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NEGLECTED INDIVIDUAL, SOCIAL AND ORGANISATIONAL FACTORS IN HUMAN RELIABILITY ASSESSMENT.

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It is argued that the narrow view of man-machine interaction found in human reliability assessment must be extended to accommodate the human errors that occur as a result of individual, social and organisational influences on behaviour. Evidence is produced from an analysis of major accidents. Error sequences are described and a list of contributory factors is given. Communication errors between individuals were found to be prevalent and a classification system is provided to accommodate these. The need for further research was stressed.

INTRODUCTION

The aim of this paper is to emphasise the need to take a wider view of the human operator in systems, extending it beyond the one-person/one-machine level. The focus for research into human error and reliability has generally concentrated on the human operator as a processor of information. The development of reliability data has, understandably, concentrated on the basic problems of the man-machine interface and on the way in which the operator is able to process and act upon task related information. There can be little doubt that the most potent influences on performance can be found in these relationships between the operator and the task. At the simplest level, design features can be shown to affect error frequency and these aspects are relatively well understood (e.g. see McCormick & Sanders, (16)). On the other hand, the cognitive states of operators and their effects on performance present a more complex problem. This has largely been dealt with by developing appropriate mental models and relating these to rules or strategies applied to the the ordering of thoughts to achieve a specific goal (e.g. see Rasmussen, (20)).

By relating a particular level of description of behaviour (e.g. sensori-motor behaviour or problem solving behaviour) to the types of errors that occur at such levels, classification systems have been derived which, in theory, should reflect our understanding of this relationship. An example of such classification, taken from Altman (1), is shown in Table 1. The classification reflects the approaches to operator and task relationships discussed above, with categories 1-3 essentially addressing the basic problems occurring at the man-machine interface, while levels 4 and 5 are more related to the concept of mental strategies.

It is at this point that difficulties emerge in attempting to classify behaviours or human factors whose effect on the success or failure of goal related tasks are indirect. For example, where would a failure to pass on important information between individuals or groups fit in? Evidence suggests that some major accidents could have been foreseen had the organisations concerned acquired information about previous similar errors or if they had linked information sources within the organisation. The accident at Three Mile Island in 1979 (President's Commission on the Accident at Three Mile Island, (19) and the crash of the Trident aircraft at Staines in 1972 (Peters, (18)) are just two examples. Interpersonal and intergroup communication errors feature prominently in a variety of systems but, because their occurrence only generally becomes evident when they result in a major system failure, they have been typically identified in accident inquiries (see Turner, (24)).

Because reliability specialists have tended to ignore the individual and social aspects of man and his or her role or position within a particular organisation, certain causal factors of error behaviour have been overlooked. Having made this statement it is interesting to note that, in a different area of research, industrial accidents and road safety, a great deal of effort has been applied to looking at precisely these factors (see Hale and Hale, (12)). For example, attitudes to risk mediated by social and cultural norms, personality on the intraversion-extraversion dimension, social integration in work groups and job satisfaction have all been found to affect accident frequency to a greater or lesser extent but the results tend to be inconclusive because of the difficulty in establishing whether these factors are causal or merely contingent. An example of the difficulty of the problem is illustrated in Figure 1 where it is shown how personal and social factors can often be interrelated in complex ways. The arrows indicate that relationships have been shown to exist or are imputed to exist between the variables. Thus, for example, the extent to which the role structure is formalised will partly determine how ambiguous the role definition will appear to be to the individual although leadership or supervision may intervene to reduce uncertainty. Role ambiguity, combined with the effects of the nature of the task, combined with the effects of whether the personal needs of the individual are met can all partly determine the level of job satisfaction. Also, job satisfaction can be influenced by how well the person feels they are actually performing. Given that some variables also have other effects on performance, the final measure of performance variability, dependent on any one of these factors, would be confounded by interactions and particularly difficult to measure if its effects are small. The question "to what extent does job satisfaction affect performance?" would therefore be difficult to research and, as this author has discovered, most of the controlled studies considering personal, social and organisational variables do not deal directly with performance accuracy at all.

Against this background of a paucity of relevant research literature, those interested in human reliability continue to point to these elusive variables. For example, Rasmussen (21) assumes that "subjective values and emotional states" must affect mental strategies, while Sheridan (22) wonders whether the error probabilities for people working together are better or worse than those working independently. However, the question concerning the nature and extent of causal relationships needs to be put into a well formulated context that would enable research relevant to determining the effects of these factors on human reliability to be better directed. Having attempted to explain the difficulties inherent in establishing the ways in which personal, social, organisational factors might influence performance, the rest of the paper will concentrate on the first stages of progress made towards reformulating the problem.

ACCIDENT SURVEY

Because there exists a vast body of literature on individual differences, social and organisational psychology, it is necessary to narrow down the field by attempting to identify key variables. Inquiries into major accidents and disasters offer a useful source because they extract previously hidden causal factors. Because the nature of an inquiry and the reporting procedure depends on the goals of those involved, it is necessary to give a careful analysis to such reports in order to organise the information into a more simplified structure to enable an understanding of the pattern of relevant pre-accident events. A number of questions can be asked, including:

(i) What caused or preceded this event?
(ii) Is this event an error or a result of an error?
(iii) Who made the error?
(iv) Why was the error made?
(v) How should each error be categorised?
(vi) Are some errors more important in terms of consequences?
(vii) Do accident preconditions show an identifiable pattern?

Pre-disaster errors are spread over a much greater length of time and over a much wider organisational area than the industrial or car driver pre-accident errors which lead to accidents almost immediately. It is very difficult for a single individual to cause a major accident or disaster all by him/herself and, consequently, the final error in the pre-disaster sequence is typically relatively unimportant. It follows, therefore, that any model to account for major accidents or disasters must take an organisational as well as an individual view. An accident occurs at the end of a chain of events but should the designer of a piece of equipment, for example, be included in this chain? The problem of infinite regress immediately becomes apparent if one wishes to establish original causes. Turner (24) says:

"The incubation network refers only to those chains of events which are discrepant" [between the way the world is thought to operate and the way it really is] "but are not perceived or are misperceived. It is meaningful to compare accidents and disasters only in terms of incubation networks, and not in terms of sets of infinite causal chains." (p.88)

It is important to bear in mind this concept of the mismatch between the actual state of the system and the perceived state of the system because this is the key to understanding the sources of human failure. In many of the accidents analysed by this author, such mismatches endured because of errors occurring within the interpersonal communication system. Altogether, 5 accidents were analysed in detail – the Aberfan disaster (Bignell, (5), the

Trident Papa-India air crash at Staines (18), the train collision at Queen Street Station, Glasgow (Great Britain: Department of Transport (8)), the explosion at Houghton Main Colliery, Yorkshire (Great Britain: Health and Safety Executive (10)) and the Flixborough chemical works explosion (Great Britain: Department of Employment (7)). Other sources of data included Baldamus (2), Beaty (4), Great Britain: Board of Trade (6), Great Britain: Department of Transport (9), Gurney (11), Howland (13), Hunns (14), Hurst (15), Moss and Sills (17), Sills, Wolf and Shelanski (23), and (19) and (24).

Errors and Causes in the Incubation Period

A list was constructed of factors that were observed in the accident analyses to have contributed to the failure of a system. The basis for selection of factors was that they should relate to personal, social or social-situational variables. No attempt has been made at this stage to classify the factors in any way, nor to redefine them or define them more precisely. The complete list is given in Table 2.

As can be seen, the list is fairly extensive but is by no means necessarily complete. In many cases, a combination of several of the factors is required in order to establish conditions sufficient to result in an accident. In this respect, a single factor in isolation is unlikely to have devastating consequences. Subsequently, many of the resultant errors would not be identifiable in themslves because they require the contingent occurrence of other errors in order to become manifest. An example of an error sequence, typically fairly lengthy, is given in Table 3. The table was derived from an analysis of the events over several days leading up to a train collision (8). On two occasions the same procedural error occurred in adjusting the brakes on a locomotive. Although the brake problem was observed in the locomotive's behaviour by a number of drivers, the decision to take the locomotive out of service was never made due to poor communications between personnel.

Another example is shown in Figure 2 portraying the poor communication of information that led up to the explosion at Houghton Main Colliery, Yorkshire in June 1975 (10). Errors are shown in the boxes. Not only was there considerable "passing the buck" in terms of delegating responsibility for the repair of a faulty fan, but also a failure to communicate the vital information to the manager despite the existence of communication channels. The analysis shows how information can be impeded in flowing upwards and downwards between the levels of a hierarchy such that individuals are unaware of the state of the system and cannot perceive the risk.

Having performed detailed analyses of events in accident incubation periods it is then possible to begin to draw up fault trees along the lines of those used to derive possible alternative root causes of hardware failures. An attempt was made to construct a fault tree for "sender fails to pass on communication in time", where such an error ultimately leads to or contributes to a system failure. This kind of error occurred frequently in the accident analysis data. On the fault tree which is shown in Figure 3 no attempt was made to represent all the possible roots or to extend the roots to an ultimate cause. One interesting aspect to emerge from this construction is the interaction that occurs between variables. Thus, one variable may affect another directly or indirectly.

Since the fault tree is only an hypothesis concerning causal relationships it does not provide any hard data. However, ideally, with a knowledge of the probability of particular relationships occurring (e.g. the probability of staff shortage and the contingent probability that this would lead to time pressure) and a knowledge of the extent of interactions, it would be possible to predict the likelihood of occurrence of the error concerned and do something about reducing this probability.

CLASSIFICATION OF INTERPERSONAL COMMUNICATION ERRORS

There is a need to identify the frequency of, or opportunity for the occurrence of the "hidden" errors that have been described that actually occur in systems without necessarily causing accidents. In this way, the likelihood of an accident can be assessed and this assessment modified by taking into account the extent to which causal or contingent factors also exist. The measurement of such factors also has its problems but a discussion of appropriate methods is beyond the scope of this paper.

Because communication errors featured prominently in the accident survey it is important that future research should be directed towards determining how these can affect the extent of the match between the perceived and the actual system state. Initial progress has been made by classifying these errors according to a model of accurate communication. This model has the following components:

1. Sender encodes and transmits the message.
2. Receiver acknowledges receipt of the message and what he understands it to mean.
3. Sender repeats the message if there is no feedback from the receiver and goes on repeating it until there is.
4. The message is recorded.

These components are neatly illustrated in the following quote:

"....I used to enjoy going to a soda fountain with a friend and ordering two tall chocolate milkshakes just to hear the waitress call out, "shake a pair in the air." To acknowledge the order, the soda jerk would repeat "shake a pair in the air". If he didn't the waitress would repeat the message saying "shake a pair in the air – echo" until the soda jerk acknowledged the order. She then wrote out a sales check." (From Barrett (3), p.161).

The error classification, with examples to clarify each error type, is given in Table 4. This system has face validity to the extent that actual communication errors encountered can be easily and unambiguously classified.

CONCLUSIONS

There is a continuing need to extend the list of factors shown in Table 2 that contribute to system failures. Research should be carried out which aims to evaluate relationships between them and between the specific errors to which they relate. In this way, a classification of personal, social and organisational factors can be linked to appropriate error classifications by quantifiable relationships to enable greater accuracy of reliability assessment to be achieved.

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TABLE 1 - Classification of Human Errors by Altman (1)

BEHAVIOURAL LEVEL	ERROR BEHAVIOURS
1. Sensing Detecting Identifying Coding Classifying	Failure to monitor the field Failure to record or report a signal change. Recording or reporting a signal change when none has occurred. Recording or reporting a signal change in the wrong direction. Failure to record or report the appearance of a target. Recording or reporting a target when none is in the field. Assignment of a target to the wrong class.
2. Chaining or rote sequencing.	Below standard response. Omitting procedural step. Inserting an unnecessary procedural step. Mis-ordering procedural steps.
3. Estimating with discrete responding and estimating with continuous responding (tracking)	Failure to respond to supra-threshold target change. Responding to subthreshold target change. Premature response to target change. Late response to target change. Inadequate magnitude of control action. Inadequate continuance of control action. Wrong direction of control action.
4. Logical manipulation, rule using and decision making.	Incorrect value weighting of responses to a contingency. Failure to apply an available rule. Application of a correct but inappropriate rule. Application of a fallacious rule. Failure to apply or obtain all the relevant decision information. Failure to identify all reasonable alternatives. Making an unnecessary or premature decision. Delaying a decision beyond the time is is required.
5. Problem solving.	Formulating erroneous rules or guiding principles. Failure to use available information to derive needed solution. Acceptance of inadequate solution as final.

Table 2 - Some Personal, Social and Social-Situational Factors that have contributed to Systems Failures.

1. Working under pressure:
   a) Group pressure
   b) Social pressure
   c) Higher authority pressure
   d) Heavy responsibility pressure
   e) Emotional pressure
   f) Time pressure
   g) Workload pressure
2. Job role/responsibilities poorly defined
3. Responsibilities of different personnel overlap
4. Pesonality clashes
5. Personnel make assumptions about task or task related activities
6. One (or more) personnel recently replaced by a deputy/fill-in/substitute
7. One or more of the workforce are inexperienced
8. More than one problem exists to be dealt with by the same person
9. The problem situation is a novel one
10. The situation has elements not usually encountered in day to day working
11. The situation requires action but the correct action is not apparent
12. There is overlearning or rigid beliefs/rigidity in system
13. Hardware considered unreliable by members of workforce using it.
14. Communication system assumed to be reliable when it is not.
15. Rules/procedures considered inappropriate for job/allowed to lapse.
16. Hierarchical system where only the personnel on the lowest or lower echelon(s) really know what the job entails
17. Informal communication system
18. The communication system is noisy
19. Blocked communication channels
20. Some messages not recorded
21. Reporting (communicating) procedures between individuals incomplete or not adhered to
22. Previous "incidents" not heeded
23. Communications pass through a series of personnel
24. Information distanced from central decision maker/coordinator plus no feedback
25. Lack of resources
26. More than one person uses same equipment
27. Reporting errors would be damaging to ego
28. Risky action would be good for the ego
29. Industrial action being taken

TABLE 3 - Sequence of Events and Errors Preceding the Train Collision at Queen Street Station, Glasgow, 24 December 1977

1. Formal procedures allowed to lapse.
2. Word of mouth and other informal communication chains concerning procedures contain insufficient information.
3. No feedback or feedforward information given/obtained from superordinates.
4. Written maintenance procedures not read. Believed to be ineffective communication method. Procedural error.
5. Inspection error.
6. LOCOMOTIVE'S BRAKES NOT ADJUSTED CORRECTLY.
7. Fault noticed when running locomotive but information not entered into correct communication channel.
8. Lack of resources and desire to achieve goal leads to attempts to achieve goal on the basis of incomplete information.
9. Decision error caused by social pressure and time pressure not prevented due to blocked communication channel.
10. Assumptions made due to erroneous beliefs about the reliability of the communication system.
11. Important information not entered into correct communication channel.
12. Ambiguous communication sent.
13. Communication misinterpreted. Danger not perceived.
14. LOCOMOTIVE STILL IN SERVICE.
15. Misinterpreted communication passed on.
16. Erroneous beliefs about reliability of communication system. Decision error because danger not perceived, time pressure and lack of resources.
17. LOCOMOTIVE STILL IN SERVICE.
18. Information passed on informally between drivers.
19. Important message not recorded. Message forgotten therefore no feedforward information provided.
20. LOCOMOTIVE GOES FOR ROUTINE EXAMINATION.
21. Maintenance department unaware of brake fault because formal communication channels do not contain the information.
22. Written maintenance procedures not referred to. Procedural error.
23. BRAKES STILL NOT CORRECTLY ADJUSTED.
24. Brake fault noticed when running locomotive but information not entered into correct communication channel. Information passed on informally.
25. Information not passed on and not recorded according to correct procedures. Considerable workload, time and social pressures contribute.
26. Information goes via another channel.
27. Receiver considers that continuing the communication is outside his responsibility. Assumes will go via another channel due to erroneous beliefs about reliability of communication system.
28. LOCOMOTIVE STILL IN SERVICE.
29. Informal communication system between drivers continues.
30. Failure to perceive potential danger.
31. Informal communication chain broken due to focus on another problem.
32. Evidence of faulty brakes not apparent.
33. Driver unaware that brakes are defective.
34. BRAKES FAIL ON ENTERING STATION.
35. TRAIN COLLIDES WITH STATIONARY TRAIN.

TABLE 4 - Classification of Interpersonal Communication Errors

1. Sender Errors

(a) In encoding information

Information not encoded (e.g. message contains no information).
Information ambiguous (e.g. semantic ambiguity).
Information incomplete (e.g. details omitted).
Information or code incorrect (e.g. wrong values given, wrong terms used).
Code inappropriate (e.g. code foreign to intended receiver).

(b) In transmitting information

Information not transmitted (e.g. not sent, not recorded).
Information not transmitted in time (e.g. too late for action to be taken).
Information transmitted via incorrect channel (e.g. standard channel not used).
Unacknowledged transmission not repeated (e.g. repeat not possible).
Acknowledgd transmission not corrected (e.g. error in the acknowledgement not noticed).

2. Receiver Errors

Failure to acquire message (e.g. does not read record book, ignores message).
Incomplete decoding of message (e.g. forgets details).
Incorrect decoding of message (e.g. misinterprets meaning).
Receipt of message not acknowledged (does not give any feedback to sender).
Receipt of message acknowledged but no feedback of decoded message (e.g. does not repeat back interpreted content of message).
Feedback of decoded message is ambiguous (e.g. semantic ambiguity).

3. Errors in Additional Recording of Sent or Received Messages

Sent information not recorded (e.g. not written down)
Received information not recorded (e.g. not written down)
Information recorded but poorly encoded (See 1a) (e.g. in written report).

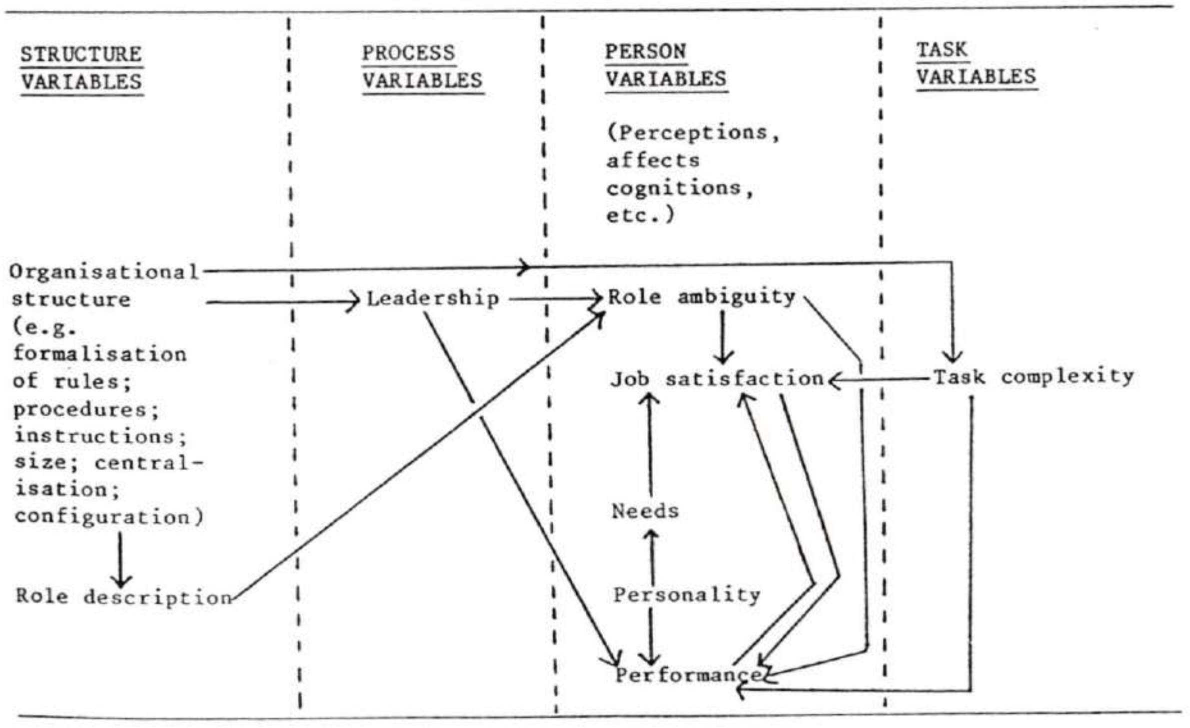

Figure 1 - Relationships between Performance, Job Satisfaction and Related Factors

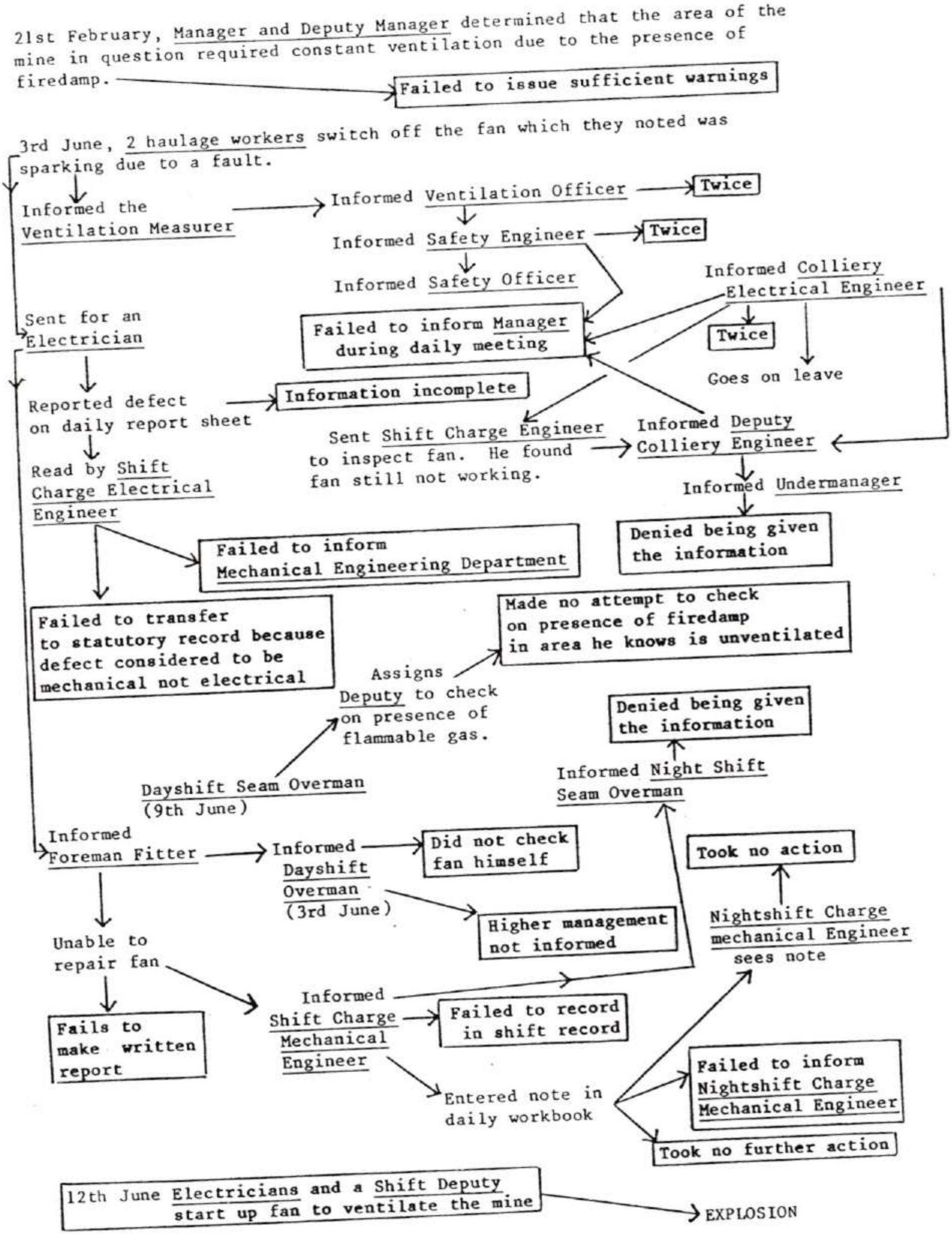

Figure 2 - Chain of Events Leading up to the Explosion at Houghton Main Colliery, Yorkshire, 1975

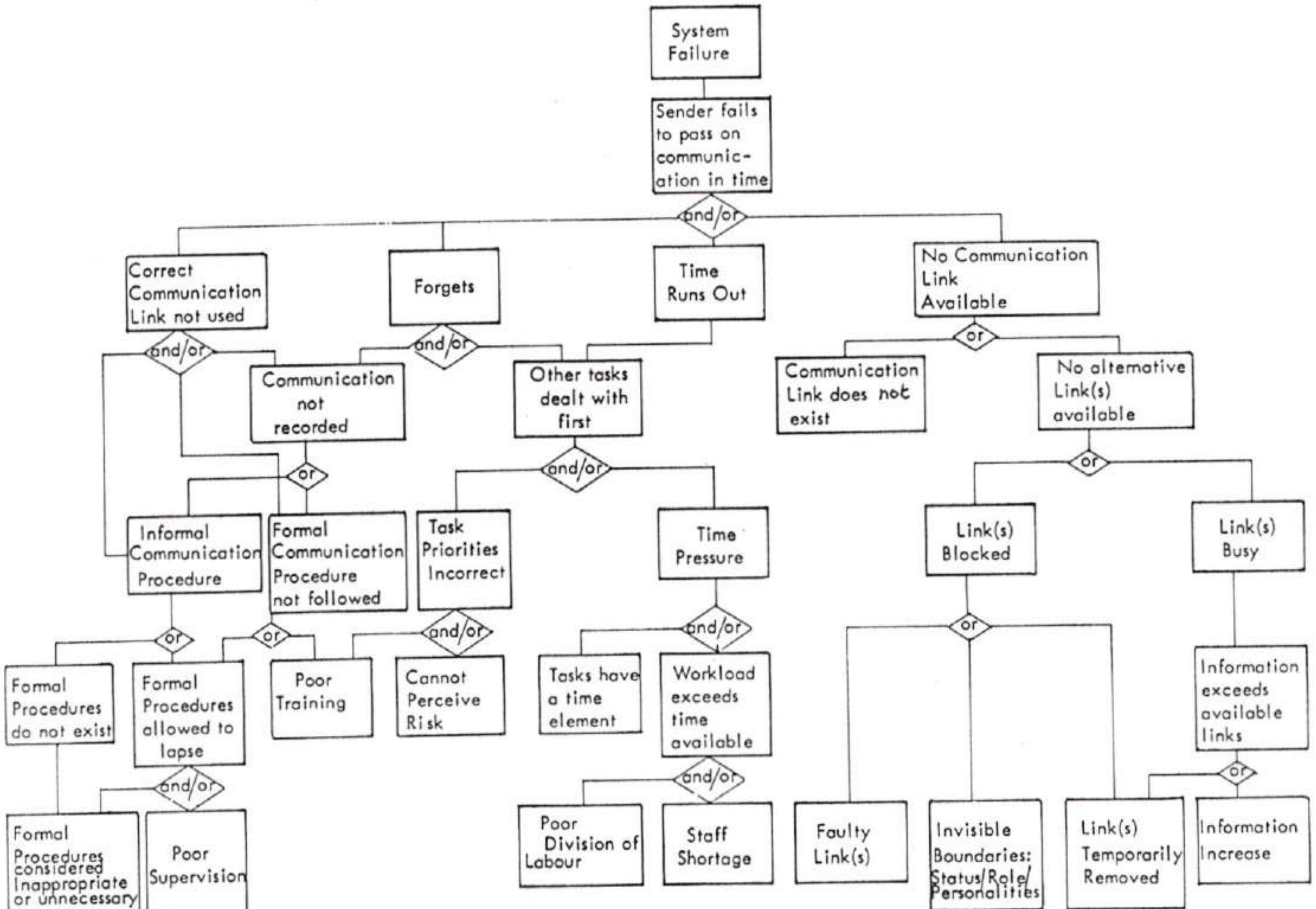

Figure 3 – Fault Tree for some Selected Factors Underlying the Failure to Pass On a Communication in Time