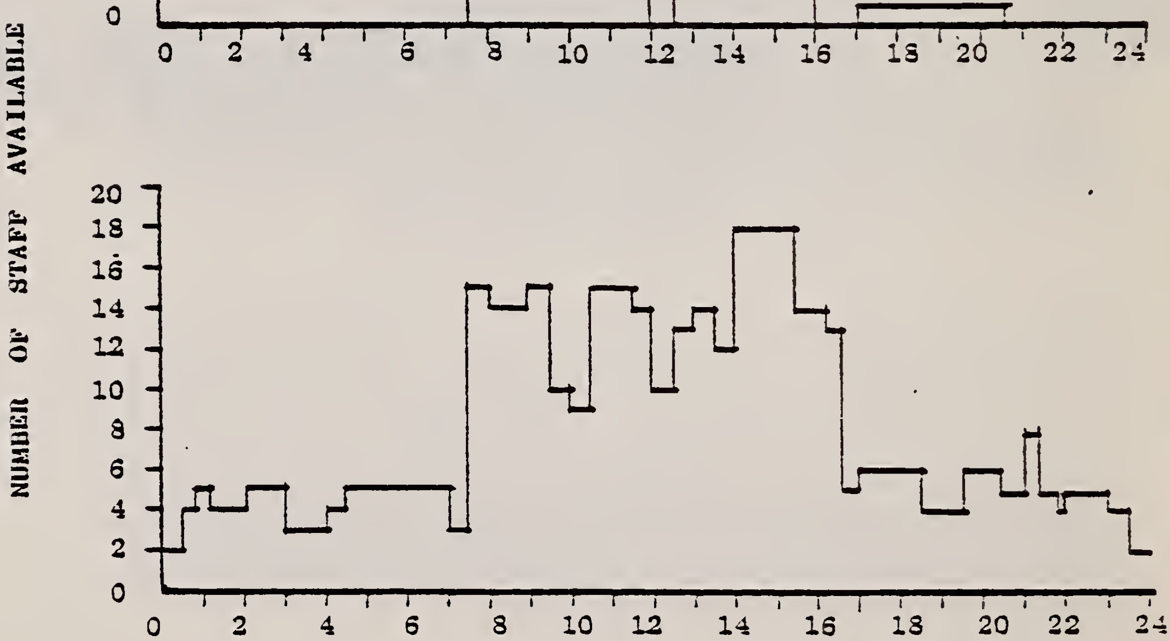


FIGURE 17d

TOTAL STAFF



NETWORK MODELS OF BUILDING EVACUATION

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This extended abstract outlines the work presented in the National Bureau of Standards Report No. NBSIR 79-1738, "EVACNET: Prototype Network Optimization Models for Building Evacuation." (Complete reference below.)

In brief, EVACNET work to date has consisted of a pilot project conducted to analyze the evacuation of buildings by means of computerized network flow optimization models. A major effort during this study involved constructing such an evacuation model of Building 101, an eleven-floor building located at the Gaithersburg, Maryland, campus of the National Bureau of Standards. A "skeletal" network model of the building has been constructed which represents the following entities (as well as paths of movement between them): workplaces, halls, doors between workplaces and halls, stairwells, doors between halls and stairwells, doors between stairwells and the lobby, and lobby doors. The model determines by itself an evacuation routing of the people in the building so as to minimize the time to evacuate the building. Further, the model is dynamic, in the sense that it represents the pattern of the building evacuation over time. Just as one might imagine photographing an actual building evacuation using automatic time-lapse cameras which take pictures of relevant evacuation activities over regular time intervals, so the model depicts the evacuation of the building as it changes over time: time is divided into discrete time periods, and the model indicates the changes in the evacuation status during each time period, as well as the evacuation status at the end of each time period.

Data for the model include such things as the numbers of people in workplaces prior to evacuation, stairwell flow-rate capacities, hall and lobby flow-rate capacities, as well as static capacities such as the total number of people a hall, workplace, or stairwell can accommodate. By making repeated computer runs of the model with different data sets, "what if" questions of interest, such as the following, can readily be addressed:

- What if there is a fire on the tenth floor?

- What if we could use "express elevators" to facilitate evacuating the building?

- What if a fire blocks a stairwell and/or some halls?

- What if we add more building exits?
- What if we add more stairwells?
- What if we want to identify evacuation bottlenecks?
- What if we want to determine the minimum time to evacuate the building, as well as routes people could follow so as to evacuate the building in the minimum time?

The fact that the model is computerized greatly facilitates asking such "what if" questions: answering them usually entails only changing model data and then making a computer run. Such data changes can often be made by an operator sitting at a remote computer terminal. Computerization permits answering such questions quickly, and is particularly useful when the model is large enough to be unwieldy if dealt with manually. Such a computer model has clear advantages over such other approaches as the use of graphical models, pictorial representations of building evacuation, and actual trial building evacuations: the computer model is often quicker, cheaper, can handle larger problems, and greatly facilitates the comparison of many alternatives. In the long run, it is hoped that such computer models will facilitate the study of the interrelationships of building evacuation with building design, building redesign, and building evacuation standards, and will also lead to improvements in design for evacuation.

While the particular model we have studied (to date) is for a specific building, the modeling methodology we have developed is rather general, and should facilitate modeling the evacuation of other buildings.

Key Words: Building evacuation; minimum evacuation time; dynamic network optimization models.

The complete reference is:

Francis, R.L. and Saunders, P.B. EVACNET: Prototype Network Optimization Models for Building Evacuation. National Bureau of Standards Report No. NBSIR 79-1738. October 1979. NTIS Order No. PB 80 113 780.

HUMAN BEHAVIOR IN FIRE DEPENDING ON TYPES OF OCCUPANCY: HEALTH CARE, PENAL AND LEISURETIME OCCUPANCIES

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Consultant

Abstract

The behavior of occupants of buildings in fire emergencies depends upon the social structure and lines of authority in the building. This paper contrasts the expected and actual behavior of building occupants in two contrasting types of buildings: (1) Total institutions such as hospitals, nursing homes and prisons where the institution is highly organized, the formal lines of authority are highly structured and the client population is provided 24-hours a day total care and is highly dependent on the staff; and (2) Places of amusement such as nightclubs, where there is limited organization, lines of authority are not structured and the patrons have limited familiarity with the layout of the building.

Key Words: Fire emergencies; hospitals; human behavior; institutions; nightclubs; nursing homes; prisons.

1. INTRODUCTION

So far, attempts at describing or explaining human behavior in fire have assumed that we could arrive at a basic pattern of human behavior in fire[1]. This paper deals with the idea that human behavior in fire varies depending on the type of occupancy. The first task of this paper, then, is to hypothesize a model of types of occupancy and then state expectations of types of behavior for these different occupancies.

Data for this paper was gathered by the author through in-depth studies of seven nursing home and hospital fires in America and Canada in 1976-77 while at the National Bureau of Standards; and in interviews with administrators and patients in regular hospitals, psychiatric hospitals, nursing homes, homes for the aged and for paraplegics, dormitories, apartment houses, houses for the retired and the aged, prisons and jails. These facilities are located in the United States, Canada, France, Italy and Egypt. Information on fires in nightclubs was obtained through the literature.

2. CLASSIFICATION OF BUILDINGS

We hypothesize a classification of four different types of occupancies. These four types of occupancies are based on the first two of the following factors:

1. Whether the occupancy is a total institution or not. See below for definition.

2. The familiarity of the occupants, except for staff, with the building.

3. Whether the occupancy of the building is voluntary as in hospitals and nursing homes, or involuntary as in prisons and jails.

4. Whether the ratio of staff to patients or inmates is high, low, or non-existent.

5. The performance of the building under fire conditions, i.e., how well the building and rooms can withstand fire.

On the basis of these variables, we hypothesize two major categories of occupancy, total institutions and non-total institutions. Total institutions are highly organized, have twenty-four hour occupancy by the majority of users, and an authoritarian staff. These institutions provide for all the needs of the occupants. This concept is taken from Goffman[2]. Non-total institutions are very loosely organized, are used for part of a day by occupants, and do not have authoritarian staffs. The non-total institutions, like nightclubs, have extremely loose organizations and have staffs who are subordinate to users of the occupancy and serve the occupants when they visit. Examples of total institutions to be used in this paper are: nursing homes and hospitals, with voluntary occupants; and prisons and jails with involuntary occupants. At the other extreme, the non-total institution occupancies are represented by nightclubs and dance halls. Both the total and non-total institutional occupancies have two types of occupants, those who are familiar with the building and those who are not familiar with the building. This leads to four possible types of occupancy:

1. A total institution with voluntary or involuntary occupants having an authoritarian staff and having occupants who are familiar with the building. Examples of such occupancies are nursing homes, hospitals, prisons and jails.

2. A total institution where occupants are involuntarily housed with an authoritarian staff. The occupants are believed not to know their way about the building. Examples of such occupancies are hospitals for the severely retarded or withdrawn, (such as autistic and schizophrenic patients) or patients with organic brain damage (such as congenital defects or senility), which could result in confusion about location and relationships.

3. A non-total institutional occupancy with a loose and nonauthoritarian staff, if any, where occupants go voluntarily, spend a portion of their day and know the territory. Examples of such occupancies are office buildings, apartment houses, dormitories and private homes.

4. A non-total institutional occupancy with a loose and nonauthoritarian staff, where occupants come only as visitors at unpatterned times, mainly for purposes of amusement and where occupants do not know the territory. Examples of such occupancies are restaurants, nightclubs and dance halls.

A model of these four types of occupancy is presented below. In this paper, however, we are only going to discuss the two occupancies at the extreme opposite of each other, occupancies (1) and (4): total institutions with voluntary and involuntary occupancy where occupants know the territory (especially nursing homes, hospitals and prisons); and non-total institutions where occupants enter voluntarily as occasional visitors and do not know the territory (such as nightclubs). We are concentrating on occupancies (1) and (4) due to the constraints of time and space, due to the fact that these categories represent the extreme opposites of the four types of occupancy, and due to the fact that there is better documentation at the present, on these two types of occupancy.

3. HYPOTHESES

1. The first hypothesis states that occupancies can be classified under the four headings described above.

2. The second hypothesis is based on the premise that occupants are mentally alert but physically dependent on the staff for their safety, due to physical restraints (as in health care institutions) or building restraints (as in prisons). It is hypothesized that such occupants will rely heavily for their safety on the staff, and on building performance in fire, so that there will be little panic, and comparatively few deaths. (If the staff and the building operate well during fire, there should be no injury or fatality, but if one or the other or both misfunction, fatalities are to be expected.) At the other end of the occupancy spectrum, most occupants are visitors, there is almost no staff leadership, and occupants do not know their way around. We hypothesize a high rate of panic and multiple deaths, as in nightclub fires. By panic we mean behavior which cannot be rationalized as being directed toward a reasonable goal, namely, behavior which does not effectively contribute to an escape from the fire danger. Non-rational behavior is believed to be largely due to ignorance as to what to do in a fire, together with some insuperable odds, like the malfunctioning of a building during fire. This non-rational behavior maximizes rather than minimizes the effects of the fire on human life.

	Total Institutions Confined Occupancies Characteristics		Non-Total Institutions Characteristics
Familiarity with the Building.	Non-Penal Institutions 1 i.e. Hospitals, nursing[a] homes, homes for the aged. Voluntary occupancy. Authoritarian staff. High ratio of staff to occupants. Familiarity with building except for newcomers and visitors. Average to high performance of building under fire.	Penal Institutions 1 i.e. Prisons, jails[b] and buildings for the criminally insane. Involuntary occupancy. Authoritarian staff. Fairly high ratio of staff to occupants. Familiarity with building except for newcomers and visitors. Poor performance of building under fire. Building designed for non-escape.	3 i.e. Private homes, apartment houses, dormitories, office buildings, retirement homes. Voluntary occupancy. Non-authoritarian staff. No staff or skeletal. Familiarity of occupants with building. Average to high building performance under fire.
Non-Familiarity with the Building	2 i.e. Homes for the severely retarded or withdrawn (autistic or psychotic). Involuntary occupancy. Authoritarian staff. High ratio of staff to occupants. Non-familiarity of occupants with building. Average to high performance of building under fire.		4 i.e. Nightclubs, dance halls Voluntary occupancy. Non-authoritarian staff. Low ratio of staff to occupants. Non-familiarity of occupants to buildings because they are mostly occasional visitors. Average to poor performance of the building under fire.

Total institutions house large concentrations of people which are all potential victims in fire; nightclubs and dance halls often run into occupancies up to or more than four thousand, as at the Beverly Hills Supper Club. The death toll from fires in health care institutions and prisons has been estimated to be about six hundred a year since 1973. The death toll from nightclub fires has been sporadic but has run as high as four hundred deaths in one fire as in the Cocoanut Grove Fire of 1942. As more high rise prisons are erected, the risk of multiple deaths or injury in fire is increased and we can visualize fires where occupants stand little chance of escape. We refer particularly to the new skyscraper prisons in New York and Chicago, thirty stories or more in height.

4. DISCUSSION

We will now discuss two of the types of occupancy, total institutions and non-total institutions, and give examples from actual fires which seem to support the hypothesis about panic. Discussion will center around the following points:

1. The type of occupancy involved.

    a. Staff-occupant relationships.
    b. Familiarity with the building.
    c. Building performance under fire.

2. The behavior of occupants and staff and the building's performance in each of the two types of occupancies discussed in this paper.

3. Considerations for design.

4.1 Total Institutions - Health Care

Type (a): i.e., total institutions with voluntary occupancy, such as nursing homes and hospitals.

4.1.1 Staff-Occupant Relationships

In a total institution occupants are in the building for twenty-four hours a day and night, and receive all of their needs in this building. Only the staff changes with each of the (usually three) shifts. Occupancy is usually voluntary. The staff is usually authoritarian and almost all decisions regarding the occupants are made by the staff. This is also true of emergencies. This would lead us to believe that occupants place great faith in the staff and will do as they are told in an emergency.

4.1.2 Familiarity With the Building

Staff is familiar with the building and occupants with any mobility at all are usually familiar with certain routes in the building. In some cases this familiarity can be dangerous for patients as in the case where able bodied nursing home residents left their rooms during fire and succumbed to smoke in the hallway. In another case, a blind girl in a wheelchair wheeled herself out of a safe area and back to her room where she succumbed to smoke inhalation.

4.1.3 Availability of Staff Assistance

In health care institutions there is usually a high ratio of staff to occupants, although this is sometimes drastically cut at night, reducing the staff's ability to handle evacuation in a fire. The high ratio of staff to occupants usually assures the occupants maximum care during emergency with three exceptions: (1) the staff may not be well trained, (2) the staff may be new to the institution, or (3), they may not have been trained to deal with fire. There seems to be a large turnover of staff in nursing homes. If a visitor is in the building, he or she may upset the work of the staff. For example, in one case the door of a fire room had been closed by a staff member but was reopened by a visitor letting out fire and smoke. Many nursing home fires seem to occur between midnight and 6 o'clock in the morning. At these times there may be only a skeleton staff which has to deal with a large number of patients. At night patients may be sedated or even tied to the bed. This presents a problem in getting the occupants to move if it becomes necessary. However, it appears that closing patient doors and leaving patients in their rooms are among the best solutions for protecting a large number of immobile people. This is one solution as pointed out by Burgun[3].

4.1.4 Building Performance Under Fire

Health care buildings are usually subject to building and fire codes, but not all such facilities fully meet the codes. The failure to have adequately protected buildings is documented by the Report of the Subcommittee on Long Term Care of the Special Commission on Aging, U.S. Senate Committee on Nursing Home Fires[4]. The report estimates there were 6,400 nursing home fires in 1973 and 551 persons lost their lives in institutional fires. Types of building deficiencies observed in nursing homes by the writer in 1976 included: an assembly room with no direct exit to the outside and only one exit route to the outside which was blocked by the fire; windows too narrow for patients to be easily rescued by firefighters, and construction of the building which does not allow firefighters to draw up close to the building as when there is a greater width to the building at the lower floors than on higher floors. (Firefighters who can usually reach up to the eighth floor cannot do so if the building curves outward at the bottom floors.) All seven health care institution fires involved bedding, mattresses, clothing or laundry[5].

4.1.5 The Behavior of Occupants and Staff and the Building's Performance

The second hypothesis suggests that in health care institutions we would expect people to depend on staff and the building in fire and that occupant chances of survival are better when they have an experienced staff and a fire resistant building. An analysis of seven health care institutions and causes of death shows that two major causes of death among patients were: disobeying staff directions to stay in safe places far from the fire or behind a closed door; and building deficiencies. Difficulties stemming from occupant behavior were, for example, when patients left a relatively safe place behind a shut door, and went into a smoke filled hallway or attempted to return from a safe place where the staff has put them, going into a smoke area. Staff had some difficulty with nursing home patients in getting them not to return to their rooms. Ironically, in a fire in a large mental institution for the criminally insane in Canada, which was studied by the author, patients were reported to have been extremely docile, and to have followed the directions of one nurse who led them to the safe side of a fire door and then shut the door. There is the possibility that they were docile due to medication, but it is thought that the severely emotionally disturbed are more likely to respond to direction. In this case in Canada, both the direction on the part of the staff was good and the building performance, in terms of a reliable fire door, was good. An entire wing of the floor of fire was demolished, but no one was hurt, not even the man who was in the room of fire origin.

4.1.6 Design Considerations

4.1.6.1 It seems impractical if not impossible for staff to carry out vertical evacuation during fire in a hospital or nursing home, where a large percentage of the occupants have little mobility. If there is only a skeleton staff at night, evacuation of occupants is even more difficult. In the light of this, other means of assuring occupant safety need consideration.

Rooms and/or balconies (in warm weather) could be used for horizontal evacuation. This method of evacuation together with locating people in refuge areas was frequently effective. A new center for paraplegics near Cairo in Egypt has clusters of nine patients in a clover leaf arrangement all on the ground floor level. There is a direct exit for every three persons, via a small ramp from the building to the outside in case of fire.

4.1.6.2 Early detection of fire is important by means of staff checks on the floor and smoke detectors.

4.1.6.3 Sprinklers have repeatedly been advocated as safety measures in health care institutions. Their use has lagged partially due to the expense.

4.1.6.4 Direct communication between health care institutions and the fire department is in order. The activating device should be inaccessible to patients to avoid false alarms. Reliance on telephone communication only, is inadvisable as in several cases telephones did not work during the fire. A box in the administrator's office is an alternative. Staff must also be trained not to delay notification of the fire department.

4.1.6.5 Heavy doors on occupants' rooms kept a number of occupants safe during fire even where they were immediately next to the fire. This was often highlighted by the fact that of two occupants in a room, the one that left the room and went into the smokey hallway, died; the one who remained in the room behind a closed door survived. Burgun[6] observes that since patients cannot be moved easily, the first refuge area should be the patient's own room.

4.1.6.6 Obviously to be avoided are such glaring deficiencies as an assembly room with no direct exit to the outside, only one escape route, and no doors on the room, to protect the occupants if the fire is in the escape route. Twenty-one people died in 1976 in such an assembly room.

4.1.6.7 Since all seven health care institution fires visited by the writer in 1976 involved bedding, laundry or clothes as the first source of ignition, this strongly suggests paying more attention to their flammability and the toxicity of their combustion products. The same materials are mainly used as fuel for beginning fires in prisons and jails. Mellam[7] observes that when the use of carpeting was on the upswing in hospitals, its flame spread rating had not been fully tested.

4.1.6.8 Windows must be wide enough for firefighters to rescue occupants, including obese occupants.

4.2 Total Institutions - Penal

Type (b), i.e., total institutions with involuntary occupancy, such as prisons and jails.

We now turn to a second type of total institution, type (b). This type is a twenty-four hour institution where inmates are confined involuntarily for a fixed time. Such places are generally called prisons or jails.

4.2.1 Staff-Occupant Relationships

The staff in prisons is definitely authoritarian, and the ratio of prisoners to staff is higher than patients to staff in a nursing home or psychiatric hospital, but lower than the ratio of patrons to staff in, for example, restaurants and nightclubs where the ratio may be 20 patrons to 1 waiter. The staff of a prison is not there involuntarily but in some respects they also are confined in their daily living. Staff in prisons appear to be familiar with the territory, with some exceptions. For instance, frequently women prisoners are housed in a wing or one floor of a prison or jail. As a group they need less space because there are fewer women who commit crimes, fewer who are arrested and fewer who are sentenced than men for each of the above categories[9].

4.2.2 Familiarity With the Building

Since the Angel case where a guard was killed by a woman prisoner who claimed he was attempting rape, male guards in America have been careful not to enter the women's section of prisons for their own protection against accusations of rape. When a fire broke out in the women's section in the upper level of a Maryland jail, the men received an emergency call and were summoned to the scene to help. They were not aware that they had been called about a <u>fire</u>: they thought they had been called about a fight or illness. They did not respond with fire equipment, which was kept downstairs. When they returned with masks and hoses, they did not know their way around the women's quarters, never having been up there. The male staff's lack of knowledge of the prison could have proven fatal in the fire emergency. In some cases one lock at the end of a row of cells lets out an entire row of cells. However, only one or two senior guards in charge of hundreds of prisoners may have keys. They have to be located in an emergency. Delays in unlocking cells have led to deaths.

4.2.3 Building Performance Under Fire

Fast action against fire in a prison is essential due to the fact that prisoners in open barred cells are exposed to toxic fumes. If it is necessary to evacuate them, it takes a great deal of time to unlock the individual cells.

Only one prison seen in five countries, the new Chicago Women's Detention House, claimed to be able to unlock all cells within a few minutes, by way of a central monitoring board. However, even there the superintendent said that she feared that in a fire the metal doors and/or locks might buckle in the heat before she could get to the inmates. She said she had had to stand by helplessly in the past when fire had buckled locks making it impossible to reach the occupants.

Prisons are dedicated to seeing that inmates do not escape. Therefore, it is difficult to arrange for safety in the case of fire. Moreover, security men interviewed in some of the most modern skyscraper prisons seemed to be very unsure as to what steps to take in the event of fire. In the Chicago Men's Detention House, which largely houses those accused of white collar crime and illegal immigrants, staff was relying on the design of the outside walls with slatted windows which allowed air to come in from the outside in the event of fire. However, although the men could move freely on each floor, there would still be the problem of unlocking the doors at each end of the floor leading to the aired stairways. Moreover, the cold air constantly coming in from the outside in winter could freeze the water hoses housed in the stairway unless a special container were to be built for fire equipment to protect it from freezing. This was planned, but the author does not know if this step has been taken.

Almost all American prisons visited claimed that fire setting inside the prisons was a constant problem and that the more psychologically disturbed the prisoner, the more likely he was to set fires. Fires were most often set by the most difficult inmates, according to guards, inmates and trustees, who made up the internal fire department at San Quentin and elsewhere. In sections of large prisons more fires occurred in the worst parts of the prison by the worst prisoners (they called this section Viet Cong), than in the honor section where almost no fires occurred. Typically inmates set fire to their bedding when angry with a roommate, disappointed by parole refusal, jealous of another prisoner, or when trying to embarrass a disliked guard whose superiors would question the frequent fires in his area. As of now much bedding in prisons and jails in America is toxic when heated and has contributed to a number of deaths in prisons.

Another factor contributing to the dangerous conditions of prisons is the fact that firefighting equipment is put out of the reach of the prisoners as prisoners are said to either vandalize the equipment or use it as weaponry. This also makes it difficult for guards to have access to fire equipment. Inmates seem to be unaware of the danger to themselves as well as to others in lighting fires in confined areas. If it were possible, it might be useful to have sprinklers in recessed and grilled areas over parts of the prison. In addition few prisons have adequate fire alarms. An exception to this is the new Women's Detention Center in Chicago.

Not all of the danger comes from inmates. The superintendent of the Chicago Center said that visitors often set fire to toilet paper and paper towels in the visitor's rest rooms. Women as well as men are known for frequent acts of arson whether inmates or visitors of inmates.

Education programs given to inmates as to the possible consequences of lighting fires might be of some help in reducing prison fires. On the other hand there is the possibility that once fires are seen as a weapon they might be set more often. Experimental programs could be tried, first on trustees, then on more and more disturbed prisoners to see if information on the consequences of fire increases or decreases fire setting in prisons. A control group could be observed to see if there is any difference in the rate of fire setting between the group which receives training and the group which does not. Meanwhile, studies need to be done on how to simultaneously release large numbers of inmates, move them to another place within the institution, and sprinkle the cells. The new high rise prisons containing large amounts of toxic materials such as nylon carpeting, synthetic bedding, plastic furniture and unbreakable "glass" windows, run the risk of becoming

"Towering Infernos". In some ways, the more old fashioned prisons, built largely of stone and with little synthetic materials as in San Quentin and prisons in Milan and Cairo, are safer because they have less flammable and toxic materials in them.

Some recent prison fires in America are as follows:

1. October 2, 1974 - Cranston, Rhode Island, Youth Correctional Center, 2 dead.

2. June 9, 1975 - Sanford, Florida County Jail, 11 dead.

3. November 18, 1975 - Williamsport, Pennsylvania, County Jail, 3 dead.

4. July 2, 1976 - Marion, Ashville, North Carolina, five inmates were killed and twenty-eight were burn victims when men in a dormitory rioted and set fire to a pile of mattresses.

5. October 12, 1976 - Prince George's County Jail, Maryland, six inmates were injured, one burned seriously, and twenty-nine firefighters and Sheriff Deputies suffered smoke inhalation. An inmate set fire to a foam plastic mattress resulting in thick toxic smoke pouring out.

6. January 31, 1976 - Portland, Main County Jail, 1 dead.

7. July 7, 1977 - Danbury prison, Connecticut, five people were killed and 71 injured, five critically, including a guard and a fireman.

8. July, 1977 - Tennessee, 42 people died in fire. Most victims died after inhaling toxic fumes emitted from burning mattresses made with polyurethane padding. These mattresses when burned produce black smoke containing toxic gases including cyanide.

4.2.4 Behavior Constraints on Occupants and Staff

As in health care institutions, which often are also total institutions, we would expect prisoners caught in a fire to be dependent upon the authoritarian staff for protection or escape from fire. Healthy inmates in prisons and jails are involuntarily confined and may be totally dependent upon staff to rescue them. Unlike health care occupancies, penal or correction occupancies have to solve the dilemma of how to release inmates from cells without letting them escape. Inmates have two strikes against them if caught in fire-- the staff may not be anxious to release them and/or they may be ambivalent. This ambivalence was clear in the case of a woman guard in charge at the time of a fire. She expressed great ambivalence and anxiety as to whether she should have released inmates or watched them as smoke poured into their cells. She chose the second alternative with great agitation.

Secondly, the buildings are designed specifically to prevent escape - at least to the outer world, and accessibility to fire equipment is constrained.

4.2.5 Design Considerations

1. The fact that escape to the outer world is not desired suggests strong consideration for providing an internal place of refuge. In the 30 story occupancy of the Men's Detention Home in Chicago, a floor half way up in the building was designated as a refuge area if necessary. However, the heavy machinery is kept on this floor which, if damaged in any way, could threaten inmates. Another prison which had a fire is adding rooms horizontally to serve as refuge areas should it become necessary.

2. Reducing the number of people in any penal institution, or increasing the <u>horizontal</u> size of penal institutions would upgrade safety. Wide and low buildings would reduce crowding and the inaccessibility to firefighters of high rise buildings.

3. Bars of cells could, in new facilities, be replaced by doors to allow protection against smoke and fire.

4. Materials in furniture, carpeting, bedding should not have unusual toxicity if heated or ignited. This development lies in the hands of chemists.

4.3 Type 2 and Type 3 Occupancies

Due to time and space considerations, this paper will not deal with type 2 and 3 occupancies. Type 2 refers to occupancies where occupants are highly disoriented and might also be unaware of their environment, e.g. autistic and psychotic patients and those with organic brain damage. Type 3 refers to residential and office buildings. While some consensus exists between people carrying out research in this last area, there is still no definitive profile of human behavior in residential or office type occupancies. There is, however, consensus among Bryan, Cantor, Haber and Woods[10] regarding some aspects of behavior in residential fires. This consensus revolves around aspects of response to fire, namely disbelief of the information that there was a fire, surprise at the speed of fire, and differential behavior between men and women at the scene of fire, with a tendency for men to fight the fire and take more risks, and a tendency for women to evacuate themselves, their children and others from the fire.

4.4 Visitor Institutions

We now come to a discussion of fires in non-total or "visitor" institutions. These are the opposite of total institutions which are characterized by twenty-four hour occupancy by the same people and an authoritarian staff. Non-total institutional occupancy is characterized by a continuously changing occupancy due to the fact that people are visitors to the occupancy. They neither live nor work there, but come there possibly once or often, but always in the role of visitor. In this capacity the visitor, or stranger, has several characteristics of his own and his own specific relationship to the staff.

We will examine four night club and one dance hall fires. Each of these had multiple deaths, ranging from a low of seven in the Cinema Follies Theatre, to a high of 491 in the Cocoanut Grove fire in 1942. When night clubs have some of the seven characteristics listed below, there is a significant risk of a tragic fire.

1. Night clubs are frequently overcrowded;

2. Exits may be obscured by low lights and drapery;

3. Exits may be locked against gatecrashers;

4. The furnishings, furniture and decorations in night clubs may be highly flammable;

5. Staff and owners may try to fight the fire themselves unsuccessfully; and,

6. They may delay calling in the fire department until the fire is completely out of hand, unlike people in institutions like nursing homes or people in their own residences;

7. Patrons do not know the territory or possible escape routes.

If the main exit is blocked by the fire and if the lights go out, patrons of a night club may become hopelessly lost and die in the fumes before finding an exit.

An additional problem with night club fires is that they are unexpected and alarms may be delayed.

The five club fires from which these conclusions are drawn are:

1. The Cocoanut Grove Club fire, 1942, 491 dead[11].

2. The Blue Angel Night Club fire, Manhattan, 1975, 7 dead[12].

3. The Cinema Follies Club fire, Washington, D.C., 1977, 8 dead[13].

4. The Beverly Hills Supper Club, Kentucky, 1977, 164 dead[14].

5. The Cinq-Sept Club, France, 1970, 145 dead[15].

The visitor comes to the occupancies voluntarily. He or she usually comes with expectations of enjoyment and leisure time activity. The visitors have a loose relationship to the staff, and often a limited knowledge of the layout of the building.

4.4.1 The Relationship of Staff and Patrons

The relationship of staff to patrons in night clubs and dance halls is totally different to that of the relationship of staff to occupants of nursing homes, hospitals and prisons. As pointed out above, relationships between occupants of total institutions are clearly demonstrated so that the patient or inmate becomes almost totally dependent on the authority of the staff. Uniforms are a symbol of authority.

In a nightclub or dance hall there is the complete reverse. Here the patron or customer is always (or mostly) right, and the staff is there to serve the customer. Uniforms are not symbols of authority but of service. There is no call for the use of staff authority unless customers become difficult and/or in an emergency. The staff wields no authority. For example, when a bus boy calmly announced the breakout of the fire at the Beverly Hills Supper Club, he was thought to be part of the comedy routine the patrons were enjoying. In this sense only, Freedman[16] is correct - crowding only causes an escalation of the mood of the crowd before it came to the occupancy. Leisure type crowds had come to the Beverly Hills Supper Club and expected to be amused, so they were also amused when a bus boy announced a fire. The same was true of the Cinema Follies Club fire. The fact that the patron is in charge often leads to a minimum of direction on the part of the staff. Attendance at a place of amusement is always voluntary.

4.4.2 Action of the Patrons

Human behavior in tragic fires in nightclubs and other places of amusement most approximates what we usually call panic. The staff, which knows the exits of the building, exerts little or no leadership on the occupants who are all visitors and rarely know their way about. Visitors may ignore staff announcements when they do occur. Moreover, by the time the staff does make such an announcement the fire may be out of control since the staff has delayed calling for help and also has tried to fight the fire alone. The exits cannot handle the exiting flow of patrons and there is a jam at the doors. After the fire, bodies are found at the exit, and in restrooms and cloakrooms.

4.4.3 Deficiencies in the Building and Contents

Most dangerous about the five nightclubs and entertainment places studied here, is the poor performance of buildings and decorations. Exits were unmarked; doors which were supposed to be open were locked (supposedly against gatecrashers); the panic bar did not work; and in one case the doors opened inwards.

In these tragic fires the staff usually procrastinated calling in the fire department while they looked for the source of the burning odor, and or tried to put out the fire themselves. By the time staff decided to call for help, the fires were raging full blast.

In all of the five places of entertainment, the decorations and furnishings provided much of the fuel for the ensuing conflagration. Night clubs and dance clubs use a great deal of stuffed furniture, flammable wall and ceiling coverings, plastic plants and flowing drapes. Other factors which make such places of leisure highly dangerous in fire emergencies are the large concentrations of people, slow discovery of fire, slowness in reaction, failure to call in firefighters, locked or obscured doors, doors opening inwards, insufficient training of staff and patrons, limited leadership by staff in some fires, light failure, and ignorance of exit routes by patrons.

4.4.4 Design Considerations

Design and operational considerations are clear and simple: (1) Occupancies must not be overcrowded; (2) exits must be plentiful and well marked and never locked; (3) fire alarms should be directly linked up to the fire station; (4) sprinklers should be installed; (5) there should be a back up system for failed lights; (6) doors must open outward; (7) swing doors should be abolished; and most important, the flammable and toxic nature of furniture, upholstery and decorations should be severely restricted.

5. SUMMARY

This paper has hypothesized that there are clearly distinguishable classifications of occupancy, and that we would not expect a single type of human response to fire in all of these occupancies, but different types of responses.

We expect to find a greater frequency of fires in total institutions such as health care and penal institutions, where confinement seems to be associated with frequency of fires. Staff and the buildings in these confined occupancies are supposed to be well prepared for fire. Occupants in these types of institutions are almost always totally dependent on the staff and the building for their safety because they are either handicapped by age and infirmity or are involuntarily confined. In actual fact, there is often insufficient performance by staff and inadequacies in the buildings, in these types of occupancies.

Although serious fires in amusement centers appear to be less frequent, the staff often has no training in fire emergencies, patrons are highly concentrated, patrons may refuse to accept staff leadership, and the staff may delay calling the fire department. Frequently buildings for amusement have unsafe features such as obscured exits, locked exits, and highly flammable furnishings. When a major fire occurs, hundreds of patrons may be directly exposed to the danger.

6. CONCLUSIONS

Since fires seem to be a regular pattern in health care and penal institutions, and it is not feasible to evacuate everyone vertically, the buildings should contain a number of fire safety features and the staff should be properly trained.

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USING BEHAVIORAL DATA IN FIRE SAFETY ANALYSIS[1]

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Decision analysis is used to evaluate alternatives for reducing fire losses. An explanation of the decision analysis approach is given in the context of the upholstered furniture fire problem. The uses of behavioral data and the needs for such data in this type of analysis are given. Three alternatives to reduce upholstered furniture fire losses are presented and compared on the basis of minimizing the total cost plus loss to society. The sensitivity of these results to changes in the model inputs and assumptions is also addressed. Good behavioral data are needed for future analyses of this type. This paper indicates areas where research on human behavior will provide an important ingredient in future fire safety planning.

Key words: Behavioral data; building fires; cost benefit analysis; decision analysis, fire losses; human behavior; smoke detectors; upholstered furniture.

1. Introduction

Decisions concerning public safety--particularly fire safety--are being made continually at all levels of government. For example, the Consumer Product Safety Commission is currently addressing the upholstered furniture fire safety problem.

Upholstered furniture fires in residences are one of the primary causes of fire fatalities in the United States today. These fires also cause many injuries and substantial property losses each year. In an attempt to reduce upholstered furniture fire losses, the Consumer Product Safety Commission is considering a mandatory flammability standard for upholstered furniture. Since most upholstered furniture fires are caused by carelessly dropped cigarettes, combinations of upholstery materials and constructions which could be ignited by cigarettes would not be permitted under the proposed standard. Because of possible increased manufacturing costs, including flammability testing and record-keeping requirements, it appears likely that the promulgation of such a standard would increase the consumer cost of new upholstered furniture.

On the other hand, some local governments have addressed the entire residential fire safety problem by requiring the installation of smoke detectors in residences. Some local laws apply to new construction only, while other laws apply to all residences in the particular jurisdiction. There are also consumer costs related to this fire loss reduction strategy.

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[1]Complete details of the work on which this paper is based as well as a complete set of references may be found in [1].

It is important to all of us that these fire safety decisions be made in a rational manner based on the best information available to the decision makers. Today, I want to show you how we, at the Center for Fire Research, are using decision analysis to provide this rationally based input to the decision makers. I also will indicate the type of assumptions related to human behavior which we had to make in order to perform our analysis, as well as the type of research that would help us to improve this type of analysis in the future.

Decision analysis provides a logical framework for addressing complex fire safety problems. The steps we use in our analysis are summarized in figure 1. Our decision problem may be defined in terms of the question, "what intervention strategy (if any) should be used to reduce residential fire losses resulting from ignition of upholstered furniture?" To date we have considered three alternatives: no government action, mandatory installation of smoke detectors, and the proposed upholstered furniture standard under consideration by the Consumer Product Safety Commission. Each of these alternatives assumes increasing levels of voluntary smoke detector installation and certain naturally evolving changes in upholstered furniture flammability.

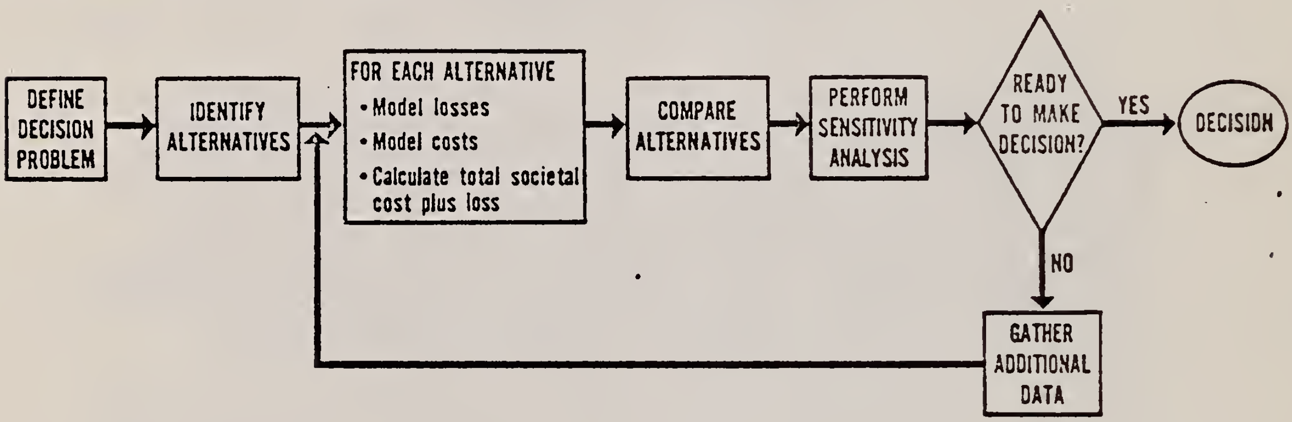

Figure 1. Steps in the Decision Analysis Procedure

Our criterion for the "best" alternative is that it result in the minimum cost plus loss to society. That is, the upholstered furniture losses under each alternative are modeled. We then model the cost associated with implementing each alternative. We then calculate the total cost plus loss to society under each of the alternatives and compare them.

After comparing the alternatives, we perform sensitivity analysis on the various assumptions and input data used in the model to determine what effect these assumptions and data have on the choice of alternatives. If the analysis shows that a particular data element has a significant effect on our choice of alternatives, we may decide to obtain better data on that particular element before making a decision.

2. Modeling Upholstered Furniture Fire Losses

Since the questions and assumptions related to human behavior are associated with modeling the fire losses, I will first direct my attention to this topic.

We develop a fire loss model to enable us to predict the upholstered furniture fire losses under each of the alternatives. The fire loss model, given in figure 2, takes the form of a probability tree. The model assumes that an ignition has occurred, and first addresses the question of whether that ignition results in a fire which is reported to the fire department. The model then addresses the ignition source. The fire loss model is actually four times as large as it appears, since only the portion associated with one of the four possible ignition sources is shown. The model then asks the following questions about the fire:

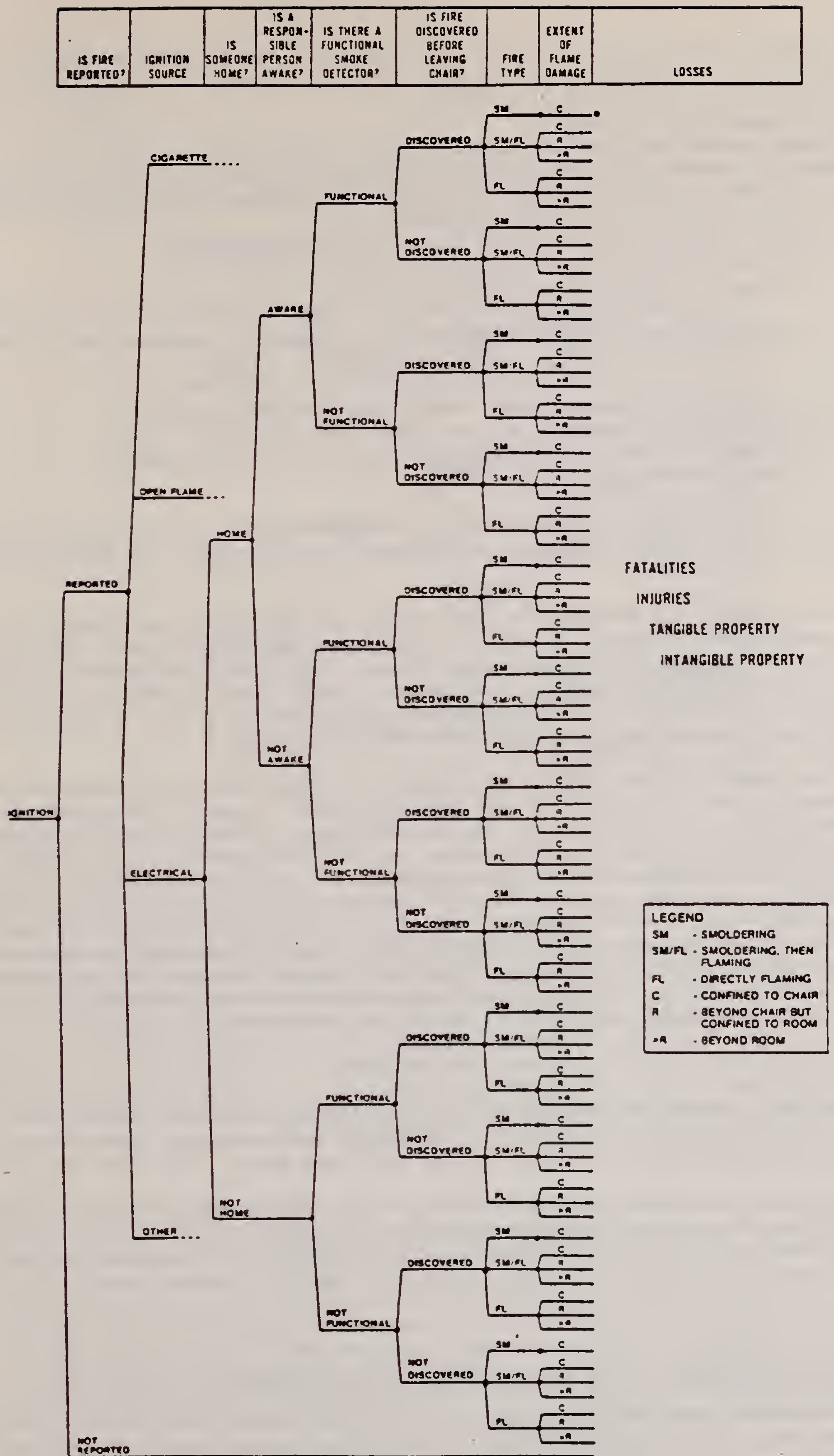

Figure 2. Upholstered Furniture Fire Loss Model

Is someone home at the time of ignition?
Is a responsible person awake?
Is there a functional smoke detector?
Is the fire discovered before it leaves the chair[2]?
Does the fire smolder only (SM)? Smolder and then flame (SM/FL)? Or was the ignition a flaming ignition (FL)?
Is the flame damage confined to the chair (C)? Spread beyond the chair but remain confined to the room of origin (R)? Or spread beyond the room of origin (>R)?

Each path through the tree represents one possible scenario or combination of events. For example:

> *A cigarette ignition occurred when someone was home and everyone was asleep in a home with no functional smoke detector. The fire smoldered and then flamed resulting in flame damage which extended beyond the room of origin.*

Each branch of the tree is assigned a probability. The probability of a particular path through the tree, is the product of the probabilities of the branches which comprise that path.

Associated with each path through the tree are the average losses associated with the corresponding combination of events: numbers of fatalities and injuries, and dollars of property loss. We consider both tangible property loss, the actual loss reported by the fire department, and intangible property loss, such as loss of family mementos or household disruption. Using the probability of each path and its associated losses, probability distributions on upholstered furniture fire losses are constructed.

The fire loss model is first used to calculate upholstered furniture losses for current conditions. Using a combination of fire loss data and expert judgment[3], we assign numerical values to the various model parameters for current conditions. Then, for each alternative, we consider some future year when that alternative is "fully implemented." For example, in the case of the proposed upholstered furniture standard, we consider some future year when all existing furniture has been replaced by furniture manufactured under proposed standard. For each alternative, we change the numerical values for current conditions to the appropriate values for the "fully implemented" alternative and exercise the model to calculate the expected losses. The losses for the years between the current year and full implementation are calculated using the rate at which the particular alternative is implemented. In this way we obtain the future annual fire losses anticipated under each alternative.

3. Using Behavioral Data

To indicate what information from human behavioral research would be useful to us in modeling upholstered furniture fire losses let us look at three auxiliary trees we use to develop some of the probabilities required for the fire loss model.

In modeling upholstered furniture fire losses, we use a combination of fire incident data and expert judgment. Our primary source for fire incident data is the U.S. Fire Administration's National Fire Incident Reporting System (NFIRS). Our primary source for the probability assignments[4] for the auxiliary trees I'm going to discuss here is the best

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[2] For convenience we may refer to any piece of upholstered furniture as a "chair."

[3] Experts in upholstered furniture flammability, fire detection and other areas of fire research at the Center for Fire Research and elsewhere.

[4] These assignments are for the class of all fires, both reported and unreported, for current conditions. The method used to combine fire incident data on reported fires, with expert judgment which applies to all fires (both reported and unreported), is discussed in detail in our full report on this project [1]. Results given in this paper are for the class of reported fires, since these account for the majority of fire losses.

judgment of *fire* research experts. We would have liked to use some human behavior data or research to provide these probability inputs, but we are not aware of any research directly related to our needs.

The tree in figure 3 assumes that a piece of upholstered furniture is ignited by a cigarette, and then asks if someone is at home when the ignition occurs. We set the probability that someone is home when the ignition occurs at 0.95, the best estimate available.

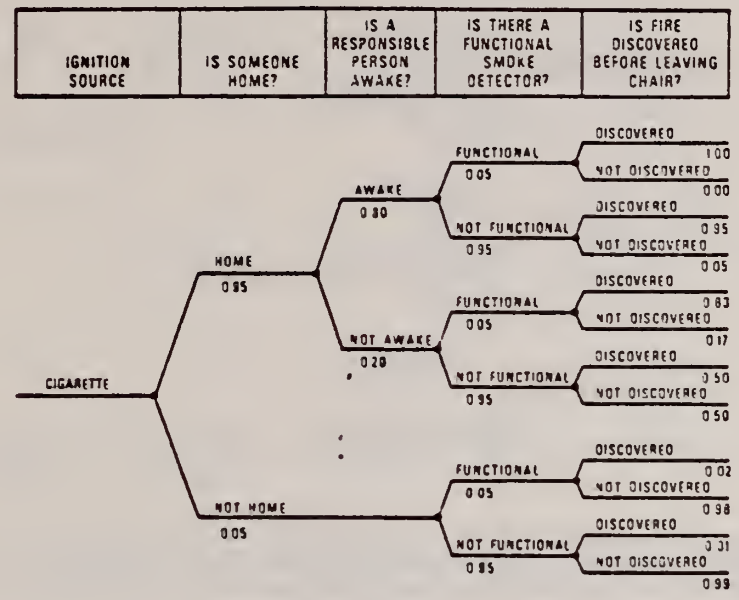

Figure 3. Probability Tree for Cigarette Ignitions Under Current Conditions

The next parameter asks whether a responsible person is awake at the time of ignition. Fire research experts believe that most upholstered furniture fire fatalities occur while people are asleep. Furthermore some data exist which seem to indicate that many of these fatalities occur when people have been drinking, or under the influence of drugs. Now you may have noticed that the question asks about a "responsible person," which we define, for the purpose of this analysis, as a person who is physically capable of responding to the fire and doing something about it. Thus, a person who is drunk, or under the influence of drugs, or an invalid, or a small child would not be a responsible person by our definition. Our best estimate of the probability of a responsible person being awake when a cigarette ignition occurs is 0.80.

Each of the three alternatives we are considering today, involves the installation of smoke detectors, on either a voluntary or mandatory basis. Under current conditions, we assume that about five percent of American homes have a functional smoke detector.

When we combine the three brances in figure 3 "home and awake", "home and not awake", and "not home" with the two functional smoke detector branches, we obtain the six discrete branches shown in the figure. Thus the next parameter "Is fire discovered before leaving chair?" requires six sets of probability assignments. To obtain the "discovery" probability in the case of no responsible person awake and a functional smoke detector present, we introduce the tree shown in figure 4. This is a simple attempt to address the questions concerning the efficacy of smoke detectors in responding to a fire situation in time to wake up intoxicated or drugged persons as well as normally responsive people. As you can see, we calculate that this probability is 0.83.

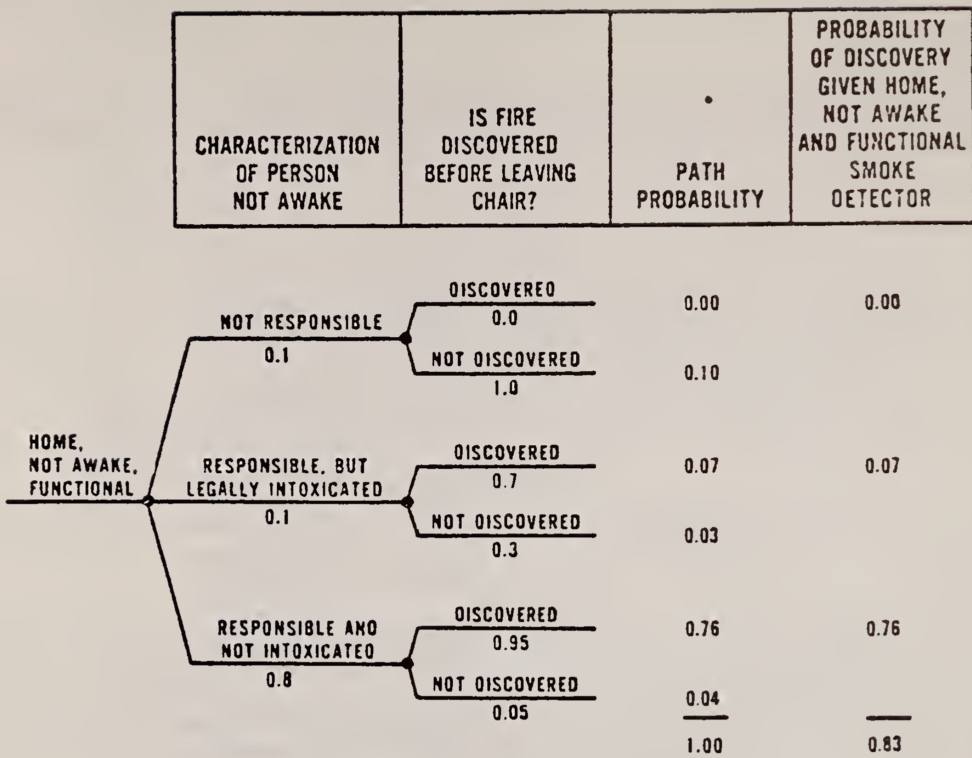

Figure 4. Calculation of Discovery Probability Conditional on Home, Awake, and Functional Parameters

This is an area where almost no data are available. We must rely upon the best judgments of experts in fire research to obtain the probability assignments. The case of no responsible person awake and no functional smoke detector requires another particularly difficult probability assignment where almost no data are available. The other four cases with responsible persons awake or no one home, although not as critical to the analysis, also suffer from a lack of available data. Some human behavioral research has been directed toward special occupancies, such as hospitals. However, our analysis concerns *residential* occupancies, where most fire fatalities occur.

Figure 5 shows how the probability assignments vary with the ignition source. The tree in figure 5 is analagous to the tree in figure 3, except that the tree is for "open flame" ignition sources. Notice that the "home" and "awake" probabilities are higher than the corresponding probabilities for cigarette ignition sources. This reflects the fact that most open flame ignition sources are matches and lighters which ignite the furniture rather quickly. Most of the other probabilities are the same for both types of ignition source.

You might be wondering at this point, why I'm asking for data when our analysis of the upholstered furniture fire problem is essentially done. In the future we expect to do a detailed analysis of the entire residential fire safety problem. We will be looking at educational programs and residential sprinklers as well as smoke detectors and product standards. Future decisions about residential fire safety will be based on analyses such as this one. If no behavioral data exist to help the analyst estimate how a person will react in a particular fire situation, then decisions will be made based on the analysts' perceptions, or the fire researchers' perceptions, or the decision makers' perceptions - whether or not these perceptions have any basis in reality. The implementation of some of these decisions may cost a great deal and affect our daily lives. It is important to direct more behavioral research toward residential occupancies because that is where most fire fatalities occur. We need to know more about how you and your family, in your home, and your neighbors, in their homes, respond to fire situations.

Another area where more human behavior data would be very useful is in making the outcome assignments on loss required for the fire loss model (figure 2).

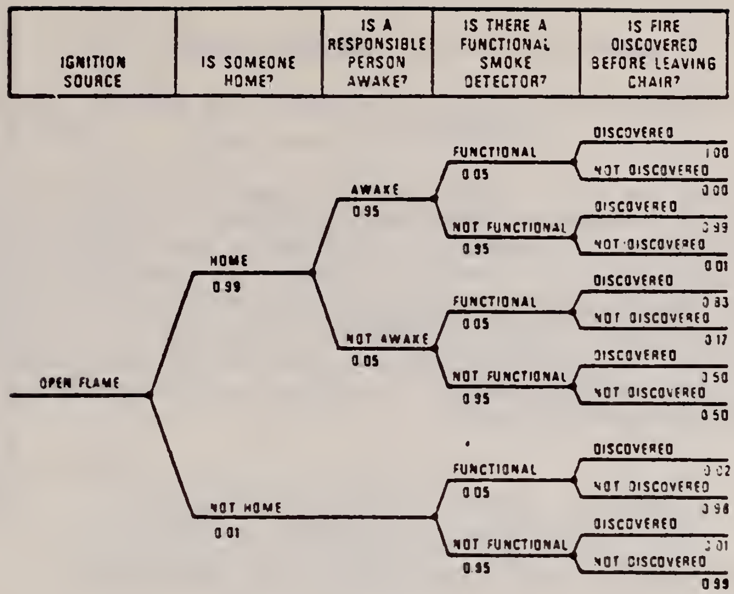

Figure 5. Probability Tree for Open Flame Ignitions Under Current Conditions

From the NFIRS data base we obtain the average loss associated with each extent of flame damage category. Thus for fires that are confined to the chair, confined to the room, or spread beyond the room we obtain the average number of fatalities and injuries and the average property loss per fire. Our common sense tells us that lower property losses and fewer casualties are usually associated with fires that are discovered early. We also know that a fire fatality or injury is more likely to occur when someone is home, and even more likely when everyone is sleeping. Even more fatalities occur among the elderly, very young, drunk or drugged, infirm, and disabled. In addition to using the relationships between losses and extent of flame damage obtained from the NFIRS data, we also wish to make our loss outcomes conditional on these factors.

For our analysis of the upholstered furniture fire problem, we have made the loss assignments conditional on the "at home" and "discovery" parameters as well as the extent of flame damage. This is done by estimating the relative likelihood of each type of loss for each combination of circumstances. For example, if someone is home and the fire spreads beyond the room of origin, the project team estimates that a person is ten times more likely to be killed, and five times more likely to be injured, if the fire is not discovered before it leaves the chair, than if it is discovered. In this way we can quantify how early discovery reduces injury and loss of life. Estimates of this type are then mathematically combined with the NFIRS data to obtain the required outcome assignments.

Although we believe that there is a strong relationship between the values of the "awake" parameter and the expected losses, there is not enough information available to make even preliminary assessments of this relationship. Neither were we able to quantify the relationship between expected losses and age, intoxication, disability, or infirmity.

Thus to use these ideas about what sets of circumstances are associated with increased (or decreased) losses, these relationships must be quantified. This is an area where there is a critical need for data on human behavior. We need to quantify the relationships between sleep, age, alcohol or drug use, physical or mental disability and fire injury and death. I'm sure that a great deal of work will be required to answer these questions, but these answers could have a profound effect on future decisions concerning fire safety.

4. Summary of Decision Analysis Results

I'd like to devote the rest of this talk to discussing the type of results we obtain from our analysis.

In section 2 I described how the fire loss model is used to calculate the future annual fire losses for each alternative. These annual upholstered furniture fire losses are calculated in terms of numbers of fatalities and injuries and dollars of property loss. In order to compare the alternatives on a consistent basis, we convert the injury and fatality totals to monetary equivalents by assigning a dollar value to the amount that society is willing to pay to avoid a single fire injury or fatality. In this way we obtain total annual fire losses in dollar units which we can combine with cost estimates. The annual losses from upholstered furniture fires for current conditions and the value assignments used in our analysis are given in table 1.

Table 1. Annual Upholstered Furniture Fire Losses for Current Conditions

	Annual Losses[a]		
Category	Number	Value Assignment	Monetary Equivalent (Millions of Dollars)
Fatalities	1310	$300,000	$394
Injuries	7570	10,000	76
Property			
Tangible			173
Intangible			26
Total			$668

[a] Calculations may not check because of rounding.

The total annual losses under each of the three alternatives we have considered to date are shown in figure 6. The losses decline from about $670 million in 1975 to about $490 million in 1980 when the detector and proposed standard alternatives are assumed to take effect. Most of this loss reduction is due to assumed voluntary and locally mandated smoke detector installation; a small part of the loss reduction is the result of assumed changes in upholstered furniture materials and construction. Both of these assumptions apply to the three alternatives considered. After 1980 the losses under the detector alternative continue to decline to about $400 million in 1985 when the required smoke detector installation is complete. After the detectors are installed, the losses under the no-action and detector alternatives decline slightly due to the furniture changes. Under the proposed standard alternative the losses decline from about $490 million in 1980 to about $160 million in 2010 as more and more household furniture is replaced by furniture manufactured under the proposed standard. (We assume that about 80 percent of the furniture manufactured under the proposed standard would be in compliance.)

As you can see from figure 6, the proposed standard alternative is the "best" alternative from the stand point of *loss reduction*. However, we must also consider the *cost* of each of the alternatives over time. For example the cost of the proposed standard over time is shown in figure 7.

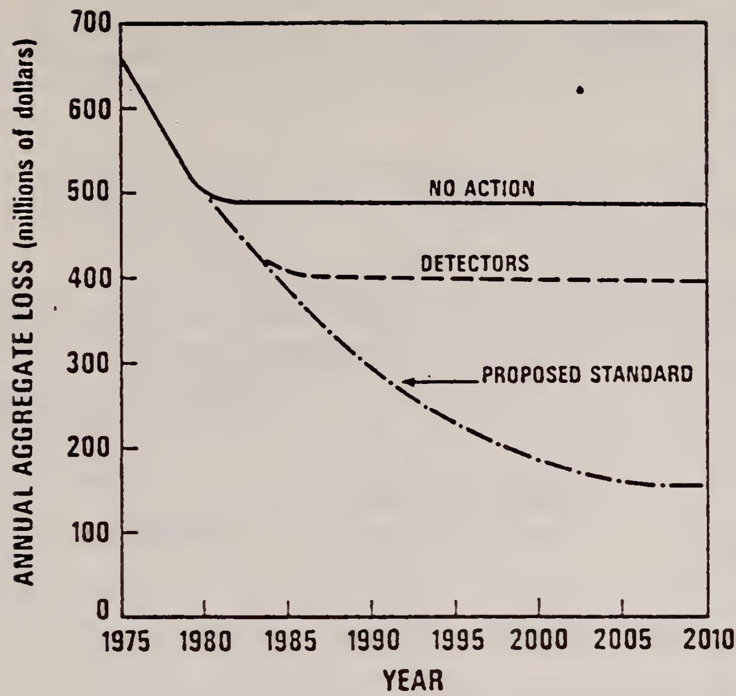

Figure 6. Total Annual Upholstered Furniture Fire Losses Under Three Alternatives

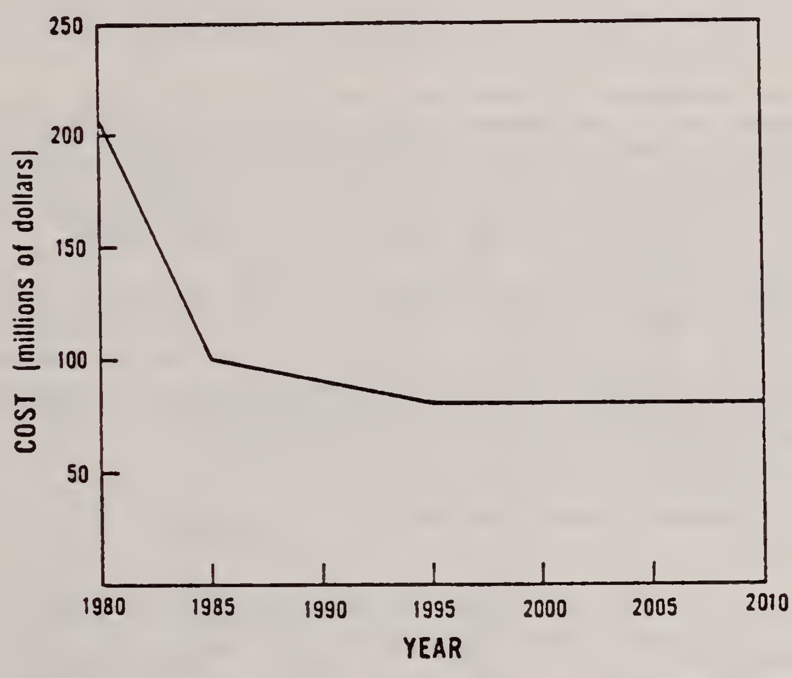

Figure 7. Annual Societal Cost of Proposed Standard

The most desirable alternative from the point of view of society as a whole, is the one which results in the lowest total cost plus loss. The cost plus loss over time for the three alternatives under consideration is given in figure 8. As shown in the figure, the cost plus loss under the proposed standard is initially quite high but becomes quite low in the long run. On the other hand the cost plus loss under the detector alternative is initially lower than under the proposed standard, but in the long run the cost plus loss is higher. The cost plus loss associated with no action varies the least over time.

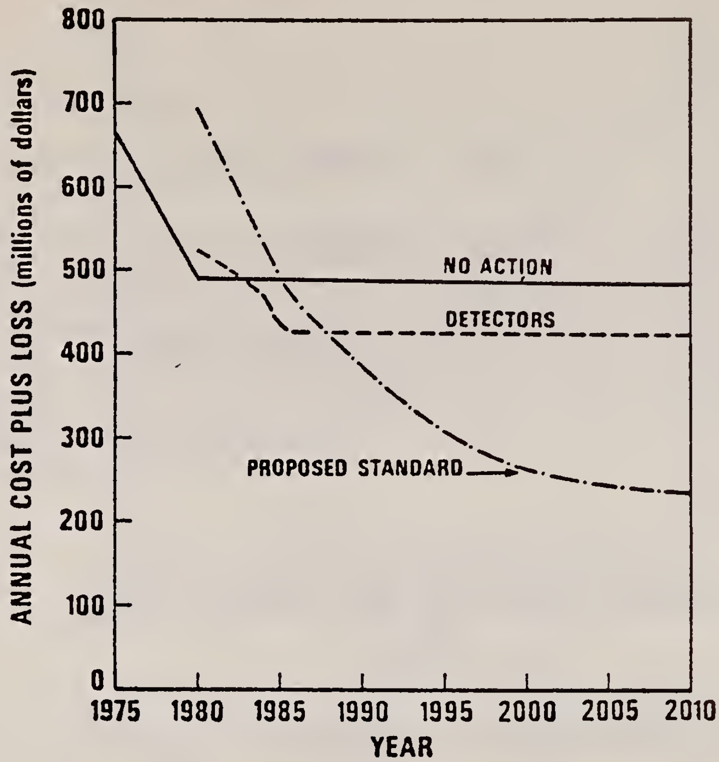

Figure 8. Total Annual Cost Plus Loss to Society Under Three Alternatives

To facilitate the comparison of these time varying cost plus loss values, we compare them on a present value basis. The present value incorporates the use of a discount rate to reflect how much society is willing to pay now to partake of future benefits. For each alternative, the cost plus loss for each future year is discounted to the present time using this (compound) rate. The sum of the resulting discounted values is the present value of the cost plus loss. In our analysis we use a discount rate of 8 percent.

The present value of the loss, cost, and cost plus loss for each of the alternatives from 1977 through 2010 is shown in table 2. As you can see, the alternatives are not very different from each other. Our no-action alternative has the largest associated loss with no cost. The detector alternative has the second largest loss, at a small cost; the proposed standard alternative has the lowest loss but at a substantial cost. Both the detector and the proposed standard alternatives are preferred to no-action.

Table 2. Comparison of Three Alternatives

Alternative	Present Value (Billions of Dollars)		
	Loss	Cost	Cost Plus Loss
No-Action	\$6.33	\$0.00	\$6.33
Detector Alternative	5.63	0.30	5.95
Proposed Standard	4.84	1.12	5.96

We can also use the fire loss model to calculate the expected losses under a combination of alternatives. As shown in table 3, the combination of mandatory smoke detector installation *and* the proposed standard would be somewhat more attractive than either alternative separately. Note that the costs are additive, but the loss reductions are not additive.

Table 3. Comparison of Combination Alternative

Alternative	Present Value (Billions of Dollars)		
	Loss	Cost	Cost Plus Loss
Combination of Detectors and Proposed Standard	$4.44	$1.42	$5.86
Proposed Standard	4.84	1.12	5.96
Detector Alternative	5.65	0.30	5.95
No-Action	6.33	0.00	6.33

5. Sensitivity Analysis

While I have been talking about how much judgment was used in our analysis, you might have wondered what level of confidence we have in our results. We address this question by performing sensitivity analysis. Sensitivity analysis is used to determine how the choice of alternatives is affected by changes in assumptions and parameter values. Rather than explain how the analysis is done, I would like to show you two examples.

The first example, a sensitivity study on the loss-of-life dollar assignment, is shown in figure 9. We assign a nominal value of $300,000 to the amount that society would be willing to pay to prevent a single fire fatality. Using that value, we find that the proposed standard and detector alternatives are essentially equal and preferred to no action. As shown in figure 9, for values between $60,000 and $300,000 the detector alternative is the most attractive alternative; for values above $300,000, the proposed standard is the most attractive alternative; for values less than $60,000, no action is preferred. Thus you can just look at the figure to see how the choice of alternatives is affected by this value assignment.

The second example is a sensitivity study on the cost of the proposed standard alternative, shown in figure 10. The choice of alternatives is more sensitive to the value of this parameter than to any of the other parameters we have tested. Furthermore, there is a great deal of uncertainty regarding this cost. A significantly lower cost makes the proposed standard clearly most attractive; whereas a significantly higher cost makes the proposed standard the least attractive alternative.

Through the use of sensitivity analysis, we are able to focus additional analytical or data gathering resources on the most critical assumptions and parameters.

In addition to considering the *total* losses, we can consider fatalities, injuries, and property losses seperately. As shown in table 4, the proposed standard is most effective at saving lives (although the associated costs are not shown).

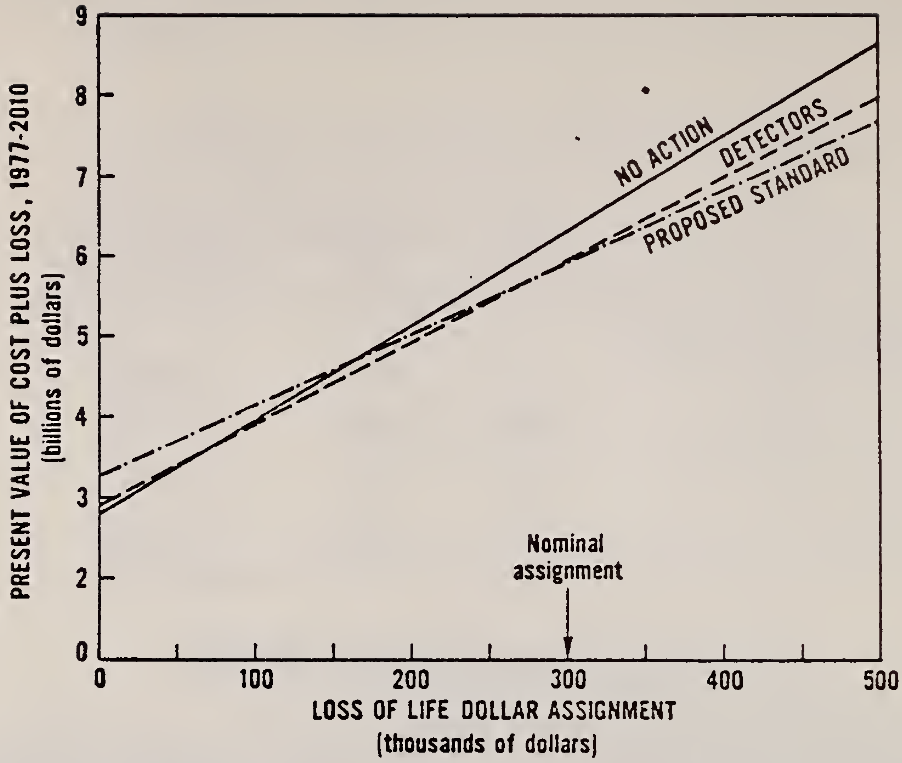

Figure 9. Sensitivity of Results to Dollar Assignment on Loss of Life

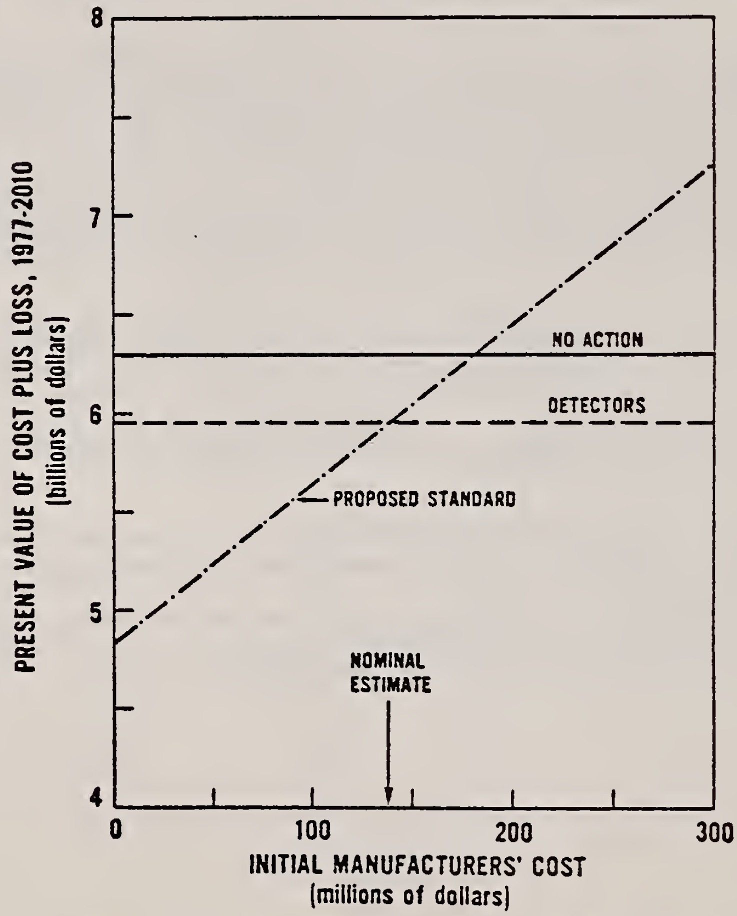

Figure 10. Sensitivity of Results to Manufacturers' Cost of Proposed Standard

Table 4. Total Number of Fire Fatalities from 1977 thru 2010 Under Three Alternatives

Alternative	Number of Fatalities	Lives Saved Relative to No-Action
No-Action	30,800	---
Detector Alternative	25,300	5,500
Proposed Standard	17,900	12,900

6. Behavioral Data Needs

In the short time available, I have tried to give you a taste of the type of analysis we are doing here at the Center for Fire Research. Through human behavioral research we would like to find the answers to a number of questions concerning residential fire scenarios. For example, we know that early discovery of a fire reduces the probability of injury and death. However, to use this information in our analysis, this probability reduction must be quantified. Some of the probabilities we require, which should be based on human behavior research are summarized below:

For common combinations of ignition sources and materials ignited in residential fires, what is the probability that
- *someone is home when ignition occurs*
- *the person at home is*
  - *awake and responsible?*
  - *asleep?*
  - *a child?*
  - *elderly?*
  - *infirm?*
  - *disabled?*
  - *drunk?*
  - *drugged?*

For each of the above cases...
- *what is the probability of the fire being discovered before it spreads if there is*
  - *a functional smoke detector?*
  - *no functional smoke detector?*
  - *an automatic sprinkler system?*

For each of the possible combinations of the above cases...
- *what are the probable losses if*
  - *the fire is discovered before it spreads?*
  - *the fire is not discovered before it spreads?*
  - *there is a sprinkler system present?*
- *what is the probability of the person doing the "right thing" or at least something reasonable?*

Reference

[1] Helzer, S.G., Offensend, F.L. and Buchbinder, B. Decision Analysis of Strategies for Reducing Upholstered Furniture Fire Losses, Nat. Bur. Stand. (U.S.), Tech. Note 1101 (June 1979)

AN EXPERIMENTAL STUDY ON EXIT CHOICE BEHAVIOR OF OCCUPANT IN AN EVACUATION UNDER BUILDING FIRE

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This study considers the problem of evacuating the occupants from a large floor of a multi-story building with multiple stairways in the event of fire. A dangerous situation may develop when concentrations of people at the entrances of stairs become too great. This study explores some factors which affect these concentrations and provides data relevant to a determination of the appropriate width of stairs needed for safe evacuation.

An empirical determination of stairway concentrations was made by an experiment conducted on the sixth floor (area - 3000 sq. meters) of a department store, using as subjects 80 members of the Kobe-City Fire Department who were unfamiliar with the building. Three theoretical calculating methods were also used to predict concentrations and were based on these assumptions: (1) no. of persons going to a given stairs is proportional to the width of the stairs' entrance, (2) each person will go to the nearest stair from his starting point, and (3) a person's choice of stairs can be affected by the visibility of the stairs' entrance as well as its nearness. The third calculating method gave the closest approximation to the results of the experiment.

Key Words: Building fires; evacuation tests, stairways.

1 Foreword

In our research group, human behaviors in fire situations have been studied by three types of methodology which are

(a) Analysis of investigations of real fires.

(b) Experiment of evacuation behavior.

(c) Dynamic evacuation by computer simulation.

This paper belongs to the methodology of (b) but the experiment itself was practiced several years ago by the 'Fire Prevention Section of Kobe-City Fire Department' and unfortunately the data have not been published until we happened to find it.

This time, as I could obtain the full data of the experiment by permission of authorities, I'll report it here by adding some analytical considerations on it.

2 Purpose

If a fire breaks out in a large floor of a multistory building as a department store that has plural stairs and no partition on it, people will run to stairs all at once to escape from the building. And if there are too many occupants on the floor, it is known by experience that the concentration of crowds is easy to occur at the entrances of stairs and it becomes very dangerous if the rate of concentration is too excessive.

In this study, we tried to find out key factors that affect the concentration of escaping persons in order to prevent a dangerous state of crowds so called a 'Panic' and also to obtain the data of reasonable width of stair for providing a safety evacuation in fire situations.

3 Experiment

(a) Building and floor

A department store with ten stories above and three under the ground was used for the experiment. It was constructed about forty years ago and extended several times. The experiment was practiced on the sixth floor whose area was 3,000 square meters. The floor is shown in Fig.1 and it is divided into eight sections.

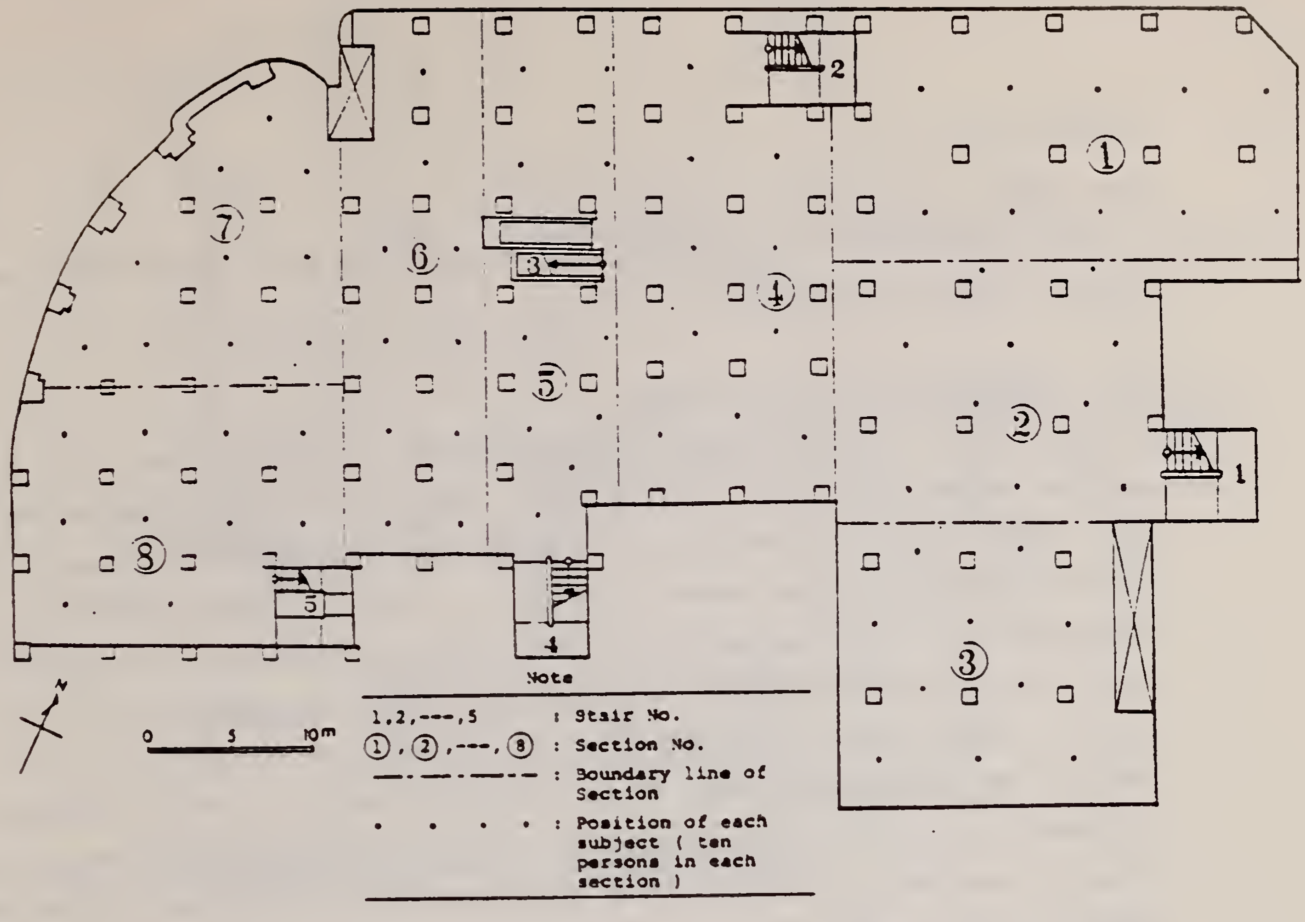


Fig.1 Plan of the sixth floor used for the experiment

(b) Stairs

The stairs available to use for the evacuation were five in all and their positions are shown in Fig.1. Effective width of these stairs are as follows.

Stair No.1 --- 2.80^m, Stair No.3 --- 1.30^m, Stair No.4 --- 2.00^m,
Stair No.2 --- 2.20^m, (Escalator) Stair No.5 --- 1.90^m,

Total width of five stairs is 10.20^m.

(c) Subjects

As the subjects of this experiment, eighty persons had co-oprated. They were all members of Kobe-City Fire Department and those people who were unfamiliar with the building had been selected especially. In the experiment, they were divided into eight groups of ten persons each and every group was supported by two assistants.

(d) Date and time

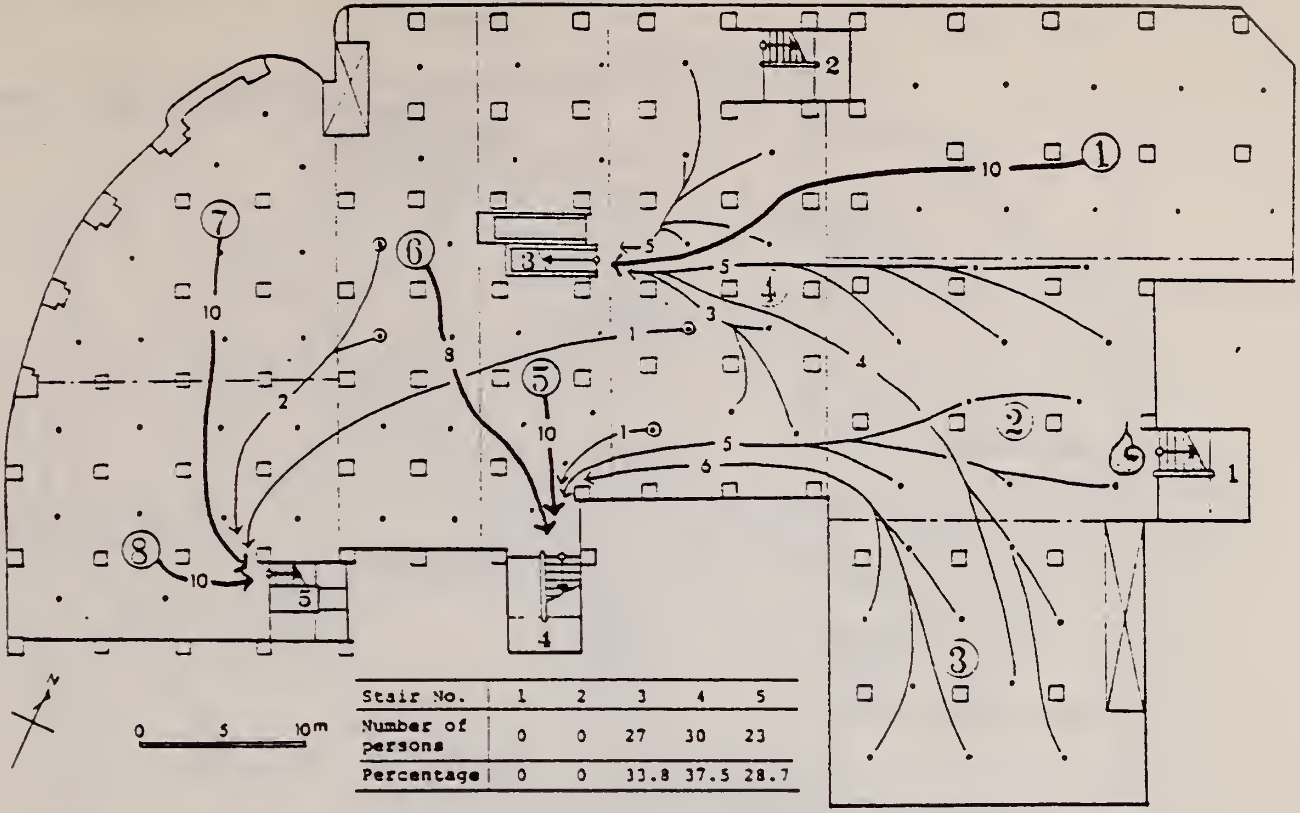
The experiment was practiced from 6:00 a.m. to 10:00 a.m. on the 11th of October.

(e) Procedure of experiment

At first, all subjects are bandaged on their eyes and lead to the sixth floor by assistants. And they are distributed on the floor with ten persons in each section holding equal distance each other as shown in Fig.1. Then, a fire outbreak point is shown to them suddenly by means of a rotating red electric lamp and an alarm whisle. For example, in the case of No.1 of Fig.2, this point is placed in front of the entrance of No.1 stair. On indicating the fire outbreak point, every subject is allowed to put off his bandage and escapes towards one of the stairs according to his free choice. And the number of persons running into each stair is counted by a staff who is stationed at the entrance of the stair. After the first experiment is over, all subjects are changed their positions at random and then, next experiment is practiced by altering the fire outbreak point to the front of another stair's entrance. Thus, five kinds of experiments from Case 1 to Case 5 each of which has a different fire outbreak point are practiced.

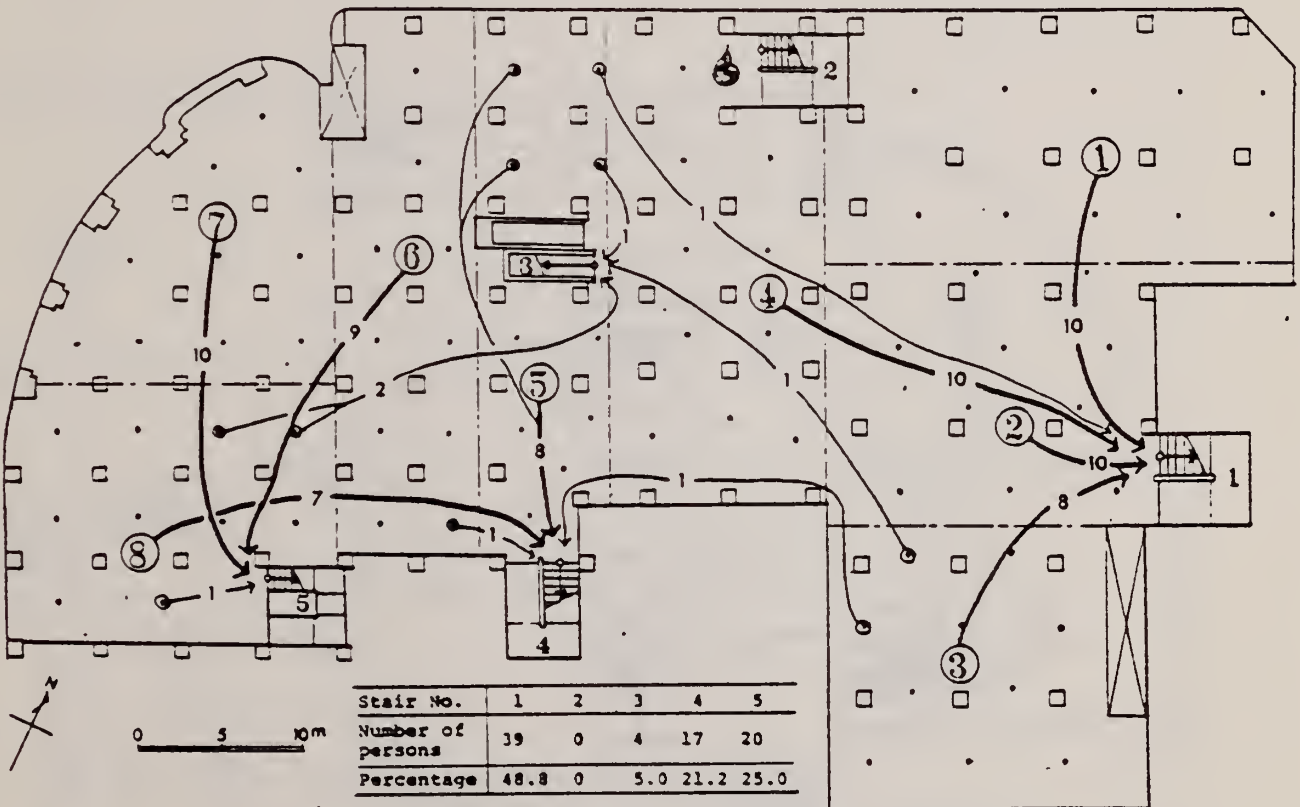
4 Comparison between the result of experiment and the results of analytical calculations

The results of five cases of experiments are shown from Fig.2 to Fig.6 and also in Tab.1-(a).



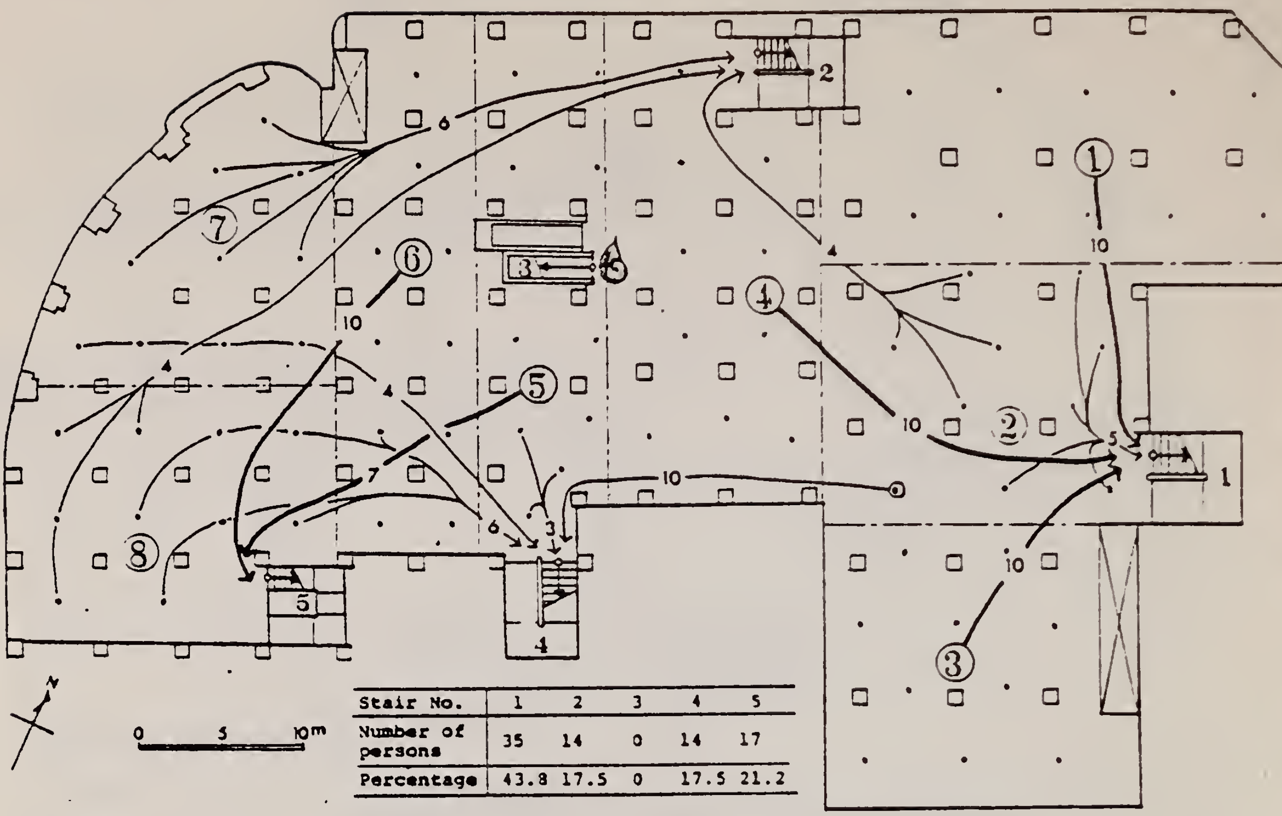
Stair No.	1	2	3	4	5
Number of persons	0	0	27	30	23
Percentage	0	0	33.8	37.5	28.7

Fig.2 Evacuation of Case 1 by experiment



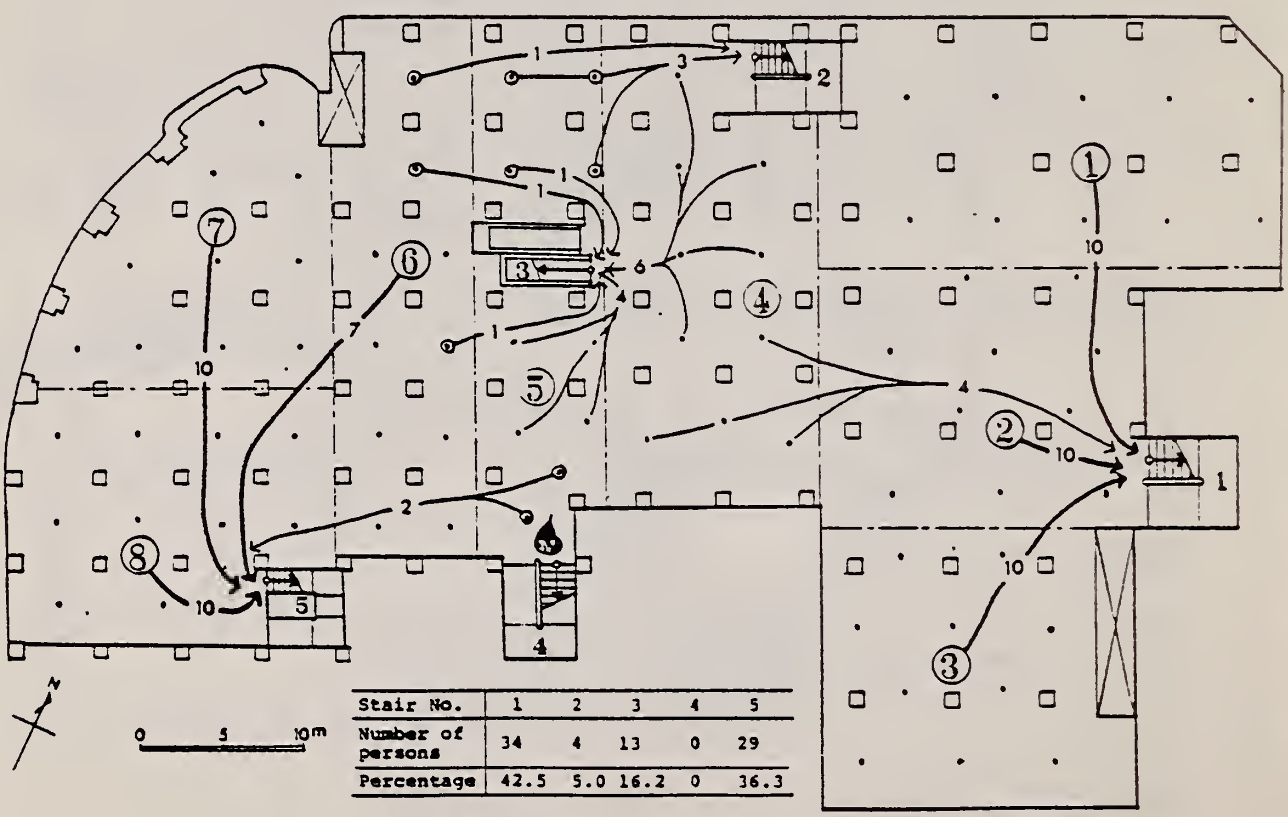
Stair No.	1	2	3	4	5
Number of persons	39	0	4	17	20
Percentage	48.8	0	5.0	21.2	25.0

Fig.3 Evacuation of Case 2 by experiment



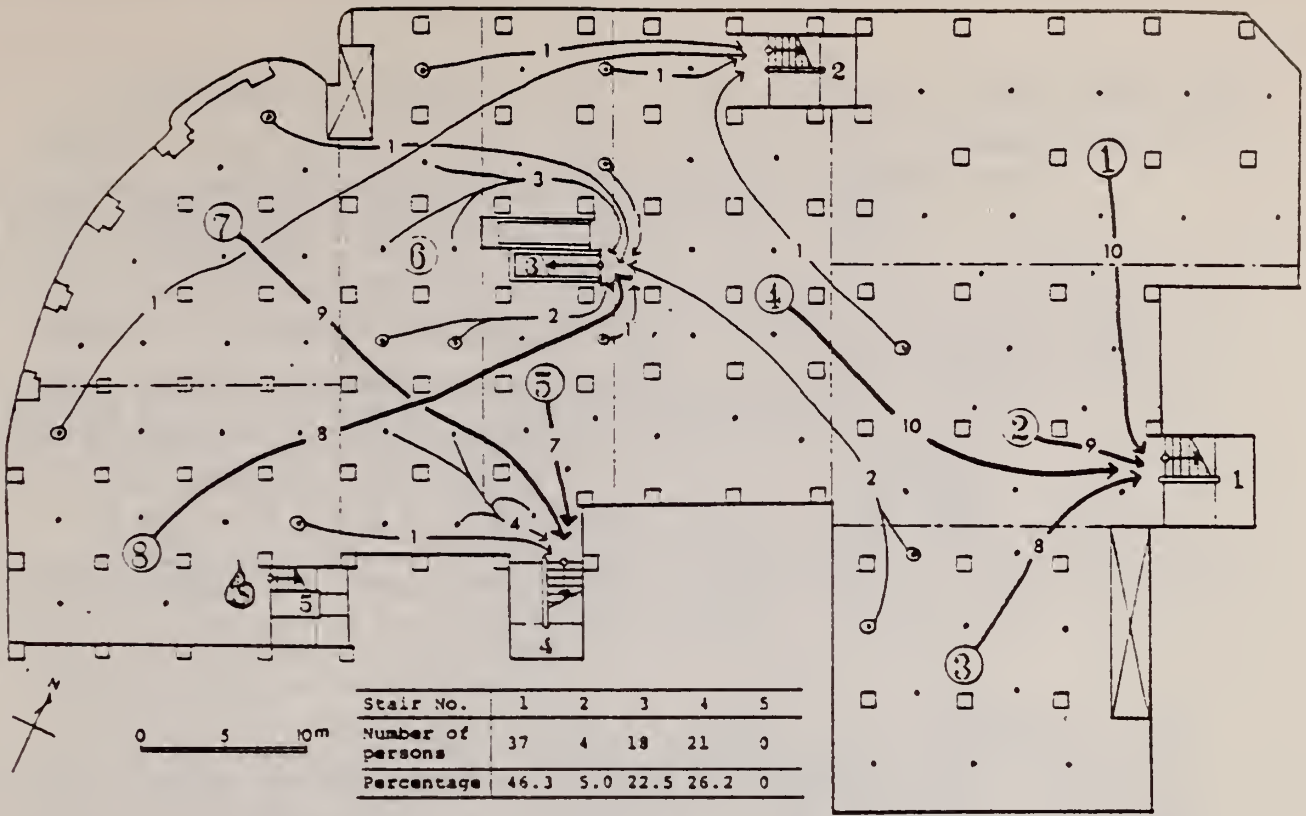
Stair No.	1	2	3	4	5
Number of persons	35	14	0	14	17
Percentage	43.8	17.5	0	17.5	21.2

Fig.4 Evacuation of Case 3 by experiment



Stair No.	1	2	3	4	5
Number of persons	34	4	13	0	29
Percentage	42.5	5.0	16.2	0	36.3

Fig.5 Evacuation of Case 4 by experiment



Stair No.	1	2	3	4	5
Number of persons	37	4	18	21	0
Percentage	46.3	5.0	22.5	26.2	0

Fig.6 Evacuation of Case 5 by experiment

Tab.1 Comparison between the result of experiment and the results of three calculating methods

CASE / METHOD			(a) Experiment		(b) 1st Calculating Method		(c) 2nd Calculating Method			(d) 3rd Calculating Method		
Case No.	Stair No.	Fire Outbreak Point	Ⓐ Number of Persons (%)	Ⓐ / Ⓑ	Ⓑ Number of Persons (%)	Ⓑ - Ⓐ	Ⓒ Number of Persons (%)	Ⓒ - Ⓐ	Ⓒ / Ⓑ	Ⓓ Number of Persons (%)	Ⓓ - Ⓐ	Ⓓ / Ⓑ
1	1		0 (0.0)	-	0 (0.0)	0	0 (0.0)	0	-	0 (0.0)	0	-
	2		0 (0.0)	0.00	24 (30.0)	+24	14 (17.5)	+14	0.58	4 (5.0)	+ 4	0.16
	3		27 (33.8)	1.92	14 (17.5)	-13	26 (32.5)	- 1	1.86	27 (33.8)	0	1.93
	4		30 (37.5)	1.36	22 (27.5)	- 8	24 (30.0)	- 6	1.09	33 (41.2)	+ 3	1.50
	5		23 (28.7)	1.15	20 (25.0)	- 3	16 (20.0)	- 7	0.80	16 (20.0)	- 7	0.80
2	1		39 (48.8)	1.39	28 (35.0)	-11	28 (35.0)	-11	1.00	28 (35.0)	-11	1.00
	2		0 (0.0)	-	0 (0.0)	0	0 (0.0)	0	-	0 (0.0)	0	-
	3		4 (5.0)	0.31	13 (16.3)	+ 9	25 (31.3)	+21	1.92	16 (20.0)	+12	1.23
	4		17 (21.2)	0.85	20 (25.0)	+ 3	11 (13.7)	- 6	0.55	20 (25.0)	+ 3	1.00
	5		20 (25.0)	1.05	19 (23.7)	- 1	16 (20.0)	- 4	0.84	16 (20.0)	- 4	0.84
3	1		35 (43.8)	1.40	25 (31.3)	-10	27 (33.8)	- 8	1.08	30 (37.5)	- 5	1.20
	2		14 (17.5)	0.70	20 (25.0)	+ 6	15 (18.7)	+ 1	0.75	12 (15.0)	- 2	0.60
	3		0 (0.0)	-	0 (0.0)	0	0 (0.0)	0	-	0 (0.0)	0	-
	4		14 (17.5)	0.78	18 (22.5)	+ 4	22 (27.5)	+ 8	1.22	22 (27.5)	+ 8	1.22
	5		17 (21.2)	1.00	17 (21.2)	0	16 (20.0)	- 1	0.94	16 (20.0)	- 1	0.94
4	1		34 (42.5)	1.26	27 (33.8)	- 7	27 (33.8)	- 7	1.00	30 (37.5)	- 4	1.10
	2		4 (5.0)	0.19	21 (26.3)	+17	7 (8.7)	+ 3	0.33	4 (5.0)	0	0.19
	3		13 (16.2)	1.00	13 (16.2)	0	27 (33.8)	+14	2.08	20 (25.0)	+ 7	1.54
	4		0 (0.0)	-	0 (0.0)	0	0 (0.0)	0	-	0 (0.0)	0	-
	5		29 (36.3)	1.53	19 (23.7)	-10	19 (23.7)	-10	1.53	26 (32.5)	- 3	1.37
5	1		37 (46.3)	1.37	27 (33.8)	-10	27 (33.8)	-10	1.00	30 (37.5)	- 7	1.11
	2		4 (5.0)	0.19	21 (26.3)	+17	7 (8.7)	+ 3	0.33	4 (5.0)	0	0.19
	3		18 (22.5)	1.38	13 (16.2)	- 5	21 (26.2)	+ 3	1.62	10 (12.5)	- 8	0.77
	4		21 (26.2)	1.11	19 (23.7)	- 2	25 (31.3)	+ 4	1.32	36 (45.0)	+15	1.89
	5		0 (0.0)	-	0 (0.0)	0	0 (0.0)	0	-	0 (0.0)	0	-

In addition to this, we have also calculated the number of persons running into each stair analytically by means of the following three types of calculating methods.

(1) 1st calculating method

The 1st calculating method is based on a rule that the number of persons running into each stair is proportional to the width of stair's entrance. And the result calculated by this method is shown in Tab.1-(b).

(2) 2nd calculating method

The 2nd calculating method is based on a rule that each person will run into the nearest stair from his starting point. And the result of this method is shown in Tab.1-(c).

(3) 3rd calculating method

The 3rd calculating method is based on a hypothesis that the visibility of stair's entrance is affecting a person's stair choice behavior in addition to the nearness which is adopted in the rule of 2nd calculating method. That is, as shown in Fig.7, if a person (P1) is within the zone of B, he runs to search another stairs because he can't recognize the stair though it is nearest to him. And if a person (P2) is within the zone of A and the stair is nearest to him, he runs into it directly.

The result calculated by this method is shown in Tab.1-(d).

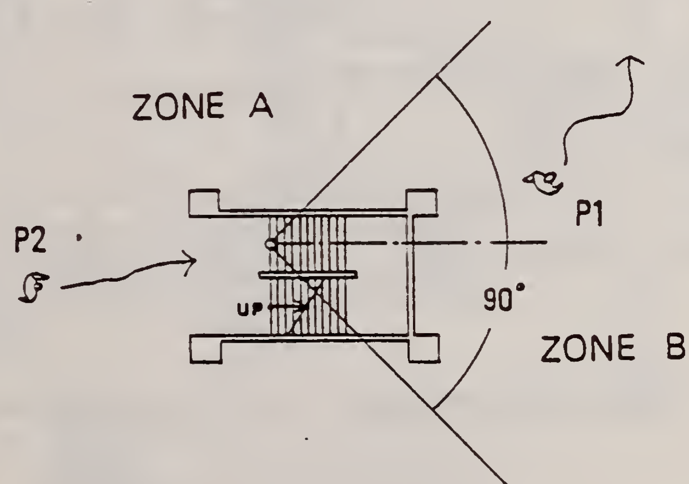
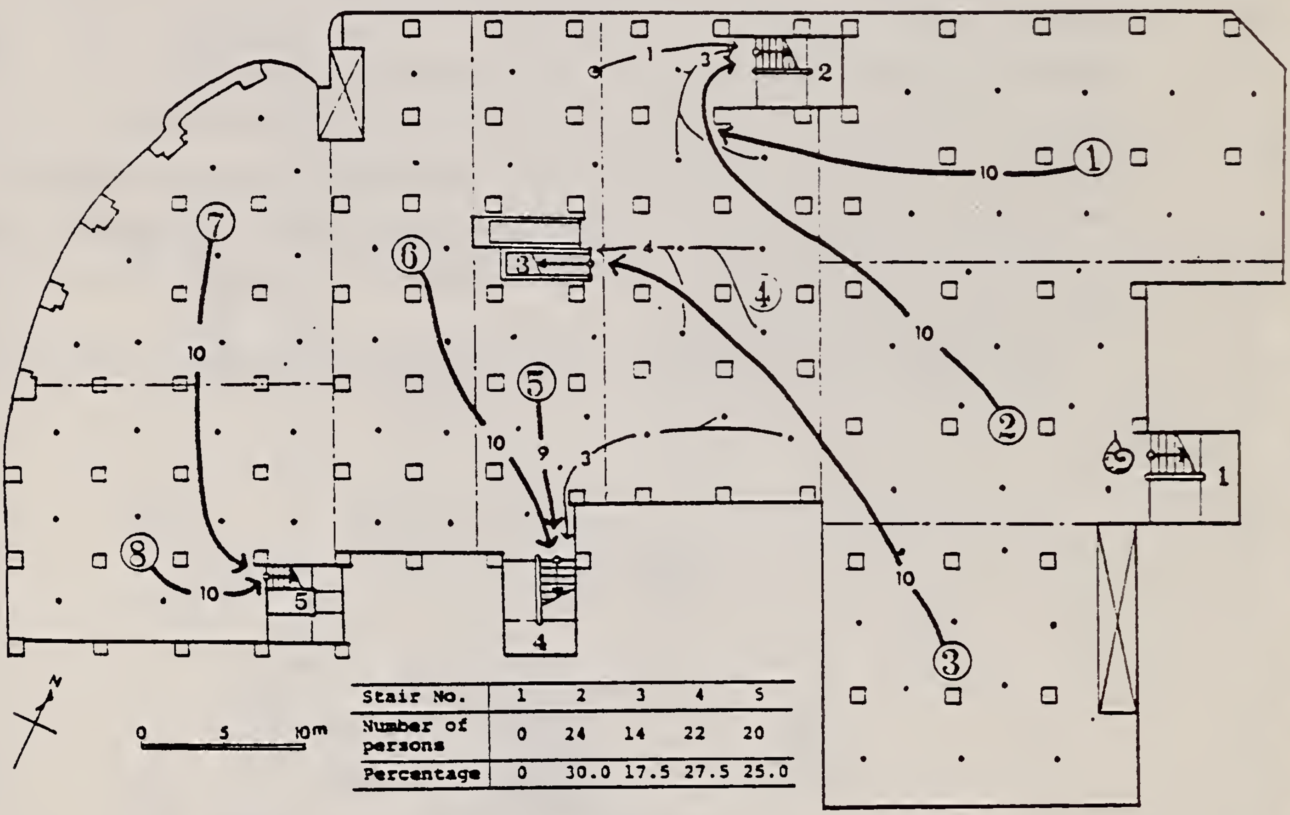


Fig.7 Visibility of stair's entrance

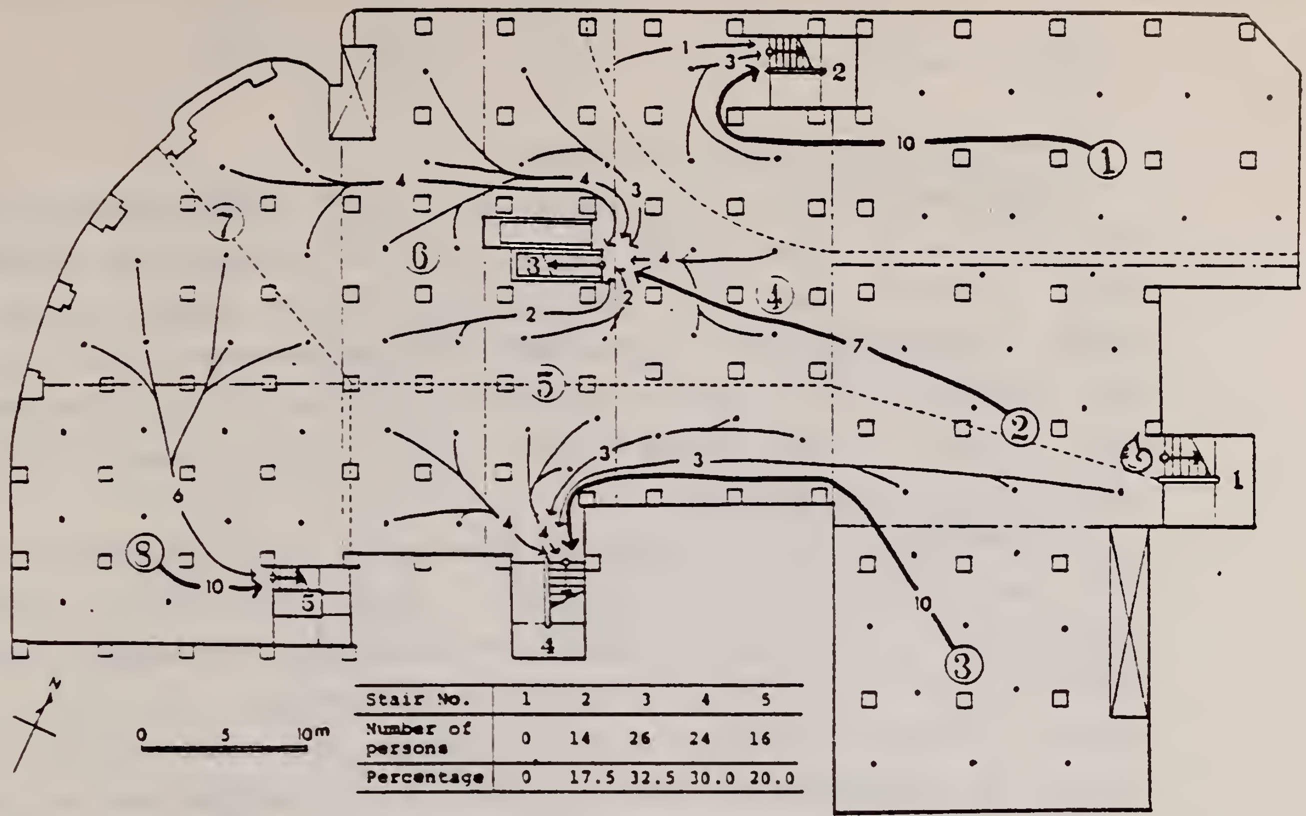
By way of example, Fig.8, Fig.9 and Fig.10 are the results of evacuation of Case 1 which are calculated by the three types of calculating methods explained above.

And Fig.11 is a graphical expression of Tab.1, in which the numbers of persons of each stair that are calculated by four different kinds of methods are compared with by the ratio of percent.



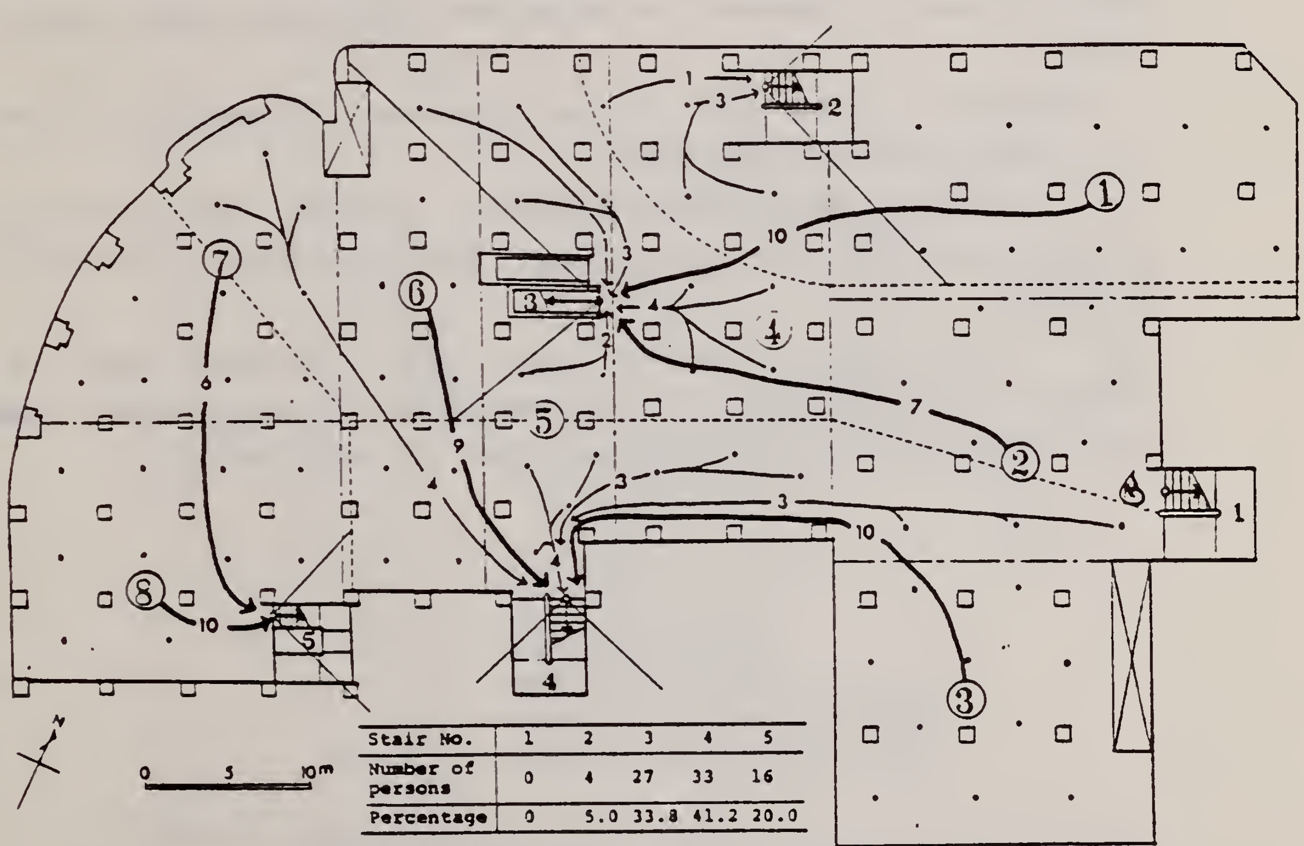
Stair No.	1	2	3	4	5
Number of persons	0	24	14	22	20
Percentage	0	30.0	17.5	27.5	25.0

Fig.8 Evacuation of Case 1 by 1st calculating method



Stair No.	1	2	3	4	5
Number of persons	0	14	26	24	16
Percentage	0	17.5	32.5	30.0	20.0

Fig.9 Evacuation of Case 1 by 2nd calculating method



Stair No.	1	2	3	4	5
Number of persons	0	4	27	33	16
Percentage	0	5.0	33.8	41.2	20.0

Fig.10 Evacuation of Case 1 by 3rd calculating method

5 Conclusion and considerations

According to Fig.11 in which the result of experiment and the results of three types of calculating methods are compared with, it can be said that the 3rd calculating method gives the closest approximation to the result of experiment. That is, the visibility of a stair's entrance is playing an important role as well as its nearness in an exit choice behavior of occupant in an evacuation.

And secondly, as is shown by the value of Ⓐ / Ⓑ in Tab.1, the number of persons running into a particular stair in the experiments is almost two times as large as the number calculated by the 1st calculating method. Therefore, if we are going to design stairs for evacuation on the basis of the data by the 1st calculating method (which is often adopted in Japan) we'd better imagine about two times of amount of users for safety. But, of course, it is necessary to practice more experiments and researches in order to explain the exit choice behavior and to decide the rules for designing the width of stairs.

In future researches, following items, for example, have to be taken into considerations.

(1) If there are any more effective factors than visibility, distance and width of stair which dominate the exit choice behavior.

(2) If there are any better experimental methods than the one adopted here, or if it is necessary to use much larger number of subjects and practice more times of experiments.

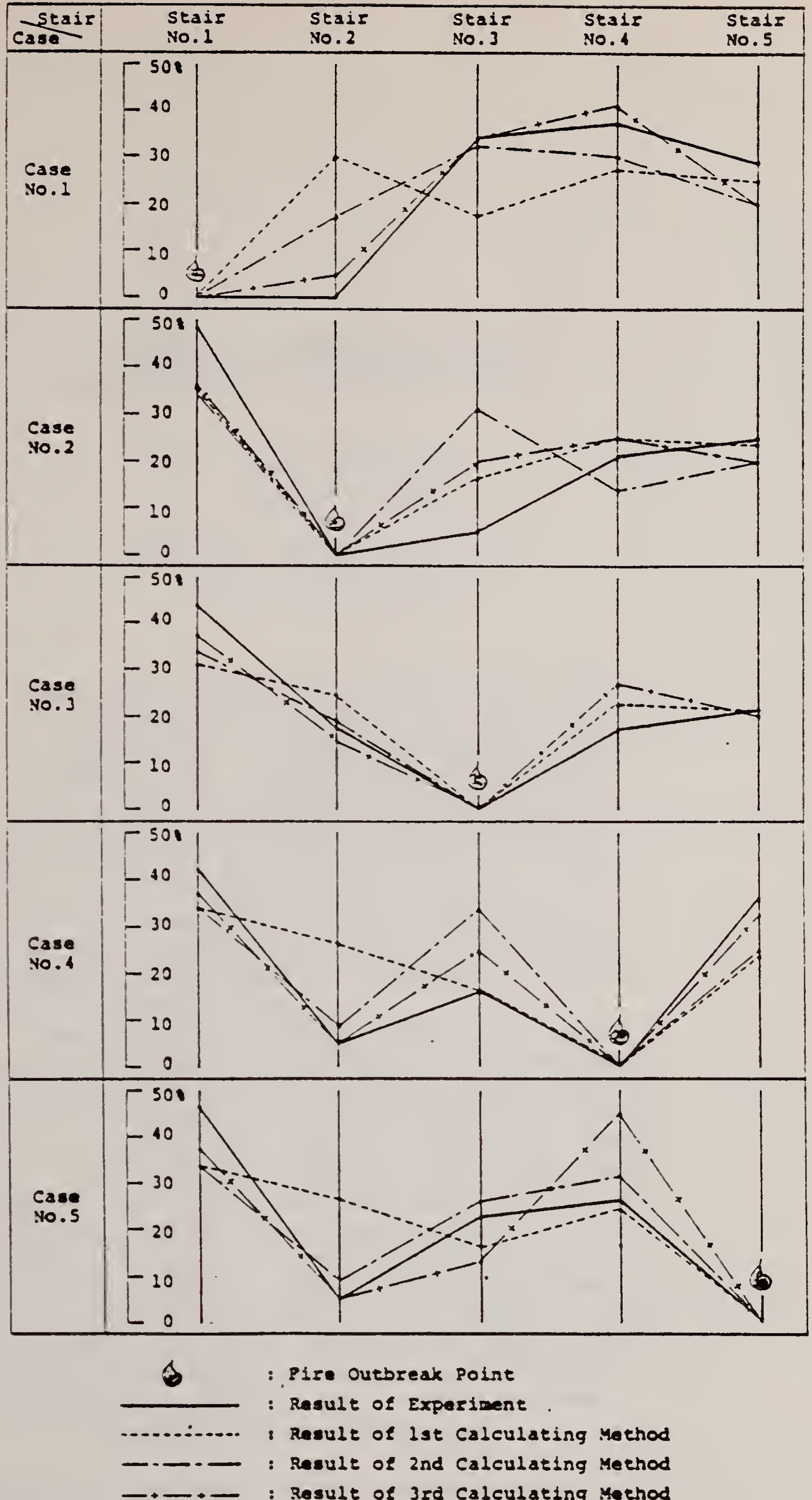


Fig.11 Comparison between the result of experiment and the results of three calculating methods

ANALYSIS OF OCCUPANT BEHAVIOR
IN AN OFFICE BUILDING UNDER FIRE

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The occupant behavior which occurred during an office building fire is analyzed. Data was obtained from a questionnaire distributed to occupants of an insurance company building in Osaka, Japan, in which a fire occurred on April 6, 1978. The building contained nine stories above and five under ground. The fire occurred at the kitchen's ventilation duct in the second basement, and smoke spread through the building through the duct and a staircase. Approximately 2000 occupants escaped from the building without injury.

The interrelationships among three items--occupation and sex, first action after perceiving fire, and evacuation behavior--were analyzed to find characteristic behavior patterns. Two types of behavior patterns were extracted. They were: the behavior of those in the occupations of store owner and male store clerk to take responsible actions when they perceived a fire and then to escape via the route that they had previously decided to take in fire situations; and the behavior of female office clerks to wait for superior officers' instructions and then to escape by following instructions and guidance. (The specific behaviors within these patterns were not the most common behaviors.)

Key Words: Building fires; evacuation; human behavior; smoke.

I Introduction

This paper deals with an analysis of occupant behavior in an office building under fire. The data for this pursuit are drawn from the questionnaire which was conducted on the occupants of 'Fukoku' insurance company building, Osaka, Japan, in which a fire had occured on the afternoon of April 6th, 1978. And the interrelationship between three items of a) individual attributes such as occupation and sex, b) first action after perceiving fire and c) evacuation behavior has been analyzed to find out characteristic behavior patterns.

The 'Fukoku' insurance company is a steel framed reinforced concrete structure building with nine stories above and five under the ground. It is an ordinary type of office building and from the 1st to the 9th floors are offices, the 1st and the 2nd basements are shopping malls, the 3rd and the 4th basements are parking places and the 5th basement is a machine room. The fire had occured at the kitchen's venti ation duct of a tearoom in the 2nd basement and the smoke had spread immediately all over the building through the duct and a staircase. The occupants at that time were estimated at about two thousands and all of them could escape from the building without injury. Therefore it was a successful evacuation in view of the results.

II Analysis

1. Method of analysis

As the method of analysis, the quantification theories of case 2 and case 3 that are developed by Hayashi* are used in this study.

The quantification theory of case 2 is mathematically in accord with multiple discrimination analysis of which explanatory variables are nominal scale of dummy variables.

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* Hayashi,C : On the predictions of phenomena from qualitative data and quantifications of qualitative data from the mathematicostatistical point of view, Annals of the Institute of Statistical Mathematics, 1952, vol.3, no.2,69-98.

And this theory can discriminate each element's (or person's) distribution to the classes of external criterion by its responses to explanatory variables which are qualitative attributes. And to enable this discrimination, it assigns value of X to the categories of each explanatory variables so that it may maximize the correlation ratio between external criterion's groups and persons' scores which are given in a form of liniar combination of responded Xs.

On the other hand, the method of case 3 can classify the categories of qualitative attributes which are given by dummy variables and have no external criterion on the basis of response patterns of persons. And to enable this classification it assigns value of X to the categories and Y which is the average value of responded Xs to the response pattern types of persons so that it may maximize the correlation coefficient between X and Y. And as the result, mutually related categories that are simultaneously responded to by many persons come to have similar values of Xs on the coordinate axis of each eigen value.

2. Items used for analysis

The analysis of ocuupant behavior is made by using three items in the questionnaire which are 'Occupation & Sex', 'First Action' and 'Evacuation Behavior'. Besides these three items, there are such items in the questionnaire as 'Means of Perceiving Fire', 'Psychology when Perceived Fire', 'Age', 'Experience of Fire' and 'Experience of Evacuation Drill'. But by discrimination analysis of quantification theory the 2nd case, these items are proved to have little influence on both classifications of 'First Action' and 'Evacuation Behavior' which are assigned as external criterions. So they are excluded from the items of this analysis.

Among the occupants, seven hundreds and four persons, who were all workers of this building, did answer the three items properly (i.e. the effective samples are 704).

The contents of each of the three items are as follows.

(1) 'Occupation & Sex'

By the distinction of occupation, position and sex, the occupants are divided into six categories shown in Tab.1.

Tab.1 'Occupation & Sex' classification

category	contents	
01	female office clerk	--- offices
02	male office clerk	
03	managerial officer	
04	female store clerk	--- restaurants & stores
05	male store clerk	
06	store owner	

(2) 'First Action'

In the questionnaire, as the first actions after perceiving fire, thirteen behaviors in Tab.2 are presented under the condition of permitting plural choice.

Tab.2 first actions (permitting plural choice)

code	contents	responded persons
1	inform others loudly	57
2	call adminstration office or fire department	31
3	go for a fire extinguisher	3
4	remove valuables	160
5	go to see fire origin	174
6	wait for instructions	164
7	waver in confusion	49
8	lead people and evacuate them	61
9	turn off the gas	40
10	shut off the power	82
11	put out kitchen fire	30
12	escape at once	96
13	call to others to escape together	247

And analyzing the occupants' response patterns by the quantification theory, these thirteen actions have been divided into four categories that are shown in Tab.3.

Tab.3 'First Action' classification

category	contents		belonging actions
F1	take responsible actions	---	1,2,3, 5,8,9, 10,11
F2	escape at once	---	12
F3	call to others to escape together, remove valuables or waver in confusion	--- ---	4,13 7
F4	wait for instructions	---	6

This classification of Tab.3 has been achieved through two stages of analyses. Firstly, by the analysis of quantification theory the 3rd case, the actions that are selected together by many persons of their first actions are put together into one group and they are (1,2,3,5,8,9,10,11) and (4,13). And at this stage, the thirteen actions are divided into five groups which are (1,2,3,5,8,9,10,11),(12),(4,13),(7) and (6). Secondly, by the discrimination analysis of quantification theory the 2nd case which takes the above five groups of first actions as the external criterion, it is proved to be difficult to discriminate the persons of group (7) from the persons of group (4,13) by the item of 'Occupation & Sex' which is adopted as an explanatory variable. So these two groups are put together into one category of F3 and this makes the 'First Action' an item of four categories.

Therefore as the item of 'First Action', the classification of Tab.3 is adopted.

(3) 'Evacuation Behavior'

This is an item which asks the occupant why he took the route to escape from the building. And for the reasons, five kinds of behaviors shown in Tab.4 are presented.

Tab. 4 'Evacuation Behavior' classification

category	contents
E1	take a predetermined route
E2	take a shorter route or choose a route instantly
E3	take a previously indicated route
E4	run after others
E5	follow instructions and guidance

3. Interrelation between three items

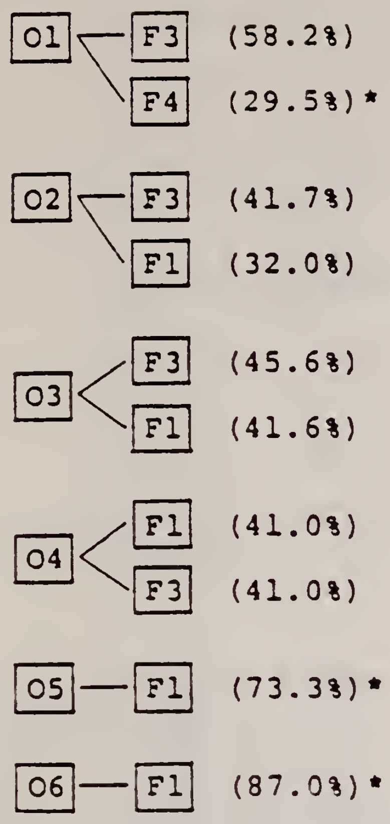
In order to find out characteristic behavior patterns in an office building under fire, mutually related categories between the three items have been selected by using the quantification theory the 3rd case.

(1) Relation between 'Occupation & Sex' and 'First Action'

Tab.5 is a cross tabulation of 'Occupation & Sex' and 'First Action' and main selection patterns of each 'Occupation & Sex' group are shown in Fig.1.

Tab.5 'Occupation & Sex' and 'First Action'

	F1	F2	F3	F4	total
O1	17	14	146	74	251
O2	66	32	86	22	206
O3	52	10	57	6	125
O4	16	3	16	4	39
O5	44	2	8	6	60
O6	20	0	3	0	23
total	215	61	316	112	704



O1: female office clerk
O2: male office clerk
O3: managerial officer
O4: female store clerk
O5: male store clerk
O6: store owner

F1: take responsible actions
F2: escape at once
F3: call to others to escape together, remove valuables or waver in confusion
F4: wait for instructions

Fig.1 Main selection patterns

The result of analyzing ten categories of two items together by the theory of quantification the 3rd case is shown in Fig.2 where the correlation coefficient of I axis (1st eigen value) is 0.8658 and that of II axis (2nd eigen value) is 0.7723.

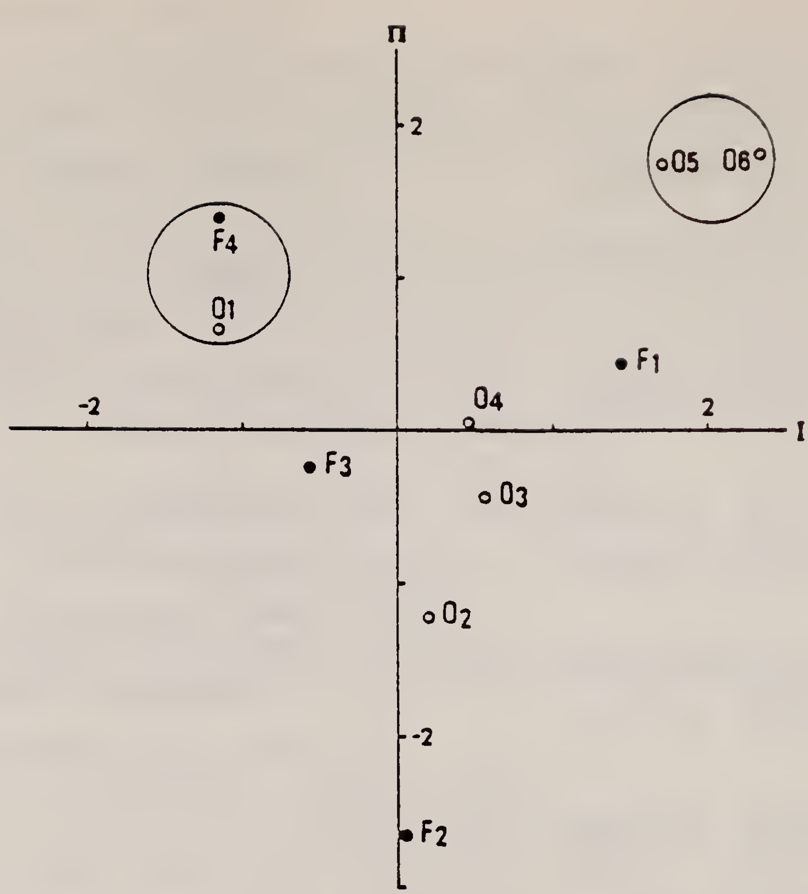


Fig.2 Categories distribution

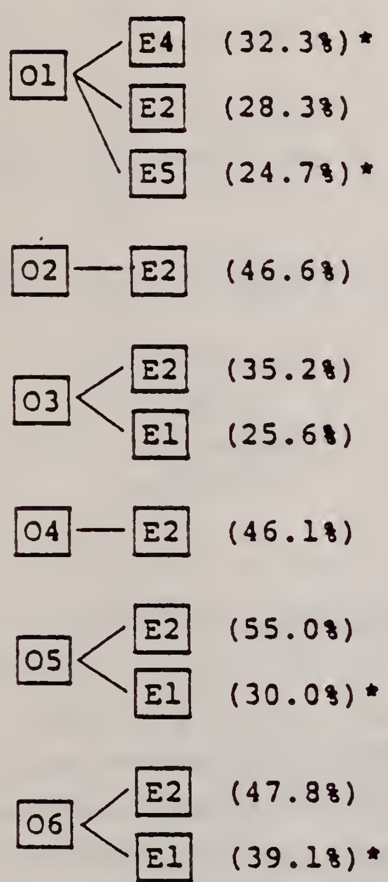
According to the distribution of Fig.2, two pairs of categories of (O1,F4) and (O5,O6) are located away from other categories. And it can be said that F4 (wait for instructions) is peculiar to O1 (female office clerk) and both O5 (male store clerk) and O6 (store owner) are strongly responding to F1 (take responsible actions), and so these characteristic patterns in Fig.1 are marked with asterisk (*). Besides this, the action of F3 (call to others to escape together, remove valuables or waver in confusion) is located near the origin of the coordinate axes and it is considered to be a general first action to the occupant.

(2) Relation between 'Occupation & Sex' and 'Evacuation Behavior'

The cross tabulation of 'Occupation & Sex' and 'Evacuation Behavior' is shown in Tab.6 and main selection patterns between them are shown in Fig.3.

Tab.6 'Occupation & Sex' and 'Evacuation Behavior'

	E1	E2	E3	E4	E5	total
O1	8	71	29	81	62	251
O2	25	96	33	33	19	206
O3	32	44	21	22	6	125
O4	3	18	3	7	8	39
O5	18	33	2	2	5	60
O6	9	11	2	0	1	23
total	95	273	90	145	101	704



O1: female office clerk
O2: male office clerk
O3: managerial officer
O4: female store clerk
O5: male store clerk
O6: store owner

E1: take a predetermined route
E2: take a shorter route or choose a route instantly
E3: take a previously indicated route
E4: run after others
E5: follow instructions and guidance

Fig.3 Main selection patterns

According to these, most of the persons of each group have chosen E2 (take a shorter route or choose a route instantly) and it is estimated that E2 is an ordinary behavior to the occupants.

Analyzing two items together by the quantification theory the 3rd case, correlation coefficients from I axis (1st eigen value) to III axis (3ed eigen value) have shown the values of r1=0.8416, r2=0.7575, and r3=0.7524, and when using the coordinates of I axis and III axis, the eleven categories have been grouped as shown in Fig.4.

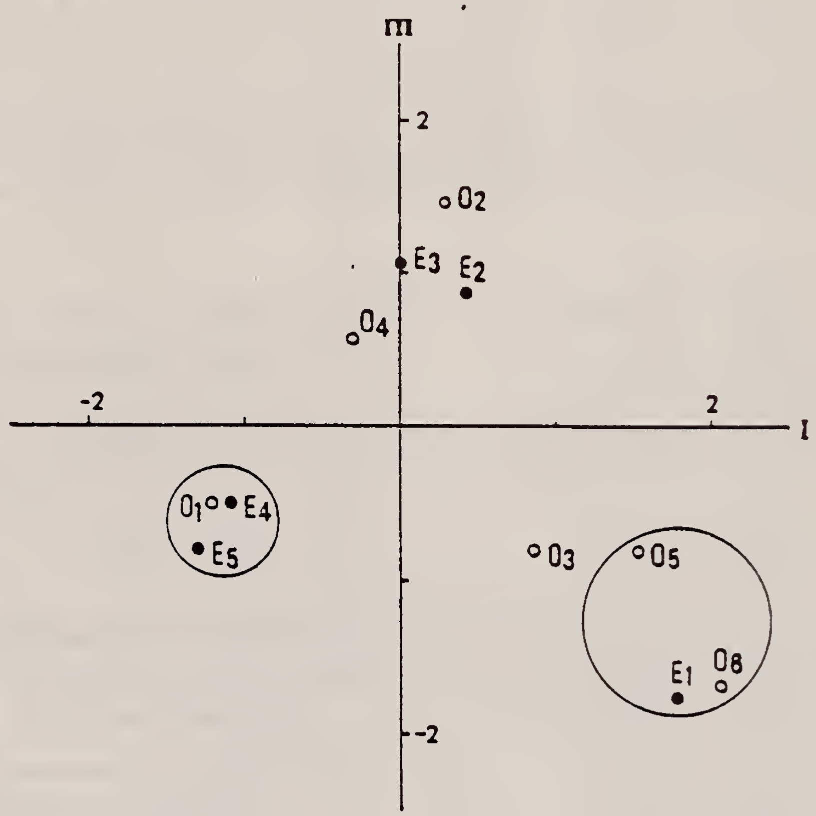


Fig.4 Categories distribution

By the distribution of the categories, it can be said that E4 (run after others) and E5 (follow instructions and guidance) are peculiar to O1 (female office clerk) and E1 (take a predetermined route) is strongly related to O6 (store owner) and then O5 (male store clerk), and so these patterns are marked with asterisk in Fig.3.

(3) Relation between 'First Action' and 'Evacuation Behavior'

The cross tabulation of 'First Action' and 'Evacuation Behavior' and main selection patterns between them are shown in Tab.7 and Fig.5.

Tab.7 'First Action' and 'Evacuation Behavior'

	E1	E2	E3	E4	E5	total
F1	50	105	24	22	14	215
F2	3	31	14	12	1	61
F3	35	110	41	87	43	316
F4	7	27	11	24	43	112
total	95	273	90	145	101	704

$\boxed{F1}$ — $\boxed{E2}$ (48.8%)
$\boxed{F1}$ — $\boxed{E1}$ (23.3%)*

$\boxed{F2}$ — $\boxed{E2}$ (50.8%)

$\boxed{F3}$ — $\boxed{E2}$ (34.8%)
$\boxed{F3}$ — $\boxed{E4}$ (27.5%)

$\boxed{F4}$ — $\boxed{E5}$ (38.4%)*
$\boxed{F4}$ — $\boxed{E2}$ (24.1%)

Fig.5 Main selection patterns

F1: take responsible actions
F2: escape at once
F3: call to others to escape together, remove valuables or waver in confusion
F4: wait for instructions

E1: take a predetermined route
E2: take a shorter route or choose a route instantly
E3: take a previously indicated route
E4: run after others
E5: follow instructions and guidance

The result of quantification theory analysis is shown in Fig.6 where the correlation coefficient of I axis is 0.8241 and that of II axis is 0.7745.

According to the ten categories' distribution of Fig.6, there can be seen distinct correspondence between F4 (wait for instructions) and E5 (follow instructions and guidance) and between F1 (take responsible actions) and E1 (take a predetermined route). Therefore these clearly related patterns are marked with asterisk in Fig.5.

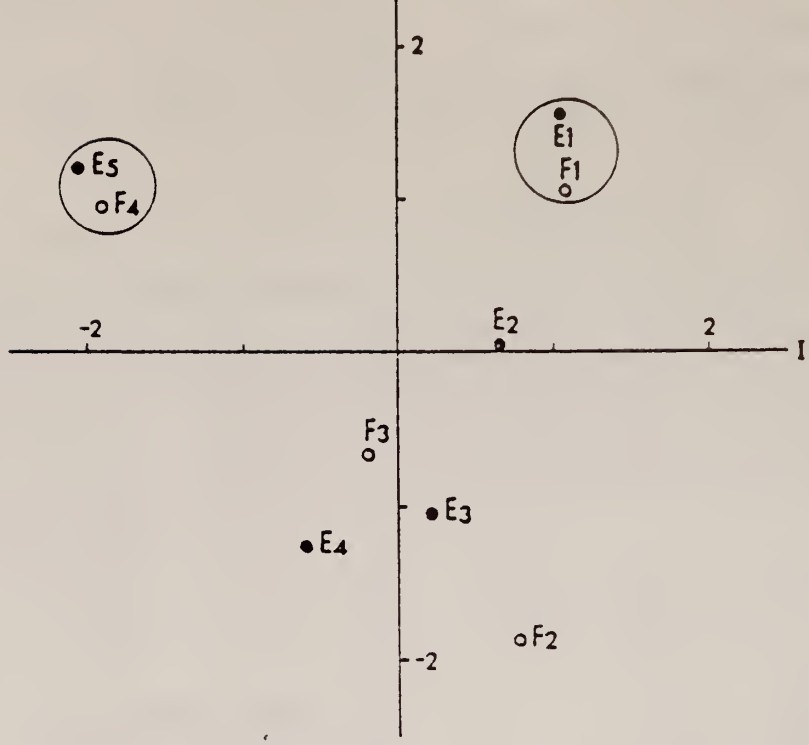


Fig.6 Categories distribution

(4) Relation between 'Occupation & Sex', 'First Action' and 'Evacuation Behavior'

By connecting the above mentioned results, it is possible to presume the characteristic behavior patterns in an office building under fire, but in this section, the three items have been analyzed together by the quantification theory the 3rd case and mutually related categories between them are extracted.

The results of analysis are shown in Fig.7 where the correlation coefficient of I axis is 0.7812 and that of II axis is 0.6748, and according to this, three pairs of categories of (O5,O6), (F1,E1) and (F4,E5) are located away from others. Therefore a behavior of O5 (male store clerk) and O6 (store owner) to take F1 (take responsible actions) and E1 (take a predetermined route) and a behavior of O1 (female office clerk) that take F4 (wait for instructions) and E5 (follow instructios and guidance) are picked out as characteristic patterns in this evacuation.

In addition, the cross tabulation of the three items is shown in Tab.8 and its main selection patterns are shown in Fig.8 in which the above mentioned characteristic patterns are marked with asterisk.

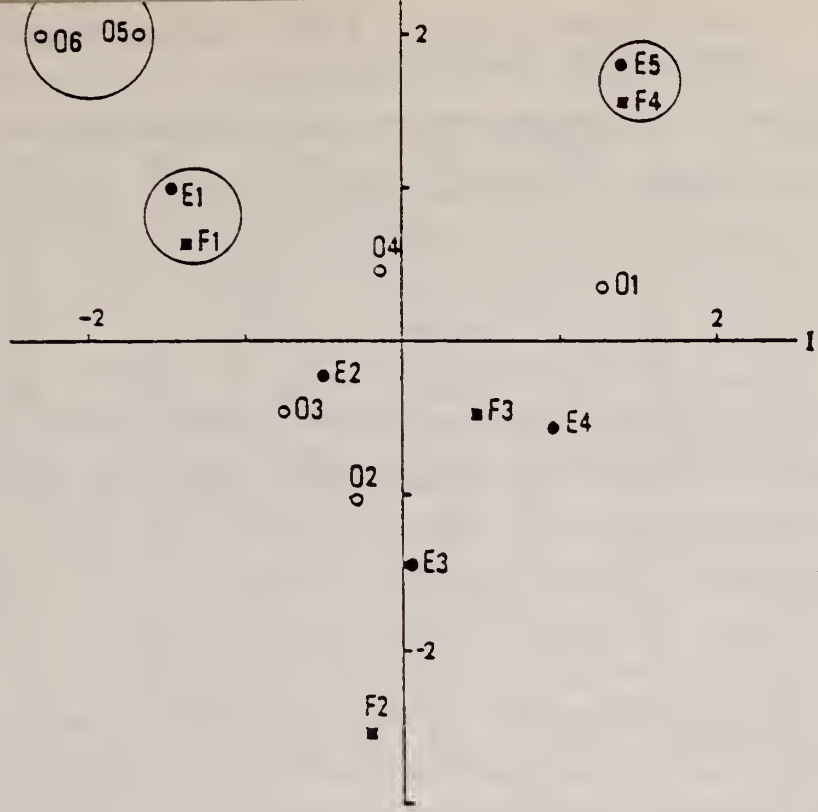


Fig.7 Categories distribution

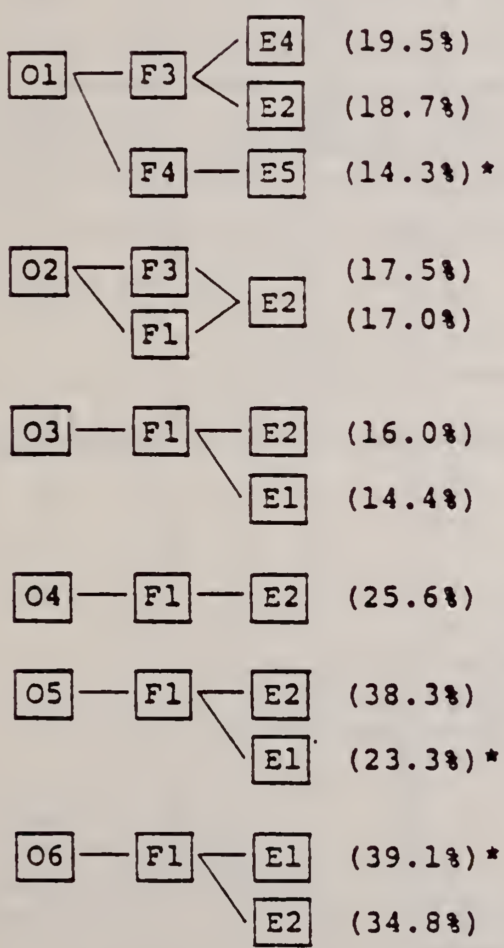


Fig.8 Main selection patterns

O1: female office clerk

O2: male office clerk

O3: managerial officer

O4: female store clerk

O5: male store clerk

O6: store owner

F1: take responsible actions

F2: escape at once

F3: call to others to escape together, remove valuables or waver in confusion

F4: wait for instructions

E1: take a predetermined route

E2: take a shorter route or choose a route instantly

E3: take a previously indicated route

E4: run after others

E5: follow instructions and guidance

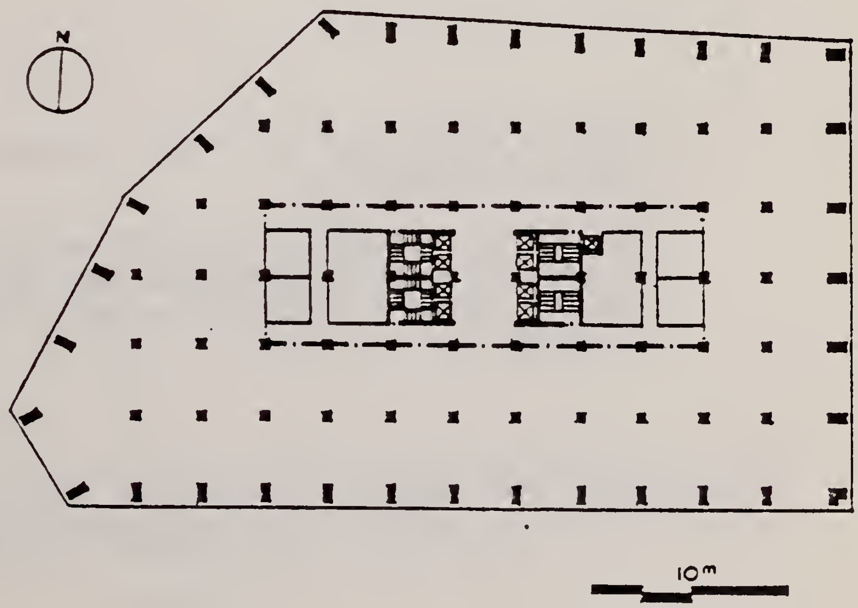
Tab.8 'Occupation & Sex', 'First Action' and 'Evacuation Behavior'

		E1	E2	E3	E4	E5	total
O1	F1	1	9	1	6	0	17
	F2	0	3	4	7	0	14
	F3	5	47	19	49	26	146
	F4	2	12	5	19	36	74
	total	8	71	29	81	62	251
O2	F1	7	35	9	8	7	66
	F2	3	18	8	2	1	32
	F3	13	36	11	19	7	86
	F4	2	7	5	4	4	22
	total	25	96	33	33	19	206
O3	F1	18	20	10	4	0	52
	F2	0	7	1	2	0	10
	F3	12	15	9	16	5	57
	F4	2	2	1	0	1	6
	total	32	44	21	22	6	125
O4	F1	1	10	0	3	2	16
	F2	0	1	1	1	0	3
	F3	2	5	2	2	5	16
	F4	0	2	0	1	1	4
	total	3	18	3	7	8	39
O5	F1	14	23	2	1	4	44
	F2	0	2	0	0	0	2
	F3	3	4	0	1	0	8
	F4	1	4	0	0	1	6
	total	18	33	2	2	5	60
O6	F1	9	8	2	0	1	20
	F2	0	0	0	0	0	0
	F3	0	3	0	0	0	3
	F4	0	0	0	0	0	0
	total	9	11	2	0	1	23

III Conclusion

By analyzing the evacuation in 'Fukoku' insurance company, two types of behaviors which are considered to characterize the occupant behavior in an office building under fire have been extracted. They are the behavior of store owner (O6) and male store clerk (O5) to take responsible actions (F1) when they perceive a fire and then to escape via the route that they have previously decided to take in fire situations (E1) and the behavior of female office clerk (O1) to wait for superior officers' instructions (F4) and then escape by following instructions and guidance. These two behaviors can be explained that the former originates from the sense of occupational responsibilities and the latter is based on the line of command in office organization. So it is pointed out that an office building has a grounding for systematized evacuation in its personnel organization of itself. But as are shown in Tab.4 and Tab.5, since most of the occupants took F3 (call to others to escape together, remove valuables or waver in confusion) as 'First Action' and E2 (take a shorter route or choose a route instantly) or E4 (run after others) as 'Evacuation Behavior', it is more appropriate to conclude that in a fire situation of an office building, people take F3 and E2 or E4 behaviors latently and among them, those who are in the position of feeling professional consciousness strongly will take peculiar behavior patterns as F1 to E1 and F4 to E5.

Appendix



Standard floor plan of 'Fukoku' insurance company building

*AROUSAL FROM SLEEP BY EMERGENCY ALARMS:
IMPLICATIONS FROM THE SCIENTIFIC LITERATURE

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A review of the sleep research and other scientific literature pertaining to the arousal of sleeping individuals by external stimuli is reported. This effort was undertaken to provide information about the characteristics of emergency alarms which will reliably awaken a sleeping population, especially nursing home residents, in the event of fire. The literature reviewed does not provide an adequate basis for specifying signal characteristics which will offer a high assurance of producing arousal. Among the factors that influence the intensity of a signal which will produce arousal are the age and physical/mental condition of the sleeper, drug use, sleep stage, time of night, and meaningfulness or personal significance of the signal. Data relevant to these variables are discussed as is the problem of performance following abrupt arousal. Recommendations regarding stimulus characteristics, measures of arousal and the experimental environment for future studies of arousal by emergency alarms are presented.

*Only an abstract of the report is presented here. The complete reference is:

V.J. Pezoldt and H.P. Van Cott "Arousal from Sleep by Emergency Alarms: Implications from the Scientific Literature." National Bureau of Standards Report No. NBSIR 78-1484. June 1978.

FIVE PAPERS FROM A PANEL SESSION ON PANIC

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Panel Chairman

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On October 30-31, 1978 the Second International Conference on Behavior in Fire was held at the National Bureau of Standards Center for Fire Research near Washington, D.C. At the request of Dr. Bernard Levin, the chair of the meeting, a panel on panic behavior was organized. Participants included Corinne Black of Princeton University, John Bryan of the University of Maryland, A. R. Mawson of Loyola University in New Orleans, Jonathon Sime of the University of Surrey, England and Dennis Wenger of the University of Delaware. E. L. Quarantelli of the Disaster Research Center, Ohio State University, acted as organizer and chair of the panel. Prior to the meeting, all panelists were asked to address themselves in some way to three questions: 1) Do you see the concept of panic as a useful one for study purposes? 2) How do you conceptualize panic and what are the factors responsible for the phenomena? and 3) What are both the research consequences and practical implications of thinking about panic in the way you do?

The initial oral remarks of the panelists, only slightly edited, follow in alphabetical order.[1]

Key words: Affiliative behavior; attribution theory; contagion; disaster research; fire emergencies; flight behavior; human behavior; panic.

[1] The extended discussion which followed the initial remarks is not reproduced here. However, interested persons can obtain at nominal cost, tapes of the remarks made by the panelists and audience members from Dr. Bernard Levin, Center for Fire Research, Polymer Building, Room A363, National Bureau of Standards, Washington, D.C. 20234 U.S.A.

PANIC: SOME ANTHROPOLOGICAL INSIGHTS

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Panic is seen as a remnant of our evolutionary past, one which became maladaptive with the advent of civilization. Four distinctions underlying panic are outlined: (1) between the subjective and objective aspects of panic; (2) between the individual and the group in a state of panic; (3) between the cooperative and the competitive aspects of panic, and (4) between panic in organized as opposed to unorganized groups. In this presentation only the subjective and objective aspects of panic are explored with the aim of presenting a working definition. The subjective aspects include: acute fear, perception of a crisis, loss of ties to others, confusion, extreme frustration, a sense of chaos and a feeling of entrapment. The objective factors include: flight, contagion and a variety of other behavioral responses. It is suggested that panic behavior develops in a number of stages. Areas where intensive work is needed are noted. These include a need for the following: sophisticated debriefing of people who engage in panic done by an interdisciplinary team; work in the area of design; more knowledge about the role in panic of the different components of a fire situation; and better understanding of the role of leadership in reducing a sense of chaos.

My work on panic can best be characterized as an exploratory conceptual study. I should say first of all that I take a long view of the behavioral phenomenon of panic. As an anthropologist, I look at any patterned behavior in its evolutionary context, trying to fathom why and how it originated. It appears from the evidence of nonhuman primates and what we know about early man that panic behavior developed originally as adaptive behavior. When nonhuman primates and early man were suddenly confronted by a predator, it is likely that they engaged in a form of random dispersal, thus making it difficult for the predator to predict their movements. Jane Lancaster, a specialist in the evolution of human behavior writes that "Helter-skelter dispersal is very common in nonhuman primates as a predator defense mechanism." It may well be that our ancestors responded to grave and sudden threats with quick, random flight and that this behavior is part of our biological makeup.

One important aspect of this assumption is that at some point in human history, panic behavior became in large part a maladaptive form of response. I suggest that this occurred during the period when the first large towns and cities arose and people were for the first time crowded together. They began to live in structures with limited egress, and they assembled in the temples and large ceremonial centers which appeared in the early stages of civilization. Under these conditions, any threat to their safety that was sufficiently serious to produce flight carried with it the possibility of body contact with others and bodily harm. Thus, crowding and the development of complex structures laid the foundation for panic as a problem rather than as an adaptive mechanism for saving lives.

A number of distinctions underlying panic are potentially useful in its analysis. Foremost among these is the distinction between the subjective and the objective aspects of panic. Other distinctions of importance are those between the individual and the group in a state of panic and between the cooperative and the competitive aspects of panic. Also significant are the factors relating to the differences between panic occurring in organized as opposed to unorganized groups.

I do not have time this morning to dwell in any depth on the implications of these four distinctions. Let me simply explore some of the subjective and objective aspects of panic and organize them into a working definition.

I would like to suggest that the subjective aspects of panic are more numerous and complex than has been stated heretofore, that feelings other than acute fear, a perception of a crisis and the loss of ties to others are present. Another subjective aspect of panic, for example, is confusion. In my opinion, without confusion there is no panic. People may be greatly threatened and feel extreme fear, but if they have a clear sense of what is happening and what to do, they probably will not panic. One can argue that a group of people pressing toward an exit and doing damage to each other in the process know what they are doing. However, there is most certainly an element of confusion in a situation in which wildly excited people compete for a small escape outlet. This feeling lays the foundation for a more destructive feeling which I shall deal with in a moment.

Another subjective aspect of panic is the feeling that one's ties to the others who are trapped in a fire are greatly weakened. In this urgent situation the norms which usually govern behavior are suspended. Nearly all scholars of collective behavior note this disintegration of connectedness and the concomitant feeling that one should concentrate entirely on one's self.

Further associated with panic, I believe, is a sense of extreme frustration. The usual solutions to problems fail in the crisis. The normal charted paths to the resolution of difficulties run into a stone wall. Stated simply, nothing works.

However, underlying the feelings of frustration and confusion is a far more devastating and important feeling, one which no analyst has more than alluded to. This is the feeling of total chaos which quickly develops in a serious fire emergency. In the space of minutes the established, dependable sense of order and control in life vanishes. The ordinary parameters of social life which constantly guide and reassure us are demolished. That which was routine, orderly and predictable a few minutes before suddenly becomes unpredictable and terrifyingly disorderly. The immediate world appears to be coming apart at the seams. An intolerable feeling of complete ambiguity is generated. The outlines of everyday reality as we know it disappear. To the human organism, dependent as it is on pattern and order as the foundation of all life, this feeling is one of the most threatening that can be experienced. It rapidly produces a breakdown in behavior, notably in the form of panic.

Another subjective feeling involved in panic which has been much explored is that of entrapment. The ramifications of this feeling are complex. Some theorists maintain that panic occurs only when the victim feels that despite entrapment, there is some possibility of escape while others feel that it is the sense of no escape that produces panic. Fires, of course, represent a special type of entrapment from that of, say, a sealed mine disaster because of the urgency of the situation. It seems likely that the possibility of escape coexisting with entrapment sets the stage for panic.

Turning from the subjective aspects of fire to the objective aspects, one can list flight, surely the most dramatic factor, as well as contagion and a range of other behavior relating to escape. Flight in its various forms and other behavioral responses range from nonsocial to antisocial, from rational to nonrational to irrational, from adaptive to non-adaptive to maladaptive. Unlike some theorists I see panic as producing acts of varied nature, the least likely being social in the sense of looking to the needs of others.

There is considerable discussion of flight in panic situations, revolving largely around whether it happens invariably, what its nature is, and whether if it does happen, it is indicative of real panic. Schultz, for example, states that flight *per se* is not an automatic indicator of panic, feeling that it is adaptive behavior. By making this distinction, he raises the question of whether flight must be maladaptive to be called a symptom of panic. This and other problems require too many words to be dealt with here.

With regard to contagion, some writers take the position that it is rare and that if it does occur, it does not include everyone. Professor Quarantelli, for example, suggests that no more than a third of the people trapped in the Coconut Grove fire were caught up in panic. Most other analysts, however, feel that contagion is part of panic. Merloo, a psychoanalyst, sees contagion as being triggered by flight.

A central idea in all discussion of behavioral contagion is whether there exists in a group one person who functions as a model for the others. This person reduces the restraint felt by others by engaging in impulsive, unrestrained behavior. Others are encouraged to follow his example.

The question of contagion, which I can only briefly touch on, brings up another important matter. I suggest that panic behavior develops in a number of stages. It is more than likely that there is something we can call a pre-panic condition in which people feel "panicky" but do not actually panic. This then can lead to what I call "partial panic," a state in which some forms of social behavior may still occur. Finally, there comes total panic during which there is complete loss of self-control and all sense of others is obliterated.

Let me then try to put all this together into a working definition as follows: Panic is a response to a major threat to survival which has both subjective and objective aspects. Subjectively, it is felt as extreme fear, frustration and confusion in the face of a perceived major threat of great urgency. It involves a situation in which a feeling of entrapment is perceived in conjunction with the sense that escape is still somehow possible. The sense exists that the immediate world is in chaos and that the basic order which holds life together has collapsed. Its most common objective manifestation is flight. The behavior is contagious. It produces a range of behavior from maladaptive to adaptive, from irrational to rational, and from antisocial to nonsocial. The loss of social bonds between those involved is typical of total panic and precludes behavior of a social nature.

Now what are the factors most responsible for panic under conditions of fire? It seems to me that the central ones are the feeling of entrapment coupled with the urgent threat of extinction compounded by a sense that chaos reigns.

As for the implications of my thoughts, I would say that we need more experiments which can reveal to us the psychic mechanisms at work during panic. We also need more sophisticated debriefing of people who have survived panic situations done preferably by interdisciplinary teams. This kind of investigation should seek to analyze on many levels precisely what happened, both subjectively and objectively. Much work needs to be done in the area of design, to develop physical ways in which people can best be oriented and helped in a fire disaster. We need to investigate ways in which individuals respond to fire disasters and the ways in which the presence of others changes this reaction. We need to know the detailed role of the various components of the fire situation. For example, fire gases and smoke are known to produce certain kinds of disorientation, surely a factor in panic. We need to know more about the preception of entrapment and most of all, how to maintain or restore, at least partially, the all-important sense of order and control during a fire emergency. This is particularly crucial during the early stages of an emergency. In this respect, the development of better design features to orient and aid escaping persons is critical, as is the further development of techniques to introduce various forms of leadership into the chaos of an emergency, through trained staff behavior, voice control and the like.

PANIC OR NON-ADAPTIVE BEHAVIOR IN THE FIRE INCIDENT, AN EMPIRICAL CONCEPT

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Panic as a term appears to have value in communicating with the public and with obtaining support for investigations and studies. As a basis for scientific study, it does not appear to be as useful as group or individual non-adaptive behavior. The observed and existing physical evidence of human behavior following a fire incident when carefully examined can provide indication of adaptive or non-adaptive outcome of the behavioral actions. Obviously the operational definition of the term used to describe the concept of behavioral action is a scientific prerequisite for a valid or reliable study. The classical definitions of panic with the implication of animalistic or instinctive behavior appear to be obsolete.

Non-adaptive behavior should not be applied solely to flight behavior, since any behavioral action in a fire incident may be adaptive or non-adaptive relative to the individual, the group, or the fire incident. It would appear the examination of the pre-existing conditions in the group, the physical conditions and structure of the fire incident environment may be of critical value to identify favorable conditions for adaptive or non-adaptive behavior.

The terminology or label we attach to the behavior is not critical as long as the term is operationally defined.

The first question asked to us was whether "panic" was a useful term. I would have to say that as far as I'm concerned I look at "panic" as it has been described in the literature as occurring in the fire situation in buildings. I prefer not to use the term "panic" after about twenty-five years of study at this time. I will admit I have used the term "panic" in the past. I think the term may be useful when we define "panic" operationally. Thus, one can use any term we may want in a study as long as we operationally define it as to how we measure and observe the phenomenon. I do not impose my concept of "panic" on you, and you do not impose you concept of "panic" on me. Thus, with an operational definition, I tell you what I mean by the term. I now prefer to use the term "group or individual non-adaptive behavior." Why "non-adaptive behavior?" Because, "non-adaptive behavior" can be determined by physical evidence or by the participants observed accounts of the behavior that occurred, and I emphasize participants, not statements from one individual. Thus, you can obtain a measure of verification from a number of participants or you can obtain verification from the physical evidence, and I want to stress the importance of the obtaining of physical evidence.

I think the term "panic" might be useful regardless of what we decide, but I prefer the term, "group or individual non-adaptive behavior." You have heard other concepts, however, panic may be a useful term because it can be related to the public. Understandably, the public misuses the term, "panic," in relation to our concepts since they do not operationally define the term. I remind you, however, the concept of "panic" when it's attached to an incident as the Beverly Hills fire, where I agree with Joe Schwartz, it did not occur from everything I've been able to collect and study, may be useful in the sense that it enables the public to indicate concern about a problem. I would remind you that Dr. Quarantelli indicated he had been studying human behavior for twenty-seven years and he started by studying personnel in fires in Chicago. The question I now have is, how many of you started and got interested in this area of study because of the "panic" phenomenon? Secondly, the newspaper accounts of "panic" are often utilized because they sell papers. I would also indicate it would appear the term "panic" has been used to obtain research and grant funds by social scientists as well as other researchers. Thus, the term "panic," may serve a useful purpose although not scientifically and I repeat, if you use an operational definition use whatever term you prefer, for your study. I personally do not prefer the definitions that are found in the classical literature which imply animalistic or instinctive behavior with an implied correlation with the herd, and I consider these definitions to be both classical and obsolete. I think at the time these definitions were formulated they were probably as useful as my definitions are now and the definitions I use now will probably also be as obsolete in time.

I would now like to emphasize two important aspects relative to "non-adaptive behavior" in the fire situation. I do <u>not</u> believe it is restricted to, and do not apply it solely to flight behavior. You may have non-adaptive behavior in the alerting of other persons, you may have non-adaptive behavior in the attacking of the fire, and you may find physical evidence of extinguishers which are actually damaged by attempts by personnel to utilize extinguishers. This is not necessarily defined "panic" behavior but it is recognized as "non-adaptive behavior," and thus may apply in other than the flight reaction. I would agree, the group concept of non-adaptive behavior or when the behavior is most mimicked and utilized by more than one person appears to be in the flight situation. Relative to this flight behavior I would like to emphasize one may find a great deal of agressive behavior, and I would not call a concept like non-adaptive behavior one of serious concern unless you have the component of agressive behavior toward others in the occurrence. When you think about it, the difference between evacuation, patient refuge performance, and flight actions may be the aggressive behavior component toward others, and you can often find physical evidence of this aggression in the types of injuries that occur to participants. Finally, I think you have to consider in the reconstruction of the fire incident the complexity of non-adaptive behavior. You will find causative factors in the literature, you've heard these causative variables here, and they are not simple causes. Relative to research needs, we have to look more at the pre-existing conditions of the environment, both the individual and the groups. You have heard some of these concepts from others; Sime indicated that familiarity with others in the group, whether group is a primary group, and the length of time in formation of the group is important. I would indicate time appears to be very critical with the perception of the time by the individual. Latane and Darley pointed out the effect of time perception by the individual in assisting other persons. The perception of time, how the individual perceives the time that is available for him to achieve the selected action is a very critical frame of reference for the choice of action. Related to exit preference, you've heard some studies on this subject at this conference, the perception of the time appears to be most important. The physical environment within a fire incident often does not leave much time. You saw the film yesterday, you saw the flashover condition, thus, it is not difficult to realize the time constraints and the time perception which may influence behavior in this type of fire incident. I think we need more study on exit preference in relation to time. The re-entry behavior, both Wood and I have identified it, will occur, and this behavior most often seems to occur in primary groups and roles. This behavior often appears to be non-adaptive for the personnel within the situation that are trying to get out when others are trying to re-enter. However, this action may be very adaptive for the individual. So what I'm pointing out is, whether you call the behavior "panic or non-adaptive behavior" in any fire situation, what may be non-adaptive for one individual may be very adaptive for another. So again this emphasizes the point brought out by Sime about the observers' or the actors' perceptions and accounts of the behavior. I think we need more study on the professional and cultural roles of people, and the roles they adopt in the fire situations. I know Joe Schwartz has examined this behavior, and there may also be a difference between the sexes and the age of the participants. I have found preliminary evidence to indicate that age is a very critical determinant relative to individuals' perception of their time context, not time to escape but their overall time in a context of a life span.

To summarize, call behavior what you like, if we use operational definitions we can use the term, "Panic." I perfer not to now. I think "panic" may be useful to communicate with the public and I think it's probably useful to communicate to obtain support and personnel as long as you operationally define the term, use whatever term you want in your research.

IS THE CONCEPT OF PANIC USEFUL FOR SCIENTIFIC PURPOSES?

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The term "panic" refers to fear and/or flight behavior that is either (a) inappropriate and maladaptive, or (b) highly intense. Both senses of the term are unreliable as descriptions of actual events, and the term "flight" is recommended as an evaluatively-neutral substitute. Current explanations of flight emphasize the perception of imminent danger and limited escape routes. However, whether or not flight occurs in a situation of danger seems to depend largely on the whereabouts of attachment objects. If attachment objects are present in the situation, the likelihood of flight is reduced; if they are absent, the probability of flight is increased. The implications of such observations are briefly discussed in relation to behavior in fires.

1. Conceptual Issues

According to dictionary definitions and lay usage, the term panic refers primarily to certain aspects of fear and flight behavior, and less commonly to immobility reactions, together with a variety of other phenomena including aggression (viz. "panic" rage) and attachment behavior (i.e., "separation panic"). The main referent in sociological writings, however, is to flight, and it is to this aspect of the term that my remarks will be addressed.

"Panic" flight is customarily distinguished from "normal" or orderly flight in two ways. First, it refers to inappropriate, excessive, or maladaptive flight; and secondly, to highly intense flight. While there is reasonable agreement about the definition of panic, the real problem with both meanings of the term is to identify actual cases of "panic" in practice. I contend that the term is unreliable as a description of actual events and should be abandoned for scientific purposes. Before addressing this issue I would note in passing that a persistent source of confusion in the literature is a failure to distinguish between definitions and empirical generalizations. Very often, for instance, an author will state that "panic involves behavior X," or "...consists of behavior Y," and it is unclear whether an observation about panic is being reported or whether the author is simply offering his own, possibly idiosyncratic, definition of panic.

In attempting to apply the term panic in practice, the question arises as to what criteria are to be employed, and from whose point of view the behavior is to be judged - that of the participant or the observer? Most authors adopt what might be described as the observer's viewpoint, but the criteria of inappropriate and/or maladaptive flight (i.e., panic) are seldom made explicit. In the case of an individual who is literally about to be engulfed by flames, flight would obviously be appropriate and would therefore fail to count as panic. However, the degree of danger in most so-called panic situations is usually less clear-cut and the exact probability of being harmed or killed if one remains in the vicinity of the danger is uncertain. Granting, also, that it makes better evolutionary-adaptive sense to flee a potential rather than an actual danger, the criteria for deciding whether flight was appropriate or inappropriate - not to mention "excessive" - in relation to the hazard, become all the more elusive as the imminence of the threat decreases. As for the manner of flight - that is, its presumed adaptiveness or the lack thereof - studies of behavior in fires have shown how arbitrary it is in practice to decide what the most adaptive course of action should have been in a particular fire. (An added complication arises at this juncture in that some authors contend that panic can be rational and adaptive. But this is surely a contradiction in terms, since panic is, by definition, inappropriate or maladaptive. Alternatively, it is possible that the authors in question are implicitly using the second major definition of panic: namely, "highly intense" flight).

These conceptual problems are far from being resolved if we rely instead on the participant(s) to tell us whether or not he "panicked." Not only would few individuals be likely to admit voluntarily that their flight was inappropriate and maladaptive; but even if they were prepared to do so their statements would be no less arbitrary and subjective than those of the observer.

Turning, briefly, to the second definition of panic as "highly intense" flight, the difficulty here is that no reliable measure of flight intensity exists at present, and the decision to label particular cases of flight as panic in this sense is likewise arbitrary and subjective. In my view, then, neither sense of the term panic can be reliably applied in practice, and although the term is likely to continue being used loosely in everyday speech, I would urge its abandonment for scientific purposes. My suggestion is that the concept of flight should be adopted as an alternative to panic, recognizing that the behavior can take on varying degrees of intensity, but without making any assumptions as to its presumed appropriateness or adaptiveness.

2. Causation

Many authors in fact use flight behavior as the referent of "panic," and the most widely-accepted explanation is that flight occurs when (a) some major physical danger is believed to be present or imminent, and (b) escape routes are either limited or closing rapidly. The data are, in general, insufficiently detailed to provide any definitive evidence for or against the theory, the main difficulty being the lack of precise knowledge of beliefs. Although the theory seems to account successfully for some of the classic, theater-fire type "panics," what limited available evidence there is suggests that these conditions are neither necessary nor sufficient for flight to occur. Flight sometimes occurs in the absence of specific beliefs in danger and in the absence of limited or closing escape routes. Furthermore, two major studies of mass reactions to highly threatening radio broadcasts, (Cantril in the U.S., and Rosengren in Sweden), suggest that flight does not necessarily occur even when both conditions are present. Of those who listened to the broadcasts, believed what they heard and were frightened, the vast majority did not flee, but instead tended to contact relatives and friends in the neighborhood.

The current theory of flight seems to me to have two main defects. First, it overemphasizes physical danger in relation to other types of threats; secondly, it assumes that the usual response to danger is self-preservative flight. To the contrary, much evidence suggests that separation, or the threat of separation, from loved objects or companions has a far more devastating effect, psychologically and behaviorally, than most natural threats and disasters, and that affiliative behavior almost always takes precedence over escape in threatening situations. To this it might be added that the presence of attachment objects has a calming, "protective" effect in the fact of danger.

These points suggest that remaining close to attachment objects is more important to the individual than escaping from physical threats, even if this involves remaining in a situation of danger. While recognizing that a variety of additional factors deserve mentioning, I would tentatively reformulate the theory of flight on the basis of the above points as follows. Whether or not flight occurs in a situation of danger depends not only on the perceived degree of danger but also on the whereabouts of attachment objects (familiar persons and places). More specifically, (1) where the individual is in close proximity with attachment objects, only the most severe environmental threats ordinarily cause flight. Increased affiliative behavior tends to occur instead. When flight does occur, individuals tend to move away as a group, thereby maintaining proximity with attachment objects, and (2) where the individual is alone, or with strangers, even mild environmental threats may cause flight and, simultaneously, approach to familiar persons and places. In short, according to this view, flight behavior is more usefully interpreted not as an isolated response system in its own right, but as part of a more general affiliative system that simultaneously involves movement away from danger and the unfamiliar and movement toward familiar persons and places.

3. Research Consequences and Practical Implications

Detailed studies of behavior in fires have only been reported very recently, at least in the English language, and these studies at once highlight the complexity of the interacting factors involved in fire escape and the need for caution in framing generalizations about behavior in fires. Previous studies have consisted mostly of anecdotal descriptions, simulation experiments, and models derived from game theory. Of the latter, the cone-pulling experiment by Mintz, and Roger Brown's "Entrapment Dilemma" (modeled after the famous "Prisoners' Dilemma"), are perhaps the most widely known. According to these models, fire situations are defined by the participants as a competition for access to escape routes. Because of the "unstable reward structure" (Mintz) of the situation, each individual rushes for the exits in the expectation that others will try to do the same - the net result being complete escape for a lucky few, and death for the remaining majority - a situation supposedly resembling such classic disasters as the Iroquois Theater fire.

Mintz and Brown claim that vigorous mass escape behavior is the result of the situation being defined in competitive terms. But the question is, why are some entrapment situations exclusively so defined, whilst others - in which similar escape contingencies appear to exist - are not? Based on the reformulated theory of flight just outlined, I would suggest that a major variable omitted in these models is the factor of "human relationships" - that is, the degree to which the individuals are either in the presence of attachment figures or in a situation (or building) that is itself familiar. If this hypothesis is correct, flight will be much less likely to occur in fires, or will be far less precipitous and intense, if groups of attached persons are involved together and the situation is a familiar one, such as home or the workplace. The investigation of behavior in fires by Wood in England provides some support for this view. He found that when fires broke out in factories, or in the home, helpful and cooperative behavior was shown to a marked degree. Many other reports similarly indicate that captains, crews, stewardesses, waiters, and other employees tend to remain at their posts during disasters, calmly helping others to escape before attempting to escape themselves.

In conclusion, then, I suggest that future research on the nature and determinants of behavior in fires should pay close attention to the affective quality of the relationship between participants, as well as the extent to which the persons concerned are familiar with, or attached to, the place in which the fire occurs. Whether or not these considerations can be translated into policy decisions aimed at minimizing the loss of human life in fires remains to be seen. But so far as understanding behavior in fires is concerned, the affective quality of the relationship between participants has evidently been under-emphasized as a determining factor in contrast to the relative over-emphasis that has been placed up to now on the purely physical aspects of the hazard and the situation in which fires have occurred.

(The preceding remarks are drawn from a more extended written paper which can be obtained upon request from the author.)

THE CONCEPT OF 'PANIC IN FIRES': A BRIEF APPRAISAL

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The aim of this paper is to examine the concept of 'panic in fires.' It is argued that rather than considering panic as a definable phenomenon that can be readily measured, more attention should be directed to the way the concept is used. The concept figures prominently as a justification for certain fire safety measures. It is also used retrospectively to explain apparently inappropriate behaviour in fires. Basic weaknesses in the way the concept is used are considered, in particular the differing perspectives of fire victim and observer of the outcome of a fire tragedy. The notion that 'panic' is a causal attribution is discussed in relation to points of contention about escape behaviour and future research. Finally, reference is made to the practical implications of understanding the way the concept is used. The most important of these concerns the information people in a public building on fire are given about the potential danger.

The main problem in studying panic in fires has been an inability to agree on what the concept of panic refers to and how to measure it as an objective phenomenon. This is not simply a result of the practical difficulties in gaining systematic information on people's behaviour in fires. The concept of panic in the past has been used synonymously with the psychological problems that are assumed to occur when the outcome of a fire is unfortunate. I would argue that rather than increasing our understanding, the use of the concept has actually delayed research of people's behaviour in fires.

The concept of panic is a useful one for study purposes but not, in my opinion, because it readily helps us to explain or summarize what happens in some fire tragedies. I am not going to direct my remarks primarily to a conceptualisation of panic as a form of "irrational," "non-adaptive," "inappropriate" or "ineffective" behaviour. I think it is important to establish what constitutes a break-down in an individual's ability to cope in a fire. However, it is more important, at the present stage, to resolve the confusions caused by the way the concept is used. The prominence of the concept in the wording of fire precautions, building regulations and as a justification for aspects of building design makes its study essential.

CONCEPTUALISATION OF PANIC

My conceptualisation of panic in broad terms is therefore as follows: Panic is a concept attributed in a retrospective, contemporary or anticipatory fashion, by and to different role groups (e.g., firemen, staff, public, journalists), with differing degrees and kinds of involvement in a fire (as participant, observer or commentator). It is used as a description, explanation or evaluation of a state of anxiety or pattern of behaviour on the part of an individual, group or crowd. The anxiety or behaviour is assumed to be irrational, since its outcome is likely to be unfortunate (e.g., jumping, crowd pressure at an exit, escape without family members).

The wide variety of ways in which the concept is used results in ambiguities and apparent contradictions. For example, it is often used to describe and explain behaviour in fires. It is used to justify the introduction of features of building design intended to ensure people's safety, (such as anti-panic bolts, lighting and alarm systems, exit size and location), and to explain their lack of use in a fire. The all-embracing way in which it is used has, in fact, undermined its validity. Panic as a phenomenon is much more intangible than is popularly assumed. This is clear from the disaster research of earthquakes, bombings, etc., carried out by social scientists and more recent fire research. Yet the concept of panic is still used in newspapers to explain large-scale fire tragedies. An illustration of this is the British Newspaper reports of the Beverly Hills Supper Club fire, 1977, which included the headline "Panic Kills 300." In contrast, a much more systematic study of the fire has failed to find evidence for panic being a major determinant of the deaths. Why, then, is there a problem in the way the concept is used?

PROBLEM IN THE USE OF THE CONCEPT

The major problem arises out of a failure to recognize or acknowledge the discrepancy which often exists, between the perspective of people who use the term panic to refer to the behaviour of others in a fire and that of the people to whom panic is attributed. What appears to an "observer" as tangible evidence for panic having occurred, may be interpreted quite differently when an individual is referring to his own behaviour and involvement in a fire.

The popular conception of panic is that of "irrational" flight behaviour. The differences between this view of flight behaviour and the actual nature and determinants of flight from a danger have been pointed out, in my opinion quite rightly, by some social scientists. In a fire context, I would place an even greater emphasis on confusions caused by the use of the concept. Any discussion of "panic" per se should consider both the individual's subjective interpretation of what was happening and his behaviour; even if the only way to do this is through retrospective accounts of a fire. The normal way in which the concept is used to refer to other people's behaviour in a fire precludes a proper consideration of an individual's experience.

In clinical psychology the concept is often used primarily to refer to aspects of an individual's experience. While it is important to examine this experience in a fire, it is not implied that an individual's acknowledgement in retrospect that he "panicked" is clear evidence for its occurrence. The use of the concept may reflect both the anxiety or fear experienced during an incident and a retrospective re-evaluation of what he or she might have done. A re-evaluation of this kind should not be automatically equated with the more serious impairment of an individual's ability to cope, which is normally implied when the concept is used to refer to other people's behaviour in a fire.

PANIC AS AN ATTRIBUTION

In recent years a large body of research in social psychology has been concerned with the differences between the perspective of the "actor," i.e., person who engages in a pattern of behaviour, and the observer of this behaviour in a variety of circumstances. An underlying principle of attribution theory is that there is a tendency for people to attribute their own behaviour, if it ends in failure as opposed to success, to the circumstances; that other people's behaviour of the same kind is more likely to be attributed by an observer to the efforts or disposition of the people engaged in the behaviour. Some recent psychological experiments have shown a reversal of the first part of this principle in some contexts. In these cases individuals may admit to failure because it is more socially acceptable to do so. There is evidence that other people's behaviour is consistently misinterpreted in the manner the principle suggests. I believe that the principle applies when panic is attributed to people in a fire. The physical constraints of the fire situation and the problems people face (e.g., unfamiliarity with exits) are seriously under-estimated.

Essentially, a confusion arises because the evidence for panic cited is usually based on "external criteria," which define the most efficient pattern of behaviour in the situation. The actual behaviour of people in a fire is most likely to be misinterpreted when the outcome is unfortunate. Options actually available in a fire situation at the time may only be clear from someone else's perspective or in retrospect. The external criteria which are adopted may be quite different from the "internal criteria" against which the behaviour should be assessed. The internal criteria are the alternative courses of actions which individuals could have been aware of at the time of their involvement in a fire. The discrepancy between different people's perspectives is, in fact, the normal basis for attributing "irrationality" to people in fires.

POINTS OF CONTENTION IN THE ACADEMIC LITERATURE

The title of this section is my attempt at paraphrasing one of the questions which I was asked to consider in this panel session, namely: What are the major factors responsible for the appearance of panic? It is often the major area of disagreement in the academic literature, but one in which the complications caused by the way the concept is used are consistently ignored.

Disagreement exists as to whether panic is an individual and/or crowd phenomenon, whether it is limited to situations in which avenues of escape are or are not available. Using the concept primarily to refer to behaviour in fires puts an emphasis on crowd behaviour, escape-oriented actions in which exits are still available although they may be partially blocked, panic causing family ties to be broken and self-destructive actions. Emphasis on use of the concept to refer to one's own experience, suggests that "anxieties" labelled as panic could occur on an individual basis, when exits are or are not blocked and because family ties in a fire have been broken. The problems in relying solely on the behaviour itself as an indication of panic have been pointed out. The concept of panic has to be distinguished from terms such as "anxiety" or "fear," which do not necessarily lead to an impairment of people's ability to cope in a fire. The idea that there are automatic animalistic or self-destructive panic responses to isolated stimuli such as smoke, or "a cry of fire," is not supported by recent fire research.

Disagreement as to whether panic can be adaptive or not (another point of contention in the literature), is dependent on the semantics involved. The concept is invariably used when the outcome of a fire has been unfortunate. In this sense it cannot be adaptive. In reality, however, the individual in the situation does not know with any certainty what the outcome of his actions will be. Panic as defined by "internal criteria" could be adaptive in its outcome, even if this outcome is due more to the circumstances than the efforts of the person. Paradoxically, a true break-down in an individual's ability to cope may not be interpreted as such by other people. For the outcome may not be unfortunate. Attention to the use of the concept enables one to understand why apparently irreconcilable points of contention exist in the literature.

RESEARCH CONSEQUENCES AND PRACTICAL IMPLICATIONS

Research of fire which begins with the assumption that panic occurred in a particular instance and looks for confirmation of this, fails to differentiate panic from a variety of escape-oriented behaviour which inevitably occurs in highly constrained circumstances. One task of future research is to examine the use of the concept within the conceptual framework outlined earlier. There is a need for more detailed examination of the sequences of behaviour and interpretations by individuals of large-scale fire tragedies in which a "crowd" is involved. The most informative area of study could be one in which the validity of people's assumptions about panic are systematically examined by cross-referencing between different individual accounts of particular fires. In this way, the use of the concept by particular role groups and people with different kinds of involvement in a fire could be compared against the accounts of the people to whom panic was attributed. Coupled with a systematic analysis of the behaviour, one would hope to establish, both the internal criteria by which behaviour in a fire should be assessed; and the external criteria which, it has been argued, are normally adopted when the concept of panic is used. Attention needs to be directed away from à priori assumptions that panic occurred in a particular instance.

A consideration of the way the concept is used has important practical implications. The strategies adopted to deal with "panic" could be replaced by an emphasis on the more pertinent problems people face in a fire. An underlying strategy advocated in building regulations, evacuation procedures and design of alarm systems, is one in which emphasis is placed on keeping information about a fire away from people in the early stages "if panic is to be avoided." This emphasis has unfortunate results when the objective danger from a fire becomes serious.

Research of fires shows that people need sufficient information about a fire before they can or are prepared to leave a building. There is growing evidence that the delay in warning people in a number of major fires has been a primary reason why people have been unable to escape in time. An emphasis on avoiding "panic" contributes to delays. The kind of rapid flight behaviour associated retrospectively with panic then becomes necessary if people are to have any chance of escape.

In conclusion, the concept of panic will remain limited in its utility unless confusions in its use are resolved. An understanding of its use is necessary because the concept has such an important part to play in decision-making. Less emphasis on panic is needed. More attention should be directed towards giving people sufficient information about a fire's development in its early stages and the location of accessible building exits. In this way, the chances of people reaching safety in a potentially serious fire could be greatly improved.

* This paper is elaborated further in J.D. Sime, "The Concept of Panic" in D.V. Canter (Ed.) "Fires and Human Behaviour." Wiley: New York, (in press).

SOME OBSERVATIONS ON THE NATURE OF PANIC BEHAVIOR: A NORMATIVE ORIENTATION

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The nature and preconditions of panic behavior are briefly discussed. Furthermore, the utility of the concept for research purposes and the implication of the formulation for theoretical and practical investigation are noted. Toward these ends, it is observed that the term, panic, has varied meanings. From a nominalist perspective, however, the concept has utility in the fields of disaster research and collective behavior. Given an interest in examining the social forms of panic, it is proposed that panic be defined as mass behavior existent within a normatively competitive situation that results in increasing the danger to self and others, rather than reducing it. It is noted that individuals in the context of a social crisis engage in behavior that may be labelled as panic when the norms that emerge from their interaction define competition, not cooperation, as appropriate activity. Panic is neither irrational nor rational behavior. As opposed to rationality, attention should be focused upon the process of social interaction that results in a collective definition of the situation which proposes that competitive flight behavior is appropriate. Those conditions which produce panic in a given situation are discussed, including the existence of a social crisis, inadequate crisis management, and the milling process. It is noted that hope spurs panic, not hopelessness. Finally, the research and practical implications of this perspective are observed.

It is understandable that some observers believe that panic is not a useful concept for purposes of studying human behavior. The concept is plagued by a variety of diverse and vague meanings. It is used to refer to phenomena ranging from the micro or personal level to the macro or societal level. It has described everything from the fleeing of humans during theater fires, to runs on banks and money markets, to non-adaptive behavior of flight crews during bombing runs, to the behavior of isolated individuals in the face of danger, and the evacuation of areas preceding hurricanes. Obviously the concept is not suffering from a premature closure of meaning! Granted, these various useages may be appropriate and justified given the intent of the user. However, this disparity of meaning, lack of conceptual rigor, and vague useage limit its utility as a concept for scientific study.

Generally, however, there is value in the nominalist perspective. The utility of a concept must be evaluated in the context of the topic under study. As with any concept, the two most important dimensions for assessing this utility are theoretical relevance and empirical operationalization. Therefore, while "my panic" may not be your "panic," this discrepancy should not automatically void the utility of either useage.

Within the fields of disaster research and collective behavior, panic is a very useful concept. Within these areas the study of panic behavior has consumed considerable interest. Panic has provided numerous disaster researchers with a marvelous myth to brandish upon unsuspecting neophyte students, emergency planning officials, and the general public. From the time of the early work of Janis and Fritz to the seminal work of Quarantelli and its elaboration at the Disaster Research Center, scholars have documented that panic flight is a rare event in natural disaster situations; particularly in the cases of such geophysical events as hurricanes, floods, and tornadoes. On the basis of current research being undertaken by the Disaster Research Project at the University of Delaware, it is possible to report that the public continues to believe that panic is the major problem confronting community officials in most disasters. However, there is some indication that the distribution of scholarly research findings with respect to panic has had some impact upon emergency officials. Approximately fifty percent of the officials of emergency relevant organizations in three communities with disaster experience are aware that panic is a rare phenomenon.

Similarly, the extent and nature of panic have been of interest to students of collective behavior. Mintz, Brown, Cantril, Foreman, Smelser, Blumer, Quarantelli, Rosengren and others have examined panic as the prototype of unstructured, non-traditional behavior. Because of the impact of contagion theory upon the development of collective behavior, the emphasis has often been upon the irrational, non-human, regressive nature of panic behavior.

There are, however, certain components of my orientation toward disaster and collective behavior that would appear to remove panic as a central topic for investigation. First, I am interested in studying the similarities in the behavior of crowds, disaster participants, and other forms of "non-traditional or non-institutionalized behavior" with traditional, organized behavior. The intrigue lies in examining the similarities and shared characteristics, not the differences and contrasts, between these forms of behavior. Second, as sociologists we must study these "rare, unusual and spontaneous" forms of behavior as we would any other form of behavior, whether it be the assembly line at Chrysler, the halls of Congress, or a burning building. Furthermore, sociologists have an arsenal of structural concepts, such as norms, power relationships, roles, division of labor, and ideology that will allow us to study these non-traditional forms of behavior, including panic behavior, as we would any other forms of human behavior. We do not need to bastardize explanations and concepts -- such as contagion and circular reaction -- in order to examine panic. Third, disaster researchers have emphasized the resourcefulness, adaptability, and reliance upon positive action evidenced by groups of individuals in crisis situations. Obviously, this perspective contrasts with many traditional views of panic which see it as highly atypical behavior that cannot be explained by concepts used to explain traditional behavior, that differs in essence from these forms of behavior, and that represents the irrational, non-adaptive behavior of individuals.

Given these interests, areas of study, and general theoretical orientation, how might one conceptualize panic? Obviously, some areas of panic study are not central to these concerns, such as economic panics or stampedes. Nor should panic be conceptualized in terms of individual behavior. It is fruitful, however, to conceptualize panic in social terms. More specifically, the concern is with a form of mass behavior that may be viewed as non-adaptive flight behavior. (The "non-adaptive" component of this perspective must be emphasized, for it is obvious that not all flight behavior is non-adaptive. A great deal of flight behavior is highly appropriate and functional in the face of danger.)

Panic can be viewed as mass behavior in a normatively competitive situation that results in increasing the danger to self and others, rather than reducing it. Obviously, acknowledgements are due to Quarantelli, Janis and others who have influenced this conceptualization. This perspective considers panic as a social response to a social crisis situation. (For the behavior of isolated individuals, it may be "nonsocial" as Quarantelli proposes.) It is a behavioral process that results when individuals are thrust into a situation in which the traditional guidelines for behavior, i.e., the normative, organizational, and ideological structures, have been destroyed, neutralized, or are no longer collectively defined as appropriate or effective guides for behavior. In such settings a new, emergent structure for behavior arises. We may view this behavior as panic if it involves the parallel, similar flight behavior of individuals that is competitive in nature.

Furthermore, it is proposed that the behavior is normative in a competitive, not a cooperative, sense. Many of the conditions that produce coordinated crowd behavior during crisis also create competitive panic behavior. The major difference in these two forms of emergent action lies in the nature of the norms that emerge out of the interaction of the participants during the milling process.

A perceived or actual threat to personal safety is an inherent element of this conceptualization. Since this perspective is concerned with actual flight behavior, i.e., motor behavior, the threat is perceived to be immediate, imperative, and beyond the control of the individuals through concerted, collective, coordinated action. Therefore, individual survival through non-random flight behavior becomes defined as normatively appropriate.

Panic, therefore, is not irrational or nonrational. Empirically, the attribution of rationality or irrationality to panic participants presents substantial problems and generally represents the ex post facto view of the observer. Although there may not be a thoughtful examination of means-ends relationships among panic participants, this lack of calculated, "rational" decision-making can also be found in many traditional settings, such as the Executive Branch of the federal government and administrative offices on college campuses.

Nor should panic be viewed as rational behavior. Concern with the element of rationality should be avoided. The concept is difficult to measure. Furthermore, it tends to lead to the negative labeling of the participants and an attempt to "blame the victims" for their plight. Instead of rationality, we should focus our attention upon the process of social interaction that results in a collective definition of the situation which proposes that competitive flight behavior is appropriate. Panic behavior represents a classic illustration of the W. I. Thomas dictum concerning definitions of the situation and subsequent behavior.

Given this view of panic, what are the major factors responsible for producing panic behavior in a given situation? In a multivariate world there are many factors. Some of these are obviously of an individual, or more exactly, of a social psychological nature. For example, perceptions of potential danger and preexisting expectations for panic in certain settings, such as a crowded auditorium with few exits, may be contributory conditions. However, let us examine additional factors of a structural nature.

Initially, fear is not a sufficient condition for panic. Probably no one on this panel would disagree with this observation. Fear can result in coordinated, collective action to eliminate the threat or highly functional, heroic action by individuals. Furthermore, it may be proposed that fear is not a necessary condition for panic. Mintz with his cones, Turner with his department store incident, and others have intimated that panic participants may engage in the behavior without perceiving the direct threat. It can be argued that they engage in panic behavior out of conformity to the emergent, competitive normative structure. Obviously, fear is present in many panic participants and may be a contributory factor; however, it has been possibly over-rated as a causal dimension. (In the instance of individual, non-adaptive behavior, fear is possibly more important.)

The first condition that is necessary for panic is that the individuals in a setting perceive an immediate and severe danger. (From this perspective there must be more than one individual.) This danger is perceived as a specific, not a general threat. The potentially precipitating event, however, will not necessarily result in a social crisis.

The existence of a social crisis is a necessary condition for panic. Whether or not a crisis occurs as a result of the perceived threat depends upon the existence and effectiveness of crisis management mechanisms which may function to control any form of emergent, or spontaneous behavior — including panic. If these crisis management mechanisms can neutralize the event, limit its effect, and provide an alternative, functional guide to behavior, panic will not occur. These mechanisms include, but are not limited to, such devices as fire drills, clearly marked exits, ample escape routes, specific warning messages, and emergency plans. If, however, it is collectively defined that the threat cannot be abated or controlled by the individuals themselves, escape and flight behavior are handsome alternatives.

These collective perceptions and definitions emerge from a process of interaction termed the milling process. A key factor in this process is the activity of individuals who perform in the role of keynoter. Keynoters offer suggestions for action, indicate appropriate behavior, and serve to cue the behavior of others. Even the phrase, "Let's get out of here before these people start panicking," may serve as a guide to others that competitive behavior is appropriate. If flight behavior is keynoted and receives support from some of the participants, a general egress may result.

Panic, however, requires a number of other conditions. As has been noted by others, it tends to occur when the participants perceive that there is only one or at best a limited number of escape routes from the danger. Where there are numerous escape routes, flight behavior tends to be more adaptive.

Hope, therefore, spurs panic, not hopelessness. Panic is future-oriented behavior. The participants will only engage in panic behavior when they perceive that escape is possible. Where this hope is not present, resignation will result. Therefore, in the panic situation it is perceived that the limited escape routes are closing (not closed) and that escape must be made quickly.

In such a setting it becomes collectively defined that one must compete for escape through the closing exit routes. Furthermore, counter-arguments that cooperation and collective action are appropriate do not receive social support. Obviously, the influence of the initial keynoters is critically important in this process.

Finally, the strength of primary group ties among the participants must be considered. Panic is less likely to occur among "known others" and tightly integrated groups. For example, family members find it difficult to accept the norms of competition. It is the rare father who perceives that "I have to get out of here before my children, or I won't make it!" The effect of these primary group ties indicates the normative character of panic behavior.

What are the research and practical implications of thinking of panic in this manner? With respect to research, this orientation implies that we must study panic behavior as we would study any other form of social behavior. Our attention should be focused upon the nature of social interaction among individuals in the crisis situation. Our research should be comparative. Certainly we need more information about actual panic situations. However, we should also examine situations that are structurally conducive to panic, but in which panic behavior does not emerge. Comparative analyses such as these should focus upon differing degrees of social integration, cohesion, crisis conditions, and keynoting activity. This perspective also suggests an examination of crisis management mechanisms that can be utilized to neutralize the initial effect of social crisis.

Practically, we should cease being overly concerned with panic in natural disaster situations. Given its infrequent occurrence, effort should be directed to other problem areas. This suggestion includes a plea for an end to sensational media reports and the labeling of adaptative flight behavior as panic. This practice results not only in the perpetuation of the panic myth, but also in apprehension on the part of emergency officials. Furthermore, greater concern with crisis management devices, including architectural and space consideration should be undertaken. Conversely, less concern should be placed upon "blaming the victims" for their plight through the attribution of irrationality.

*GROUP HOMES FOR THE DEVELOPMENTALLY DISABLED: CASE HISTORIES OF DEMOGRAPHICS, HOUSEHOLD ACTIVITIES, AND ROOM USE

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The major objective of the present study is to provide data necessary for the development of life safety codes appropriate for group homes for the developmentally disabled. Survey techniques were used to compile summary data on residents' room use and activities, characteristics of the group home facilities, and demographics of the supervisors and residents. Data are presented for room use and activities of developmentally disabled residents and these data are compared to results available for the normal population. Recommendations are presented regarding fire safety for developmentally disabled residents of group homes.

*Only an abstract is presented here. The complete reference is:

A.M. Ramey-Smith and J.V. Fechter "Group Homes for the Developmentally Disabled: Case Histories of Demographics, Household Activities, and Room Use." National Bureau of Standards Report No. NBSIR 79-1727. April 1979.

The actual presentation at the Seminar emphasized one aspect of this report and was entitled, "Fire Drill Performance of the Handicapped."

* HUMAN BEHAVIOR IN A FATAL APARTMENT FIRE

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An examination of the Fort Garry Court Fire, (Winnipeg, Manitoba, February 2nd, 1976), with emphasis upon the gathering of data, (methodology) by the Emergency Communications Research Unit, (E.C.R.U.) of Carleton University, Ottawa, Canáda. The report notes the problems of tracing persons in the building at the time of the fire incident, partially due to incomplete lists of building occupants. The E.C.R.U. team managed to interview roughly 92% of the total survey population. The author notes the irrational behavior of some occupants within the fire crisis, and emphasizes the need for secondary warning alarm systems. The author cites problems with the conditioning effects of frequent false fire alarms within the building, and concludes that a single warning alarm system is insufficient for assuring the evacuation of all occupants at the time of a fire. There were also problems of communication by language as a number of building occupants did not speak English. The author notes that research into human behavior in fire situations requires substantial commitment by the research team; (E.C.R.U. Team is constantly on stand-by to travel to emergencies anywhere in Canada), the need for preparation and planning, and the need for development and maintenance of relationships between researchers and various community authorities.

*Only an abstract of this study is printed here. For a complete account, see:

Joseph Scanlon "Human Behavior in a Fatal Apartment Fire" <u>Fire Journal</u>. May, 1979, pp. 76-79, 122-123.

EVACUATION TESTS IN HIGH-RISE OFFICE BUILDINGS AND IN LARGE 2-STORY SCHOOL BUILDINGS

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This study reports on real evacuation tests carried out in three high-rise administration buildings and three large-area integrated schools in cooperation with the professional fire brigades in Köln, Düsseldorf and Hamburg in October 1976. Video cameras were used to record the movement flows of people. From these video records, the factors of density of people and rate of flow of people were determined. In the evacuation tests in the three administration buildings, only the flow of people on staircases was studied; while in the three integrated schools, the flow of people in corridors was investigated. Data showing rate of flow of people as a function of density of people for the various test settings are presented graphically.

The results found in these evacuation tests are compared with the results predicted by three theoretical calculation methods. The calculated values, using all three methods, were below the measured values. This can partly be explained by the fact that none of the calculation methods allows for a delay time between the time of the alarm sounding and the beginning of the evacuation. However, if an allowance for reaction time is added to the values calculated using the methods of Predtetschenski et al and Müller, then the resultant values are in close agreement with the real evacuation times obtained during the evacuation tests in the three administration buildings.

Key Words: Evacuation tests; high-rise buildings; schools.

INTRODUCTION

The number of multi-storied buildings, as office- and apartment buildings on the one hand, and large-area buildings as shopping centres and integrated schools (Gesamtschulen) on the other hand which during the past decade has increased considerably, caused the authorities responsible for the safety of people living in such buildings to investigate in all details the problem of evacuating these buildings in case of a fire or other emergency. This required to include such considerations already in the preplanning of buildings of this type with respect to the number, design and arrangement of escape routes. A number of extensive fires in high-rise buildings in other countries where - in some cases - hundreds of people died, roused echoes all over the world and underlined the need to investigate this problem in order to find adequate solutions. For this reason, the Bundesminister für Raumordnung, Bauwesen und Städtebau gave an order of research to the Forschungsstelle für Brandschutztechnik already at the end of 1973, to investigate, in cooperation with the fire brigade, the various processes of evacuation in buildings as a basis for the development of escape routes by means of theoretical formulae and real evacuation tests, under his research program "Baulicher Zivil- und Katastrophenschutz (Constructional protection of civilians in emergencies)".

A thorough study of literature carried out on behalf of the first part of this research program (Establishment of reasonable evacuation theories for specific uses of buildings based on existing scientific and technical publications at home and abroad) /1/ has shown that basic information and theoretical calculation formulae have been developed in particular in the USSR by Predtetschenski et al., /2,3,4/, in Canada by Galbreath,/5/, and in the GDR by Müller, /6,7,8/, whereas no such studies have been, so far, performed in the Federal Republic of Germany.

In the 2nd part of this research program (Theoretical study) /9/ the evacuation times for a lot of buildings where number of floors, width of stairs and number of persons per floor had been varied, were calculated on the basis of the mathematical methods developed by the above mentioned authors. As shown by the calculation results, evacuation times in buildings of the same height, same number of stories and lengths of corridors decreased, normally, according to the increasing width of stairs but increased with the growing number of persons per floor. The longest evacuation times were obtained when calculated with the method by Predtetschenski. On an average, these results were about 2 to 3 times higher than with the methods by Galbreath and Müller. The shortest evacuation times resulted from the calculation method developed by Galbreath.

The present study reports on evacuation tests accomplished as the 3rd part (Real evacuation tests) /10/ in three administration buildings and three large-area integrated schools (Gesamtschulen) in cooperation with the professional fire brigades in Köln, Düsseldorf and Hamburg in October 1976.

REAL EVACUATION TESTS

To obtain information on the motion process of flows of people in real evacuations as a function of type and geometry of a building, and in order to find out whether and how far assumptions in the theoretical formulae and calculation results obtained by applying these formulae are in agreement with test results, real evacuation tests were carried out. Planning of the first test series of this kind was based on the following requirements:

1. The flow of people should, if possible, represent a homogeneous crowd of people, i.e. for example, persons of an age capable of working, pupils and students etc.
2. To estimate the motion process of flows of people on vertical escape routes (staircases) tests should be carried out in multi-storied buildings with short corridor-lengths.
3. To estimate the motion process of flows of people on horizontal escape routes (corridors) tests should be carried out in large-area buildings with some floors only.

In order to fulfil these requirements, large administration buildings and integrated schools (Gesamtschulen) were selected for the evacuation tests to be carried out.

The following buildings were used for the evacuation tests:

High-rise Buildings
Administration building of the Mannesmann AG in Düsseldorf
Administration building of the Bayer AG in Leverkusen
Unileverhouse Administration GmbH in Hamburg

Integrated Schools (Gesamtschulen)
Integrated school in Köln-Holweide
Integrated school in Köln-Höhenhaus
Integrated school in Hamburg-Mümmelmannsberg

The administration building of the Mannesmann AG in Düsseldorf (see Fig. 1) finished in 1959, has a total height of 88.55 m above street level. It includes 3 basements, one ground floor, 1 mezzanine, 22 upper floors and 1 attic. The safety measures specified for this building, provide that in a case of emergency, all persons present on floors with even numbers leave the building via the first staircase whereas the persons on floors with odd numbers leave the building via the second staircase. In order to obtain during this evacuation test a density of people as high as possible on one staircase, the general rule of keeping open all existing staircases had been waived for the time of the evacuation test and one staircase was barred so that about 500 people present at the time of the evacuation test could leave the building via one staircase only.

The administration building of the Bayer AG in Leverkusen (see Fig. 2), completed in 1962, with a total height of 122.12 m above street level includes 9 basements, one ground floor and 32 upper stories. For the evacuation of this building, both existing staircases were available as escape routes to approximately 1500 persons staying in this building at the time of the evacuation test.

The high-rise building of Unilever-Administration GmbH in Hamburg (see Fig. 3) has a total height of 90.67 m above street level. It consists of one ground floor, one mezzanine, 21 upper floors and two tower stories. As shown on the ground plan illustrated on Fig. 4, the building is arranged around a triangular core with a staircase in each corner. Within these staircases also stairs are arranged in a triangular form. To get from one floor to the next one, people must walk up three stairs. Also during the evacuation of this building, all three staircases were available for about 1400 persons present in this building at the time of the evacuation test.

During the evacuation tests in the three integrated schools, the evacuation process on the 1st floor of the two floors in these buildings has been observed.

A view of the integrated school (Gesamtschule) in Köln-Holweide is shown on Fig. 5. At the time of evacuation test, approximately 560 pupils and teachers were present on the 1st floor, distributed over 20 classrooms.

Fig. 6 shows a view of the integrated school (Gesamtschule) in Köln-Höhenhaus. At the time of the evacuation test about 700 pupils and teachers were present on the 1st floor in 26 classrooms.

The integrated school (Gesamtschule) in Hamburg-Mümmelmannsberg, the first building section of which has been finished so far, is illustrated on Fig. 7. Due to the extension of the building complex, only one portion of the first floor could be observed during the evacuation test. In this part which was the most occupied one of this school, about 350 pupils and teachers were distributed over 18 classrooms.

The evacuation tests were in each case performed in close co-operation with the competent experts of the firm and the local professional fire brigade. Date and time of the beginning of the evacuation and the executive program had been agreed upon with the firms concerned. Evacuation was accomplished according to the directions of the firms,as far as possible. The day of evacuation was made known to all persons staying in the buildings to be evacuated.

To allow during these tests the determination of factors (like density of people and rate of flow of people at various points in the building to be evacuated) which characterize the motion process, the course of movement of flows of people was recorded by video cameras. This video system had been developed, particularly, for the purpose of these tests by the Forschungsstelle für Brandschutztechnik in cooperation with a television production firm. The functional diagram of this system is illustrated on Fig. 8. It operates as follows:

The video cameras 1 to 20 are installed in corridors and staircases of the building underneath the ceiling in such a way that all local conditions affecting the course of evacuation can be recorded. Signals of these 20 video cameras are fed into the video switching system 21. This video switching system with a synchronous alternator, synchronous distributor and change-over generator switches automatically each time after 3 half-images in the V-gap to the next video camera. With an image frequency of 50 half-images per s, this switching system allows questioning of all 20 video cameras within 1.2 s which, more or less, means synchronous observation of the entire process of evacuation. The distance between the video cameras and the video switching system may be as far as 50 m. The signal originating from the video switching system is fed into the video mixer 22 together with the signal of the additional video camera 23. This additional video camera takes up the indicator position of clock 24 which through the video mixer is shown in one corner of the main image of the momentary video camera so that the timely coordination of the various images can be seen. The signal coming from the video mixer is received by the 1/2 inch video recorder 25 and controlled by means of the monitor 26. By activating microphone 27, all instructions and announcements made during the evacuation test are, in addition, recorded on the sound track of the video tape.

From the video records the density of people present is determined by counting up all persons taken by each video camera and then relating this figure to the ground surface occupied by them. The rate of flow of people is obtained by determining the distance which people have covered within 1.2 s, by means of the special arrangement of the various video cameras in connection with a wide-angle lens and marks of length on the walls. Evaluations are made by reproducing still-video images. In order to be able to pursue the movement of various persons from their working place to the exit of the building and to assess the encounter and mixing of flows of people coming from different rooms or floors, some persons had been wearing headdresses with different signs.

In addition to this determination of the processes of motion, observers accompanying persons on the escape routes reported their observations into portable cassette recorders.

TEST RESULTS AND DISCUSSION

Factors determining the evacuation or time of evacuation of a building, are the number of persons present in this building, P, and the flow of people, $\dot{P}$, i.e. the number of persons able to pass a definite cross section of the escape route per unit of time. The extent of this flow of people depends on the rate of this flow, v, on the density of people, D, which is the number of persons related to the ground surface of the escape route, and on the width of the route, b. With the evacuation tests in the three administration buildings mentioned above where only the motion process of flows of people on staircases was studied, the values shown in Table 1 referring to the number of persons observed P, the mean flow of people $\dot{P}$ leaving the staircase on the ground floor and the time for evacuating the building τ_H have been determined.

Table 1. Determining factors of the motion process of flows of people during the evacuation tests carried out in three high-rise administration buildings

		Mannesmann AG	Bayer AG	Unileverhouse
$\underline{P}$		427	502	567
$\dot{P}$	Pers./min	54.7	52.0	59.3
$\bar{v}_T$	m /min	40.0	37.0	46.0
$\bar{v}_{TR}$	m /min	40.0	34.8	37.5
$\bar{D}_T$	Pers./m^2	1.35	1.38	1.30
$\bar{D}_{TR}$	Pers./m^2	1.21	1.36	1.43
D_{Tf}	Pers./m^2	1.34	1.36	2.67
D_{TRf}	Pers./m^2	1.22	1.38	2.91
v_T at D_{Tf}	m /min	40.0	37.0	35.8
v_{TR} at D_{TRf}	m /min	40.0	35.0	28.2
$\dot{P}_T$ at D_{Tf}	Pers./min	55.0	52.3	91.8
$\dot{P}_{TR}$ at D_{TRf}	Pers./min	55.0	53.0	92.0
τ_H	min	8.78	10.47	10.48

Since the analysis of the video tape records has shown that between the persons following each other on the stairs, a distance of one step was left in each case between two persons, the reference value for the density of people, D, was based on one step (D_{St}) or its surface (D_T) respectively. The pattern of the rate of flow of people v as a function of the density of people D_{St} as determined according to the motion processes of flows of people observed at various points of the staircases during the evacuation tests of the three high-rise administration buildings is shown on Figs. 9 to 11. Thereat, curve v_T represents the rate of flow of people on the stairs between two landings, curve v_{TR} the rate of flow of people required to walk from one floor to the next one, downstairs. The frequency distribution of the density of people is also shown on Figs. 9 to 11 as curve f.

With the evacuation tests in the three integrated schools mentioned above, where only the motion process of flows of people in corridors was investigated, the values compiled in Table 2 have been determined for the number of persons observed P, for the mean rate of flow of people $\bar{v}_F$, for the mean density of people $\bar{D}_F$, and for the time required to evacuate the floor concerned or parts of it τ_F and for the entire building τ_H.

Table 2. Determining factors of the motion process of flows of people during evacuation tests carried out in three integrated schools

		Köln-Holweide	Köln-Höhenhaus	Hamburg-Mümmelmannsberg
P		560	700	350
$\bar{v}_F$	m/min	79	91	79
$\bar{D}_F$	Pers./m^2	0.47	0.18	0.47
τ_F	min	2.1	1.95	1.55
τ_H	min	3.8	4.0	2.7

During these three evacuation tests, the reference value for the density of people, D_F, was the ground surface of corridors. The pattern of the rate of flow of people, v_F, as a function of the density of people D_F which was determined according to the motion processes of flows of people observed at various points on the corridors of the 1st floor in the three integrated schools during the evacuation tests, can be seen on Fig. 12.

The motion process of a flow of people on a staircase is subdivided into the vertical movement leading downstairs on stairs and the horizontal movement on landings. In order to be able to compare the rates of flow of people on stairs between two landings, v_T, or on the staircase between two floors, v_{TR}, the pattern of the rates of flow of people v_T and v_{TR} as a function of the density of people D_T and D_{TR} respectively is represented on Figs. 13 and 14. The flows of people $\dot{P}_T$ and $\dot{P}_{TR}$ calculated by means of the rates of flow of people and densities of people, are also shown on Figs. 13 and 14 as a function of the density of people. Values taken from these graphs which refer to the mean rate of flow of people $\bar{v}_T$ and $\bar{v}_{TR}$ and to the mean density of people $\bar{D}_T$ and $\bar{D}_{TR}$ at the mean flow of people $\dot{P}$ measured, and values for the rates of flow of people v_T and v_{TR} and for the flows of people $\dot{P}_T$ and $\dot{P}_{TR}$ at the most frequent density of people D_{Tf} and D_{TRf} respectively, measured during these tests are also included in Table 1.

As values in Table 1 show, the rates of flow of people on the stairs between two landings and on the staircase between two floors were nearly the same in evacuation tests 1 and 2. On the other hand, evacuation test 3 proved that the rate of flow of people in the staircase was considerably lower than on the stairs. This means that persons walked down the 5 steps of the stairs between two landings quickly whereas on landings people crowded, consequently resulted in a lower rate of flow related to the total walking length between two floors. This walking behavior of the persons can be traced back on the one side to the arrangement of the stairs, on the other side, however, also to the slight lighting on the staircase which may have an adverse effect on the rate of flow when people turn round on landings. In the Unilever-house, the intensity of illumination was only 15 lx compared with 100 lx to 300 lx in the other two high-rise administration buildings. In spite of the different rates of flow of people on the stairs and in the staircase during the evacuation test 3, however, the mean flow of people $\dot{P}$ leaving the stairway on the ground floor was about the same as those determined in the evacuations tests 1 and 2.

The time required for the evacuation of one floor, τ_F, consists of the following single periods:

1. Time up to the beginning of evacuation of various rooms τ_{F1}
2. Time for evacuating various rooms τ_{F2}
3. Time for walking up to the door opening to staircase or exit τ_{F3} and
4. Time for walking through this door τ_{F4}.

For above periods, the following assumptions can be made according to the results obtained from the evacuation tests in the three integrated schools:

τ_{F1} = 0 min to 1 min.

τ_{F2} = 0.1 min to 0.7 min.

Values for τ_{F2} refer to rooms with a ground surface of 8 m x 8 m and mean occupancy of approximately 25 pupils per classroom.

τ_{F3} = 0.33 min to 0.38 min.

These values for τ_{F3} were obtained from the mean rates of flow of people $\bar{v}_F$ (see Table 2) determined during evacuation tests, based on a maximum length of escape route of 30 m as being existent in the integrated schools tested.

$\tau_{F4} = 0.43$ min.

The maximum flow passing through a door of 1.1 m width, determined during the evacuation tests in the integrated schools amounted to 233 pupils per min. The value for τ_{F4} is based on the assumption that in schools, in general, 100 pupils may pass each time through a door of 1.1 m width.

To assess the total time necessary to evacuate one floor, it must be checked whether the walking time on the corridor, τ_{F3}, or time to pass through the door to the stairway, τ_{F4}, is longer. The higher one of both values must be added to τ_{F1} and τ_{F2}. If τ_{F4} is less than τ_{F3}, the flow may pass the door without obstruction, if, however, τ_{F4} is greater than τ_{F3}, there will be an obstruction in front of the door which determined the time required for leaving the floor.

Therefore, the evacuation of one floor requires the following time:

τ_F = 0.53 min to 2.13 min.

From values for the single periods it can be seen that the total time necessary to evacuate one floor depends on how quickly the individuals react to alarm signal for evacuating the building (τ_{F1}) and how quickly they leave the room where they are staying at the time being (τ_{F2}).

Since the evacuation tests in the high-rise administration buildings were limited to the investigation of the motion process of flows of people on stairways, values for times required to evacuate single floors of a high-rise administration building are not available. However, by the application of conclusions from analogy it can be shown that the evacuation of floors in a high-rise administration building requires approximately the same times as in integrated schools.

Finally, times for evacuating the three high-rise administration buildings were calculated with the methods according to Predtetschenski et al. /2,3,4/, Galbreath /5/ and Müller /6,7,8/ and compared with measured evacuation times. Due to the limitation of time, the calculation methods cannot be described here. It is recommended, instead, to study the papers listed in the bibliography.

Values for evacuation times in the three high-rise administration buildings calculated with the mentioned methods are listed in Table 3 together with values measured during the evacuation tests. As shown by comparison, the calculated values according to all three methods are below the measured values. This can partly be explained by the fact that none of the three calculation methods allows for a delay time between the time of alarm to evacuate the building and the beginning of evacuation. As can be seen, however, from the evacuation tests in the integrated schools, this so-called "reaction time", τ_{F1}, is about 0.5 min to 1 min. Therefore, if 0.8 min for the mean "reaction time" are added to the calculated values, values are obtained which are also included in Table 3. Comparing these values with the measured values reveals that the calculation methods according to Predtetschenski et al. and Müller are in good agreement with the real evacuation times obtained during the evacuation tests in the three administration buildings.

Table 3. Comparison of evacuation times calculated with the methods according to Predtetschenski et al. /2,3,4/, τ_{HP}, Galbreath /5/, τ_{HG}, and Müller /6,7,8/, τ_{HM}, with those obtained by measuring during the evacuation tests in the three high-rise administration buildings, τ_H

		Mannesmann AG	Bayer AG	Unileverhouse
τ_{HP} (f = 0.1 m^2/Pers.)	min	7.89	9.79	8.38
τ_{HG}	min	5.86	8.62	6.89
τ_{HM}	min	7.68	8.63	9.67
τ_{HP} + 0.8	min	8.69	10.59	9.18
τ_{HG} + 0.8	min	6.66	9.42	7.69
τ_{HM} + 0.8	min	8.48	9.43	10.47
τ_H	min	8.78	10.47	10.48

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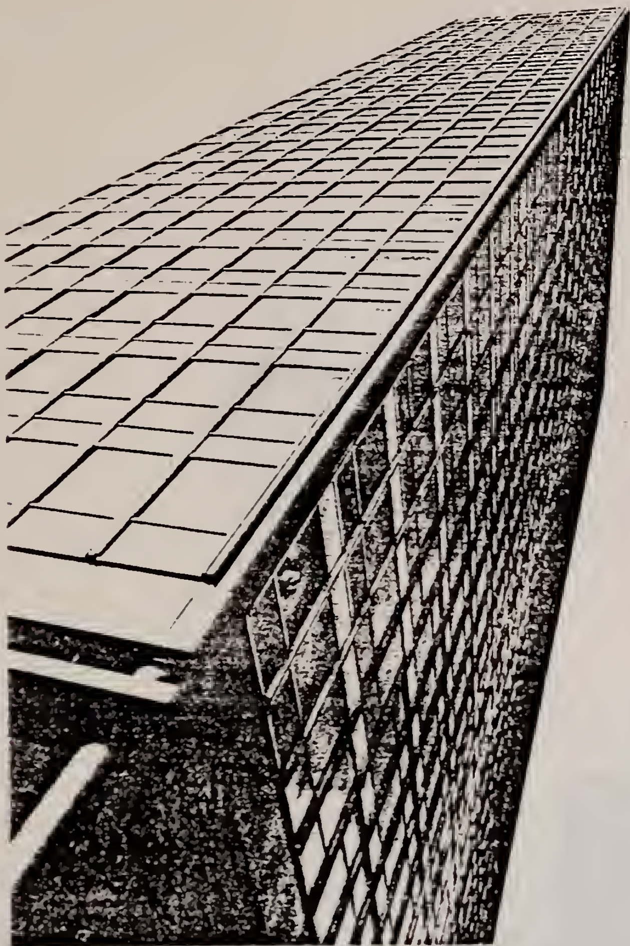


Fig. 1. Administration building of the Mannesmann AG in Düsseldorf

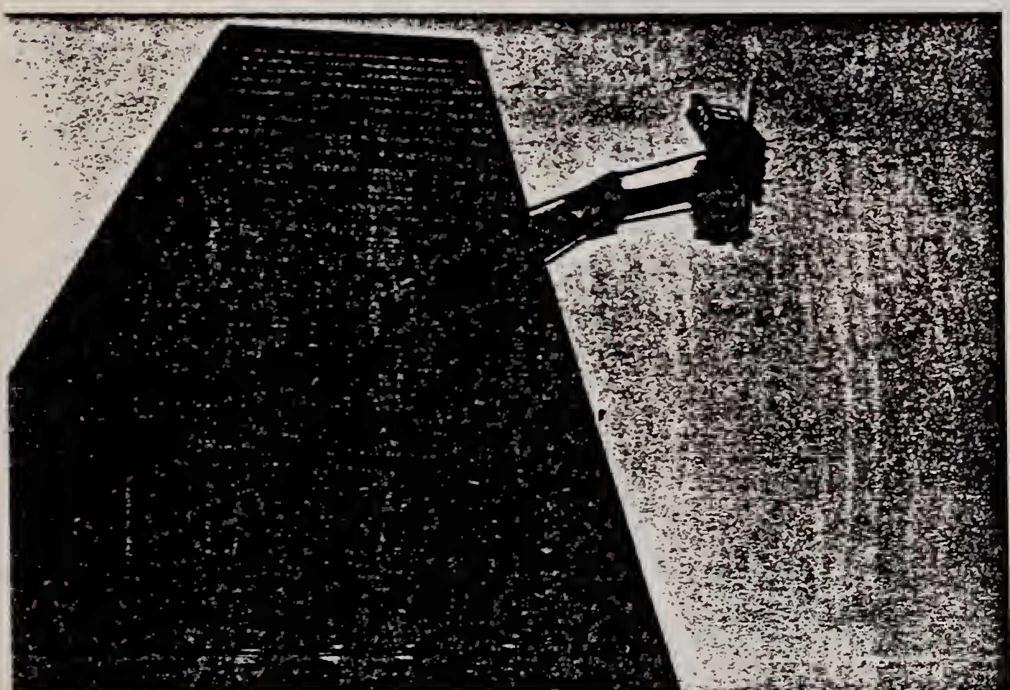


Fig. 2. Administration building of the Bayer AG in Leverkusen

Fig. 3. Unileverhouse Administration GmbH in Hamburg

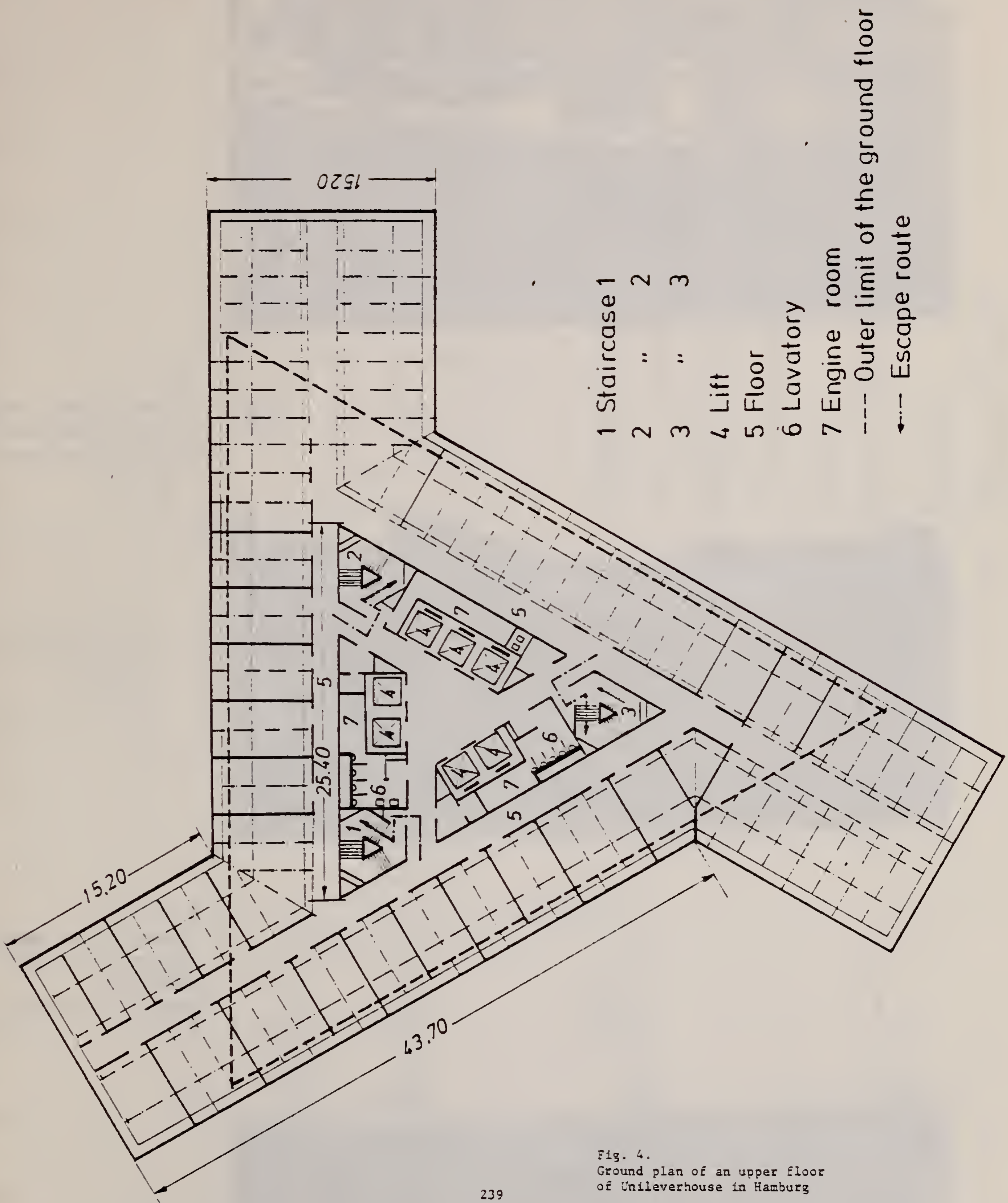


Fig. 4.
Ground plan of an upper floor of Unileverhouse in Hamburg

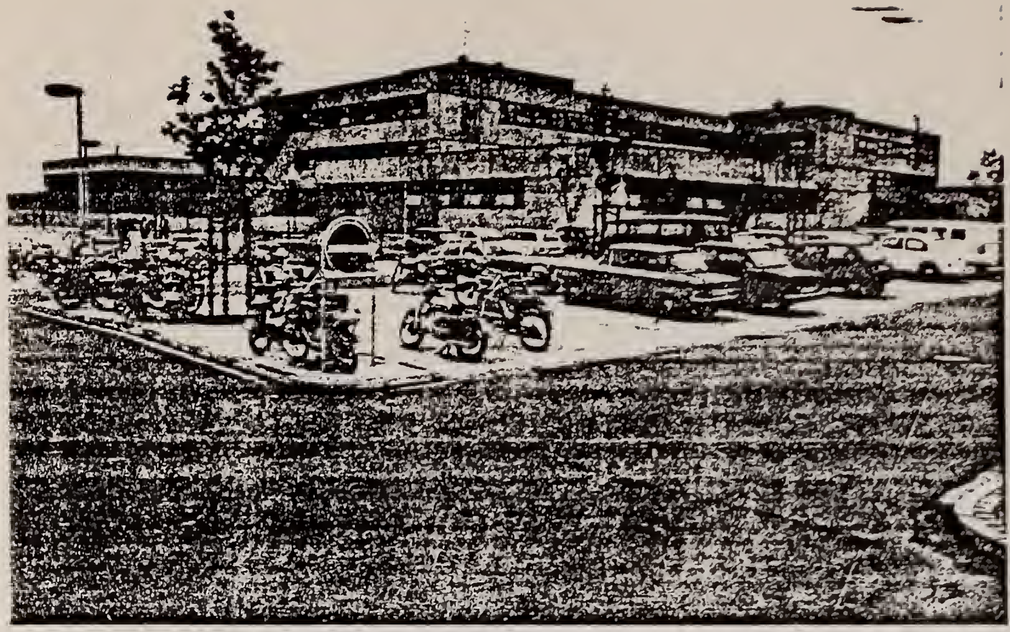


Fig. 5.
Integrated school (Gesamtschule) in Köln-Holweide

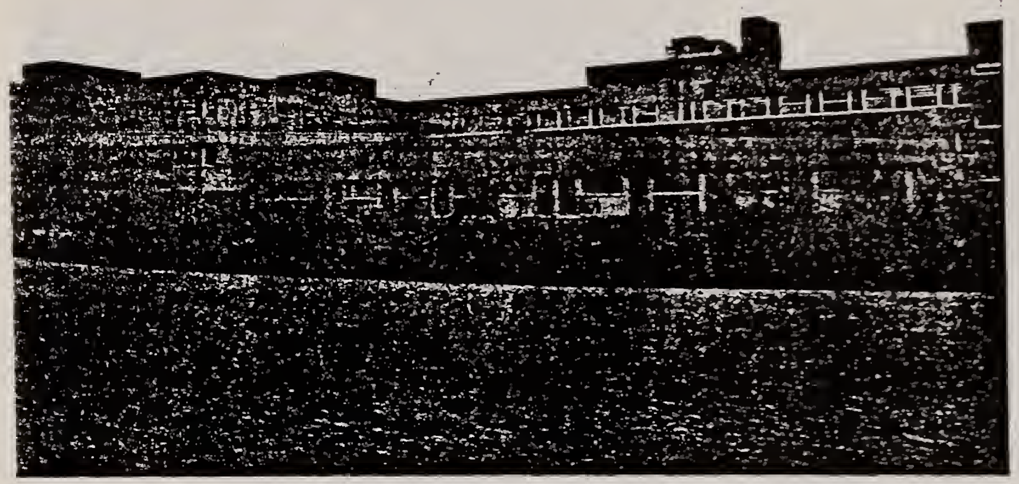
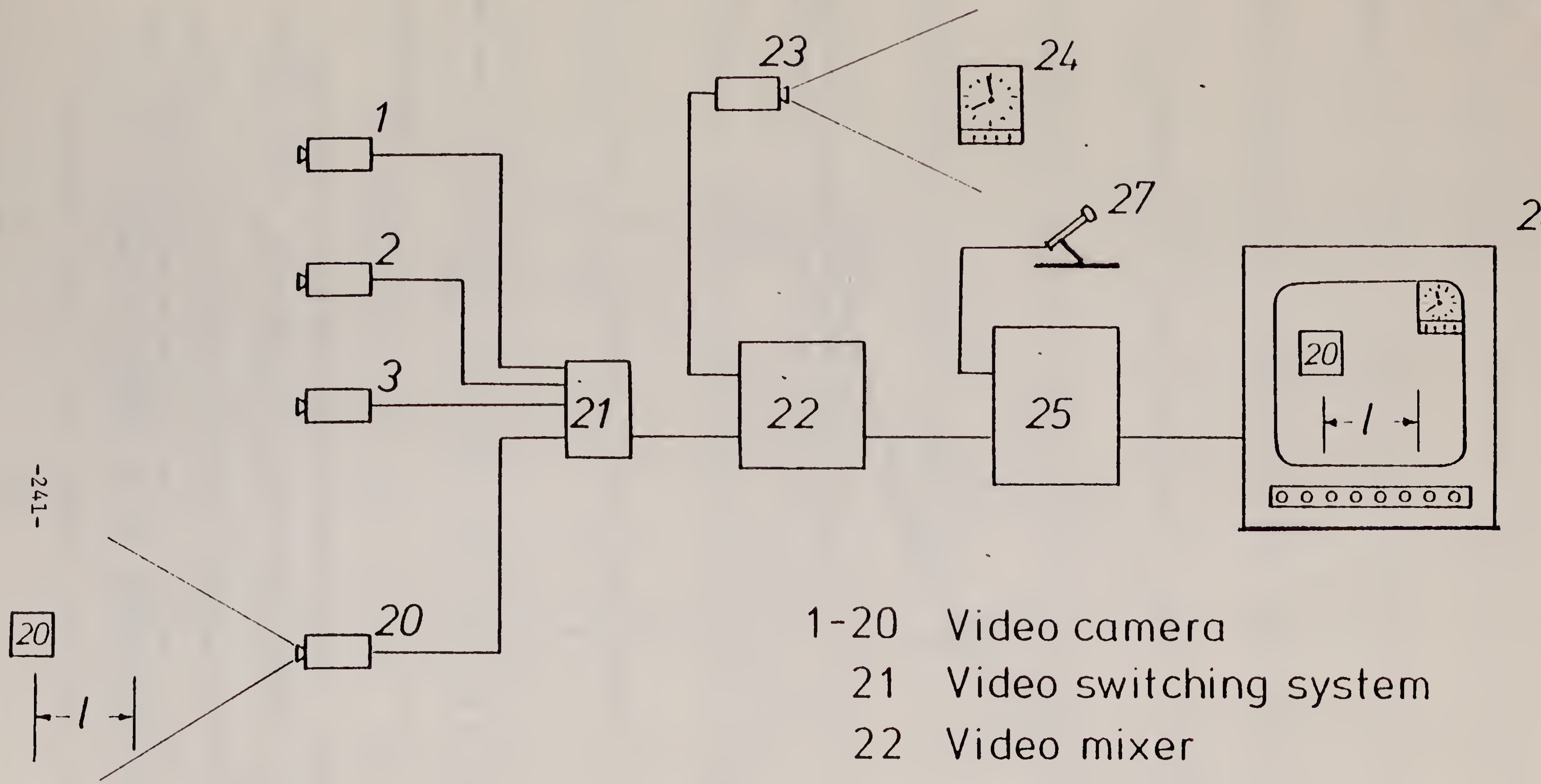


Fig. 6.
Integrated school (Gesamtschule) in Köln-Höhenhaus

Fig. 7.
Integrated school (Gesamtschule) in Hamburg-Mümmelmannsberg



1-20 Video camera
21 Video switching system
22 Video mixer
23 Video camera
24 Clock
25 Recorder
26 Monitor
27 Microphone

Fig. 8.
Functional diagram of
the video system

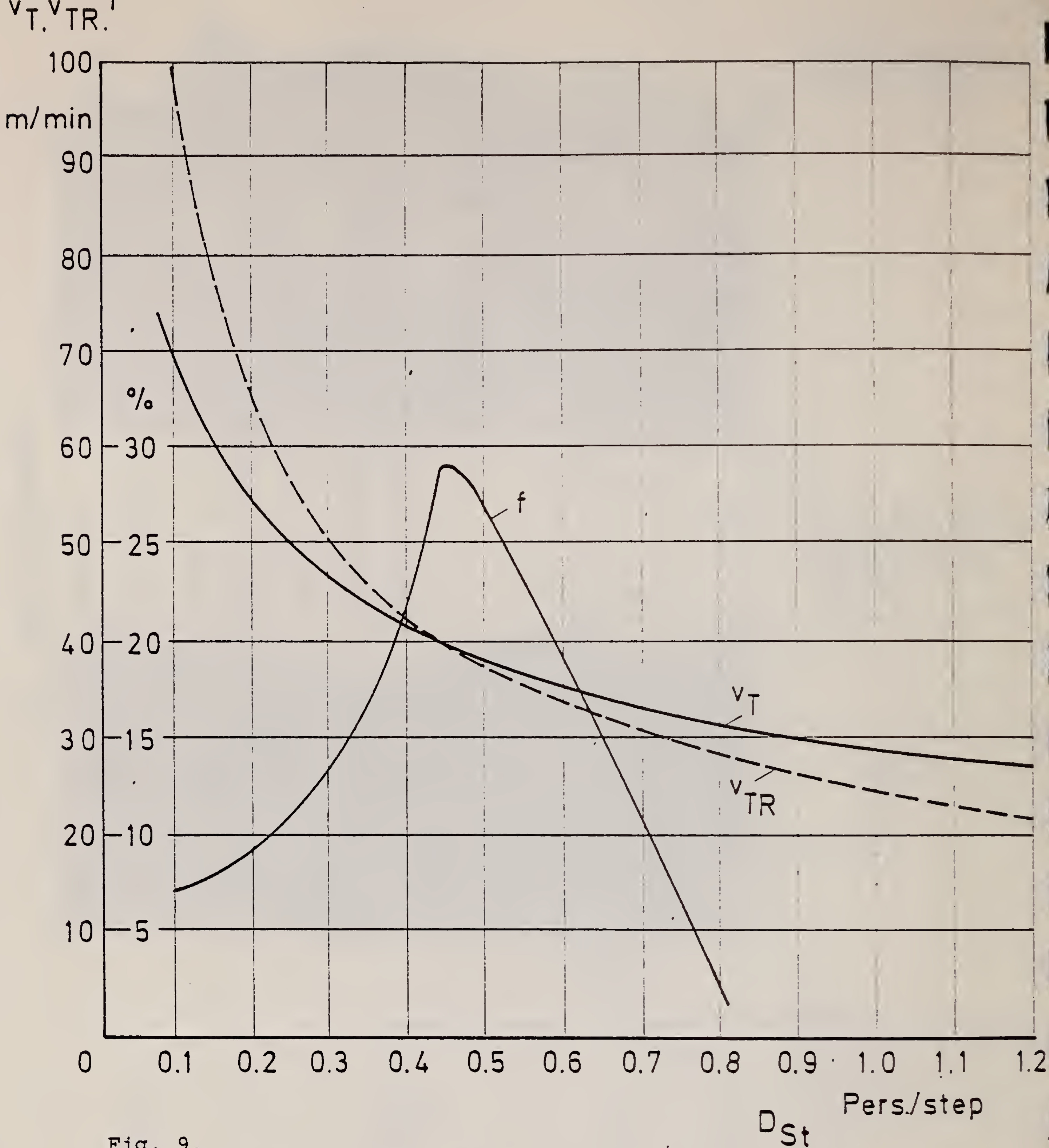


Fig. 9.

Evacuation test 1: Administration building of the Mannesmann AG
Rate of flow of people downstairs as a function of the density of people D_{St}

v_T Rate of flow of people on the stairs between two landings
v_{TR} Rate of flow of people on the staircase between two floors
f Frequency distribution of the density of people

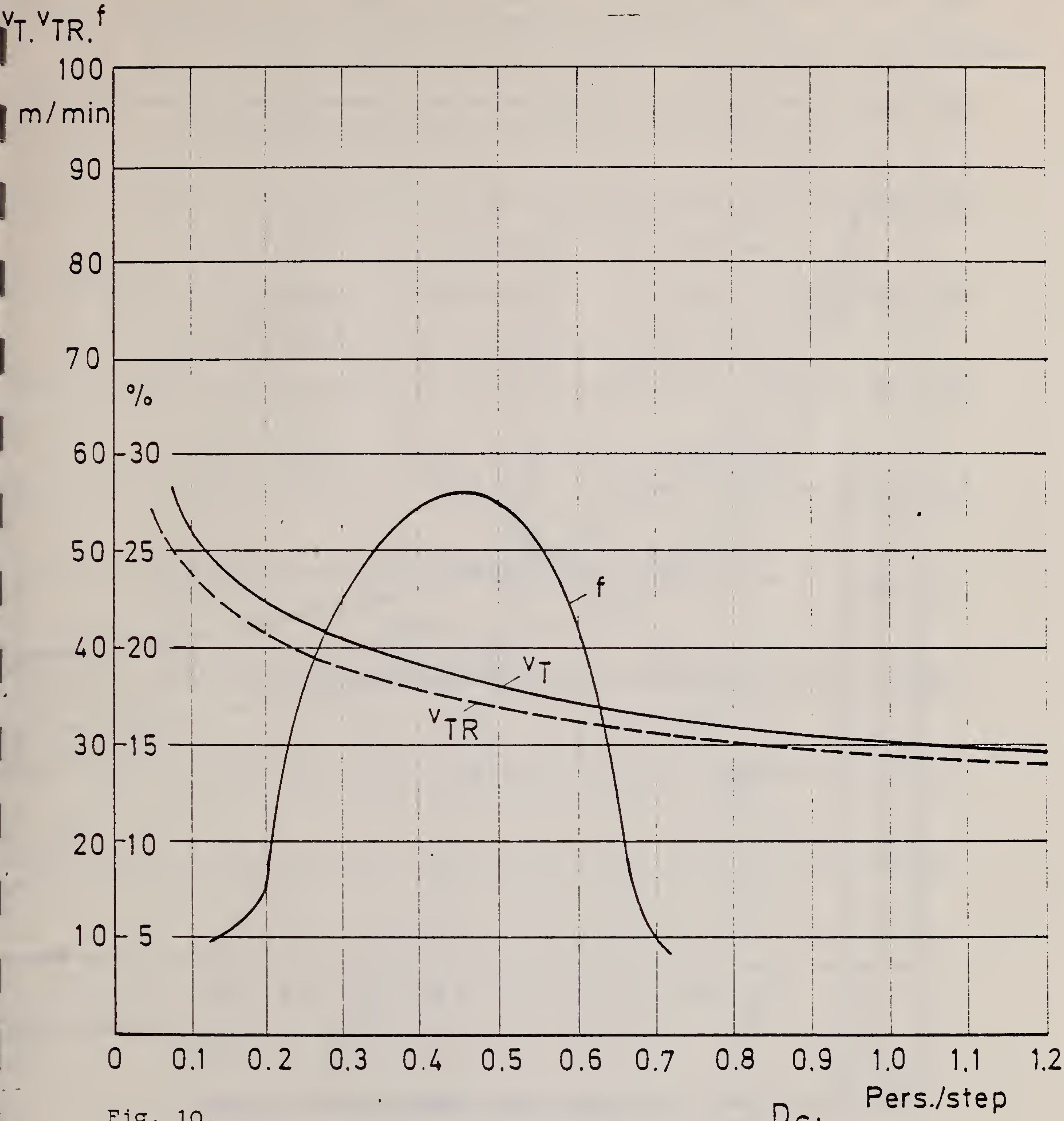


Fig. 10.
Evacuation test 2: Administration building of the Bayer AG
Rate of flow of people downstairs as a function of the density of people D_{St}

v_T Rate of flow of people on the stairs between two landings
v_{TR} Rate of flow of people on the staircase between two floors
f Frequency distribution of the density of people

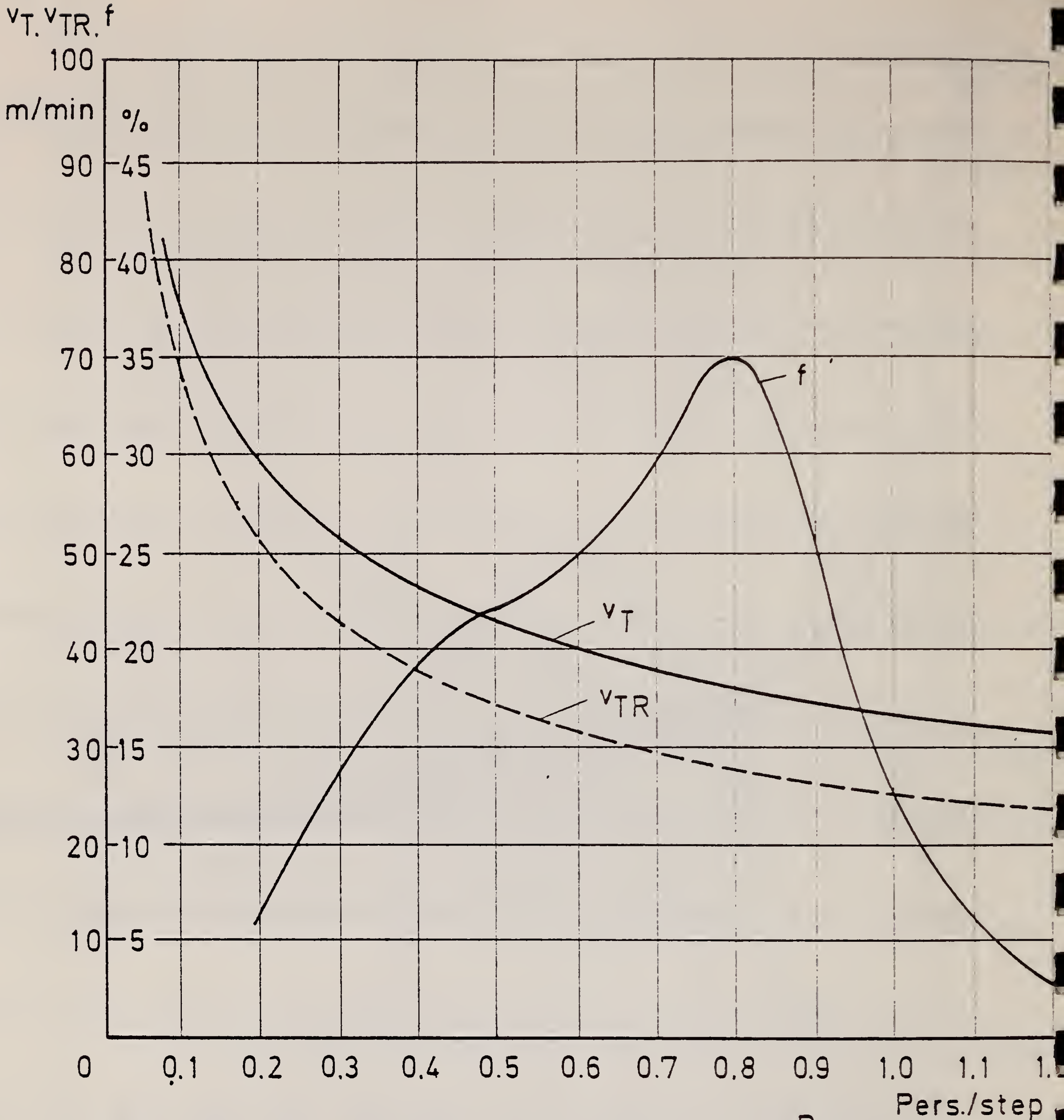


Fig. 11.

Evacuation test 3: Unileverhouse Administration GmbH

Rate of flow of people downstairs as a function of the density of people D_{St}

v_T Rate of flow of people on the stairs between two landings

v_{TR} Rate of flow of people on the staircase between two floors

f Frequency distribution of the density of people

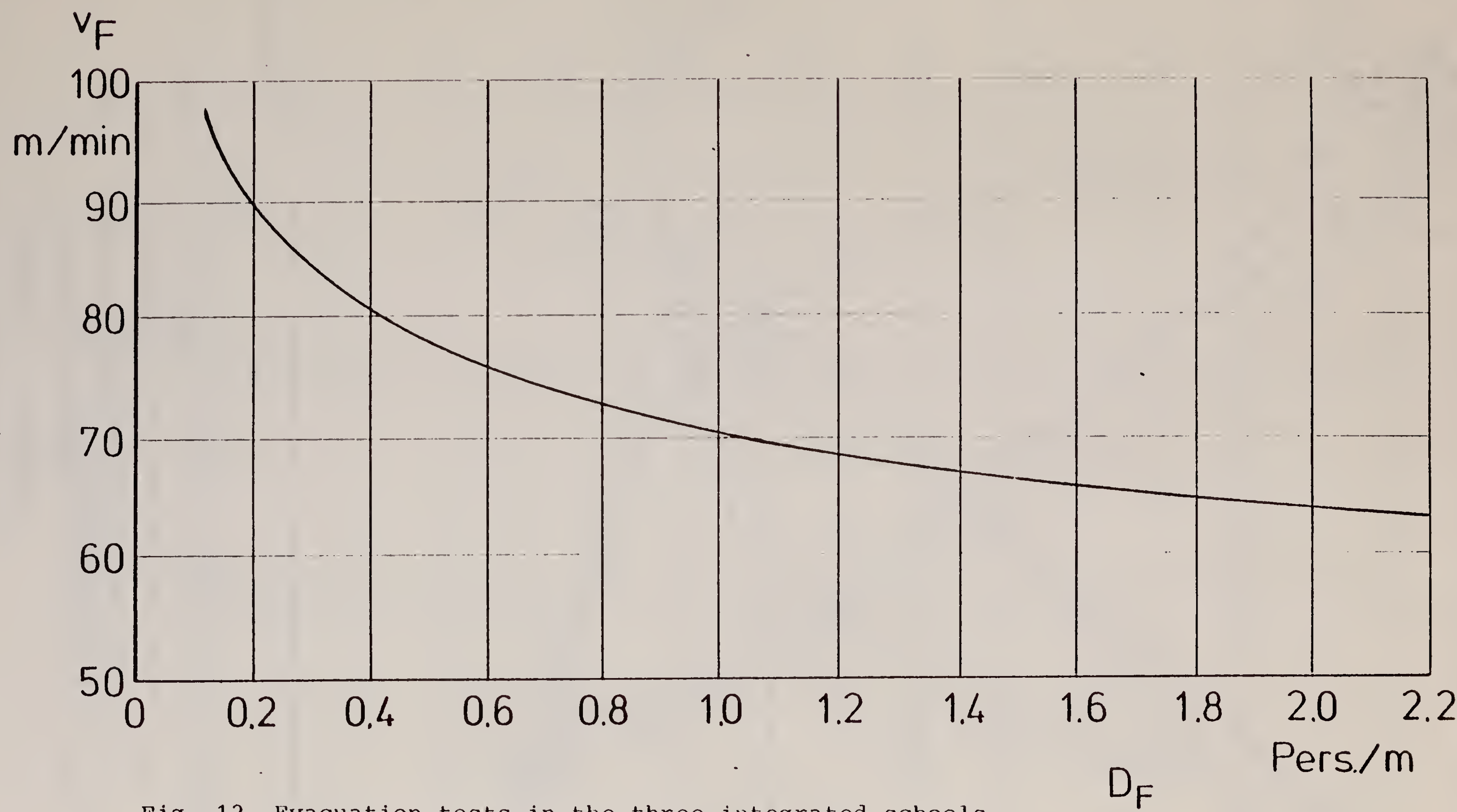


Fig. 12. Evacuation tests in the three integrated schools
Rate of flow of people in the corridors v_F as a function of the density of people D_F

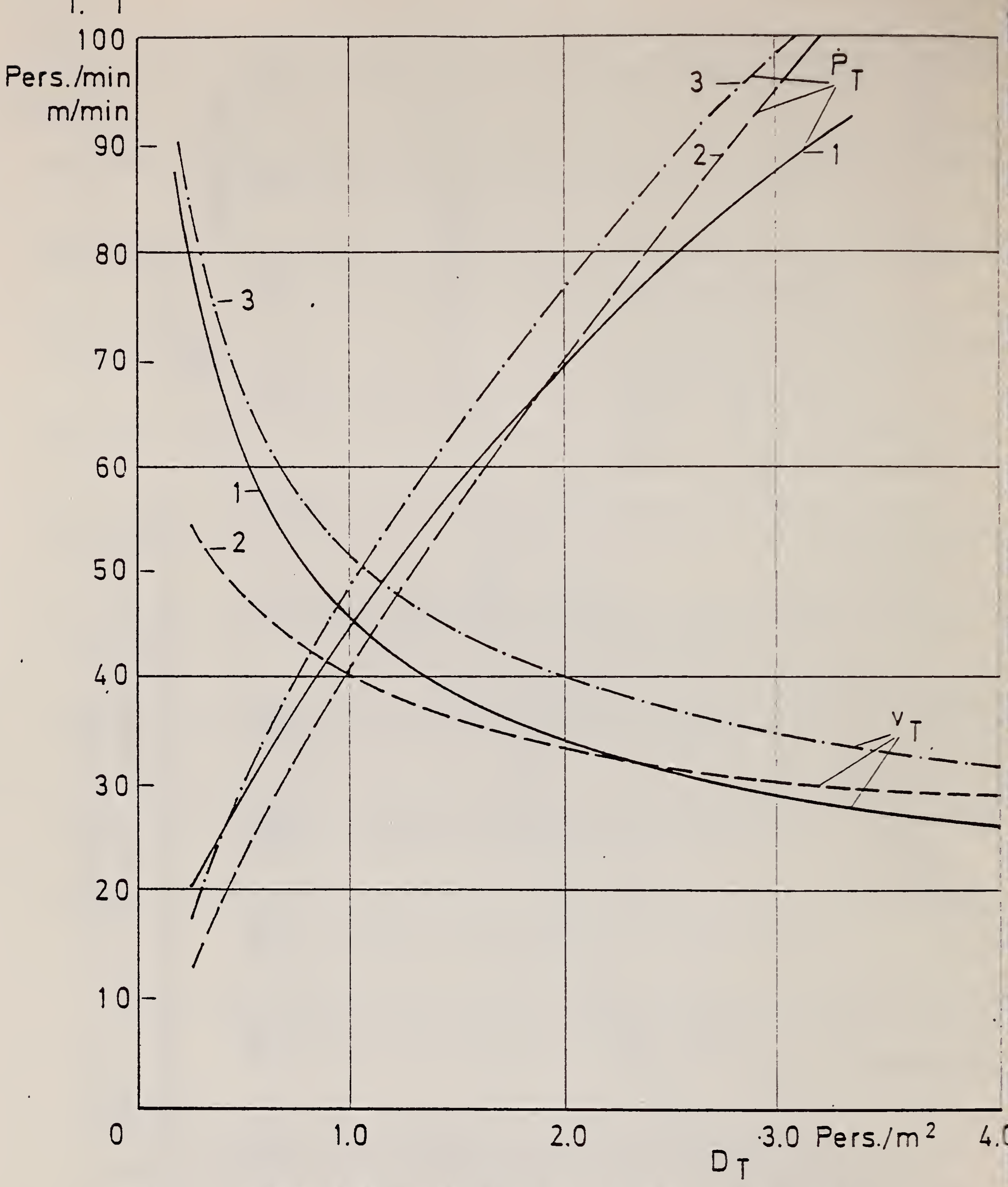


Fig. 13. Rate of flow of people v_T and flow of people $\dot{P}_T$ downstairs between two landings as a function of the density of people D_T
1,2,3 Evacuation test 1,2,3

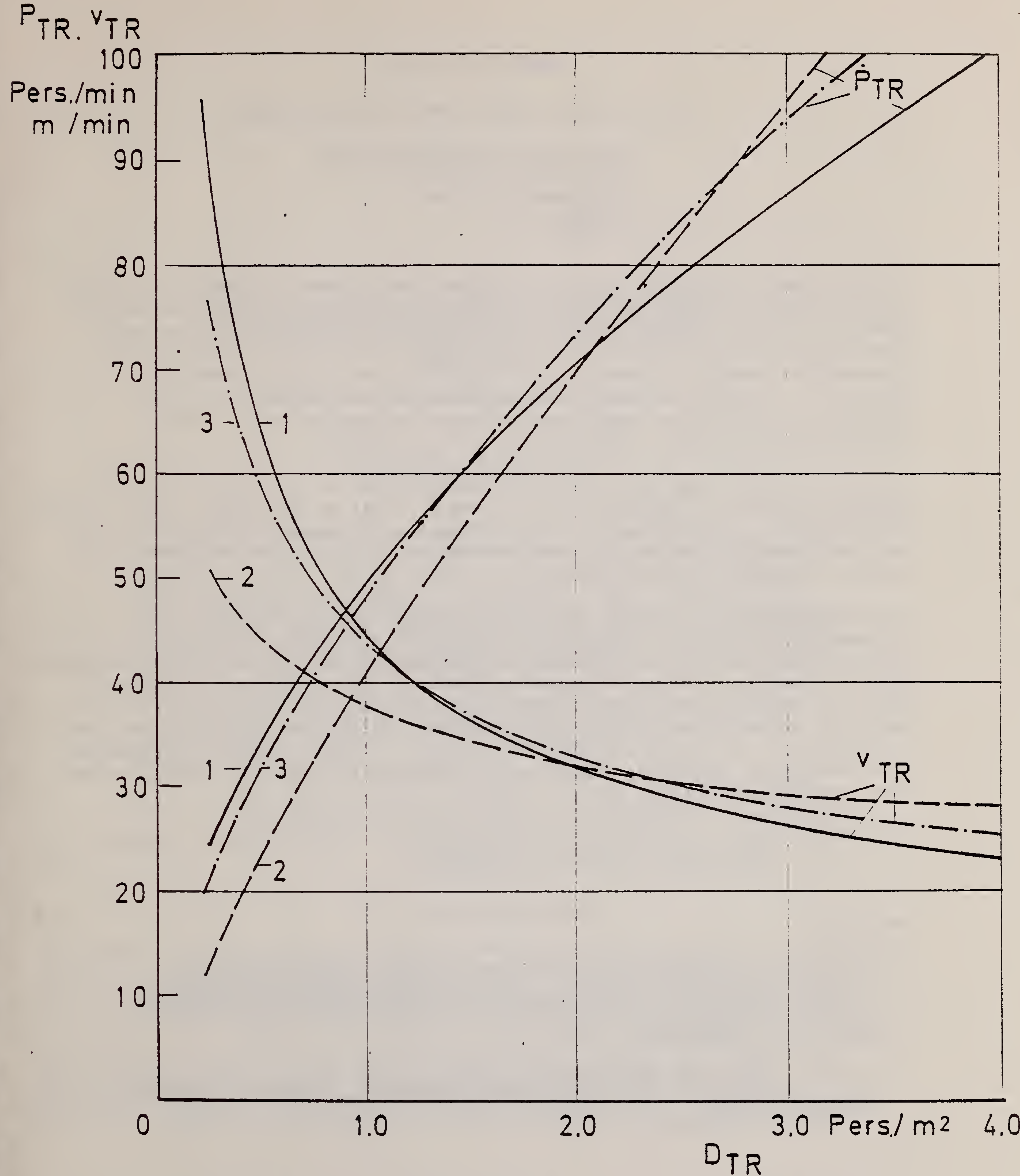


Fig. 14. Rate of flow of people v_{TR} and flow of people $\dot{P}_{TR}$ downstairs between two floors as a function of the density of people D_{TR}
1,2,3 Evacuation 1,2,3

FIRES IN DWELLINGS

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Over the past few decades new fire problems have arisen as a result of changes in the planning, construction and contents of dwellings. There has been a number of fires in houses of both modern and traditional construction which have caused multiple deaths, creating considerable national concern and a demand for remedial treatment, particularly where modern construction is concerned. However there is no agreement about the nature of the new hazards, partly because there has been very little feedback of detailed information from real fires.

To help fill this gap, the Field Investigation Section of the Fire Research Station undertook a detailed study of over 50 fires in dwellings, mainly houses and bungalows. They concentrated on cases involving some fire spread beyond the item first ignited so that the hazards due to the nature of the building and its contents could be assessed.

The first part of the report[1] deals with hazards due to ceiling and roof constructions. Part 2[2] deals with fire growth and spread in kitchens and living rooms, and the life hazards to occupants in other parts of the dwelling. Part 3[2] summarises the physiological effects of fire and gives some details from post-mortem examination reports of the 58 fatal casualties. Further parts of the report will deal with aspects of building construction, the use of detectors, and people's behaviour in fire. A final paper will summarise the findings of the investigation and the hazards it identified, and discuss some possible remedies.

Key Words: Fires; dwellings; multiple-deaths; construction; contents; physiological effects; behaviour.

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PRELIMINARY FINDINGS CONCERNING THE VALIDITY OF "BFIRES": A COMPARISON OF SIMULATED WITH ACTUAL FIRE EVENTS

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This report presents preliminary findings regarding the validity of BFIRES/VERSION 1, a computer program developed at the National Bureau of Standards to simulate egress movement by building occupants during fires. A computer simulation experiment was conducted in order to compare outcomes from BFIRES runs with data selected from an archival file summarizing actual fire results. Findings from this experiment suggest that BFIRES is capable of reproducing such important fire outcomes as loss-of-life and numbers of persons ultimately escaping. In addition, patterns of egress behavior produced by BFIRES were compared with those found in the literature, with professional opinions, and with impressions gathered from anecdotal accounts. With few exceptions, these comparisons illustrate agreement between simulations and other data sources.

Keywords: Architectural research; building fires; computer-aided design; computer simulation; environmental psychology; fire research; fire safety; human performance; modeling technique; simulation.

1. Introduction

1.1 Problem and Objective

Numerous attempts to simulate pedestrian movement in buildings appear in the literature [1, 2, 3, 4][1]. In addition, several investigators addressed the specific problem of emergency egress during fire conditions, using computer simulation techniques [5, 6, 7, 8, 9, 10].

These studies represent a wide variety of approaches to conceptualizing pedestrian movement behavior. For example, the discrimination learning model employed by Studer and Hobson contrasts with the information processing approach used by Wolpert and Zillmann, and by Stahl. Similarly, a broad spectrum of simulation techniques have been employed. Almost the entire range from deterministic input/deterministic simulation, through stochastic input/stochastic simulation, is represented in the literature.

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[1] Figures in brackets indicate the literature references at the end of this paper.

None of the investigators discussed above, however, has published results of research illustrating the predictive validity[1] of a simulation program. As a result, it is not yet possible to make specific statements regarding the usefulness of these programs to building design, regulation, and evaluation. The objective of this report, therefore, is to report preliminary findings concerning the external validity of BFIRES/VERSION 1. This computer program was designed to simulate egress movement behavior by building occupants, and was developed at the National Bureau of Standards [9, 10].

1.2 Overview of BFIRES/VERSION 1: State-of-the-Art

The conceptual development, structure, and function of the BFIRES computer simulation program was presented in detail by Stahl [9]. In brief, the model underlying this program was derived from a nonstationary, discrete time Markovian analysis of the building fire problem. The model postulates that occupants formulate strategies, make decisions, and take actions dynamically, in response to social and environmental information fields which change over time. The model recognizes the transactional relationship between occupants and their environment, which results when the responses of humans are influenced by features of the environment which the occupants themselves change or control. The computer simulation of these processes is accommodated through BFIRES, a library of FORTRAN V routines. This report presents an analysis of outputs from BFIRES/VERSION 1. A second generation of this program is currently under development at the National Bureau of Standards.

Stahl [10] documented results of experiments designed to calibrate BFIRES, to determine its range of applicability, and to assess the program's sensivity to important parameters. That study illustrated a number of important findings. Namely:

(1) a variety of general egress situations could be simulated by BFIRES;

(2) every such event is unique, and is defined by the set of user-supplied parameter values which describe the building, the fire threat, and the occupants;

(3) BFIRES is useful in simulating environments of known (or desired) spatial dimension, and events of known (or anticipated) temporal duration; and

(4) BFIRES outcomes are sensitive to variations in a number of parameters of immediate interest to the building designers (e.g., floorplan configuration, exit arrangment, occupants' locations).

2. An Examination of the External Validity of BFIRES

2.1 Levels of External Validity, and General Approach

Two criteria are essential to the validation of computer simulation models. These involve questions of predictability and plausibility: Does the computer program generate outcomes predictive of those found in the real-world under the conditions allegedly simulated? Are behavioral scenarios and outcomes produced by the program reasonable, or likely to occur in the real world (i.e., do they exhibit face validity)?

The predictive validity of BFIRES outcomes was tested indirectly, not by attempting to predict results of future fires, but rather by measuring the degree to which the program could replicate actual historical fire events for which appropriate data was available. The plausibility criterion was examined by comparing simulation outcomes with conclusions drawn by other investigators.

2.2 Test of Predictive Validity: A Case Study

The objective of this case study was to determine whether data describing simulated fire outcomes conformed with those found for real events. Meyers [11] reviewed the

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[1] Predictive validity concerns the ability of a simulation to predict future real-world events.

NFPA-FIDO[1] data base in order to determine whether certain trends were strong enough to justify various design recommendations. Data in the FIDO files are derived from news media, reviews of accounts published in trade and technical journals, NFPA investigative reports, fire department reports, and insurance company reports.

This data base contains information in a number of categories, primarily: (a) property identification; (b) fire origin; (c) fire spread; (d) casualties; and (e) physical losses. For some incidents, floor plans of residential units are also provided. Three types of data were of particular interest in this study:

(1) dwelling unit floor plan;
(2) dwelling unit loss-of-life index;
(3) adjacency of dwelling unit exit to room-of-origin entry.

These are explained below.

Meyers reviewed the FIDO files, and selected those incidents in which residential fires originated in kitchens. All dwelling units chosen had substantially similar floor plans and numbers of occupants, and varied primarily in the degree of exit adjacency. For such cases, he recorded loss-of-life index data reported in the files. For this study of predictive validity, the floor plans reported in the FIDO files were idealized for input into BFIRES, and to as great a degree as possible, the fire events were recreated.

All simulated fire events were run for several variations of a basic floor plan. These variations were constructed to simulate those found in the FIDO files. In all cases, four occupants were assumed to inhabit the dwelling units. It was also assumed that the events occurred during the night hours, and that the occupants were located in the bedrooms. The floor plans varied across classes of events, in order to reflect: (a) adjacency of dwelling unit exit to kitchen entry; and (b) number of exits from the dwelling unit. The floor plans are exhibited in Figure 1.

Two levels of the adjacency variable were studied. In the adjacent condition (Condition A), an occupant would be forced to pass within a single "step" (in BFIRES terms)[2] of the kitchen entry in order to reach the dwelling unit exit. In the non-adjacent condition (Condition B), an occupant could reach the dwelling unit exit without even entering a space adjacent to the kitchen entry.

Floor plans with both one and two dwelling unit exits were studied. In the two-exit case (Condition C), one exit was relatively near the kitchen entry, while remote from the sleeping areas. The second exit was located within one of the bedrooms, and was remote from the room of fire origin (the kitchen).

In order to make direct comparisons with data reported in the FIDO files, dwelling unit loss-of-life (D.U. LOL) indices were computed from simulated fire outcome data. The loss-of-life index was intended by NFPA as an indicator of the number of fire fatalities relative to the total number possible for a given dwelling unit. Since the actual number of occupants must be expected to vary from time to time for any dwelling, the index was defined in terms of average potential occupancy (determined by the number of bedrooms present). Thus:

$$LOL = \frac{1}{b+1} \qquad (1)$$

[1] National Fire Protection Association Fire Incident Data Organization.

[2] BFIRES simulates pedestrian movement as a sequence of discrete spatial relocations, or "steps." In the current experiment, such a step is equivalent to 30 inches (0.76 m).

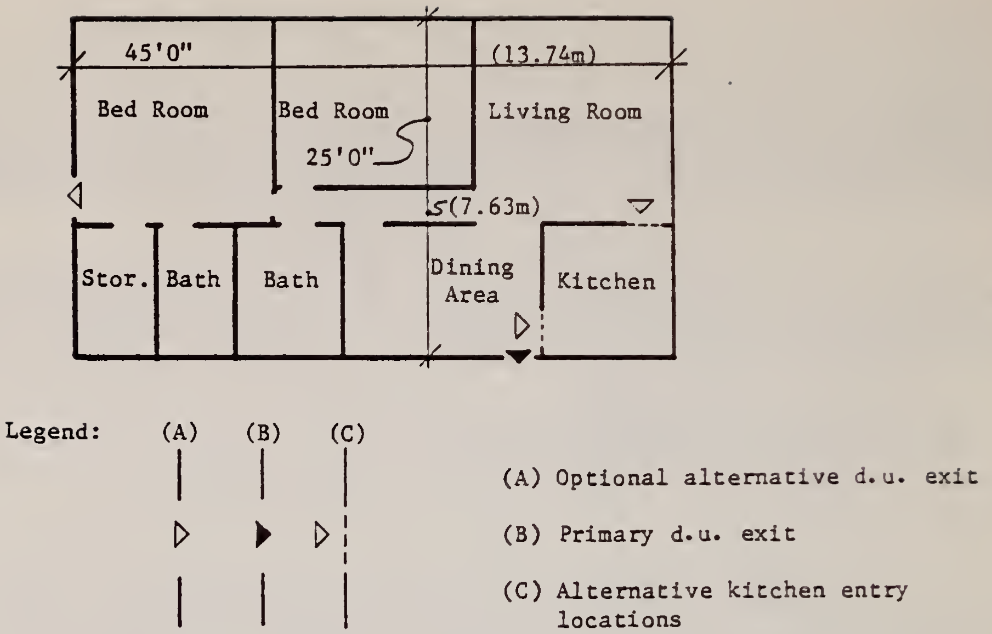

Figure 1. Schematic Plan of Dwelling Unit Showing Variations in D.U. Exit and Kitchen Entry Locations

where:

LOL = dwelling unit loss-of-life index;
f = number of fatalities in the dwelling unit;
b = number of bedrooms in the dwelling unit.

Simulated events were run for 200 time frames, corresponding to approximately four minutes of real time. Most fire professionals agree that, in general, a person who has not been removed from a fire in a small area (such as an apartment) within four minutes has a very low chance of survival at all. Thus, the simulated D.U. LOL index was computed as:

$$LOL' = \frac{f'}{b + 1} \tag{2}$$

where:

LOL' = simulated dwelling unit loss-of-life index;
f' = number of simulated occupants in the dwelling unit at the 200th time frame;
b = number of bedrooms in the dwelling unit.

Comparisons between simulated events, and those reported in the NFPA-FIDO files were studied through the examination of three of hypotheses:

(1) In simulated one-exit dwelling units, LOL' is greater in cases where there is kitchen entry/d.u. exit adjacency, and lower in cases where no adjacency exists.

(2) In simulated cases where there is kitchen entry/d.u. exit adjacency, LOL' is lower when an alternative d.u. exit is provided, and higher when no alternative is available.

(3) For all exit and floor plan arrangements, simulated data does not differ significantly from actual fire data reported in the NFPA-FIDO files.

As mentioned above, LOL data for cases corresponding to the experimental design were extracted from the FIDO files [11]. Data from simulated cases were obtained by establishing computer input files corresponding to each hypothetical condition, and then by replicating each condition ten times[1]. Because the FIDO sample was quite small, comparisons were made using only five of the original ten computer replications, and in particular, zero values of LOL' were selectively omitted. This was done to bring the balance between cases having fatalities and those having no fatalities more closely in line, beteween the simulated and real situations. It is recognized, however, that the selective omission of cases may have biased results reported below. The hypotheses enumerated above were examined by means of one-tailed t-tests for independent groups.

2.3 Findings and Discussion

Simulated data are reported in Table 1. Comparisons between simulated and FIDO data are shown in Table 2. When comparing differences between simulated fire conditions, it was found that: (a) the dwelling unit loss-of-life index was significantly greater for the plan exhibiting kitchen entry/d.u. exit adjacency, than for the plan in which no such adjacency was present ($t=16.00$, 18 degrees of freedom (d.f.), significant at the .01 level); and (b) the loss-of-life index was significantly lower for the floor plan which provided a second means of egress from the dwelling unit, than for the plan containing only a single exit adjacent to the kitchen entry ($t=10.00$, 18 d.f., significant at the .01 level).

Table 1. Loss-of-Life Indices for Simulated Residential Fires

Replication	Condition A	Condition B	Condition C
1	.00	.33	.33
2	.00	.00	.33
3	.00	.00	.00
4	.67	.33	.00
5	.00	.00	.00
6	.33	.00	.33
7	.33	.00	.00
8	.00	.00	.00
9	.33	.00	.00
10	.67	.00	.33
Means	.23	.07	.13
Std. Devs.	.28	.14	.16

Note: Condition A: kitchen entry/d.u. exit adjacency

Condition B: no adjacency

Condition C: two d.u. exits

[1] BFIRES generates stochastic simulations. Thus, numerous runs conducted under identical starting conditions result in a distribution of outcomes.

Table 2 Comparisons of Loss-of-Life Indices Between Real and Simulated Residential Fires

	Condition A		Condition B		Condition C	
Replication	Simul.	Real	Simul.	Real	Simul.	Real
1	.67	.67	.33	.00	.33	.00
2	.33	1.00	.33	.00	.33	1.00
3	.33	.67	.00	.00	.33	.00
4	.33		.00		.33	.33
5	.67		.00		.00	
Means	.47	.78	.13	.00	.26	.33
Std. Devs.	.20	1.10	.14	.00	.10	.47

When simulated data were compared with those obtained from the FIDO files, the following results were found: (a) no significant difference in D.U. LOL was noted for the one exit/adjacency condition ($t=-1.29$, 6 d.f., n.s.); (b) D.U. LOL was significantly higher in simulated fires than in the actual events, for the one exit/non-adjacent condition ($t=13.00$, 6 d.f., significant at the .01 level); and (c) no significant difference in LOL was noted for the two exit condition ($t=-1.40$, 7 d.f.).

The analyses of comparisons between the simulated conditions support hypotheses (1) and (2), and indicate that, for the environmental and occupancy situations specified, BFIRES produces trends conforming to those found in an actual historical data base. For two of the three conditions studied, analyses of comparisons between simulated and historical data support hypothesis (3), and suggest that BFIRES is capable of reproducing certain kinds of event outcomes.

These comparisons with the NFPA-FIDO data reinforce the possibility that BFIRES is sensitive to certain important parameters, as illustrated earlier by Stahl [10]. In particular, variations in factors under the direct control of building designers and regulators (floor plan and exit arrangement, and numbers of exits) seemed to have a substantial impact upon the likelihood of escape.

The study illustrating the sensitivity of BFIRES also suggested that this effect should be especially pronounced in cases where occupants could be assumed not to vary in such factors as exit knowledge (familiarity with the building's layout) and mobility. In the comparisons described here, occupants were assumed not to vary in both the simulated and historical cases. A test of the hypothesis that occupant factors interact with environmental variables, such that under certain conditions variation in occupant factors wash out environmental effects, is left for future study.

Finally, it must be noted that while simulated fire outcomes (i.e., loss-of-life indices) generally conformed to those found in an actual historical data base, these findings offer only indirect evidence of the correctness of the behavioral processes simulated by BFIRES. Important tasks for future research will be, therefore, to examine BFIRES-simulated behavior under a very wide spectrum of cases, and similarly to examine alternative models and explanations of emergency egress behavior.

2.4 An Examination of Face Validity

Comparisons such as the one discussed above provide primary evidence concerning the validity of a computer simulation program, and help to delineate the boundaries and conditions of its application. Of somewhat less obvious value are analyses of a simulation's "face validity," in which correspondence between simulated events and results reported in the literature is sought, and in which comparisons between simulations and conventional and professional wisdom are considered.

Comparisons between BFIRES outcomes and phenomena reported independently by other investigators may be of value in determining (at least on some qualitative level) the external validity of the simulation model. Moreover, such comparisons should further illuminate the boundaries within which BFIRES is applicable.

Perhaps the most important contribution by the London Transport Board researchers [12] was their realization that complex pedestrian systems must be studied in their entirety, since various segments of such systems tend to vary in terms of their carrying capacities and other characteristics. BFIRES sensitivity analyses reported by Stahl [10] appear to conform with the overall opinions of the former investigators. That is, BFIRES data suggest that varying degrees of route "constriction" produce differences in movement behavior, and variation in such important outcomes as egress time. These simulated data indicate that, to a point, increased constriction results in more direct movement toward the exit goal, and thus shorter egress time.

Appleton and Quiggen [13] reported that stress, fatigue, and indecision all had negative effects on rescue performance during a mock evacuation on an actual hospital ward. Although rescue activities are not accommodated by BFIRES, sensitivity tests reported by Stahl [10] suggest that, in general, indecision and mobility impairments act to increase occupants' egress times, and reduce their overall performance during computer-simulated fire events.

Finally, Wood [14] and Bryan [15] reported that evacuation often is <u>not</u> the first action taken during residential fires, and that it often occurs in conjunction with such other actions as alerting other occupants, rescuing others, and calling the fire department. BFIRES directly simulates pedestrian movement only, and on the assumption that the decision to evacuate has already been made <u>prior to the onset of a simulation run</u>, such movement may be construed as "evacuation." However, the movement of occupants during the simulated events frequently deviated from an optimal path toward a safe exit, even when simulated individuals were "familiar" with the building (i.e., knew the location of the safe exit), were mobile, and were making decisions on the basis of unambiguous and correct information. Although simulated occupants did not "investigate the fire," "alert others," etc., <u>per se</u>, each of these activities has the effect of <u>using up potentially valuable time</u>. It is this characteristic of the Wood and Bryan findings which appears to be simulated by the deviations and detours generated by BFIRES. Thus, both the Wood and Bryan surveys, and BFIRES simulations all agree that uni-directed exiting behavior is not necessarily an outcome of a fire alert. Occupants may choose to traverse a less direct--but equally purposeful--route to that final exit goal.

Bryan and Wood also reported that, on the basis of their findings, familiarity with the building layout correlated with neither evacuation speed nor the directness of the egress route. These findings do not support BFIRES results which indicate that, despite the deviations and detours described above, familiarity is a necessary component of rapid and direct evacuation.

Over the years, professional architects, fire protection engineers, and building regulatory officials have developed a body of opinion concerning various aspects of occupants' emergency egress behavior patterns. Much of this conventional/professional wisdom has been built into design and regulatory practice, and concerns: (a) the provision of appropriate numbers of exits; (b) the problem of blocked egress ways; (c) the clarity and simplicity of egress system design; (d) dead-end corridors; (e) occupant density; (f) familiarity and emergency training; and (g) the effects of special occupant capabilities (e.g., those of elderly or handicapped populations). In many ways, <u>independently derived</u> outcomes from BFIRES simulations concur with professionals' opinions and beliefs about many of these issues.

Design professionals have long agreed that no building occupant should ever be trapped in a situation where the only egress path was blocked. As a rule, a minimum of two exits are therefore provided in buildings larger than two-family dwellings. The possibility that a single exit could, if blocked, easily entrap occupants, and the notion that this problem is readily mitigated by the provision of an alternative exit, are amply demonstrated by the simulated data presented in Section 2.3 of this report.

Professionals have also believed that in general, shorter and more direct pedestrian circulation paths reduce ambiguity and increase the likelihood of safe emergency escape, especially where occupants are unfamiliar with the building layout and exit locations. This belief was partially replicated by BFIRES simulations, which suggest that well-defined paths result in short egress times when people are familiar with exit locations. However, simulated occupants who are not familiar with exit locations are not likely to escape, regardless of the clarity with which the circulation system was designed.

Finally, building professionals generally agree that: (a) persons familiar with exits and egress routes (whether through continual use or through training) are more likely to escape in a reasonable period of time; and (b) mobility impaired occupants will require more time for evacuation than will their unimpaired counterparts. Both of these expectations are amply supported by BFIRES data presented earlier by Stahl [10].

Fire reports published by the National Fire Protection Association in the last five years were reviewed during the course of this investigation. Fires in various types of residential facilities were selected for content analysis. These included: (a) multi-family dwellings; (b) hotels; (c) dormitories; and (d) nursing homes. A number of general patterns were recorded, and BFIRES-produced behaviors appear to conform with these:

(1) After being alerted to the fire danger, occupants frequently took time to dress and collect their belongings. In these cases, evacuation was neither immediate nor direct.

(2) Where dead-end corridors were present, some occupants reported overshooting emergency exit doors.

(3) Walking toward the fire was occasionally reported by persons specifically seeking the exit, even in cases where the safe exit was in the opposite direction.

(4) Evacuees tended to move toward the most familiar exit.

(5) Mid-stream direction changing was often reported, even in cases where such behavior could not be traced to any sudden change in environmental circumstances.

(6) Indecision was frequently reported.

3. Summary and Conclusions

The external validity of the BFIRES simulation program was evaluated. An analysis comparing outcomes from BFIRES simulation runs with data selected from an archival file was discussed. Results of this analysis suggest that, within the boundaries established by the sample, BFIRES is capable of reproducing certain important fire outcomes, such as numbers of persons ultimately escaping, and loss-of-life.

In addition, the general patterns of emergency egress behavior produced by BFIRES were compared with those found in the earlier research literature, with professional opinions about such behavioral patterns, and with general impressions gathered from anecdotal accounts. In general, these comparisons illustrate agreement between simulation results and various independent sources, and suggest that convergence is possible. Two important exceptions are: (1) BFIRES results exhibit a positive correlation between occupants' familiarity with the building layout, and the speediness and directness of their escape, although no such correlation was found during the field surveys by Wood [14] and Bryan [15]; and (2) BFIRES results suggest that occupants unfamiliar with the physical layout of the building will not be helped by designs providing shorter and more direct egress routes, while conventional wisdom suggests that short, direct, and unambiguous routes should be especially helpful to unfamiliar occupants.

In view of the findings discussed above, several directions for future research are anticipated. First, additional simulation studies of the type presented in Section 2.2 will be conducted over as broad a range as permitted by available data bases. These studies will provide BFIRES users with much needed empirical evidence concerning the boundaries within which the simulation program may be considered valid and applicable. Further, as the program is validated against a broader range of occupancy categories, the boundaries will themselves be expanded. Second, other methods of validating BFIRES will be examined and applied, in order to demonstrate convergence more analytically than has been attempted thus far. One candidate method is a variation of "Turing's Test", in which experts in the fire field would be asked to distinguish real fire scenarios from those generated by the computer. Finally, it is expected that future validation efforts will illuminate important aspects of emergency egress behavior that either have not been accommodated by BFIRES, or have been treated incorrectly within the program. Thus, future research concerned with validating BFIRES will be simultaneously directed toward modifying and improving the capabilities of the computer simulation program.

Funds for this study were provided by the Center for Building Technology, National Bureau of Standards (NBS). The research was partially supported by the Center for Fire Research, through the NBS-HEW Fire/Life Safety Program.

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* The Importance of Role Assumption in the Behavior of People in Fires

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A tragic fire in the Beverly Hills Supper Club[1/] caused the deaths of 165 people; yet, close to 2400 escaped under the most adverse fire conditions. An investigation was undertaken to identify what factors may have contributed to, what proved to be, a very orderly and cooperative egress. Two sources of data were utilized. They were (1) 1100 questionnaires, completed by patrons who were at the club this fatal evening, and (2) 131 interviews by police and arson investigators with patrons and staff. From a study of these data sources it became apparent that a very consistent pattern of leader-follower behavior, which was termed role assumption, took place. Further, it was hypothesized that staff actions were predominantly "other" serving while patron actions were predominantly "self" serving. This hypothesis was formally tested and shown to be true to a very high level of statistical confidence ($\alpha = .001$). The behavioral climate which apparently produced this phenomenon were:

(1) The staff respected the owners as capable, even if tough, leaders.

(2) Staff took care of the patrons at the tables, rooms or stations assigned to them before and during the fire emergency.

(3) Patrons looked to the staff for guidance.

A number of behavioral research questions were posed relative to the conditions under which this altruistic behavior in fire emergencies might be expected.

1/ R. L. Best, "Reconstruction of a Tragedy; the Beverly Hills Supper Club Fire," The National Fire Protection Association Boston, MA, May 28, 1977

* Only an abstract of the talk is printed here. For the complete reference, see:

Joseph Swartz "Human Behavior in the Beverly Hills Fire" <u>Fire Journal</u>. May, 1979, pp. 73-74, 108.

FIRE PREVENTION IN SCHOOLS AND BOARDING SCHOOLS FOR HANDICAPPED

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Ministerie van Nationale Opvoeding
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This study was designed to assist in developing new safety requirements for schools and boarding schools for handicapped children and adolescents. Existing requirements did not satisfy the Belgian School Building Fund (SBF).

The deficiencies of the handicapped fall into the areas of perception, response, and mobility. Eight general categories of disabled--children with mental handicaps or with emotional disturbance, children with physical handicaps only, children with auditive deficiencies, and children with visual deficiencies--are described in terms of these areas and recommendations are made with regard to building design, construction, equipment and staffing. Under existing classifications of the handicapped, children who are both bodily and mentally handicapped are classified according to their mental impairments. Hence the SBF organized an investigation (December 1977) to get information on the number of pupils in mentally handicapped groupings who also had mobility problems. Data are given for schools and boarding schools on percentage of nonambulatory among mentally, emotionally, or functionally handicapped students and on the percentage of nonambulatory among the physically handicapped.

This paper considers the problem of evacuation in schools for the handicapped. It describes a hypothetical egress pattern for schools for mentally or physically handicapped housing a mixture of ambulatory and nonambulatory students; discusses existing and desirable personnel/pupil ratios; gives data on two nighttime fire drills from special boarding schools; discusses limited versus complete evacuation, and recommends those building levels on which children with various types of handicaps might be placed.

Key Words : Ambulatory people; boarding schools; children; egress; evacuation; fire drills; fire prevention; fire safety; handicapped; mental retardation; mobility; schools.

1. Science and technology are soaring so boldly, that our industrial capabilities are constantly being expanded. Overwhelmed by these brilliant achievements, we are insufficiently aware of the greater risks sometimes inherent in such advances. Our very existence has been entwined by the wires and pipes of a treacherous energy-web. The potential for disaster is sitting at our morning table; it is hiding in our daily avocations; it is slinking around our nightly bed. Living safely is getting more difficult.

Major fire disasters of the last decade in all industrialized countries have underlined the need to devise adequate protection measures against traditional and especially against new hazards. In this extensive field, the Belgian Institute for Normalization (B I N) and the Belgian Commission of Fire Technology have been active for several years in setting up norms (NBN) relating to fire prevention in buildings.

2. Adequate fire protection is built up through ongoing consideration of some constant and many alterable factors. Safety in a building is a complex notion indeed, depending on
- the design and construction of the building (constant factor);
- the contents of the building (variable factor);
- the occupants' behaviour (highly variable factor).

2.1 The building, as a solid environment, holds and protects its contents and the human activities inside. In its design and structure it should closely match all the dimensions of these functions, including those which aim at fire safety.

2.2 The contents, in their turn, are relative to the occupants' activities and to their mental and physical abilities. These activities often require apparatus, machines, equipment, furniture and stocks that may hide unsuspected fires and associated risks such as smoke and toxic gas generation.

2.3 Finally, the users' daily avocations breed a multicellular mosaic of hazards which are constantly challenging safety in the building. Prospect and caution, prevention habits, self discipline, regular checking and maintenance are the positive poles of sound safety behavior. Age, mental and physical condition, education, assimilated information and applied experience together draw the daily safety diagram of a community.

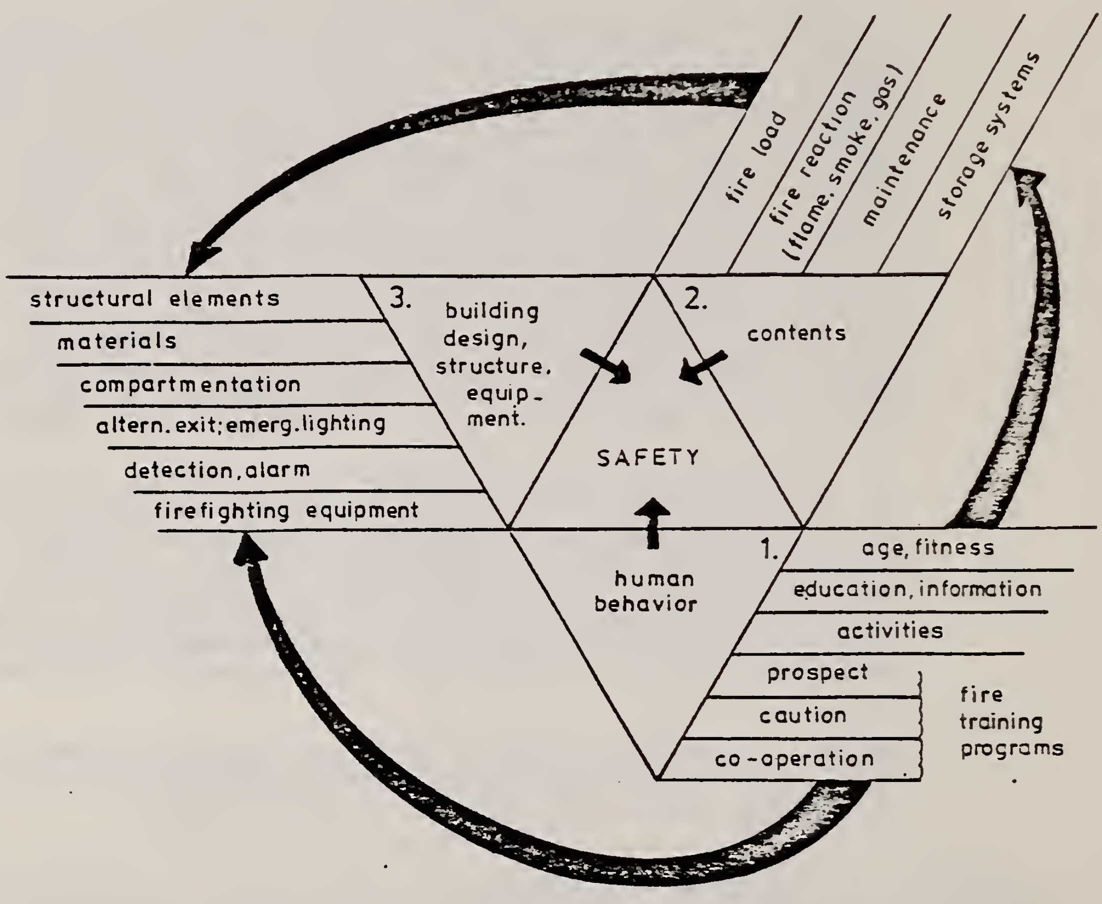

Diagram 1: Components of the SAFETY notion; logical growth philosophy of fire prevention norms.

But above and beyond this day to day preventive consciousness stands the overwhelming question of the human response to imminent disaster situations : what do the occupants know, how do they judge, what are they able to do and how do they actually respond ? Only well trained readiness of mind, quick decision making and drilled co-operation may, together, shape an adaptive behavior pattern in stressful conditions.

3. This analysis shows that fire prevention norms and standards should actually take their roots in research on human behavior and activities. The respective tasks are clearly defined : the users of buildings should prevent a fire from breaking out; the architect, by his design, must prevent a fire, once started, from expanding so rapidly that lives are endangered (1)[1].

Thus the draft of building safety regulations should start with measuring hazards originated by daily activities in the premises and with the prospect of human abilities and failures on the threshold of disaster. The risks do not stem from the contents only, but more importantly in the way people act, with or without manipulation of these contents.

According to these risks, fire preventive, fire protective and fire restrictive settings should be included in the building at the start. When planning a building, one should study the fire resistance of structural elements; the fire reaction of the building materials; the fire and smoke compartmentation; the alternative exit ways, horizontal and vertical, with their emergency lighting; the systems of detection, warning and alarm; the firefighting equipment (cf. diagram 1).

4. Although a code relating to fire prevention in buildings only deals with their design, structure and equipment, it has now become evident that such a code cannot be set up without primary reference to the human factor, i.e. the analytic research on what people might do in normal and in emergency conditions.

Throughout the scientific formulation of prescriptions and regulations, this human factor must always be the first and most important criterion, because the physical setting must match the users' abilities and shortcomings.

5. This is the predominant philosophy in the following considerations on safety in schools and homes for handicapped children and adolescents.

* * *

6. Motivation of the study : the publication, for critics, of a draft norm (2) on safety requirements for school and boarding-school buildings. Three chapters of the draft norm deal with institutes for handicapped children and adolescents in a way that did not satisfy the School Building Fund (= the office responsible for school construction in Belgium : SBF). Obviously the amendments SBF wanted to introduce needed a solid base of real facts and actual situations, and that is what originated the study.

7. For educational purposes, handicapped children and adolescents are organised in 8 types, according to their deficiencies :

1. light mental handicap
2. moderate and severe mental handicap
3. troubled character (emotional handicap)
4. physical handicap
5. chronic illness
6. auditive deficiency
7. visual deficiency
8. functional or learning deficiencies.

8. These groups can be consolidated into mental or psychological (1, 2, 3 and 8), physical (4 and 5) and sensorial (6 and 7) deficiencies, or finally into mental and physical handicaps. This however is a dangerous generalization stemming from the fact that nearly all schools for the handicapped provide education for types 1, 2, 3 and 8 and also, in most cases, type 4. Children of types 6 and 7 respectively attend specific schools.

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[1] Figures in brackets indicate the literature references at the end of the paper.

9. Logical research for safety in these special schools and homes calls for a fundamental analysis of the pupils' shortcomings as to <u>perception</u>, <u>response</u> and <u>mobility</u>, the negative results of which should be met by special arrangements in

- the <u>design</u> of the building layout (number of levels; nature, length, width, number and situation of exitways; compartmentation).
- the <u>construction</u> of the building (fire resistance of structural elements; fire reaction of materials).
- the <u>equipment</u> of the building (detection, warning, alarm).

10. <u>Such analysis, in comparison to normal childrens' capacities</u>, results in the following findings :

10.1 <u>Children with mental handicaps or with emotional disturbance</u> suffer from slower and sometimes confused perception, hence their slower and often wrong reactions :

a. longer exposure to growing danger, owing to delayed egress :

longer fire resistance (Rf) of structural building elements; more favourable fire reaction of building and equipment materials.

b. faulty control of movements, resulting in slower progress on stairs :

as few levels as possible and/or horizontal proceeding to safety.

c. panic readily occurring, so crowding should be avoided :

more and smaller compartments.

d. closer guidance by staff (the teacher/pupil ratio being higher) :

intense and frequent fire-drill of staff.

10.2 <u>Children with physical handicaps only</u> : have normal perception capacities and are able to deduce normal reactions which however they are not able to perform, owing to lack of mobility :

a. most of these children cannot evacuate without help, nor can they proceed on stairs :

need of more fire trained staff; horizontal proceeding to safety; if possible, avoid location on levels other than ground floor; no stairs in evacuation routes.

b. if pupils stay on levels above or beneath the ground floor :

fewer stairs and more protected elevators; dimensions of elevator cabs should allow several wheel chairs or stretchers.

c. panic is likely to occur, owing to helpless condition; so crowding should be avoided :

more and smaller compartments.

d. waiting in wheelchairs or on stretchers needs time and space :

more shelter area in protected compartments; stronger Rf of structural building elements.

10.3 <u>Children with auditive deficiencies</u> :

alarm should be adequately transmitted by staff, or : by day visual alarm; by night : electronic alarm.

10.4 <u>Children with visual deficiencies</u> : no visual perception of fire outbreak, but other sensorial faculties may be developed more intensely than normal.

a. emergency egress needs assistance; stairs are unsuitable :

need of more attending staff; horizontal proceeding to safety; sojourn on evacuation level only; no stairs in evacuation routes.

b. panic is more likely, owing to helplessness in unseen danger; therefore avoid crowding :

smaller and more compartments.

11. If separate schools and homes were to be built for each type of handicap, the framed insights stated in § 10 might well generate the specific prevention philosophy on which should be founded building and organization norms and regulations. But as already mentioned (§ 8), school structures (apart from deaf and blind institutions) always contain several different sections for specific handicaps.

12. Moreover, the classification (§ 7) seems to ignore the <u>multiple handicap</u> of the bodily and mentally disabled, because these most unfortunate children are classified according to their mental or emotional impairments. Still, in the study of security measures for this kind of schools and homes, it is obviously important to know whether there are bodily handicapped among the mentally or emotionally disturbed.

13. For this purpose, the SBF organized an investigation (December 1977) in the special schools and boarding schools of the Flemish community in Belgium. The aim was to get information :

- on one hand : on the number of pupils in sections 1, 2, 3 and 8 (refer to § 7) and among these, on the number of pupils who would not be able to escape from a building under fire, without help, owing to shortcomings in mobility;

- on the other hand : on the number of pupils in category 4 (physically handicapped) and among these, on the number of pupils unable to escape without help, on account of mobility shortcomings.

13.1 Schools : it was established that in 38 schools

- the total total number of mentally, emotionally and learning handicapped children and adolescents is 4316
- among these, the no. with impaired mobility is : 529 or 12,37 % .

Considering the schools separately, this average percentage varied from 0 to 57 % (cf diagram 2).

- number of physically handicapped : 503
- among these, the no. with impaired mobility is : 295 or 58,54 % .

Considering the schools separately, this average percentage varied from 20 to 100 % (cf diagram 2).

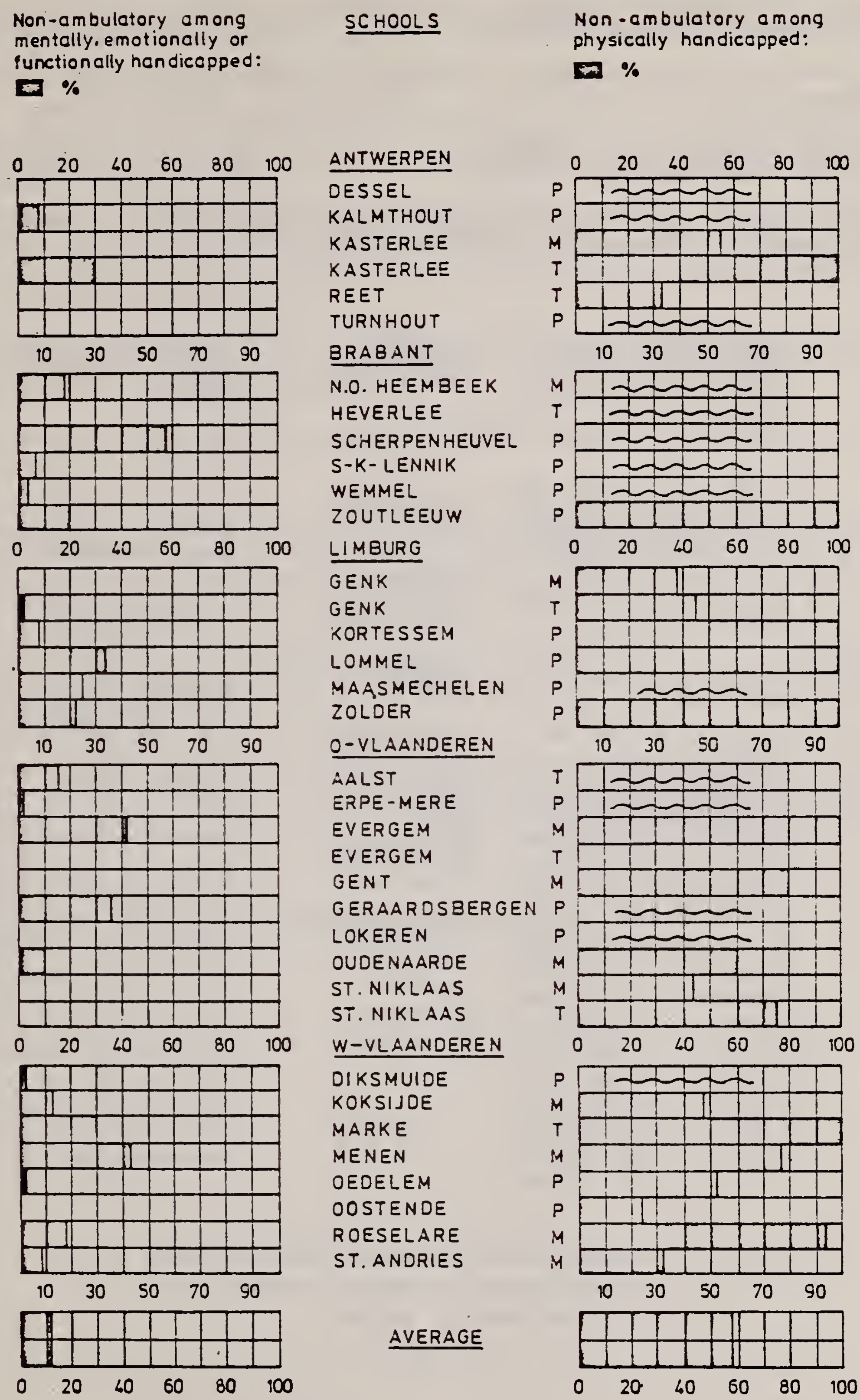


Diagram 2: Percentage of non-ambulatory among pupils in State Schools for Special Education.
P : Special Primary School
M : Medical-Educational Institute
T : Special Technical School
~ : non existing section

13.2 Boarding-schools : in 13 homes there appeared to be

- mentally, emotionally or learning handicapped : 382
- among whom with impaired mobility : 47 or 12,30 %

As to this average percentage, separate boarding-schools number 0 to 39,4 % (cf diagram 3).

- number of physically handicapped : 99
- among whom with mobility impairment : 83 or 83,8 %

Considered in separate boarding-schools, this percentage varies from 60 to 100 % of the physically handicapped (cf diagram 3).

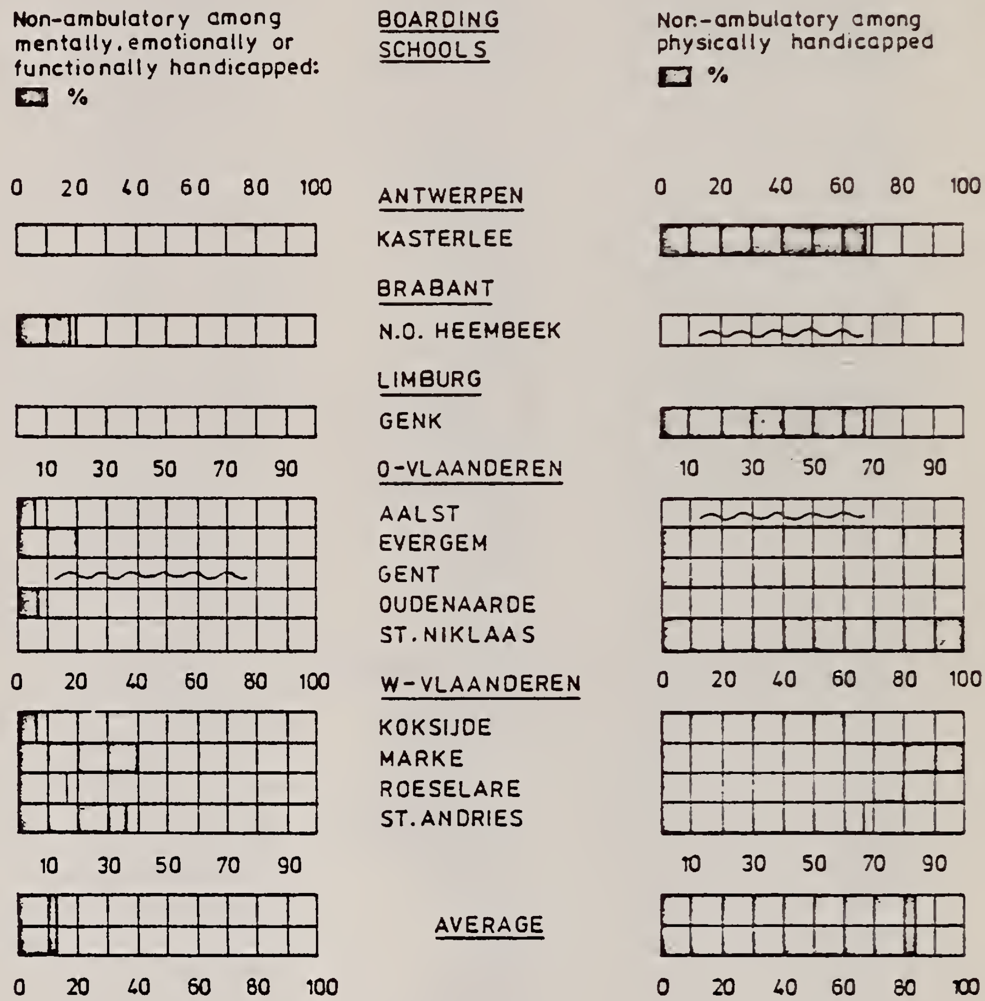


Diagram 3 : Percentage of non-ambulatory among the pupils of State Boarding Schools for Special Education

non existing section

14. For normmaking bodies, special schools and homes management, school building authorities and architects, this statistical approach contains some important information :

14.1 In special schools it appears that a 12 % average of the mental, emotional and learning handicapped have also mobility impairments. But this proportion may well go up to 60 %. In special boarding-schools this average also numbers 12 %, but it might well reach up to 40 %.

14.2 Not all physically handicapped in special schools have mobility impairments; the average is nearly 60 %, but in some schools 100 % was stated. In special boarding-schools 84 % of the physically handicapped suffer from mobility impairment, but this proportion sometimes rises to 100 %.

14.3 This outcome needs to be considered in the organic structure of schools and homes for handicapped, in building design and construction, in number and qualification of educational and medical staff.

15. Beyond all doubt the non-ambulatory handicapped raise substantial problems in the emergency egress procedures.

15.1 In normal social patterns handicapped individuals occur sporadically among the normal building occupancy. In case of fire they may rely on their fellowman's moral sense to assure assistance in getting out of danger in due time. This consideration also applies to the rare cases of physically handicapped pupils who attend schools with normal occupancy : for only one handicapped person, there are many helping hands.

15.2 Quite different is the situation in communities where the non-ambulatory make up a considerable minority, a big majority or even the entirety of a school or home occupancy. Here, many fewer hands are able and ready to help any one individual in case of disaster.

15.3 When a fire occurs in a school building with normal occupancy, the emergency egress proceeds according to a fixed and relatively simple pattern : the teacher (or the ward tutor at night) takes his group to the outdoors, or if such appears impossible, to another unthreatened building compartment from where, if need be, the fire brigade can rescue them.

15.4 But in a special school or home housing a considerable number of non-ambulatory handicapped, the egress pattern is quite different :

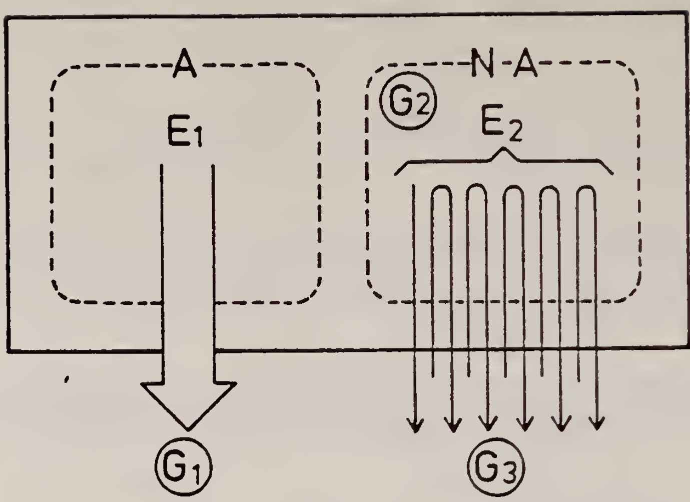


Diagram 4: Evacuation pattern of handicapped pupils.

- The ambulatory pupils (A) can be evacuated (E_1) in a group by the teacher or tutor to a place of safety, where they are guarded (G_1).

- To comfort, to guard (G_2) and to prepare the waiting non-ambulatory pupils (N-A) are combined actions that require a second teacher or tutor.

- Evacuation (E_2) of the non-ambulatory (N-A) pupils must be done individually and successively. They need to be escorted in wheelchairs, on stretchers etc. Even if one staff member can evacuate the pupils, it is better done by two or more, and preferable by as many staff members as possible. Once brought to the outdoors, these pupils must also be guarded (G_3) and comforted but this may be combined with G_1.

Even on combining $G_1 + G_3$, it appears that in cases of fire at least 3, preferably 4 or more supervisors are needed to lead a heterogeneous group of mentally and physically handicapped pupils to security.

On the other hand slightly and moderately handicapped children and adolescents have been reported (in daily life and in fire-drills) to drive away their non-ambulatory companions in wheelchairs : touching confirmation of the fact that most mentally handicapped children (especially those with Down's syndrome) are so affectionate. Yet it remains highly questionable whether one can count on this kind of help in real fire circumstances. Stress and fear situations (think of epilepsy patients) may engender incalculable reactions. On this account, most interrogated educators ($\pm$ 80 %) responded negatively to reliance on children assisting one another.

The above fictitious case (diagram 4) represents the egress scheme of a group of 20 pupils (8A + 12N-A); in phase E_2 two staff members are operating; they each evacuate one non-ambulatory pupil, in six repetitions. If only one educator were available he would travel twelve times, which would require twice as much time, assuming that there are no corpulent adolescents who need two persons to evacuate them.

15.5 It is obvious that the time spent for egress of N-A pupils is proportional to the number of staff members who can assist them.

Evidently the second important factor in egress duration is to be found in nature and length of the evacuation path; § 17 will be dealing with this aspect.

15.6 <u>In daytime</u>, the presence of more numerous personnel offers fair chances of performing emergency evacuation in due time, since besides teachers, other staff members (administrative, medical, social) and even manual service workers are expected to take part in the egress operation. Its mechanism however requires precise arrangements, accurate emergency provisions and practical drill of readiness to concentrate and co-ordinate activities in the most critical spot where the largest number of non-ambulatory pupils are located.

Counting all normally available staff and service and maintenance personnel, the ratio of personnel/pupils in special schools appears to attain an average of 1 to 3.6 in day time.

15.7 At night, conditions prove to be substantially worse. Each tutor is in charge of a number of pupils. In his permanent affection, devotedness and protection he can hardly take care of more than 10 children or adolescents while fostering the homelike atmosphere which is part of the proper therapy. For security's sake also, the number of 10 pupils entrusted to one tutor should not be overstepped. All of them might indeed be non-ambulant and in case of danger entirely dependent on help. As a rule, a night tutor does not leave his pupils, surely not when they are threatened by smoke or flames. Being quite alone, he faces an impossible task with discordant duties : global action in charge of the group and individual action in charge of the non-ambulatory whom he must help to escape one by one. Theoretically he may reckon on the assistance of a colleague whose group is not in immediate danger. But in practice (e.g in case of extended smoke spread) he should not rely on this questionable help. In addition we already know from diagram 4 that even two staff members cannot clear the situation without serious difficulty.

The average ratio of actually present personnel/pupils in special boarding-schools over night proved to be, at present : 1 to 13 (cf day-time ratio 1 to 3.6 - § 15.6).

In ordinary homes and boarding-schools one tutor is in charge of 21 pupils. We may assume, and experts confirm, that a handicapped child requires three times more care than a normal pupil, which already gave rise to claims for limiting to 7 or 8 the number of handicapped children and adolescents trusted to one night tutor. To be sure, such a criterion would engender more and smaller groups, but it would not do away with the problem of the conflicting tasks : to stay and to leave.

15.8 Combining the needs of medical care on one hand (night medication, indisposition, attacks, etc., which the tutor cannot face in full competence) and the security needs on the other hand, a solution might come from a ratio of one night tutor per 10 pupils and an infant nurse per 30 pupils who can assist in cases of emergency egress. This arrangement would result in a ratio of 1 to 7.5.

16. A school with normal occupants should be evacuated in 4 1/2 to 5 minutes, a boarding-school in 6 1/2 to 7 minutes after the alarm. A similar performance seems hardly possible in special schools and boarding-schools on account of the physical and intellectual condition of bodily or mentally or multiply handicapped children and adolescents. Let us have a close look at a couple of reports on fire-drills.

16.1 Night evacuation from a special boarding-school, built all over in ground level, in two pavilion complexes :

A. one organized in wards (I, II, III, IV)
B. one containing individual rooms only (V).

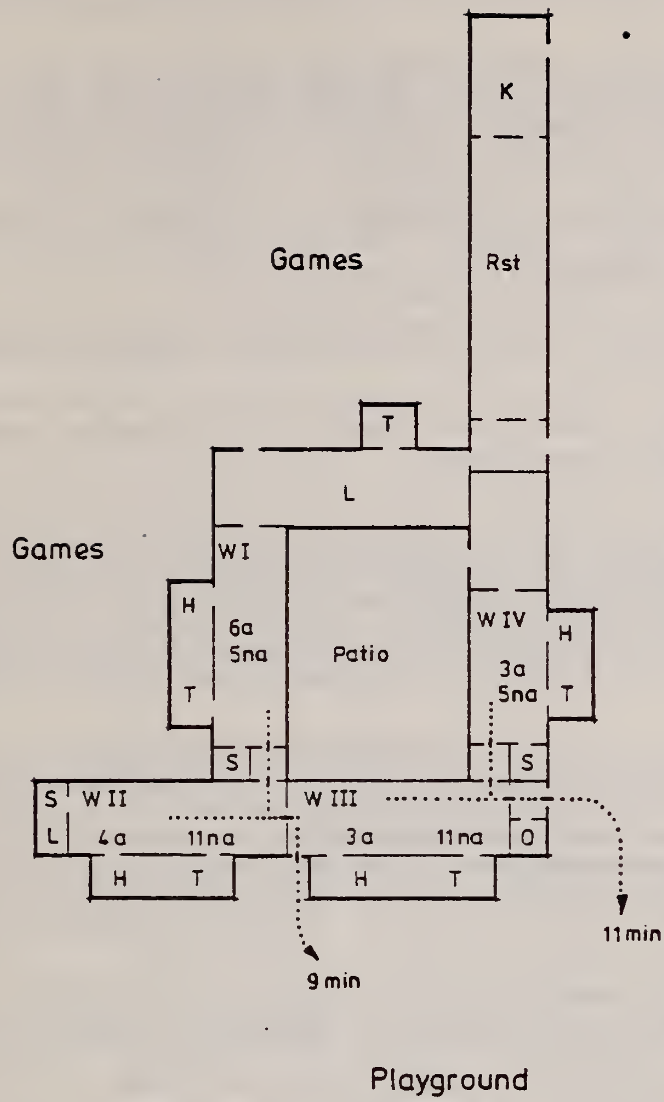
All 69 children are physically handicapped :

ambulatory (A) : 21
non-ambulatory (N-A) : 48 (cf diagram 5)

Location of pupils	Personnel	Egress time	
Ward I 6A + 5N-A = 11 " II 4A + 11N-A = 15	1	3 min 6 min	Pavilion A : 20 minutes as evacuation was performed successively
III 3A + 11N-A = 14 IV 3A + 5N-A = 8	1	8 min 3 min	
Bedrooms 5A + 16N-A = 21(*)	1	10 min	Pavilion B : 10 minutes for the same reason

(*) two of whom are corpulent adolescents who need to be carried by 2 persons.

Note that the tutor/pupils ratio is, on the average, 1/23.



a	ambulatory
na	non-ambulatory
B	individual bedroom
H	hygiene
K	kitchen
L	living
O	office
Rst	restaurant
S	staff bedroom
SL	staff living
T	toilets
W	ward
.....	egress road

Scale 1/500

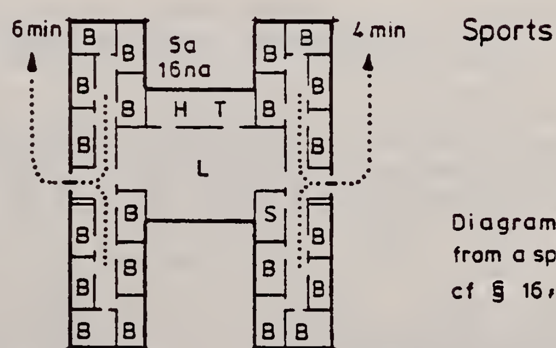


Diagram 5: Night evacuation from a special boarding-school cf § 16,1

16.2 Night evacuation from a special boarding-school, built on ground level only and composed of 3 pavilions linked by a gallery. All 55 children are mentally handicapped; 46 are ambulatory; 9 are not. Each of the pavilions was "evacuated" within 2 minutes; this means : the childeren were brought out of the wards into the gallery. No wonder that this very limited egress did take so.little time. Owing to the presence of 1 night tutor per ward with respectively 18, 20 and 17 pupils, the tutor/pupils ratio was an average of 1 to 18.

16.3 From several reports of and interviews with educators it is noteworthy that :

- One should not count on moderately and severely handicapped ambulatory children to assist their non-ambulatory fellows in case of fire. They will themselves be disturbed in such measure that they cannot possibly act without firm guidance of the educator.
- Egress procedures used to evacuate non-ambulatory handicapped : in wheelchairs, borne, transported on stretchers, dragged along on blankets and, with young children only : rolled off in their movable beds.
- There is a general request to build on ground level only.

17. In the search of a useful model for handicapped children's evacuation, § 15.5 mentioned two duration factors :

- the teacher/pupil ratio;
- the distance to be covered to reach a safe place without hindrances that might delay or stop the evacuees in their egress route.

What is a place of safety ?

17.1 The radical answer is : the outdoors. A. Tait's relevant statement on this matter is : "The ideal arrangement is the provision of escape routes so arranged that any occupant or member of the staff in a building can turn his or her back on a fire and proceed to make their way without hindrance, in the direction of open air until safety is reached " (3).This radical evacuation model can only be performed by non-ambulatory occupants if they are located on the ground floor and do not have to tackle steps and stairs problems on their way out.

17.2 In the limited evacuation scheme, egress from endangered rooms provisionally does not go farther than the next compartment which is not (yet) threatened by smoke or flames, owing to the fire-resistive capacities of its walls, ceilling, floor and doors. Thus such a compartment is a provisional shelter for the occupants of a nearby endangered compartment. If the egress routes from this shelter are practicable, the total evacuation can be done at a slower pace. If its egress ways prove to be cut off (as a result of extended flame or smoke spread) the evacuees must rely upon rescue by the fire-brigade.

For non-ambulatory handicapped located on a floor above or beneath ground-level, this model of limited evacuation offers quick but provisional safety in case of fire.

Moreover it should be noted that the limited evacuation model is in agreement with the general care system of treating the mentally handicapped in reducing or avoiding uneasiness, agitation, anxiety and other negative emotions. Limited evacuation, in search of quick provisional safety, applies the principle of minimal disruption. As E.W. Marchant (4) defines it, this amounts to moving as few people as possible as short a distance as possible.

18. One cannot make a preliminary choice between radical and limited egress. Fire conditions, even in the same building, may well impose either of the schemes.

18.1 At the outbreak of a fire nobody is able to predict its further evolution. The general rule to be applied in schools and boarding-schools with normal children demands radical evacuation, at once, for all and to the outdoors (1). Only if the further exits of a threatened compartment are blocked by smoke or flames should one accept the limited evacuation to a refuge compartment from where rescue by the fire-brigade can bring safety. The fewer occupants that are involved in such action, the better. In other words : radical evacuation whenever possible.

18.2 Properly speaking, there is no reason why this principle should not apply to special schools and boarding-schools. But pace and cumbersomeness here evidently compel the provision of more refuges with a view to offering quick provisional safety (5).

18.2.1 For the ground floor occupants these refuge compartments lie on the evacuation level; if they have the prescribed exits to open air, safety conditions may be seen as optimal : for the mentally and physically handicapped, mere horizontal evacuation is the quickest and the surest.

18.2.2 For the handicapped on other floors, horizontal evacuation to a refuge compartment also proves to be the most rapid and realistic route to safety, albeit provisional safety. For at the next phase, vertical evacuation, the non-ambulatory handicapped are stopped by stairs on which they cannot proceed or by elevators which go out or are put out of use during a fire. As long as smoke or flames do not burst into this refuge compartment, the occupants will remain in relative, yet anxiety-bound safety. In most small scale fires there will be no further action.

Conversely, the fire circumstances may necessitate leaving the shelter compartment.

If the escape route is still practicable, the non-ambulatory handicapped should either

a. be carried down by the staff members (as long as the fire-brigde has not arrived). But think of the skeletal staff at night (§ 15.7);

b. or be brought to the groundfloor in specially conceived protected elevators which in spite of traditional power failing can be run by an autonomous energy source for a given time (1/2 h or 1 h). At first sight, the idea looks revolutionary because up to now protected elevators are not used except by firemen in high buildings (*). But the principle of using such elevators for evacuating old people's homes has been accepted by the Scottish Home and Health Department for more than a decade (6), whereas in the U.S.A. "elevators are usually not considered as emergency exits for handicapped people, even if they are fire-protected and used by a fire department for fire-fighting" (7).Why not ?

If the evacuation route is blocked, then

a. the pupils must be rescued by the fire-brigade. There is no denying that rescuing non-ambulatory children and adolescents by means of fire-escape ladders is a hazardous performance both for rescuers and evacuees; or

b. inflatable (pre-mounted) slides may be used, at least for the 1st floor. When applied to higher floors, the slope grows too long and the speed too high for helpless handicapped;or

c. rescue is possible by way of an adequately built outer terrace leading to a fixed downward slope of max. 5 % to the ground. Flames and smoke may impede the proceedings if the slope is situated too close to the facades. Moreover, this system again should not be applied to floors higher than the 1st.

* * *

19. This analysis of
- mental and physical conditions and possible achievements,
- composition of pupils'groups,
- staff availabilities,
- supplementary risks resulting from these factors

allows us to draw some principal conclusions to assist all those who are involved in conception, construction, functional organization and mangement of special schools and boarding -schools :

19.1 Conception, construction and equipment of buildings for handicapped children and adolescents must always take into consideration the presence of non-ambulatory handicapped, figuring among both mentally or emotionally and bodily disturbed pupils (§ § 13 and 14).

19.2 The compartments prescribed in all school and boarding-school buildings should be smaller and more numerous in special schools, still smaller and more numerous in special boarding schools so as to limit smoke and flame spread and to procure sheltering spaces that offer quick but provisional safety by way of limited horizontal egress (§ ° 10, 17, 18).

(*) In this function they are actually called elevators with priority call.

19.3 No doubt the evacuation process in boarding schools for handicapped does require more time than in boarding schools for normal children. Moreover their stay in a shelter compartment may be delayed. For these reasons the fire resistance of structural and compartmentation elements should attain 1 h (§ § 10 and 18).

19.4 Limitation of risks and furthering total evacuation conditions (which are essential in case of extended smoke and flame spread) undoubtedly call for arrangements in time and space whereby the handicapped should not be located farther from the evacuation level (E) or ground floor (O) than the * marked levels in the tables below :

	Disability \ Level	- 1	O or E	+ 1	+ 2
In day-time	Non-ambulatory	-	*	*	-
	Ambulatory	*	*	*	*
	Visual deficiency	-	*	-	-
	Auditive deficiency	*	*	*	*

	Disability \ Level	- 1	O or E	+ 1	+ 2
At night	Non-ambulatory	-	*	-	-
	Ambulatory	-	*	*	*
	Visual deficiency	-	*	-	-
	Auditive deficiency	-	*	*	*

These tables clearly reflect the need to limit the height of school and boarding school buildings to 2 floors above the ground floor or evacuation level. There is a strong preference towards a design which limits the building to a ground floor or to levels which may be evacuated horizontally to the outside (§ § 10, 15, 16, 17).

19.5 In densely built urban centres it may prove impossible to find a site big enough to apply the principles of § 19.4. In such case exceptions should be allowed, provided special precautions regarding the alternative vertical evacuation be proposed to and accepted by a standing safety commission composed by experts in that matter (§ 18).

19.6 It appears that, in daytime, staff and maintenance members are sufficient in number to secure the evacuation of handicapped children, but there is a problem at night. In special boarding school the ratio of available personnel to pupils should be raised to 1 - 8, whereby at least one staff member should not be groupbound (§ 15).

19.7 Owing to the pupils' perception capacity, response and mobility, it is of utmost importance that, in special schools and boarding schools, fire-drills should more than anything else aim at preparing staff members to co-ordinate their exiting behaviour and to manage the egress (§ § 9, 15, 16).

* * *

20. Meanwhile it is hoped that draft norm S 21-206 in its chapters II, IV and VI (Special Education) will take into account the above conclusions 19.1 to 5 in an indispensable attempt to integrate behavior, contents and building.

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NBS-114A (REV. 9-78)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 80-2070	2. Gov't. Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE Second International Seminar on Human Behavior in Fire Emergencies: October 29 - November 1, 1978 Proceedings of Seminar	5. Publication Date June 1980 6. Performing Organization Code
7. EDITORS Bernard M. Levin and Roseanne L. Paulsen	8. Performing Organ. Report No.
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, DC 20234	10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (Street, City, State, ZIP) National Bureau of Standards Department of Commerce Washington, DC 20234	13. Type of Report & Period Covered Final 14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The safety of building occupants in fire emergencies depends on both the fire protection features of the building and the actions of the occupants. Until recently fire protection experts have relied mainly on experience and intuition regarding the capabilities and actions of building occupants in the development of fire protection systems and training programs. Research projects underway can assist the fire protection experts by providing them with needed information to supplement their experience and intuition. This report contains summaries of some of the recent research in this field as reported at an international seminar on the subject. It also contains the invited papers presented at the seminar on the topic of panic.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Communications; evacuation; fire alarms; fire safety; human behavior; human factors; panic; safety; smoke; symbols.

18. AVAILABILITY	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PRINTED PAGES
☒ Unlimited ☐ For Official Distribution. Do Not Release to NTIS	UNCLASSIFIED	282
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