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A MANAGEMENT INFORMATION SYSTEM FOR ACCIDENT PREVENTION IN A LAND-BASED OIL-WELL DRILLING INDUSTRY

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THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

A MANAGEMENT INFORMATION SYSTEM FOR ACCIDENT PREVENTION IN A LAND-BASED OIL-WELL DRILLING INDUSTRY

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

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degree of

DOCTOR OF PHILOSOPHY

By

JULI SOEMIRAT SLAMET

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A MANAGEMENT INFORMATION SYSTEM FOR
ACCIDENT PREVENTION IN A LAND-
BASED OIL-WELL DRILLING
INDUSTRY

A DISSERTATION
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CIVIL ENGINEERING AND
ENVIRONMENTAL
SCIENCE

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INTRODUCTORY SUMMARY

1.1. Introduction

The term "accident" is not a rigorously defined scientific concept but a word generally used by layman to describe some unforeseen or chance event that produces injury and/or property damage. The above term which also implies the unpredictability and the uncontrollability of accidents was strongly carried over to the twentieth century (Hahn, 1980). These implications are also the main reasons for the lack of an early scientific effort to prevent accidents which is, however, not unusual since there was neither the requisite understanding of the accident process nor the incentive to do so. It took the Industrial Revolution to create the conditions which led to the development of accident prevention as a specialized field.

It was not until the last half of the nineteenth century, during which the American factories were expanding their production lines and producing goods at high rates, that the ugly consequences of industrial accidents became obvious. When this was brought to the attention of some community and business leaders, they felt a moral obligation to prevent accidents in this country (NSC, 1978). Various efforts to make employers financially liable for accidents led to the enactment of the Workers' Compensation Law. This law provided the first and the major incentive for understanding the accident process in order to reduce the resulting economic losses, property damages, injuries, and fatalities (Hahn, 1980). The early concept of the underlying causes of accidents was basically derived from work in the industrial setting so that the consequent corrective activities were mainly applications of engineering solutions to accident prevention.

The economic losses and the increasing awareness and sensitivity to human losses, however, induced scientific interests in the accident field. Researchers, seeking more universal solutions to the problems, developed many accident causation models and came to the same conclusions: accidents do have causes or etiology and they are mostly preventable. The causes of accidents, however, are very complex because they consist of multiple factors which interact with each other to cause accidents. These causes are classified as direct causes and indirect causes. The relationships between accidents and these causes are best described by Heinrich (1980) in his well-known domino theory which is based on the following theorems:

(1) Industrial injuries result only form accidents.
(2) Accidents are caused directly only by
    (a) the unsafe acts of persons or
    (b) the exposure to unsafe mechanical conditions.

(3) Unsafe actions and conditions are caused only by faults of persons.
(4) Faults of persons are created by environment or acquired by inheritance.

Theorems 3 and 4 are also referred to as the quality, the enforcement, and the implementation of the Management Safety Policies (MSP), because management is responsible for the work condition and safety in an industrial environment. A management safety policy includes: management's intent; production and safety goals; staffing procedures; use of records; assignment of responsibility, authority and accountability; employee selection, training, placement, direction and supervision; communication procedures; inspection procedures; equipment, supplies, and facilities design, purchase and maintenance; standard and emergency job procedures; and housekeeping (Heinrich et al, 1980).

Accident prevention models were developed based on the accident causation models and motivated by the legal requirements; their application in industrial settings have reduced accidents significantly. At present, unsafe working conditions as causes of accidents comprise only 20% of all accidents. On the other hand, the unsafe acts of persons cause 80% of all accidents occurring at this time (Denton, 1980; Heinrich, 1980; NSC, 1978). Most of these accidents are now occurring in the so-called "high hazard" industries. The oil-field industry is the most hazardous within this classification; its accident rates between 1972 and 1978 were double the rates of all private industries combined in the U.S.A. Half of these accidents were incurred in the oil-well drilling industry (NIOSH, 1982).

The consistently high accident rates incurred by the oil-well drilling industry reflect the maximum ability for accident prevention that could be achieved by the present safety practices. Safety activities are generally motivated by the existing legal requirements and emphasis is placed on eliminating major accidents, unsafe acts, and unsafe conditions (Denton, 1980; Heinrich, 1980). Hence, the underlying causes of accidents have not yet been addressed. Recently, Levitt (1975) found that the major difference existing between the high and the non-high hazard companies in the construction industry is that, in the latter case, top management is knowledgeable about the safety aspects of the company. This finding suggests that the approach to safety in a high-hazard industry should now shift from engineering to management. It could also be concluded that if top management is to be adequately informed about the safety aspects of their operations, reports addressed to top management must contain meaningful information. Traditionally, management is presented with accident records or accident rates which might not mean anything to them. To make these reports useful, the accident data should be converted into other parameters which induce interest or which contribute to their performance of managerial duties such as making, evaluating, and controlling safety decisions. A model that converts data into meaningful information to aid management decision is called a Management Information System (MIS) which originated from the business world.

Most accident prevention models currently take the legal requirements as a source of motivation. Such a source, however, only leads to the following conditions:

(1) Safety activities are not designed to prevent accidents, but rather to avoid the inconveniences created by legal citations.

(2) There is no allowance for a cost-effectiveness evaluation of any safety activity which, in turn, creates a negative attitude of management towards safety.

Since legal requirements always exist in an industrial setting, it has become necessary to include incentives other than legal ones in a prevention model.

A study by Robinson (1979) found that the total accident costs incurred by the construction industry, which is also classified as highly hazardous, can be used to motivate managers in accident prevention. A total accident cost consists of the direct or insured costs and the indirect or uninsured costs. The direct costs are those costs covering compensation payments, first aid, medical and surgical expenses, legal fees and overhead costs. The indirect costs, on the other hand, consist of costs of decreased production output due to the interruption caused by the accident, costs of man-hours lost because of the absence of the injured worker and others helping the injured at the time of the accident, costs of man-hours used to train a replacement, and costs of the damaged materials and tools. It had been reported that the ratio of direct to indirect costs ranged from 1:2 to 1:13. Using the ratio of 1:2 Robinson (1979) developed a matrix method to estimate the total accident costs. This method uses three accident variables (nature of injury, part of the body injured, and whether the injury resulted in lost time) to estimate the direct costs. This direct cost is then used to estimate the total costs by multiplying it by three. These total costs are then presented monthly to the managers to be used in the accident costs accounting, i.e., costs are charged to the individual projects as losses. This accident cost accounting system is a new concept which stimulates management interest in preventing accidents. Traditionally, projects are charged with costs for accident prevention, but should an accident occur, the projects are not held responsible for its costs. This type of policy does not promote accident prevention; it is, however, understandable since up to the present time the total accident cost estimates could only be obtained after one or two years lapse time. This is true for the severe injury cases which need extended medical treatments. Robinson's method of estimating these total costs in a very short time can reverse existing conditions and induce management to prevent accidents. Robinson (1979) also reported that his method was applied in some construction industry with successful results. Also, the magnitude of these total costs were reported to be significant enough to increase motivation of management in the area of accident prevention.

Since most of the accidents are preventable, the costs incurred are unnecessary losses. For the cost-conscious manager, such costs should be eliminated or reduced. Also, the benefit of accident prevention goes beyond economic losses; it will reduce human suffering and losses and will also increase productivity and standards of living.

1.2. Purpose and Scope

The purpose of this dissertation is to develop a management information system (MIS) which in an oil-well drilling industry could reduce the accident rates. The MIS represents a better model than traditional safety activities and it has the following qualities:

(1) The MIS can convert accident/hazard data into meaningful information, hence the name MIS.

(2) The model will serve to motivate managers to prevent accidents.

(3) This model will involve managers in safety activities so that they become knowledgeable about the aspects of safety.

(4) The MIS provides for setting priorities for corrections other than those based on the psycho-

logical impacts of the consequences of a major injury.

(5) Finally, this MIS will eliminate or minimize the underlying causes of accidents.

Since an MIS generally has a very broad scope covering the data base management subsystem (DBM), the decision models subsystem, and the structured reporting subsystem, this dissertation will concentrate on the decision models subsystem only. The part of the DBM and the structured reporting subsystems which will be addressed are limited to the required input and output of the MIS. Also, since the direct causes of accidents are numerous, methods of categorizing unsafe conditions and acts will be defined to make them manageable. Finally, the MIS will be designed for safety activities specifically applicable to the oil-well drilling industry; the term "oil", however, is used here to refer to petroleum only.

1.3. Method

The method used in the development of the MIS model started with a literature review followed by design and development phases. The literature review analyzed the existing oil-well drilling operation, accident causation models, sources of motivation, and the accident prevention models. It was performed to identify the prevailing problems and to search for methods, techniques, and models applicable to the solution of the problem. The outcome of the literature review was then carried over to the design and development phases.

The design phase started with the determination of the goals and objectives of the MIS which helped specify the output of the MIS. This output, in turn, determined the required decision models from which the necessary input was identified. At the end of the design phase, the MIS was illustrated as a total system. This was accomplished through the identification of each subsystem necessary to perform the MIS functions and their interrelationships so that the total system could be outlined.

The development phase was carried out by testing to see whether the model could perform its expected functions. The tests were carried out with the use of a hypothetical and an authentic accident data set. The hypothetical data set was designed to fulfill the exact required input of the MIS. The real data set was an example of the existing accident data in an oil-well drilling industry. The degree of compatibility of the real data set with the input of the MIS was expected to show some important aspects of accident prevention activities as related to the information system existing in the oil-well drilling company. It was also expected that the test results carried out with the real data set could support some of the test results using the hypothetical data set.

1.4. Summary of Conclusions

This summary is divided into two groups:

(1) The conclusions deducted from the literature study.

(2) The conclusions drawn from the design and development phases.

1.4.1. <u>The Conclusions Deducted from the Literature Review</u>

The conclusions drawn from the literature study are as follows:

(1) The MIS model should be based on the management and the system causation models. The management causation model provides the "people" approach needed by the oil-well drilling industry. According to this model, the underlying causes of accidents are related to poor management practices. The system causation model will give a feedback mechanism to the MIS to monitor how well the management safety policies are being executed so that the underlying causes can be reduced or eliminated.

(2) The sources of motivation which assure the functioning of the MIS are the existing legal penalties and the total accident cost as was previously discussed.

(3) The priorities for corrections and the consequent alternative assessment should basically follow the model developed by Fine (1980). The priorities are determined based on the severity or consequences of accidents, the frequency of exposure to the direct causes, and the probability that similar accidents

will occur. The alternative assessment is based on the relative cost effectiveness of each alternative.

(4) To be able to provide feedback on the implementation of the management safety policies, the "4x4 problem-solving technique" (Jones, 1980) should be used. This technique provides a method of accident investigation which reveals the underlying causes of accidents correlated to levels of management (Superintendent, Toolpusher). These underlying causes of accidents should then be reported so that they may be used for the improvement and the evaluation of the safety performance of the managers.

(5) The most useful categorization for unsafe acts, at present, is suggested by Siskind (1982) which is based on the period of time a worker has been employed.

(6) The unsafe conditions should be categorized based on the task of the crew members, namely the task of the toolpusher, the driller, the motorman, the derrickman, the floorhand, and the maintenance man. The selection of this categorization is supported by the result of a direct observation of the oil-well drilling operation in the field.

1.4.2. The Conclusions Drawn from the Design and the Development Phases

The conclusions derived from the design and development phases are as follows:

(1) This MIS uses a system causation model as its basis because it has a feedback mechanism. It requires the investigation and monitoring of hazard and accidents so that the underlying and the direct causes can be found and fed back into the system as inputs.

(2) The MIS is based on a management causation model because it considers inferior management practices to be the underlying cause of accidents which can be reduced or eliminated. The safety activities reflect the reports this MIS produces:

(i) The accident causation reports show the errors made by levels of management in the previous month and how they should be corrected.

(ii) The reports resulting from the two-stage process reveal the underlying causes of accidents/hazards of the prioritized rigs (i.e., rigs prioritized for correction). Such reports identify the causes in accordance with the accident sequence described by the management causation model.

(iii) The report on priority rigs provides a list of all rigs ranked by their respective risk scores. The magnitude of the risk scores accumulated by each rig depends on the degree of frequency and severity of the accidents/hazards incurred.

The same type of accident might occur in several different rigs, but the consistency of their occurrence in the prioritized rigs determines the high risk scores. Hence, the risk scores indicate the degree of safety performance of the managers (both the superintendents and the toolpushers) and the report is eventually a safety evaluation of managers.

(3) This MIS uses the legal requirements as a source of motivation as shown in its definition of hazards. A hazard is considered to exist only if an identified safety problem violates the effective standards, laws, or regulations.

(4) The MIS also uses total accident costs as another source of motivation as shown in the communication of the monthly costs reports to all levels of management. The use of these reports in the accident cost accounting will motivate managers to prevent accidents. Total accident costs (losses) reported are charged to the individual projects, but the costs of accident prevention will be the responsibility of the company. This total cost report can also be used to see the trend of accidents incurred in each rig over time. The low but consistent costs incurred by a rig indicate poor management practices and also serves as a safety evaluation report.

(5) The ability of the MIS to convert data into meaningful information can be seen from several reports:

(i) The total accident cost report, which shows the man-hour losses due to accidents by rig (for all rigs) is prepared from injury data (nature of injury, part of the body injured, and whether the injury resulted in lost time). This injury data would normally not reflect any cost value when presented to the reader.

(ii) The report on prioritized rigs, which shows the list of rigs ranked by their respective risk scores, is made based on the severity and frequency of accidents. These severity and frequency data are, in turn, derived from accident experience existing in a company. Without this conversion process, the accident records by themselves will not show the urgency for corrections.

(6) This model, which sets priorities for corrections, as determined by the magnitude of the risk scores accummulated by each rig, attempts to predict the long-term effect of the present safety management. This MIS is a tool to help management identify complex problems; without decision models like those incorporated in this MIS, the urgency for correction will not be recognized.

(7) Major accidents which create large losses seldom occur and, therefore, are of short-term importance only. Minor accidents, on the other hand, are incurred frequently and the consistency of their occurrence has long-term adverse effects. Thus, both major and minor accidents deserve equal attention and should be investigated with equal thoroughness.

(8) Priority determination, which predicts the long-term effect of the present safety management, is therefore an evaluation process needed to revise the existing management safety policies (MSP).

(9) All of the conclusions above show the activities induced by the existence of the MIS. These activities lead to the improvement of faulty management practices or of the underlying causes of accidents. Therefore, it can be concluded that this MIS attempts to reduce accidents through the elimination of their underlying causes.

(10) The Robinson matrix, which has been used throughout this dissertation to calculate the total accident cost, was originally designed for the construction industry. Its compatibility with the oil-well drilling industry has not been verified. Because of its importance in the process of preparing the total accident cost reports for management moti-

vation, it is recommended that such a matrix be developed for the oil-well drilling industry in the future.

(11) It is also recommended that a safety data base management system be developed since it is an indispensable unit for an MIS and also serves as a valuable source of reference.

(12) The real data set used in the testing procedure does not contain any data pertaining to the causes of accidents (both the direct and the underlying causes). However, specific entries to record this data in the forms used are available. Consequently, the data included in real accident reports are obviously not intended to be used for accident prevention. It would be ideal if providers of data were also the users so that the quality of the data set could be guaranteed, and the benefit of recording data would justify the cost of data collection.

(13) The consistently high risk scores found for Task 4 and Length of Employment 1 (LE 1) indicate that the most unsafe conditions and acts result from the task assigned to floorhands and the acts of workers employed within the 1-3 months category, respectively. There is an obvious need to train all new workers, irrespective of their experiences in order to eliminate or reduce accidents incurred by workers in

LE 1. As for the alleviation of the hazards associated with Task 4, further research is recommended. These findings are examples of additional advantages obtained by having an MIS which could be used to find problem areas which need further study.

(14) This MIS is adaptable to changes due to the advancement of technology. Changes of models, as well as categorizations used in this MIS, can easily be changed without changing the basic concept of this MIS.

(15) This MIS is also flexible. The routines used to prepare reports are very simple, consisting mostly of short command statements. Hence, they can easily be changed or edited whenever management feels that it is important to communicate additional information, or that the same reports should also be addressed to other personnel who are not presently included.

1.5. Summary of the Organization of the Report

The rest of this dissertation is organized in accordance with the method of development discussed previously. It starts with a literature review chapter which analyzes the problems existing in the oil-well drilling industry and identifies possible solutions to the problems.

The design phase follows the literature review; it discusses the design process and the design itself by using the criteria and findings carried over from the previous chapter.

The next chapter is used to discuss the testing procedures and the results of the tests, followed by the conclusions, bibliography, appendices, and glossary of terms.

Chapter 2

LITERATURE REVIEW

This chapter attempts to analyze the existing accident causation and accident prevention models, sources of motivation, and prevention practices to find any prevailing problems and to search for some possible criteria or qualities for an improved model applicable to an oil-well drilling company. The findings deduced in this chapter will be carried over to the design phase of the MIS in the next chapter. The discussions of the aforementioned topics will be organized according to their relationships as follows:

(1) Accident causation models.

(2) Sources of motivation.

(3) Accident prevention models.

(4) Traditional accident prevention practices.

(5) Qualities and/or criteria for a better model.

The review on accident prevention models is preceded by short reviews on accident causation models and sources of motivation because they are the basis for the development of prevention models. The effectiveness of accident prevention models depend very much on how they are being implemented; therefore, the review on accident prevention activities should follow that of the accident prevention models.

2.1. Accident Causation Models

In the past, the word "accident" was taken to represent an event without cause, an unintended happening, a chance or a mishap (Webster's New World Dictionary, 1979). Therefore, accidents were considered to be non-preventable. However, as the number of accidents increased over time, it motivated the search for their causation (NSC, 1978; Heinrich et al, 1980). This search resulted in several causation models, all of which have two important opinions in common, namely, (1) accidents do have causes or etiology, and (2) they are mostly preventable. The etiology, however, is not simple because it consists of multiple factors which act and interact with each other to cause accidents (Heinrich et al, 1980; Hahn, 1980; Denton, 1982). These multiple factors can be divided into two large categories: (1) immediate causes which are also very often called direct or primary causes and (2) real causes, which are also known as indirect or underlying causes. The first category can further be subclassified into (a) the unsafe acts of workers and (b) the unsafe conditions of the working environment and machinery. The second category is subclassified into (a) personal factors (physical and psychological), (b) environmental factors (physical, chemical, biological, psychological), and (c) management factors (policies, decisions, evaluations, control, administration).

Accident causation models are grouped into several categories according to which of the above factors is being stressed in a model (Heinrich et al, 1980):

(1) Behavior model.

(2) Human factor model.

(3) System model.

(4) Epidemiologic model.

(5) Decision model.

(6) Management model.

Behavior models place behavior as a prime causative agent in accidents. These models were historically based on the theory that affirms the existence of accident-prone workers. Such models, including their modifications, have been described by Shaw and Sichel (1971); Hahn (1980); and Kerr (1957). Presently, however, statistical, and clinical findings, as well as daily experiences question the justification of this theory and necessitate the re-examination and/or further study of these models.

Human factor models place human factors as a prime causative agent in accidents. These models affirm the theory that accidents are caused by human error. The underlying causes of these errors are considered to be due to work overload, incorrect responses of the workers, and improper acts of personnel. Among the studies of these models are those described by Ferrell, as cited by Heinrich et al (1980); and Petersen (1978).

These human factor models have resulted in the specification of human capabilities or characteristics which, in turn, are used for two purposes: (i) to design machinery and/or a working environment and (ii) to select employees to meet certain requirements to do a specific job or to operate specific equipment. Most of these studies have been done in the laboratory with well-controlled conditions, so that generalization of these findings cannot be advised. Also, studies that could be related to the oil-well drilling industry are not available at this time.

System models place man-machine interactions as a prime causative agent in accidents, in which the personal factors of workers play a very important role, namely, as the controlling agent. Compared to the other models, these system models have one outstanding advantage; they have a feedback mechanism. This feedback mechanism is an indispensable part of a monitoring procedure which reveals how well an accident prevention policy is being implemented. An example of the system model is that which has been described by Firenze as cited by Heinrich et al (1980).

Epidemiologic models place the results of the interactions among the host (man), the agent (cause), and the environment as the primary causative agent in accidents. These models are analogous to those used in the study of epidemics and the causation of diseases. Instead of searching for the causes of epidemics and diseases, the studies now look for the causes of accidents. According to the epidemiologic model, injuries and damages are the measurable indices of accidents, but the accidents themselves are still considered to be unexpected, unintentional, and unavoidable. Hence, as a preventive measure, these models are inadequate. An example of studies on these models is described by Suchman as cited by Hahn (1980).

The decision model as described by Surry (1974) places the human capability to make safety decisions as its prime causative agent in accidents. This model states that if the above capabilities do not exist, then danger will build up, become imminent, and an accident will occur. The human capability to make safety decisions starts with the ability of the workers to recognize and analyze hazards, and then decide to take proper actions to prevent accidents from occurring. Thus, this model stresses personal factors required to make safety decisions such as knowledge, skill, emotional status, awareness, and motivation.

Management models place management policy as a prime causative agent in accidents and are the updated domino theory with modifications. The domino theory itself describes the sequence of accident occurrence and reveals the causes of accidents. The theory is based on the following theorems or sequence:

(1) Industrial injuries result only from accidents.
(2) Accidents are caused directly only by:
    (a) the unsafe acts of persons or

(b) exposure to unsafe mechanical conditions.

(3) Unsafe actions and conditions are caused only by faults of persons.

(4) Faults of persons are created by the environment or acquired by inheritance.

(Heinrich et al, 1980)

Based on these theorems several management models were developed, such as those described by Bird Jr. and O'Shell (1980); Adams (1976); and Weaver (1971). Bird's model is an update of the domino theory to which a fifth sequence has been added, namely, that behind the faults of persons lie managerial errors such as not setting up appropriate safety management policies. Adams's model updates Bird's by redefining the direct causes of accidents, or the second sequence, as tactical errors of workers, behind which lie managerial and supervisor operational errors. On the other hand, Weaver's model updates the domino theory by redefining the second sequence as symptoms of accidents, behind which lie poor management practices.

In summary, all these causation models could actually be grouped into two categories based on their orientation. The first category consists of those models oriented toward "people" and their faults, which can include the behavior, the human factor, the decision, and the management models. Among these four models, only the decision and the management causation models are presently acceptable as a basis for an accident prevention model in an oil-well drilling company.

The second category contains those models oriented toward the interactions among people, machinery, and the environment. This latter category includes the system and the epidemiologic models, of which only the system causation model is presently adoptable for the basis of an accident prevention model.

2.2. Sources of Motivation

Accident prevention models could be developed based on the causation models. For example, a model could be developed based on a management causation model by simply eliminating and/or modifying either the second, the third, the fourth, or the fifth accident sequence. But such a model is useless whenever the incentive to prevent accidents does not exist. Hence, a model should also be equipped with an incentive to motivate the prevention of accidents. The incentive is usually referred to as the source of motivation.

Sources of motivation are situations and conditions that could induce or stimulate people to prevent accidents. Basically, there are four sources of motivation: the legal requirements imposed upon industries by the Occupational Safety and Health Administration (OSHA); the humanitarian concern; the company's safety image; and the total accident costs (Levitt, 1975; Robinson, 1979; Simonds and Grimaldi, 1956; Hammer, 1976).

The legal requirements as imposed by OSHA are expressed as laws, rules, and ordinances that require workplaces and equipment to be kept in safe condition. Furthermore, adequate first-aid facilities must be provided, accidents and diseases must be recorded, employees must be trained, and employees must also be compensated for injuries or occupational diseases. These legal requirements are made clear, and so are the penalties for non-compliance. For these reasons, much time and resources have been spent on safety activities to avoid legal citations, irrespective of their lack of cost effectiveness. Hence, this type of motivation can be thought of as a negative incentive because the activities induced thereby have as their main purpose compliance with the law, and any reduction of accidents has been only a side-effect of these activities (Denton, 1982; Petersen, 1978). These legal requirements, however, will always exist in an industrial setting, so that the presence of another source of motivation is necessary to stimulate a real accident prevention activity.

The humanitarian concern for the injured workers and their families appears to be an important source of motivation to managers. This is especially true in small companies where there is strong personal contact between managers and their employees (Levitt, 1975). In general, such motivations are difficult to create in large companies such as oil-well drilling companies.

The company's safety image creates a motivation for safety whenever this image could promote sales of their products and/or their services (Levitt, 1975). The determination of this safety image, however, is only based on the number of spectacular injuries; the less severe, but nevertheless frequent, accidents are not being reported. Since both severity and frequency of accidents are equally important in the evaluation of safety, this source of motivation is considered inadequate for accident prevention.

The total accident cost is another important source of motivation, especially whenever these costs account for a substantial portion of the operational cost of the company, such as those found in the high-hazard industries (Levitt, 1975; Robinson, 1979). The total accident cost consists of the direct and the indirect costs of an accident. The direct costs, in turn, consist of compensation payments, first aid, medical and surgical expenses, legal fees, and overhead costs. These costs are mostly insured, and are being used in the determination of the company's future insurance premium due to experience rating. Experience Rating is a procedure utilizing past insurance experience of the individual policy holder to forecast or predict future losses (NCCI, 1981). The future insurance premium can be increased or decreased depending on the magnitude of these direct costs incurred in the last three years. Cases of severe injury, i.e., where the direct costs account for more than a pre-specified value, like $2,000 (NCCI, 1981), the company will be charged primary values which can be looked up in a table or calculated from a formula (NCCI, 1981; Petersen, 1978). All other injuries resulting in losses less than $2,000, the whole amount is taken as the primary value. Hence, in these cases, the company will be charged fully for the actual cost. In other words, the experience rating plan gives greater weight to accident frequency than to accident severity. Thus, it can be understood that the elimination of the frequent but minor injuries could result in an almost equal, if not greater, reduction of future insurance premiums than by the elimination of a single major injury. This is especially true if the direct costs of the minor injuries exceed those of the major injury.

The indirect costs are hidden costs in the sense that they are costs related to the indirect consequences of accidents. These costs consist of: (i) costs of decreased production output due to interruptions by accidents, (ii) costs of man-hours lost due to the absence of the injured employee and others helping the injured at the time of the accident; (iii) costs of man-hours used to train a replacement; and (iv) costs of damaged materials and tools. The indirect costs are uninsured and their magnitude is in the range of two to thirteen times higher than the direct costs (Heinrich et al, 1980; NSC, 1978, Simonds and Grimaldi, 1980; Robinson, 1979; Samelson, 1977). Thus, the value for indirect costs could be estimated by multiplying the direct costs with any factor between three and fourteen whichever is acceptable to the company. The problem, however, lies in the determination of the direct cost itself which may take quite some time; this is especially true for those costs related to a severe injury which needs prolonged medical treatment.

Recently, Robinson (1979) has developed a matrix method to estimate total accident costs. Its principal method of development, the resulting matrix, and an example of how to use this matrix are shown in Appendix A. To get the estimate of the total cost of an injury by this matrix, one needs to know only three variables of the injury: (i) the part of the body injured; (ii) the nature of the injury; and (iii) whether the injury resulted in lost time (by OSHA definition). Once the values of these three variables are known, the total cost can be estimated in a few minutes by using the matrix. This matrix has been developed for the construction industry; it has been tested and used in several industries with successful results (Robinson, 1979).

The above method of total cost estimation has made possible the communication of these costs to all desired levels of management in an organization that includes this information in their monthly cost reports. This monthly cost report is a basic medium of communication between levels of management; it is generally used to predict or evaluate whether the job or project will make money and how management can control costs to insure that it does. The inclusion of the total accident costs in these monthly reports can be useful in several ways, depending on the magnitude of the losses incurred: (1) it can be used in the accident cost accounting, i.e., the projects can now be charged with the reported total costs incurred; (2) it can aid management in the evaluation of their personnel performance in safety; (3) it can help locate safety problems and needs in order to allocate resources accordingly; (4) it can attract management interest in safety; and (5) it can create a situation that could motivate managers to actually prevent accidents and possibly reduce the magnitude of losses incurred by being utilized in the accident cost accounting.

2.3. Accident Prevention Models

Accident prevention models are developed based on accident causation models and sources of motivation. If the same causation models were taken as their basis, the prevention models would show some similarities in their step-by-step procedure of prevention. They might differ in their basic approaches if different sources of motivations were used. The review on accident causation models suggests that only the system, the management, and the decision causation models are now acceptable as the basis for an accident prevention model. The decision model, however, is already included in the management causation model (see Sequence 2a and 4). Hence, the review on the accident prevention models will be limited only to those based on the two aforementioned causation models. Most accident prevention models have also taken the system model, or the combination of the system and the management causation models as their basis for development. The legal source of motivation, to a certain extent, is always present in a model. It would therefore be appropriate if the accident prevention models be discussed by type with the use of some examples.

2.3.1. Examples of Accident Prevention Models

Examples of three types of models will be presented: (i) two models that are based on the system causation model only; (ii) one model that is based on the combination of the system and the management causation models, and (iii) those models adapted for safety from management decision models.

The examples for those models based on the system causation model only are the models described by Brown (1976) and Peters (1980), the most important subsystems of which are illustrated in Figures 1 and 2 respectively. Brown's model is called the Safety Control System; it defines accident as an uncontrolled condition of men, machine, and material to the point where physical damage or injury will result. The word "control" in this case is defined as an action that would bring the system up to standard and would lead toward a specified goal whenever measurements indicate that this goal is not being met. Hence, according to this model, there are three important elements necessary in the control of safety: (i) the goals or standards to be achieved, which are stated

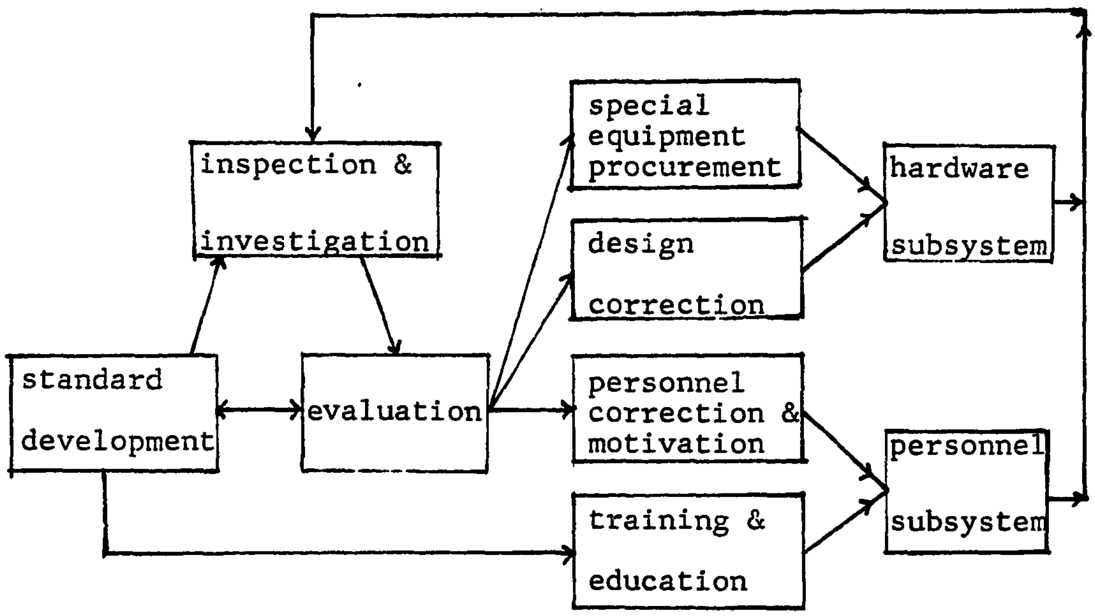


Figure 1: Brown's Safety Control System

so as to comply fully to OSHA standards; (ii) the methods of measurement to determine whether goals and standards are being met (the methods to be used, however, are not specified), and (iii) the means of correction to get the system up to standard (in this model, they are specified as the hardware and the personnel subsystems).

As is shown in Figure 1, Brown's model starts with the setting of its goals and standards to be met; it then continues with the inspection and investigation subsystem for the identification of any existing safety problem. If any problem is identified, it should be evaluated to see whether correction is necessary, i.e., whenever standards are not being met. If it is decided that correction is necessary, the respective correcting subsystem(s) is determined (there are three correcting subsystems). After the required remedy has been applied, the changed system may not be completely free from hazards and may need to be further monitored. The results of this monitoring procedure serve as feedback to the system for that particular correction and safety problem. It can be noted that the training and education subsystem is being separated from the choices for correction procedure because they are considered to be a routine activity as specified by OSHA. Hence, this model is solely based on the legal source of motivation as expressed in its goal statement; it has also taken the system causation model as a basis since it has a feedback mechanism.

The Peters model differs from the Brown model in several ways. Firstly, it does not state its goal explicitly other than a general statement to achieve safety. Secondly, it shows different consecutive steps in the evaluation of a safety problem. Once a problem is identified and it is found that standards are not being met; a hazard exists, which according to Brown's model should always be corrected. In this model, however, hazards will not be corrected unless they present risks that are not acceptable. Risk is defined as the probability that injury will occur, while danger denotes the acceptability of a risk. Finally, this model specifies explicitly the methods that should be used to evaluate

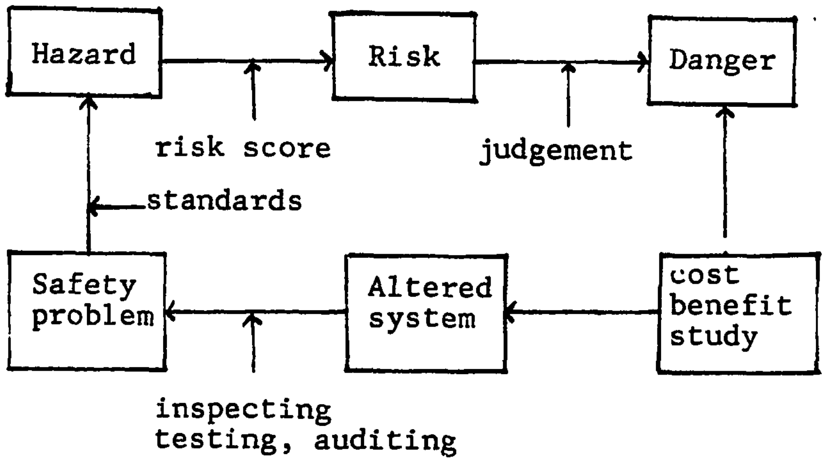


Figure 2: Peters' Systematic Safety Cycle

a safety problem, a hazard, a risk, and a danger; namely, the comparison to the existing standards, the risk score calculation, the value judgement, and the study of the cost and benefit respectively, as can also be seen in Figure 2. These stated differences show that this model uses another source of motivation besides legal requirements, namely, a cost benefit factor, in the correction of a hazard. Otherwise, the general outline of investigation, evaluation, control, and monitoring procedures is the same as that described by Brown, indicating the use of the system causation model as its basis. This model suggests that not all safety problems presenting hazards should be corrected, which would make a user vulnerable to legal citations. On the other hand, it tries to introduce objective methods for the evaluation of hazards and for the selection of control procedures. The risk score calculation used in the evaluation of hazards will not be discussed in detail, until later in this chapter. It suffices to say, that this method was developed by Fine (1980), whereby both the severity and the frequency of a hazard are taken into account in the risk score calculation.

The example for models based on the combined system and management causation models is the model developed by Heinrich (1980); its main subsystems are shown in Figure 3. This model explicitly specifies its basic philosophy (theorems of accident occurrence and prevention) and approach before going into its main activities. The word "approach" denotes ways and means for the reduction of accidents based on the existing and available knowledge and incentives for accident prevention. In the management causation model, poor safety management policies or practices are considered the underlying cause of accidents, hence, safety management is taken as the basic approach of this model. Its step-by-step procedure, however, is very similar to the previously described models, implying the use of the system causation model as its basis. This model ends by listing the long-term and the short-term safety activities. It can be concluded that this model introduces only its very basic ideas so that it is still not clear how the philosophy and approach are being integrated into the model. It is also not clear what source of motivation is used to make sure that safety policies will be determined and enforced.

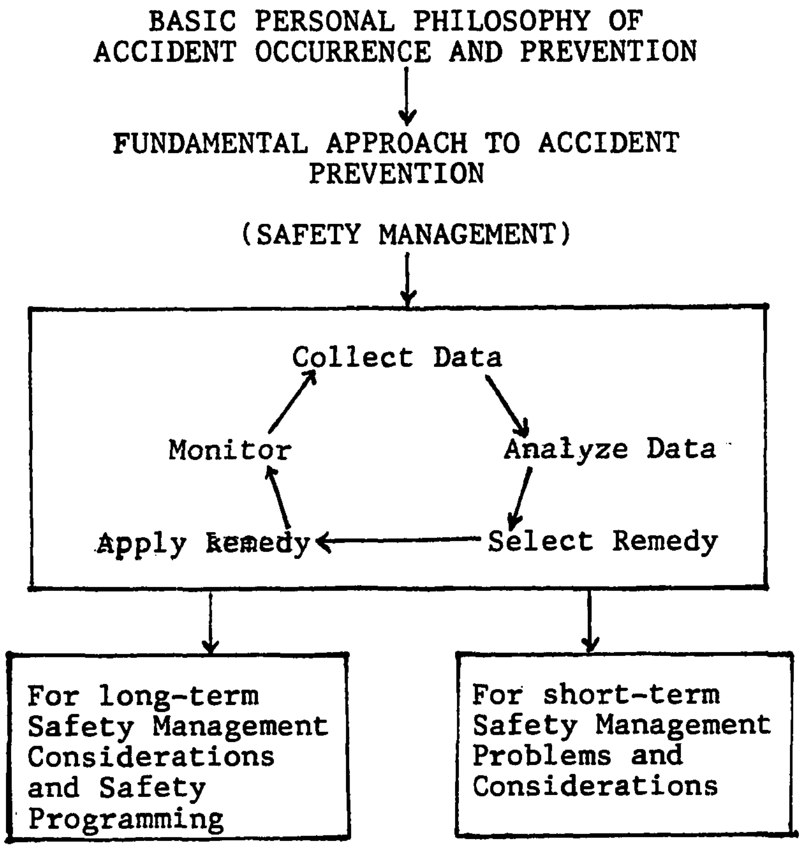


Figure 3: Heinrich's model

The examples for models that are adapted for safety from management decision models are the Kepner-Tregoe and the Johnson human performance models. The Kepner-Tregoe model, as illustrated in Figure 4, was cited by Heinrich et al (1980). This model was originally developed for the U.S. Air Force by the Rand Corporation, but is now widely used in other U.S. corporations. The subsystems described are very similar to the previously discussed models, only different terms are used for the same procedures. It is therefore self-explanatory.

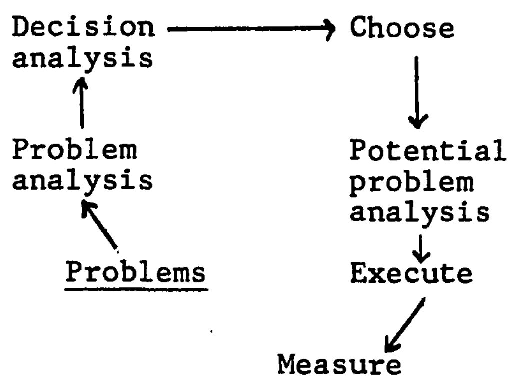


Figure 4: Kepner-Tregoe's model

Johnson (1973) in his Management Oversight Risk Tree (MORT) provides a model that closely approximates the accident prevention steps and is known as the performance cycle model, as illustrated in Figure 5. This model was originally designed to improve human performance by the reduction of human error. Its basic steps are very much like the Kepner-Tregoe model and, again, different terms are used for the same procedures.

Hence, this is also self-explanatory.

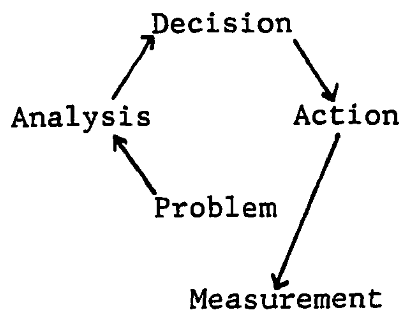


Figure 5: Johnson's Performance Cycle Model.

Based on the similarities of the Kepner-Tregoe and Johnson models to the basic procedures of a system prevention model, they are considered to have more value for safety than the other management models (Heinrich et al, 1980; Petersen, 1980). Actually the name "management model" does not denote the use of the management causation model as its basis, but rather that it originated in the business world.

Therefore, it can be concluded that most accident prevention models are based on the system causation model and use the legal requirements as their source of motivation. Those adopting the management causation model are still deficient in the integration of their philosophy and their approaches into the model.

2.3.2. The Traditional Accident Prevention Activities

In general, traditional preventive activities have been motivated by legal requirements. The step-by-step procedures are very much like those described in the Brown model, but its applications have been limited to major injuries and the elimination of unsafe acts and conditions. Hence, the underlying causes of accidents have not yet been addressed. Denton (1982), classifies these traditional activities into the work and the employee-centered or "people" approaches. The work-centered approach emphasizes the elimination of unsafe working conditions, while the employee-centered approach stresses the elimination of personal factors that would lead to unsafe acts. It was further suggested that work-centered approaches have resulted in the production of safer machinery so that at the present time, there are fewer machines that would cause accidents. The causes of accidents would, therefore, more likely be due to unsafe acts. The fact that accidents are mostly caused by unsafe acts (80%) has been reported by others (NSC, 1978; Heinrich et al, 1980; Surry, 1974; Levitt, 1975), but they differ from Denton in their opinion that unsafe acts have not been reduced as much as unsafe conditions because the underlying causes have not yet been addressed by this traditional practice.

From the preventive point of view, these traditional activities could be better classified into retrospective and prospective practices. Retrospective activities are those activities related to the prevention of accidents after an accident has occurred. These activities include accident investigation, analysis, evaluation, and control; they are meant to prevent similar accidents from occurring in the future. These activities could actually be used as a learning experience, but so far their application has been limited to major injuries. This limitation cannot be considered a good policy for several reasons: (i) accidents do not always result injuries; (ii) major injuries occur only in one out of 600 injuries (Heinrich et al, 1980; Petersen, 1978; NSC, 1978); and (iii) severity and frequency of accidents are of equal importance in the evaluation of safety. This limited activity also shows that the only source of motivation for preventing accidents is the legal requirements, which state that only those accidents requiring more than first-aid treatment should be recorded. Hence, the great potential of the learning experience has not been well utilized.

The prospective activities are those activities related to the prevention of accidents before they can occur. These activities are represented by routine hazard inspections, analysis and control, education and training, and supervision. Compared to the retrospective activities, the prospective activities are more positive in nature. The retrospective activities, however, could be very useful as a source of experience and could provide input to the prospective aspect. Because of the existence of these retrospective and prospective activities, many terms in the field of safety need clarification. The most important and most frequently used terms are: accident, injury, safety, hazard, and danger. A definition for each one of them can be found in the glossary.

Despite the limitations of traditional safety practices, many industries are now considered to have outstanding safety records (Heinrich et al, 1980; Levitt, 1975). Heinrich is of the opinion that this outstanding record could not have been achieved solely by traditional safety activities. This statement has been supported by Levitt, (1975), who found that in the construction industry, distinctive accident records are achieved when top managers are well-informed about all aspects of safety of the company. These top managers know the company's safety organization and its performance. They also include safety in the detailed planning and implementation of their work, (i.e., the evaluation of their personnel and projects based on safety performance), the use of accident cost accounting to promote safety, (i.e., allocating resources for safety based on accident costs), and the training of new employees in safety methods. It can be deduced that if safety is integrated into management policies, accidents can be reduced. Hence, Levitt's findings support the relevancy of the application of the management causation model in the construction industry.

However, the oil-field industries, together with the heavy construction, bituminous coal mining, and durable goods industries, are still classified as high-hazard industries. For the period between 1972 and 1978, the accident frequency and severity rates were 20 per 100 employees per year and 200 workdays per 100 employees per year respectively (NIOSH, 1982). Oil-well drilling industries were responsible for 56% of the frequency and 50% of the severity rates of the oil-field industries. It can be noted that these frequency and severity rates within the same period were almost constant despite the existence of techniques, skilled man power, and information that could have been used for accident prevention. This consistency denotes that the present accident rates can no longer be reduced by the existing safety practices.

From the above review it can be concluded that there is a need for a better model to prevent accidents in the high-hazard industries such as oil-well drilling. This improved model should have the following qualities:

(1) It should be based on the management causation model as supported by Levitt (1975).

(2) It should be able to eliminate or modify the underlying causes of accidents, i.e., poor management practices.

(3) It should have a feedback mechanism that would serve as part of a learning process; hence, it should be based on the system causation model.

(4) It should have the total accident cost as another source of motivation besides the existing legal requirements.

(5) It should be able to give equal weight to both the frequency and the severity of accidents in the pro-

cess of the determination of priorities for corrections.

2.4. Qualities For a Better Model

Available literature on each of the aformentioned qualities of the model will now be reviewed so that they can be integrated into a better model in the next chapter. However, qualities number one, three and four, i.e., the management model, the system causation model, and the total accident cost have been discussed previously and will therefore not be repeated. To be able to integrate quality number two into a model, a technique that can reveal the underlying causes of each accident is needed. These causes need to be specified as errors made by each level of management involved in a particular accident. These underlying causes are then reported to the respective management levels and to the top manager, to serve as feedback on how the existing management safety policy is being implemented and enforced. Based on these reports, evaluation and improvement of managers' safety performances can be accomplished. In so doing, the underlying causes of accidents can be reduced and/or eliminated. Such a technique has now become available and is called the "4x4 problem-solving technique". It is also referred to as the "reverse sequence investigation technique" developed by Jones (1981). The Jones technique and the Fine model which determines priorities for corrections as specified in quality number five, will be discussed in the next two sections.

2.4.1. The 4x4 Problem-Solving Technique

The 4x4 Problem-Solving Technique was developed by Jones (1981). It is a technique that can be used as a tool to determine the underlying causes of accidents as well as establish the correct organizational levels at which opportunities for correction lie and the area of correction. According to this technique, there are three levels in the organization where accident prevention can be accomplished; namely, the management's, the supervisor's, and the worker's level. There are four corrective areas at each level of correction:

At the management's level:
- (1) Establish and communicate policy/procedure.
- (2) Apply policy/procedure consistently where applicable.
- (3) Establish and communicate procedural monitoring.
- (4) Enforce policy/procedure based upon procedural monitoring.

At the supervisor's level:
- (1) Communicate what is wanted.
- (2) Assure means to comply.
- (3) Be consistent in setting a good example.
- (4) Be consistent in enforcement.

At the worker's level:
- (1) Remove obstacles to proper performance.
- (2) Communicate what is wanted.
- (3) Train/motivate/enforce.
- (4) Recognize/reward improved performance.

The levels involved in the correction of a certain accident could be one, two, or all three levels. Thus, this form of accident prevention is not strictly limited to the activities accomplished by the safety staff, but rather involves the participation of the operational employees and the managers in the elimination of the underlying causes of accidents. The basic process of this technique is quite simple. It starts with the end result of an injury or hazard and asks "why?" until the causes, the proper levels of correction, and the area of correction are revealed. Appendix B shows the flow chart of the basic operational procedure, the basic rules, and the definitions of terms used in this technique.

In order to illustrate the effectiveness of this technique in the involvement of all operational, administrative and managerial resources, an example will be presented. Suppose that an accident occurred and resulted in an injury of the left eye of a worker. The supervisor investigating the accident should ask himself why that injury occurred and generates an answer that shows permitting or generating influences such as: "He was not wearing his goggles." Then ask "why?" again, and the best answer could be: "He disregarded instructions," or "He is used to doing this work without goggles." Then both answers should be checked separately to reveal the real cause of this accident. If the worker had disregarded instructions, the level of correction would be at the worker's level only, and the area of correction would be that area indicated as number three under the worker's level of correction; the underlying cause would then be expressed as "W3." If, instead, the second answer were right, then besides the worker, the supervisor was also involved because of his lack of consistency in the enforcement of safe working procedure. Thus, the correct organizational level for correction would be at the supervisor's and the worker's levels, while the areas of correction would be those indicated as number four and three under the supervisor's and the worker's levels, respectively. The underlying cause of this accident would then be expressed as "S4W3." The results of these investigations would then be reported to the appropriate levels so that similar accidents would not happen again in the future. The continous use of this technique will result in the involvement of all levels of the organization in accident prevention through the elimination of the underlying causes; it will also help monitor how the company's safety policies are being implemented and how they should be improved.

2.4.2. Models for Priority Determination

Models for the determination of priorities that closely resemble the above-mentioned quality are described by Smith (1982) and Fine (1980); both models are designed to evaluate hazards and will be discussed separately.

Smith derived his model from Dr. V. L. Grose's system safety known for its application in the space programs. Smith, however, used the drilling hazards evaluation for application. This model uses three variables in its determination of priorities: (i) the severity of the injury damage; (ii) the probability that an accident will occur; and (iii) the cost effectiveness for correcting the hazards. For each hazard that is identified, the values for all three variables are obtained by rating them subjectively in a qualitative manner, i.e., expressed as high (H), medium (M), and low (L). Based on these rates, all hazards identified are then ranked so that the highest rank will have the highest priority to be corrected. The hazard that will have the highest rank is the one that has high (H) rates for all three variables. However, the exact procedure of ranking was not described. If there were only one variable involved, the ranking procedure would be easily understood. But, in this model three variables were used; the relationships among them should also be considered in the ranking procedure. The cost variable could perhaps be considered as independent from the other two, but the severity of an accident and its probability of occurring are known to be very dependent on each other (NSC, 1978; Heinrich et al, 1980; Petersen, 1978). It is known that the less severe the injury, the more frequently it occurs. From a sample-ranked list shown, it is evident that Smith considered frequency as less important than severity; for instance, a hazard having rates of H, M, and L has a higher rank than another with M, H, and L rates for severity, probability, and cost respectively. Since it is required that both the frequency and the severity of accidents should be equally weighted in the process of priority determination, this model cannot be utilized.

Fine's model for priority determination of hazards differs from that of Smith in its basic concepts. In this model, priorities are selected based on the relative risk caused by a hazard; the greater the risk it causes, the higher its priority for correction. Hence, cost for correction does not play any role in the priority determination. However, it will become important at a later stage when the best alternative for correction is being determined. The priorities are measured by the risk score, as calculated by the following formula:

$$RS = C \times E \times P$$

where RS = risk score,
C = consequence of a possible accident due to hazard,
E = frequency of exposure to the cause, and
P = probability that the complete accident sequence will occur.

The consequence of a possible accident represents the severity of an accident. The frequency of exposure (E) in this case does not represent the frequency of the accident, but rather, the exposure to the direct causes of an accident. P stands for a probability that identical causes will lead to similar accidents resulting in the same consequences. The values for each variable are obtained through a rating procedure using a pre-determined range of numbers. The calculated risk scores (RS) are then ranked according to their magnitude. The larger the number of the RS, the higher the priority of a hazard will be.

The resulting risk score is then further used to decide on the best available alternative as expressed by the justification factor "J", calculated by the following equation:

$$J = \frac{RS}{CF \times DC}$$

where J = justification for correction,
RS = risk score,
CF = cost factor,
DC = degree of correction.

The risk score is the number acquired from the previous calculation, while the cost factor (CF) and the degree of correction (DC) are, again, rated values based on the relative cost and degree of hazard elimination respectively. To be able to use this method, a critical justification rating (CJR) should be set, above which the expenditure for correction is justified. However, if the value of J is below the CJR then two possibilities exists; namely, the J value is very close to CJR, in which case all factors should be re-examined carefully or J is far below the CJR, in which case the expenditure cannot be justified. In this model, all values assigned to the variables in consideration are based on a rating procedure that depends heavily upon the available experts involved as is the determination of the CJR.

As compared to Smith's model, this model considers the severity and frequency equally important; it also provides a method for the selection of the best alternative and it is quantitative in nature.

In summary, a model that will have the aforementioned qualities should eventually convert accident data into meaningful information to support managers in making decisions. Managers will not be supplied with data of injuries, damaged materials, and equipment, but instead they will be presented with information to identify causes of accidents, how safety policies are being implemented and enforced, what kinds of safety problems exist, what alternatives are available for correction, and how to choose the best corrective procedure. This type of a model can be identified as a management information system (MIS). The MIS originated from business practices where information has always been considered a resource. All levels in the organization need information in the performance of their duties, even if the degree of accuracy or the method of presentation may be different. As a business increases in size and in activities, the information needed from the inside as well as from the outside of the organization increases as well. To be able to provide this needed information in a systematic, orderly manner, an MIS was developed to collect, process, communicate, and store information (Matthews, 1976).

In summary, the qualities and/or criteria for the MIS which will be carried over to the next chapter are as follows:

(1) The management and the system causation models will be used as the basis of the MIS.

(2) The MIS should reduce or eliminate the underlying

causes of accidents as supported by the 4x4 problem-solving technique.

(3) The total accident cost will be used as another source of motivation besides the existing legal source.

(4) The determination of priorities for correction will basically follow the model developed by Fine (1980).

(5) The MIS should be applicable to an oil-well drilling industry.

Chapter 3

DESIGN OF THE MIS MODEL

A management information system is a system that provides information to all levels of management to help them make, carry out, and control decisions (Kanter, 1977). It consists of both the physical and the information systems so that it will show both the contents or "what" is going on as well as the means or "how" something is being accomplished. Definitions for system, management, and information can be found in the glossary section.

An MIS generally has three subsystems: (i) the data base management subsystem; (ii) the structured reporting subsystem; and (iii) the decision models subsystem (Sprague and Watson, 1975). Due to the extremely broad scope of the MIS, this dissertation is limited in several ways:

(1) The data base management subsystem, is important, but since specialized knowledge is required for its discussion, it will not be presented in its entirety.

(2) The structured reporting subsystem which consists of the external and internal reports will be only partially included, i.e., encompassing those reports required for communication within the organization

only, and those which are eventually needed by a safety activity in a company.

(3) The MIS model will be concerned with safety activities only.

(4) The model should be applicable to a land-based oil-well drilling industry.

Hence, the model will focus mostly on the decision models subsystem.

The goal of this design phase is to get the MIS model on paper so that it can be tested in the next phase of its development. The procedures that will be followed to achieve this goal are as follows:

(1) A description of a land-based oil-well drilling operation will be presented to provide sufficient background information for the design process.

(2) The goals and output of the model will be elaborated so that the type of decision models required can be identified.

(3) The processor element, which consists mostly of decision models can be determined.

(4) The input required by the processor element can be identified.

(5) The necessary subsystems of the MIS and their relationships will be discussed, as defined by the input, the processor, and the output of the system.

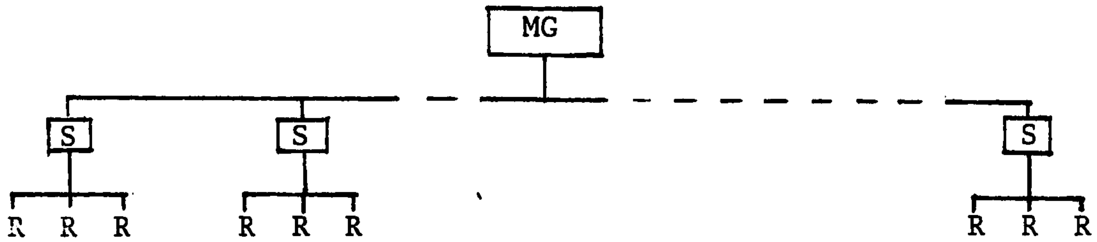
(6) The model will be illustrated through flow diagrams and drawings on paper.

3.1. Land-Based Oil-Well Drilling Operations

The purpose of the following description is to give sufficient background information for the development of the MIS model. The description will be divided into two parts; namely, the management and the drilling operations.

3.1.1. Management of the Drilling Operation

The following description focuses on the functions of the different levels of management so that the right information can be addressed to the relevant level. In an oil-well drilling industry, as in most other organizations, there are three levels of management; namely, the top, the middle, and the lower levels, as illustrated in Figure 6.



MG : Management group
S : Superintendent
R : Rig Manager or Toolpusher

Figure 6: Three Levels of Management

The top management is usually referred to as the management group and consists of the executive committee. This management group determines the short-term and long-term objectives (1-5 years) of the company, its personnel, monetary and physical resources needed to realize them, and the policies and strategies that best utilize the resources. They also implement and control the decisions that have already been made. Hence, this top level of management will need information that relates to the determination of objectives, budgets, and policies.

The middle management, the superintendents, are those reporting to the top managers. Each of them supervises the operation of three rigs on the average, and their main functions are to acquire and control the resources necessary to implement the company's plans so that the objectives can be achieved efficiently.

The lowest level of management is the operating management, i.e., the rig managers or toolpushers who report to the superintendents. Each of them supervises the operation of one rig. They also direct the work crew. There are four to five work crew members in a tour or shift and there are three tours in a day with one additional relief crew. The crew members consist of a driller, a derrickman, a motorman, and one or two floorhands or roughnecks. These rig managers are the representatives of management who have daily contact with the employees so that they become the key people in a safety program. Their duties in safety include the inspection and observation of work practices, the orientation and training of employees in safe work methods, the investigation of accidents, the administration of first aid, the maintenance of safety records, and the communication of safety rules and methods (Terry and Rue, 1982).

3.1.2. Drilling Operation*

The following process description summarizes the drilling operation with the use of a rotary rig. It should be noted that any drilling operation is always preceded by the erection of the derrick and its associated gear ("rigging up"), the construction of the substructure supporting the drill deck and the derrick, and the augering of a starter hole ("spudding in"). After the drilling is completed, these structures are again disassembled ("rigging down"). All the hazards associated with these activities are not considered specific to a drilling operation and are included in general construction hazards.

The rotary drilling rig consists of several functional components associated with the following activities/systems, as illustrated in Figure 7 and in the functional diagram in Figure 8 (NIOSH Report, 1982):

(1) Power generation and transmission.

(2) Hoisting the drill string.

(3) Rotating the drill string.

(4) Circulating fluid system.

(5) Material handling during drilling.

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*The technical terms used in this description are explained in the glossary.

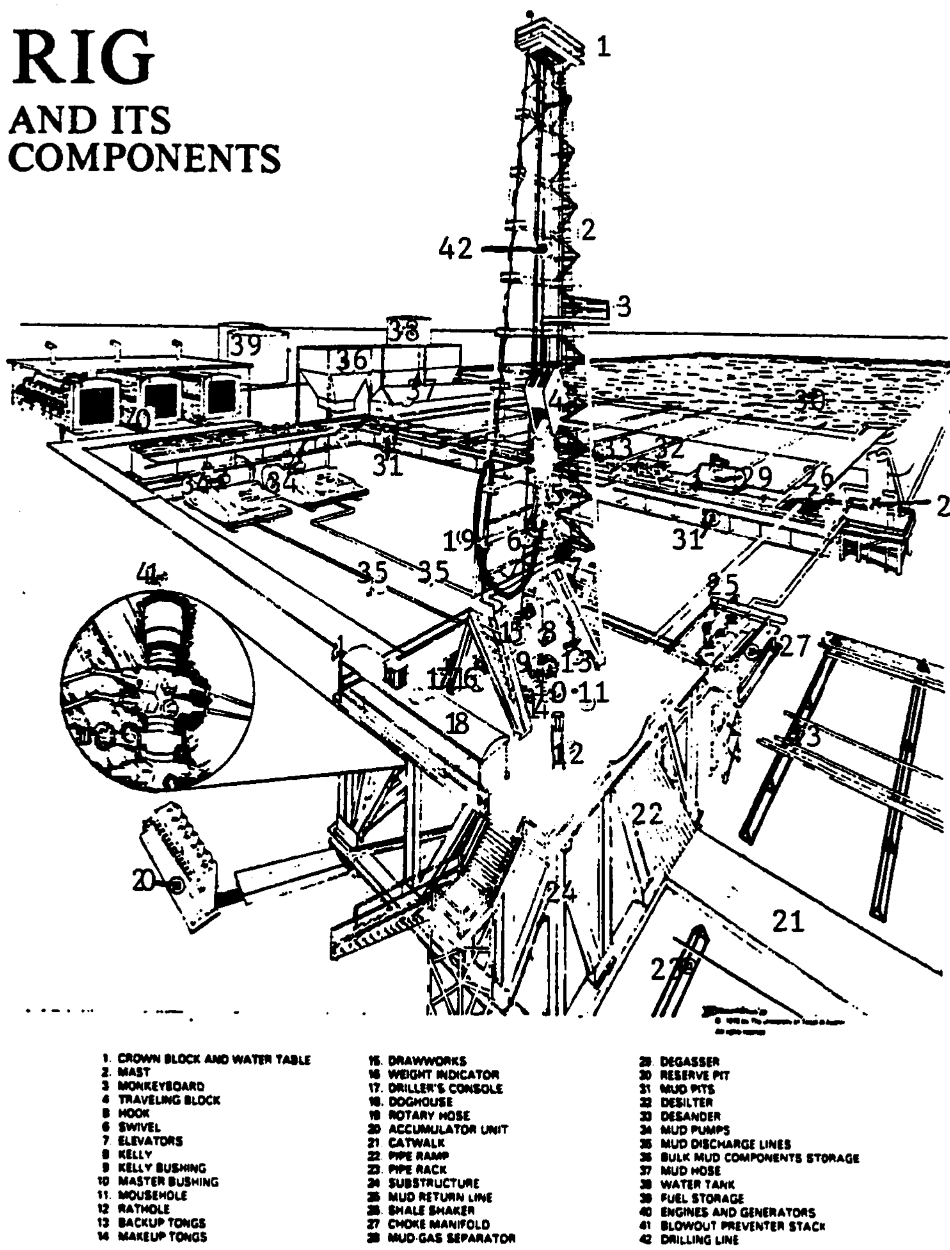
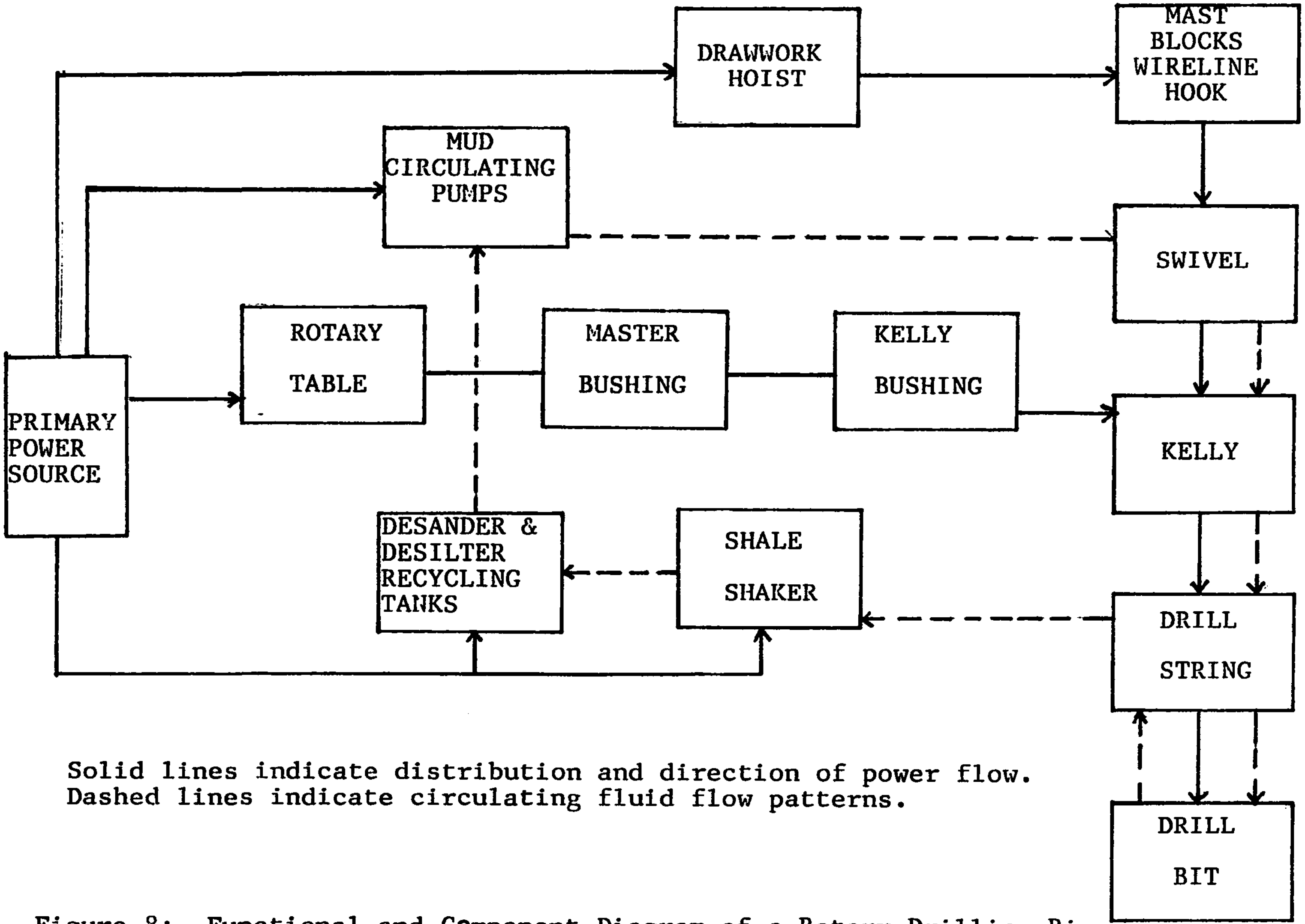


Figure 7: Rig and its Component. Source: Petroleum Extension Service, 1980.



Solid lines indicate distribution and direction of power flow.
Dashed lines indicate circulating fluid flow patterns.

Figure 8: Functional and Component Diagram of a Rotary Drilling Rig

3.1.2.1. Power Generation and Transmission

The primary power source is normally one or more internal combustion engines. These engines are usually mounted immediately next to the derrick. The most common fuel used is diesel, but gasoline, natural gas, and purchased electricity are also used. The power produced and used in a rig is several hundred horsepower.

The transmission may be mechanical or electrical. Mechanical transmission is more common at older rigs; it employs a number of driving and driven shafts, clutches, chains and sprockets, and belts and pulleys. Electrical transmission used in newer rigs transmits the power to motors at the work points.

Exposures to hazards in the above activities occur during maintenance, fueling, and lubricating. Other hazards include high voltage, chemical burns or irritations, fires and explosions, and noise.

3.1.2.2. Hoisting the Drill String

The primary functions of a hoisting apparatus are to raise and lower the drill string components during tripping and drill-stem lengthening, and to support the drill string at the desired bit weight during drilling. It consists of the draw-works, the crown block, the traveling block, the anchor and reel, and the wire ropes, as illustrated in Figure 9. The draw-works is essentially a rotating spool located on the drill deck, which is controlled by a clutch and brake system operated

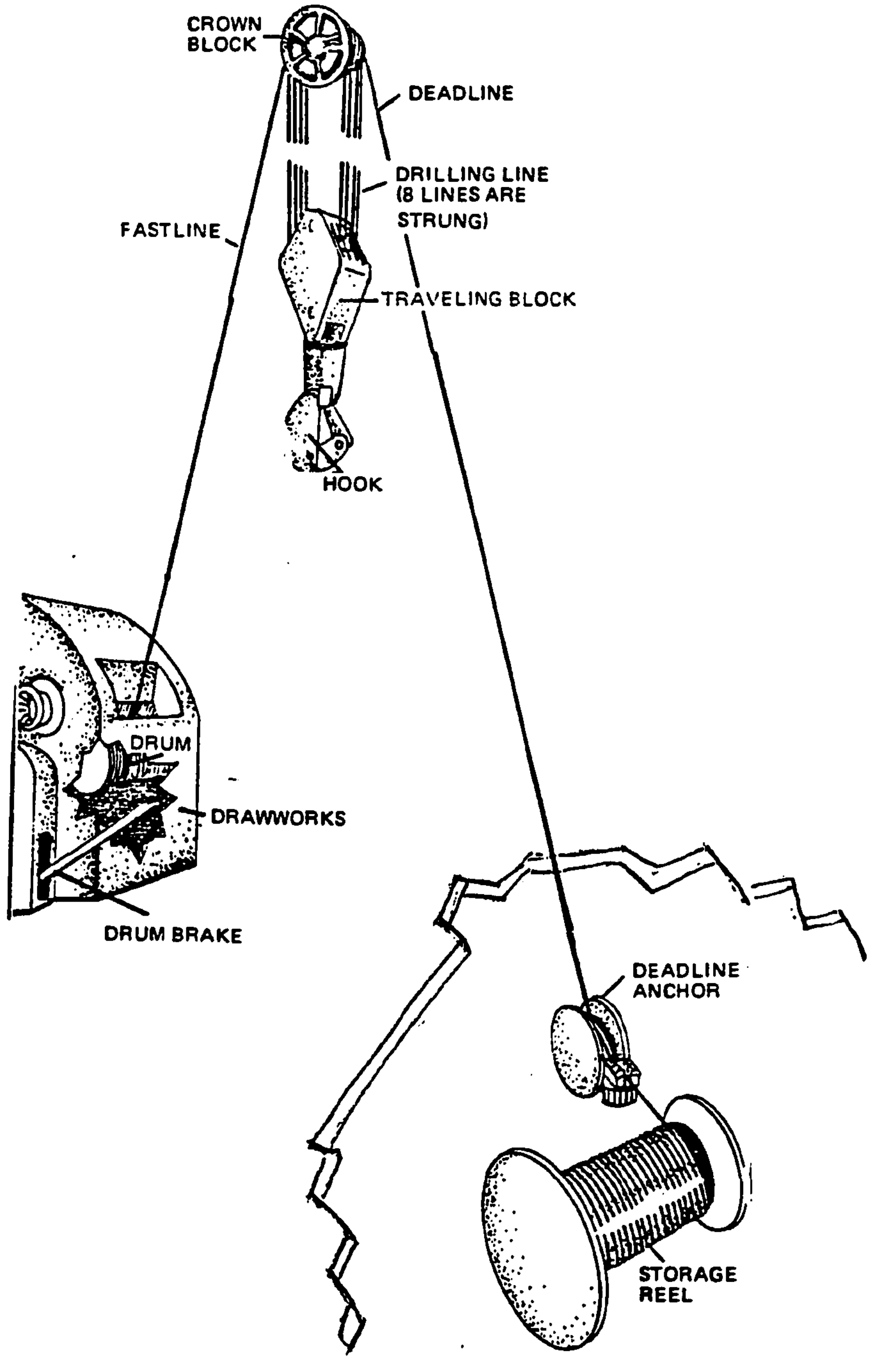


Figure 9: Rotary Rig Hoisting System. Source: Petroleum Extension Service, 1980.

by the driller. The wire-rope drill line runs from the draw-works to the crown block at the top of the derrick and then to the traveling block and hook, which is attached to the drill string. The deadline anchor, located on the derrick substructure, serves as an adjustable terminal anchor point for the wire rope.

Exposure to hazards associated with hoisting should be slight unless structural defects or system overloading occurs. However, there are risks of falls, pinched fingers, and injury from wire rope splinters when inspecting the elevated hoist mechanisms.

3.1.2.3. Rotating the Drill String.

The drill string consists of 30-foot sections of drill pipes, male and female-threaded, that weigh between 14-18 pounds per foot. Several heavy thick-walled joints of pipe, called drill collars, are "made up" (see glossary) in the drill stem, just above the bit so that the bit will penetrate the formation being drilled. A single drill collar can weigh between 2,500 and 4,000 pounds. The rotary rig provides free vertical motion as well as rotation of the drill string so that the bit can penetrate the earth. To rotate the drill string, the power source is connected to the rotary table; torque is then transmitted from this rotary table to the drill by the kelly, which also conveys the drilling mud that is pumped into it through the swivel (see diagram in Figure 8). The kelly is a 40-foot long conduit (four - six sides) that threads into the drill pipe and is connected to the hoist traveling block by the swivel. The swivel supports the buoyed weight of the drill string while allowing the kelly to rotate and allowing pressurized drilling fluid to enter the drill stem. The kelly is rotated by the kelly bushing which transfers rotational force without impeding the continuous downward movement of the kelly. During operations such as tripping, the kelly bushing must be easily removable to permit the drill pipe to be withdrawn from the well. When the kelly is hoisted and stored in the rathole during a trip, the kelly bushing is removed as an integral part of the kelly assembly. To facilitate this maneuver, the kelly bushing sits inside a four or six-sided master bushing that is a fixed portion of the rotary table. The rotary table turns at rates of 25-100 r.p.m. and the driller operates the rotary table clutch controls and hoist controls from the same station.

Exposure to the rotating parts of this system may create hazards such as slips, falls, bruising injuries, and there is a chance of being caught between stationary and rotating parts.

3.1.2.4. Circulating System.

Drilling fluid or "mud" is typically a mixture of water and bentonite (an absorbent, gel-forming clay) and sometimes oil and other components. Presently, chemical as well as biopolymers are also used as drilling fluids (APT, 1969). It has four primary functions: (i) cooling, lubricating, and cleaning the bit; (ii) removing cuttings; (iii) providing hydrostatic pressure to support the well wall until casing is inserted; and (iv) reducing the risk of hazardous blowouts. This circulating fluid system, as illustrated in Figure 10, consists of pumps, a standpipe, a swivel, a mud return line, a shale shaker, mud pits and a mud mixing hopper. The mud pumps force the mud up the standpipe and through the flexible kelly hose to the swivel, where it enters the drill string via the kelly and eventually emerges at the bit in the well bore. Continuous pressure forces the mud up the well annulus and out the mud return pipe, where larger cuttings are screened at the shale shaker and then processed through a series of desanders and desilters prior to recycling.

Mixing the mud exposes workers to airborne respirable dust and chemical splashes. Mechanically stirred tanks require guarding and effective lockout procedures during maintenance operations. Walking surfaces nearby may be slippery especially in wet or icy weather. Pressure surges which cause line ruptures are also occasional hazards.

3.1.2.5. Material Handling During Drilling Operations.

Material handling equipment that is unique to the oilfield consists of devices used in the working routines of raising and lowering the drill string, adding new sections of drill pipe, and tripping. This equipment and its operation are described in the operation of adding a joint to the drill

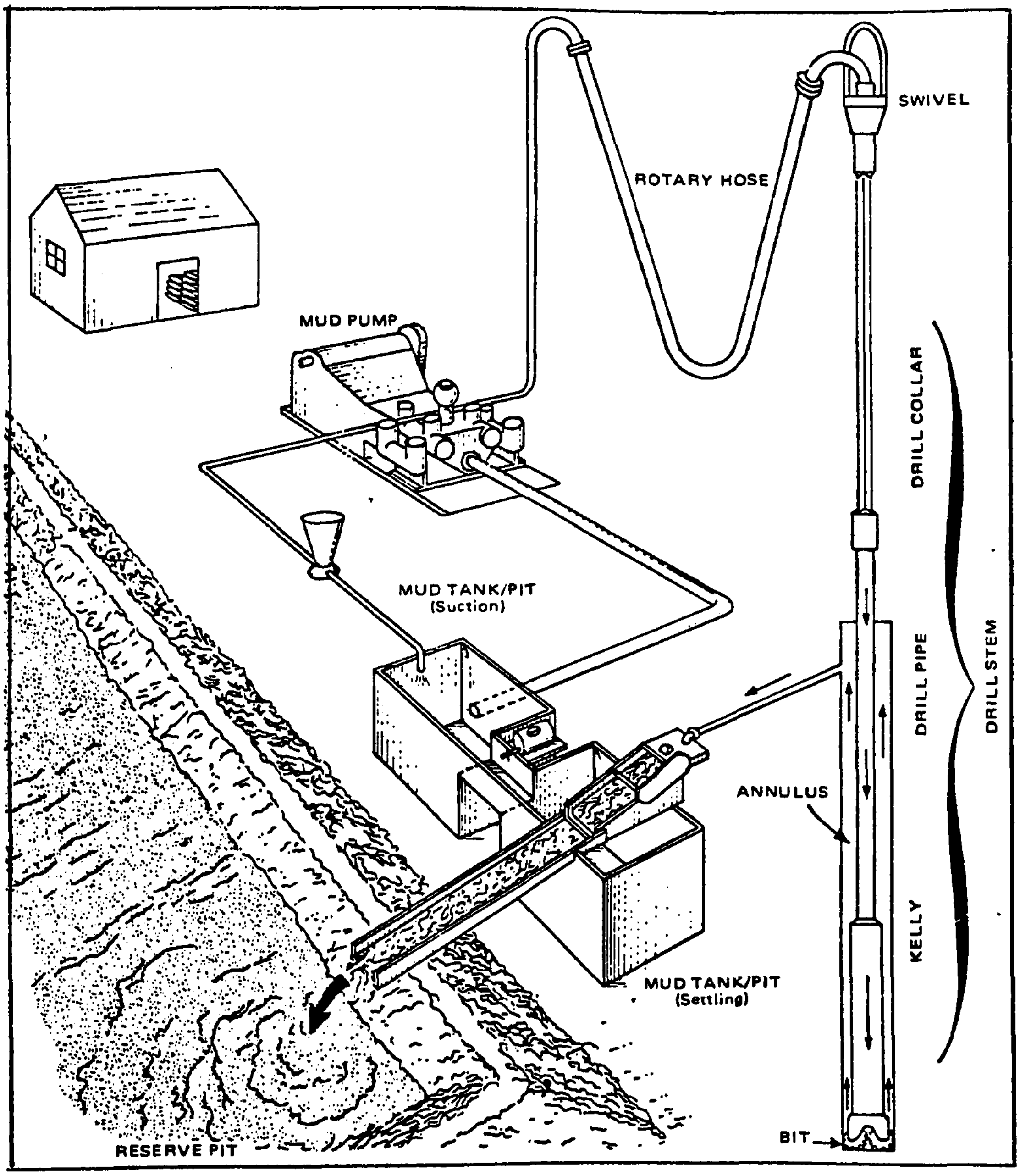


Figure 10: Systems for Fluid Circulation and Mud Treatment on a Rotary Rig. Source: Petroleum Extension Service,1980.

string and tripping.

3.1.2.5.1. Adding a Joint to the Drill String

A joint is stored in the mousehole until extension of the length of the drill string is needed. It is hoisted from horizontal pipe storage racks located at ground level to the drill floor, after which it is lowered into the mousehole. When the kelly is at the level of the kelly bushing, extension of the drill string is required. The rotary table and mud circulating pumps are stopped. The driller raises the drill stem until the bottom of the kelly-pipe joint connection is about two feet above the level of the rotary table. A set of "slips" is wedged into the space between the master bushing and the drill stem to maintain the drill pipe position. A large pair of tongs is then used to "break out" the torqued kelly-pipe joint connection. Once the tongs are clamped above and below the connection, mechanical force is applied to the handle of the tongs by a tong pull line originating from a mechanical cathead located on the drawworks. When the connection has been loosened, the joints are "spun out." To spin out the pipe from the kelly, the tool joint is "broken" by the use of tongs, and the pipe is then spun out with the rotary table.

Once disengaged, the lower end of the kelly, suspended by the hoist, is pushed or pulled by the floorhands until it is centered over the pipe joint which has been temporarily stored in the mousehole. The kelly then, is "stabbed" into the pipe joint, spun up, and tong tightened. Next, the driller engages the drawworks and raises the kelly and pipe-joint assembly, which in turn is stabbed into the stem that is held by the slips. This connection is then spun up and tong tightened. The slips are then removed, the mud pumps and rotary table are reactivated, and the drilling operation proceeds.

3.1.2.5.2. Tripping

Tripping is a procedure that is performed to inspect a well bore and make the necessary bit changes. The entire drill string must be removed from the hole and later returned if the drilling is to proceed.

During a "round trip" (cycle of removal and replacement), the kelly is disconnected and stored in the "rathole." Elevators, a set of clamps affixed to the bails on the swivel below the traveling block, are used to raise the drill string from the hole. Pipe tongs and the rotary table are used to disconnect the stands (90 feet of drill pipe) as one unit. The derrickman, using a fall-arresting derrick climber, climbs the derrick and works from the monkey board, located at 90 feet above the rig floor. His task is to coordinate the placement of the stands between the fingers of the "finger board" for temporary storage during the trip and to disconnect the drill pipe from the elevators.

Once the bit has been removed from the hole, it is inspected for wear and replaced as necessary. If the well drilling operation is to continue, the above sequence is reversed, completing the round trip.

Workers are directly involved in moving equipment, while they also have to perform tasks that require substantial exertion and good coordination between individuals. Transferring drill pipe from the rack to the platform or mishandling suspended loads may result in crushing injuries. Handling of tongs requires well-coordinated efforts and proper body-limb placement. Mistakes in "hands-on" spinning chain operations can lead to entanglement resulting in crushing, amputation, and death. Lifting and moving heavy items while standing on wet surfaces may lead to slips, falls, and overexertion. Eyes are at risk because of material falling off the drill pipe. Hazards in these operations can be increased if the drilling crew has not worked together very long, since teamwork is necessary to carry out these operations effectively and safely.

From the above descriptions, several conclusions can be made:

(i) hazards associated with drilling operations are numerous, ranging in severity from minor bruises to death,

(ii) drilling operations require good teamwork among workers,

(iii) mechanical errors could occur, but their probability is low.

The above facts support the relevancy of the use of the management causation models as a basis for the proposed MIS because it will provide the "people" approach in the prevention of accidents (see page 23).

3.2. Goals and Output of the MIS

3.2.1. Goals of the MIS

As was discussed in Chapter 2, a better accident prevention model is needed for high-hazard industries; the required model should have the following qualities:

(1) It should be based on the system and the management causation models.

(2) It should be motivated by the total accident costs as well as the legal requirements.

(3) It should be able to determine priorities for prevention.

(4) It should be applicable to oil-well drilling, one of the high-hazard industries.

(5) It should be able to convert data into meaningful and timely information to support decisions and to involve managers in accident prevention activities.

Other criteria should now be added in accordance with the previous discussion of the oil-well drilling operation:

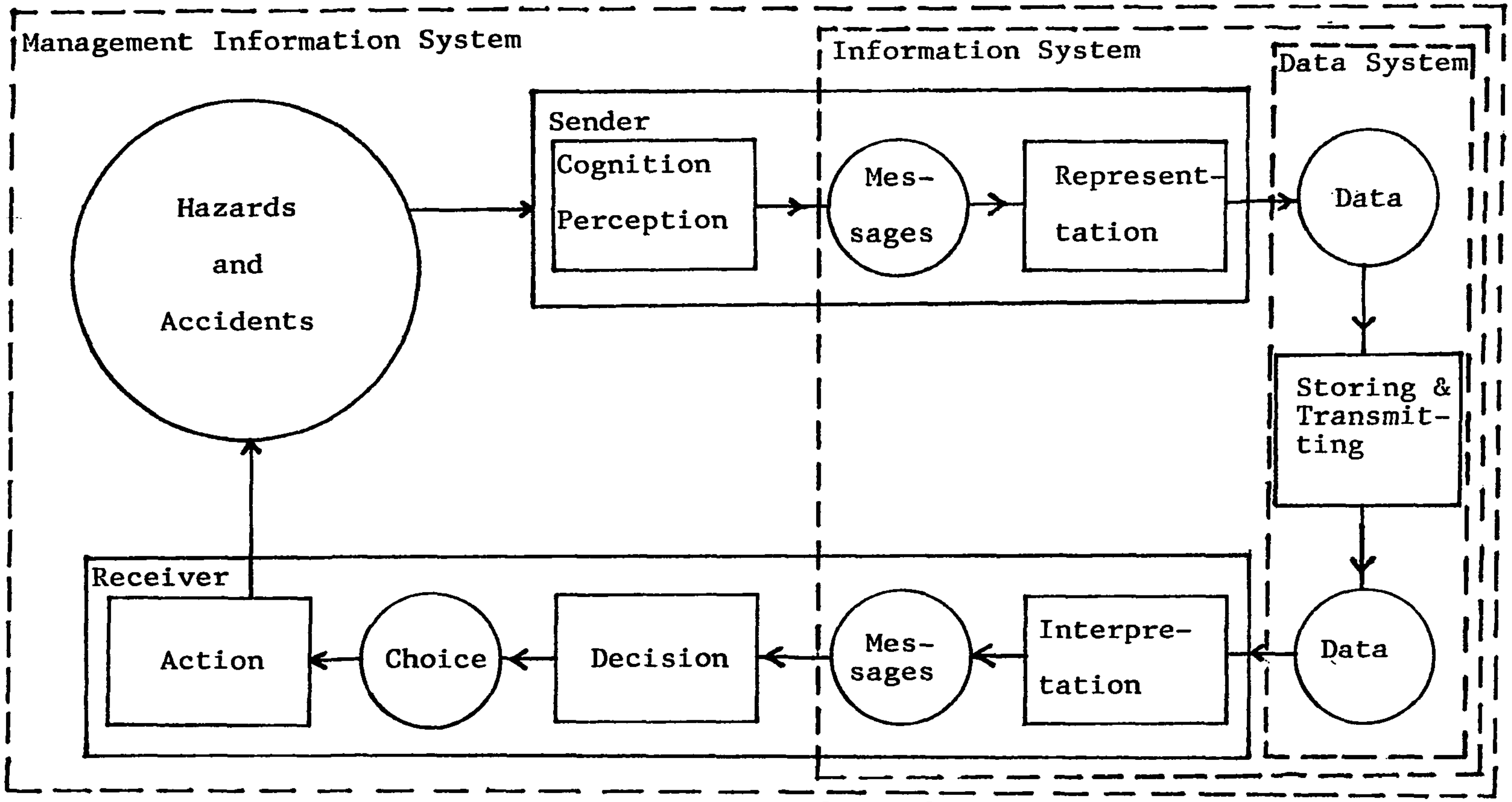
(1) The MIS should be flexible enough so that information can be presented to different organizational levels.

(2) The MIS should also be able to adapt to advancements

in safety technology, i.e., updating or replacing the outdated technology should be made possible.

Thus, the goals of the development of the MIS are basically to set up communication channels in the organization and to convey information between people. The information transferred should become knowledge so that it can be used to support decision-making and to initiate, coordinate, and control activities (Methlie, 1978). Knowledge is defined as information existing in a human mind; additional knowledge can be obtained only if the information received can be related to the existing knowledge (Mehtlie, 1978). A general model of a communication process with its basic control elements is illustrated in Figure 11. It shows how knowledge is being accumulated as a result of learning by direct observations of the real world (accidents/hazards) and by communication using data. Whether a communicated message will convey information to the receiver depends very much on the receiver's knowledge, beliefs, and expectations prior to the communication. Thus, reports for managers should be designed in such a way that the information contained will be received and become knowledge to aid managers in making decisions and coordinating activities. This general communication model explains why accident data needs to be converted into other parameters (costs, management errors, risk scores, cost-effectiveness) which can be related to the managers' previous knowledge.

For the purposes of this dissertation, the scope of the



Source: Leif B. Methlie, 1978, p 32, modified for safety

Figure 11 : MIS as a General Communication Process Model

communication process model has been narrowed down, emphasizing the decision subsystem, which is the "interpretation" part of the receiver's subsystem of the communication process model. The MIS should convert accident data into other parameters which are useful and familiar to the receivers (managers). Thus, the components of the communication process model are simplified while still maintaining the basic elements of a system, i.e., the input, the processor, and the output, as illustrated in Figure 12.

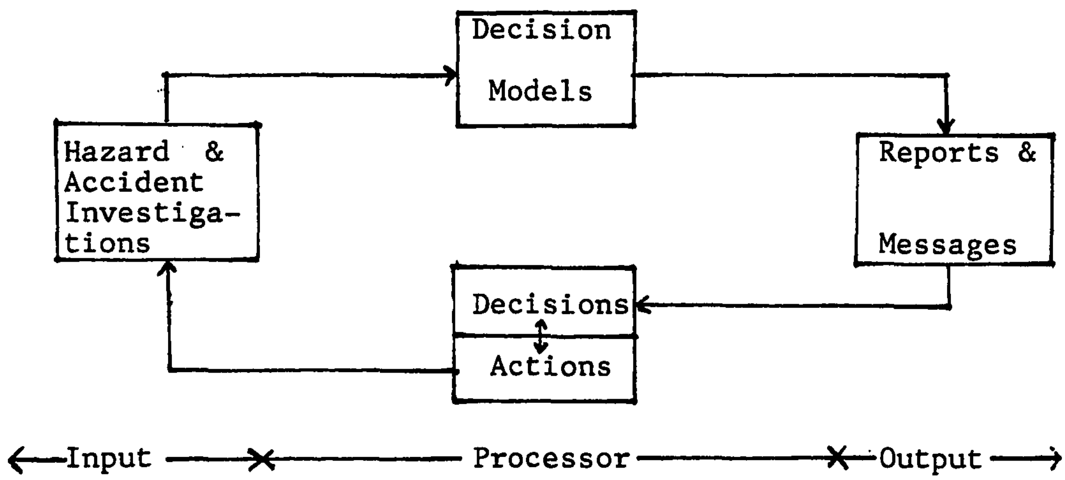


Figure 12: Main Components of the MIS to be Developed

3.2.2. Output of the MIS

The output of the MIS will be listed and/or discussed so that the decision models required in the processor element of the model can be identified. The output will be divided into two groups:

(1) Output for motivation purposes.

(2) Output for managers' involvement to eliminate the underlying causes of accidents.

3.2.2.1. Output for Motivation

The output for the purposes of managers' motivation is limited to only one, namely, motivation that is associated with the total accident cost; the legal requirements already in effect do not need to be discussed, but will be directly used in the assessment of safety problems. Their discussion will be included under the input of the system. It is then expected that the MIS prepares the total accident cost reports and includes them in the existing monthly cost reports for several reasons:

(1) Monthly costs reports are the single most valuable resource for the managers who are trying to predict whether the job will make money and how they can control costs to insure that it does. As total accident cost reports reveal losses due to accidents, they should be included in the calculation of profits. The traditional cost accounting however, charges a project manager for expenditure to prevent accidents, but does not charge him if an accident should occur; this practice implies that the present cost accounting system does not encourage safety activities (Robinson, 1979). The existence

of these total accident cost reports, however, reverses this condition and will, in turn, force managers to prevent accidents.

(2) Total accident costs also show the magnitude of losses due to accidents by projects on a monthly basis as well as the monthly total for the company. The magnitude of these total accident costs for the oil-well drilling industry can be expected to be significant as is the case in the construction industry, which is in the same high-hazard classification. The significant magnitude of the total accident costs and the above accident cost accounting will create a situation that will motivate managers to prevent accidents.

Based on the above discussion the reports should then be expressed by rigs, superintendents, and month, as shown in Figure 13. The total costs are expressed in man-hours to make these numbers comparable among superintendents and rigs over a period time and in different geographic areas. The superintendents, and toolpushers are identified by code numbers (1...k, and 1...n). These monthly total accident cost reports, as presented in Figure 13, are also useful for several reasons other than motivation (see Chapter 2, p. 30). Because of the aforementioned benefits, these reports should be conveyed to all levels of management.

XYZ Drilling CO., Total Accident Cost Report in Man-hours by Month, 19--.

Superintendent #	Rig #	Jan.	Feb.	...	Dec.	Total
1						
	1					
	2					
	3					
2						
	4					
	5					
.	6					
	.					
.						
	.					
.	.					
k	n					
	Total	--	-	. . .	-	-

Figure 13: Monthly Total Accident Cost Report

3.2.2.2. Output for Managers' Involvement in Safety

Once managers are motivated to prevent accidents, the MIS should be able to involve them in the real safety activities by providing them with other reports. These reports will be grouped in two ways, based on the following activities:

(1) Analysis of underlying causes of accidents which will involve all three levels of management.

(2) Priority determination and alternative selection for correction will be addressed to the management

group (the policy and strategy developers) only.

3.2.2.2.1. Analysis of the Underlying Causes of Accidents

In this model, the underlying causes of accidents are considered to be poor management practices; hence, cause analysis becomes the business of all levels of management. The management group which determines safety policies in a company should also monitor how these policies are being enforced so that they can take the necessary actions to improve them. The superintendents and the toolpushers who enforce and implement these safety policies should also get feedback on their own and their workers' performance so that they can also sustain the effectiveness of management control. Thus, continuous causation analysis can reduce the underlying causes of accidents.

To be able to provide meaningful information to each level of management, the reports should contain information which is of interest to the managers. These reports should be distributed monthly so that enough cases have accumulated to make the reports significant. The above causation reports can only be prepared if accident cases and their respective underlying causes are available. These underlying causes can only be revealed if accidents are being investigated with the use of the "4x4 investigation technique" (see Chapter 2). Since it is the toolpusher's duty to investigate accidents, this MIS requires that special training in the above technique be given to toolpushers and the supervising safety experts.

Reports directed to the management group contain overall accident causations listed by superintendents and have a format similar to the one shown in Figure 14.

To : The Management Group
From : Safety Department
Subject: Accident cause analysis
Period : January, 1983

Superintendent #	Underlying causes at Levels of Correction						
	M	M -S	M -S -W	M -W	S	S -W	W
1	1	3 -4	0 -0-0	1 -1	3	1 -1	2
2	0	0 -2	0 -0-0	1 -3	1	2 -2	3
.							
.							
.							
k							
Total	-	- -	- - -	- -	-	- -	-

"M" stands for only a management influence
"M-S" stands for the existance of a management and a supervisor influences
"M-S-W" stands for a management influence, a supervisor influence, and a worker influence
"M-W" stands for a management influence, and a worker influence
"S" stands for only a supervisor influence
"S-W" stands for a supervisor influence and a worker influence
"W" stands for only a worker influence

Figure 14: Accident Causation Report

The word "management" in Figure 14 refers to the operating manager (superintendents) and "supervisor" to the toolpushers. The arabic numerals following "M" / "S" / "W", refer to the total corrective steps that should be taken at that particular level.

By examining these reports, the management group can assess the safety performance of the superintendents. For instance, in Figure 14, Superintendent 1 has to take a total of five corrective actions at his level while Superintendent 2 is responsible for only one for the same month. The management group, therefore, may want to know the reasons for these kinds of differences and may want to start an investigation and ask for more detailed information. The system is able to provide the required information; it is, in fact, the same information that will be distributed to the superintendents, as shown in Figure 15. If Superintendent 1 proves to be inconsistent in safety enforcement most of the time; the management group will know what measures to take to prevent further similar accidents from occurring.

Reports that will be addressed to the superintendents will use the same general format as those directed to the management group, except that they are more detailed; the reports are made based on toolpushers and case numbers (see Figure 15). The arabic numerals following "M" / "S" / "W" refer to the corrective steps to be taken at the respective organizational levels.

To : Superintendent #1
From : The Safety Department
Subject: Accident cause analysis
Period : January, 1983

Toolpusher #1 Underlying Causes at Levels of Correction

Case #	M	M -S	M -S -W	M -W	S	S -W	W
83 1 01	M4	0 -0	0 -0 -0	0 -0	0	0 -0	0
83 1 02	0	0 -0	0 -0 -0	0 -0	0	S3-W4	0
.							
.							
.							
n							
Total	1	- -	- - -	- -	.	. .	-

Toolpusher #2 Underlying Causes at Levels of Correction

.
.
.

Toolpusher #3

.
.
.

To : Superintendent #2 ...p

.
.
.

Figure 15: Accident Causation Report for Superintendents

The superintendents can perform the same analysis as the manage-group, in respect to the toolpushers. In addition, the super-intendents can use these reports as feedback about their own performance so that they can recognize their own weaknesses in the implementation of safety policies and make improvements accordingly. For the superintendents, these reports also summarize the previous individual reports they receive routinely after the completion of any accident investigation.

Reports made for the toolpushers will have a format and notations similar to those reports intended for the superintendents, except that they are based on case numbers and only those corrections/underlying causes at their levels and at the workers' level will be printed. An example of this report is shown in Figure 16.

To : Toolpusher #1 .....k
From : Safety Department
Subject: Accident Causation Analysis
Period : January 1983

Case #	Underlying Causes at Levels of Correction			
	M	....	S	S - W
83 109	0	....	S3	0 - 0
83 113	0	....	0	S3- W4
:				
n				
Total	. . .			

Figure 16: Accident Causation Report for Toolpushers

For the toolpushers, as for the superintendents, these reports are also summaries of the individual reports they receive routinely after the completion of any accident investigation. Based on the above reports, the toolpushers can do at least two things:

(1) They can evaluate the safety performance of the workers under their supervision, find the most troublesome causes existing among their workers, and try to eliminate their causes.

(2) They can use these reports as feedback; e.g., to determine which corrective steps at their level are required for all accident cases for that particular month and how to improve themselves accordingly.

3.2.2.2.2. Priority Determination and Alternative Selection for Correction

Accidents and hazards can happen anytime and anywhere within an organization. It has been also pointed out before that both frequency and severity of accidents are important in respect to cost reduction. It is therefore necessary to determine which underlying cause of accidents has a correction priority. An accident cause is said to have a correction priority when the consequences (severity) are great and/or the probability that similar accidents will occur is high (frequency of exposure to cause and frequency of occurrence). As was discussed in Chapter 2, priorities can be expressed as risk scores.

Once the priorities have been determined, the alternatives for correction can be determined and assessed so that the best alternative can be chosen and implemented. Priority determination and alternative assessment can be considered as activities that transform data into useful information to support decisions and to develop prevention strategy. Hence, this information should rightfully be addressed to the management group periodically. The time period could be quarterly, semi-annualy, or yearly, depending on the frequency of accidents occurring within the company. For the oil-well drilling industry, with an incidence of about 50 cases per month, a bimonthly or quarterly evaluation is recommended in the beginning.

To make the report significant, the risk scores should be presented by rig numbers so that management's attention can be drawn to some particular rigs only. Presentation by rig number is especially useful because priority determination is actually a process that evaluates which of the underlying causes or poor management practices should be corrected first. These corrections take place at the rig level being the smallest operational unit. Although similar accidents may occur in the non-prioritized rigs, priority is only assigned to rigs having accummulated high risk scores unacceptable to the management group. These risk scores represent predicted long-term losses of the present management's performance in safety; they consist of risk scores assigned to accidents and hazards. The output of the system should contain a ranked list of rig numbers based on their respective risk scores, as shown in Figure 17. The rigs having priorities for corrections are those rigs ranked as number one to ten or one to five, depending on the magnitude of the risk scores within a certain period of time.

To be able to reveal the causes of the high risk scores in a priority rig, further refinement of information becomes necessary. The causes should be known so that correction al-

To : The Management Group
From : The Safety Department
Subject: Priorities by Rigs
Period : January 1983

Priority Rank	Rig Number	Risk Scores
1	9	5800
2	.	.
3	.	.
.	.	.
.		
.		
n		

Figure 17: Priority Rank by Rig Number

ternatives to eliminate the underlying causes can be specified. The refinement of the information should be based on both the worker and the task variables. These two variables are chosen for several reasons:

(i) They are essentially the two groups into which the direct causes of accidents (the unsafe acts and conditions) are classified.

(ii) The underlying causes can only be found by going through the direct causes, as postulated by the accident sequence.

(iii) The direct causes of accidents are many, so they need to be grouped to make them manageable to the MIS.

(iv) The task is chosen as a basis for grouping the unsafe conditions because a task is the smallest unit of work that is still considered meaningful from the management's point of view (Methlie, 1978). Hence, the direct causes of accidents can be categorized by task. The other category for refinement of the information is chosen based on the worker so that personal influences in the causation of accidents can be accomodated. As was discussed in Chapter 2, studies using the human factor models are not applicable to the oil-well drilling industry. However, Siskind (1982) found that there is a link between work injury and job experience. He found that workers are more likely to experience injury during their first few months on the job than after longer periods, irrespective of age and skill. These findings are very interesting because other researchers (Surry, 1974; Simonds and Grimaldi, 1956) are of the opinion that younger individuals are more apt to get injured than are the older workers. Siskind however, found that if the older and the younger age groups are compared based on the same length of employment, the older workers eventually experience more injury than the younger workers. Based on the above findings, the output of the information refinement will be categorized by task and length of employment which represent unsafe conditions and acts respectively. To accomodate the risk scores caused by hazards identified in that rig, a column will be provided in the output to show the risk scores caused by them. The report will have a format like shown in Figure 18. From this report, the manager can find the most hazardous task and length of employment in a particular rig.

To : The Management Group
From : The Safety Department
Subject: Priority Rig by Task, Length of Employment, and Hazards.

For Priority Rig #9

Risk Scores By Tasks and Length of Employment

Task #	Length of Employment Category				Hazards
	1	.	.	m	
1	-			-	-
2	.	.	.	.	.
3	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.					.
n	.	.	.	.	.

Figure 18: Priority Rig By Task, Length of Employment and Hazards

If a report, like that shown in Figure 18, shows that the risk scores caused by hazards are significant, the management group should enforce the MCP (Maintenance Control Program) to decrease accident rates. If on the other hand the hazards do not constitute a significant problem, the most dangerous task and length of employment should be identified. The information can now be further refined for that particular task and length of employment to disclose the underlying causes. Hence, two steps of refinement procedure are necessary to reveal the underlying causes of accidents. This last step elaborates the task and employment category by case numbers, unsafe acts, unsafe conditions, and underlying causes. An example of the report can be seen in Figure 19. The cases are numbered by year, month, and frequency number within that month. Unsafe acts and unsafe conditions are coded by the American National Standards Institute (ANSI) classification (1969); they are included in Figure 19 for the purpose of providing insights for supportive actions in cases where the underlying causes cannot be eliminated completely. For this purpose, the management group should be supplied with information to decode them. The man-hours lost are also included for the purpose of showing that not only severity, but also frequency of accidents are included in the determination of priorities.

For Priority Rig # X
For Task # Y
Length of Employment Category Z

Case#	Unsafe Act Code#	Unsafe Cond. Code#	Underlying Causes	Man-hours Lost
1	300	100	M4W3	580
.	-	.	.	.
.	.	.	.	.
.	.	.	.	.
n	.	.	.	.

Figure 19: Priority Rig, Task, and Employment Category by Case Numbers

Analysis of this report by the management group should lead to the enumeration of alternatives for correction. For instance, if a report shows information for Length of Employment Category 1, and the underlying causes point to a need for better enforcement, training, and motivation, then the alternatives for correction should be as follows:

(1) Enforce and motivate.

(2) Train the new employees.

(3) Combination of (1) and (2).

The next step is to assess the alternatives using the economic justification factor. Once the alternatives have been identified, the MIS should be able to produce another report showing the economic justification factor for each alternative. For this purpose, the system will need some other input from the management group and the safety experts concerning the degree of correction and the cost factor for each alternative. The resulting report will be similar to the illustration in Figure 20.

Based on this type of report, the management group can decide on the best alternative and its corrective actions. The management group, together with their safety experts, should then make a plan to implement the chosen course of action. Messages containing information about the newly developed strategy for safety should also be distributed to the superintendents and toolpushers of that particular rig.

For Priority Rig #X
For Priority Task #Y
For Employment Category #Z

There are three correction alternatives:

1. Enforce and motivate
2. Train new employees
3. Combination of (1) and (2)

Alternative #	Degree of Correction	Cost Factor	"J" Factor
1	_	_	a
2	_	_	b
3	_	_	c

For J:-a-,Consequence will be reduced by ----- man-hours
For J:-b-,Consequence will be reduced by ----- man-hours
For J:-c-,Consequence will be reduced by ----- man-hours

Figure 20: Report for Alternative Assessment

In summary, the output of the MIS will be in the form of the following reports:

(1) The monthly total accident cost in man-hours, by superintendents and rigs, and by month, addressed to all levels of management (see Figure 13).

(2) The monthly accident causation report by superintendents, addressed to the management group (see Figure 14).

(3) The monthly accident causation report by toolpushers and by case numbers, directed toward the superintendents (see Figure 15).

(4) The monthly accident causation report by case num-

bers, addressed to the toolpushers (see Figure 16).

(5) The priority rank of rigs, directed to the management group (see Figure 17).

(6) The priority rig by task and length of employment, directed to the management group (see Figure 18).

(7) The priority rig, task, and employment category by case numbers, addressed to the management group (see Figure 19).

(8) The report for alternative assessment, addressed to the management group (see Figure 20).

3.3. Processor of the MIS

The processor of the MIS is that component which contains the decision models. A decision model can be defined as a model that processes data into information necessary to support decisions. Therefore, the type of the decision model is practically defined by the type of output required from the models, however, a brief review of decision and the decision-making process will be presented to show how this decision-making process will affect the requirements placed on the MIS.

Decision-making, one of the key roles of management (Radford, 1973), is a process whereby a specific course of action is selected among a set of alternative actions. Subsequently, action is the process by which changes can take place. Although decision-making processes usually differ with the nature of the problem, the situation, and the individual decision maker, there are usually five steps in the decision process: (1) defining the problem; (2) analyzing the problem; (3) developing alternative solutions; (4) deciding on the best solution; and (5) converting the decision into a plan of effective action (Horton Jr., 1972). A general model of the decision-making process with its elements is shown in Figure 21. This model shows that the nature of the problem may influence whether or not a decision maker moves through the process slowly or quickly. If the problem is perceived as routine (by experience), the decision maker may go immediately to the selection of the best alternative solution. If the problem is familiar, little time is needed for its definition. If the problem is well-defined, the search for an alternative

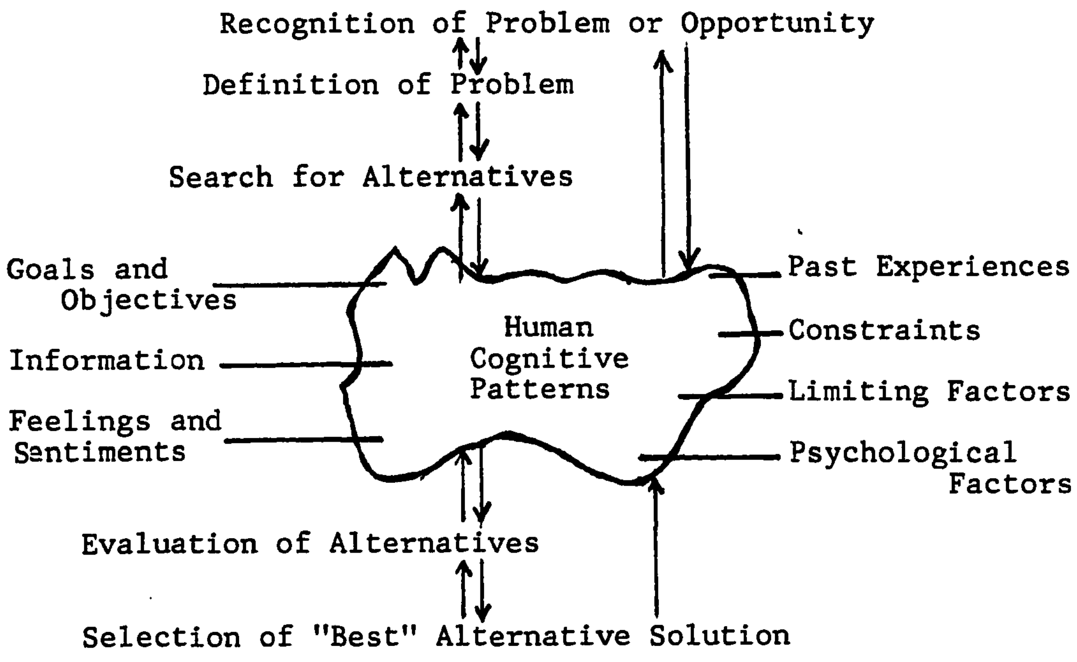


Figure 21: Elements of Decision-Making Process.
Source: Wm E. Souder, 1980, p13.

solution may be brief. If the relative effectiveness of the alternatives are known, very little time may be spent in analyzing and evaluating the alternatives and choosing the best one. If the decision has been predetermined, the decision maker may skip the problem definition and the search for alternatives. In a predetermined decision there are finite numbers of alternatives with known effectiveness, and the decision maker must match up the appropriate alternatives with the problem. If the problem is complex and poorly understood, the decision may be quite lengthy and deliberative.

In this MIS, the routine problems are handled by the Maintenance Control Program (MCP), which has a definite format for work procedure:

Identify Problem ⟶ Solution Determined
⟶ Work Scheduled ⟶ Agency Assigned Task
⟶ Activities Monitored ⟶ Records Maintained
⟶ Hazards Assessed.

The processor of the MIS will aid management with the decision processes concerning complex and poorly-understood safety problems only. The MIS will aid management in defining problems, in providing information to enhance analysis, in calculating the relative effectiveness of each alternative, and in monitoring the implemented course of action. The decision-making process will require the participation of the managers. The MIS will provide as much relevant information as possible, but eventually the decisions will be made by the managers using their value judgements.

As was specified in the output element of the MIS, the decision models consist of two parts:

(1) Decision models that will process data into information for the motivation of managers.

(2) Decision models that will process data into information for the involvement of managers in safety activities.

3.3.1. Decision Model for the Motivation of Managers

The output required to motivate managers is a report that contains the total accident costs by superintendents, by rigs, and by month; the total costs are expressed as man-hours lost, as shown in Figure 13. As was discussed previously, this report should be produced on a monthly basis, i.e., the total costs of all accidents occurring in a month should be reported at the beginning of the next month. The only model that is suitable to process accident data into total accident costs in a timely manner is the model developed by Robinson (1979) discussed in Chapter 2. The Robinson model however, was developed for the construction industry; it may or may not be applicable to the oil-well drilling industry. Also, the Robinson model used a ratio of 2 between the direct and indirect costs of accidents. If an industry adopts the Robinson model and the magnitude of the total costs is not significant, this conservative ratio between the direct and the indirect costs may help explain the phenomena. Each type of industry, like the oil-well drilling industry, could actually develop such a model by using the methods described by Robinson, but it may take quite some time to do so. For the purpose of this dissertation, the Robinson model will therefore be adopted with notations mentioned.

To be able to produce the required report, accidents occurring within one month are filed and processed by the Robinson model. As described in Appendix A, the process of total costs determination is very simple, but if many accidents occur in a month, processing by computer is preferred for two reasons: (1) to prevent mistakes and (2) to reduce costs and time, especially since the reports will become a part of the monthly routine.

3.3.2. Decision Models for the Involvement of Managers in Safety.

Manager involvement in safety can be divided into two activities:

(1) The involvement in accident causation analysis.

(2) The involvement in priority determination and alternative assessment.

3.3.2.1. Accident Causation Analysis

The output required for the analysis of accident causations are reports illustrated in Figures 15, 16, and 17. To be able to present the above output, the processor component only has to arrange the input into the mentioned format; thus, there is no decision model needed for this activity. It is only necessary to feed relevant input into the processor. The technique used to collect this information is the 4x4 Problem-Solving Technique, which was discussed in Chapter 2 and will be referred to again under the input of this MIS. The application of the above technique in each accident investigation will reveal the underlying causes of accidents and the corrective steps to be taken at levels where correction opportunities lie. These reports can be prepared easily; automation, however, is preferred because of the periodicity of the reports, which can be prepared using the same program.

3.3.2.2. Priority Determination and Alternative Selection

Priority determination and alternative selection consists of four steps:

(1) Priority determination by rigs.

(2) Refinement of information by tasks, employment category, and hazards for each priority rig.

(3) Refinement of information by case numbers for each priority rig, task, and length of employment category.

(4) Alternative selection.

3.3.2.2.1. Priority Determination by Rigs

As was discussed previously, it is preferable that priorities be determined by the three following variables: (1) the severity or consequences (C) of the accidents, (2) the probability (P) that similar accidents will occur in the future, and (3) the frequency of exposure (E) to that particular cause of accidents. The model that determines priorities by these three variables is the Fine model (see Chapter 2). In this model, the priorities are expressed as risk scores (RS), whereby RS = C x P x E. The values for C, P, and E are determined by rating procedures, so the participation of experts is required to exercise value judgements. Hence, it is a subjective procedure; a more objective way, however, is available and will be discussed in the following sections.

An objective way to express the consequences of accidents is in terms of their total costs. The calculation of these total accident costs were previously performed for the motivation of managers to prevent accidents. It is therefore advantageous if the same method is also used to express the consequences of accidents so that one process can serve two purposes.

The values for the probabilities (P) can also be determined objectively by using past accident experiences as shown in the accident records. For each type of accident, its probability (P_i) can be defined as follows:

$$P_i = \frac{f_i}{N}$$

where P_i = the probability that similar accidents will occur, resulting in the same consequences and having the same etiology,

f_i = the frequency of similar accidents occurring within a period of time (one-two years),

N = the total number of accidents occurring within the same period of time.

The values for the frequency of exposure to the same etiology (E_i) can also be derived objectively by using the past accident data.

The values of C, P, and E, as determined by the methods suggested above, are more realistic and relevant to the individual company compared to the values obtained by value judgements. Also, these values of C, P, and E will change over time; hence, their periodic assessment is necessary. Thus, having a model that will do all the necessary work periodically is very useful to the company. The decision model for priority determination will use the above methods to obtain the values for C, P, and E.

Once the values for C, P, and E are obtained, the risk scores for each accident can be calculated:

$$RS_i = C_i \times P_i \times E_i$$

where RS_i = risk scores for a particular accident,

C_i = consequences of that particular accident,

P_i = probability that similar accidents will occur resulting in the same consequences and having the same etiology, for the accident under consideration,

E_i = frequency of exposure to the same direct causes.

The risk scores for hazards can also be determined in the same way with the use of past accident data. For this method of calculation, hazards, as is also the case with accident causes, should be classified by tasks; the risk scores assigned to a hazard identified in a task category equals the average risk score value (ARS_{ti}) :

$$ARS_{ti} = \frac{RS_{ti}}{N_{ti}}$$

where ARS_{ti} = RS assigned to a hazard identified in task t_i,

RS_{ti} = the sum of the risk scores of accidents occurring in task t_i,

N_{ti} = the total number of accidents occurring in task t_i.

This method of risk score estimation for hazards is realistic because it is based on the actual accident data of the individual company. Also, as accident rates change over a period of time, these risk scores can be adjusted using the same method. Figure 22 is an example of a chart which contains the average risk score values for each hazard in a task which is to be used as a reference.

To present the priorities by rig, two further steps are necessary:

(1) The step which adds up all RS_i occurring in each rig for all rigs.

	Task #		
Rig#	1	. . .	m
1	ARS_{ti}	. . .	.
.	.	. . .	.
.	.	. . .	.
.			
n	.	. . .	.

Figure 22: Average Risk Score for Hazard by Task and by Rig

(2) The step that ranks the rigs based on their total risk scores and prints out the report.

3.3.2.2.2. <u>Refinement of Priority Rigs by Task and Length of Employment Category</u>

Once the rigs are ranked according to their magnitude of risk scores, the "top ten" or the "top five" priority rigs will be presented in terms of tasks and length of employment category. The "top ten" or "top five" policy is taken in accordance with the rule of thumb suggested in the concept of management-by-exception (Radford, 1975). In the long run, however, as experiences accumulate, the management group will be able to decide what magnitude of risk scores is acceptable to the company for a certain time period. This ability to assess the acceptability of risk scores for the company will lead to a smoother operation of the MIS; i.e., a periodic guideline for the refinement of priority rigs by task and length of employment has been set.

The process of information refinement itself is very simple because it is a matter of presentation, but its repetitiveness is very time-consuming. It is therefore preferable to have the process automated. A sample report is shown in the previous Figure 18.

3.3.2.2.3. Refinement of Priority Rig, Task, and Length of Employment Category by Case Numbers

The report presenting priority rigs by task and length of employment category reveals the most dangerous tasks and employment category for the particular rig. Once these tasks and employment categories are identified, their refinement into case numbers is a matter of presentation. Again, because of its repetitiveness, automation is preferable. A sample report is presented in Figure 19.

3.3.2.2.4. Alternative Assessment

The refinement of information about the priority rig, task, and employment category into case numbers is meant to reveal the underlying causes of accidents. The resulting report should help the management group and the safety experts in the enumeration of alternatives for correction. Also for each alternative, values for their effectiveness (degree of correction) and cost of correction (cost factor) should be estimated. The information on alternatives, with their associated degree of correction and cost factor, should be fed back into the system so that the economic justification factor (J) for each alternative can be determined. As was discussed in Chapter 2, this "J" factor is calculated in the following way:

$$J = \frac{RS}{DC \times CF}$$

where J = the economic justification factor,
RS = the risk score,
DC = the degree of correction,
CF = the cost factor.

Since these "J" factors are used as criteria to assess the existing alternatives, it is necessary that they refect relative cost effectiveness among the alternatives. One way to satisfy this criteria/requirement would be to rate the above values of DC (degree of correction) and CF (cost factor). Rating is a method used to assign unique numerical values to each variable in such a way that the differences between the numbers become meaningful (Souder, 1980). In a rating procedure, the highest and the lowest rating values could be determined arbitrarily. Fine (1980), however, suggested the use of 0.5 and 10 as the lowest and the highest values, respectively, for rating the CF; the higher the cost, the higher the rating value:

Cost	Rating
Over $50,000	10
$25,000 to $50,000	6
$10,000 to $25,000	4
$1,000 to $10,000	3

\$100 to \$1,000	2
\$25 to \$100	1
Under \$25	0.5

As for the degree of correction, Fine suggested the following ratings which are contrary to the CF: the higher the DC, the lower the rating values:

Description	Rating
Hazards eliminated 100%	1
Hazards reduced at least 75%	2
Hazards reduced by 50% to 75%	3
Hazards reduced by 25% to 50%	4
Slight effect on hazard (less than 25%)	6

The rated values of DC and CF for each alternative are then used to calculate the associated "J" factor.

The process of calculating the "J" factor and presenting the report for alternative assessment, as shown in Figure 20, is simple, but since all processes in this MIS are automated, it would be easier to computerize this last report as well.

In summary, the decision models contained in the processor component are as follows:

(1) The Robinson model is used to calculate the total accident costs, which at the same time represent the consequences of accidents.

(2) The Fine model is modified in terms of the methods used for obtaining the values of the probability (P), consequences (C), and exposure (E).

3.4. Input of the MIS

The input of the MIS is that element which provides relevant information to the processor component. It contains procedures for collecting, storing, retrieving, and treating information (Ackoff, 1967). These procedures are the functions of the data-base management subsystem of an MIS, which this dissertation will not address. The discussion of the input component in this MIS will therefore be limited to the discussion of the information required by the processor only. The decision models contained in the processor are well defined, as is the other information needed to present reports on accident causations. Thus, the relevant information needed by the processor can also be easily identified. The discussion on this input component will be divided into two sections:

(1) The information required by the decision models.

(2) The information required for the presentation of accident causations.

3.4.1. Information Required by the Decision Models

Since the decision models accomodate both the prospective and the retrospective accident prevention activities, the discussion on the information required will again be grouped into two parts:

(1) The information required from retrospective activities.

(2) The information required from prospective activities.

3.4.1.1. Information Required from Retrospective Activities

Information from retrospective activities will be processed by both the Robinson and Fine models. The input required by both models can be deduced from the variables used in each one of them.

The Robinson model is used to calculate the consequences or total costs of accidents. Thus, besides the Robinson matrix, the input needed by this model is the nature of injury, part of the body injured, and whether the injury resulted in lost time. The Robinson matrix can be obtained from his publication. This input can be easily obtained from both the OSHA 101 Form (to record accidents) or any Workers' Compensation Claim form (NIOSH, 1978; see Appendix C).

The Fine model is used to calculate the priorities and the relative effectiveness for each alternative for correction. The variables used to calculate priorities are the consequences (C), the frequency of exposure (E), and the probability (P) that similar accidents will occur. The consequences are already calculated with the use of the Robinson model. The values for E and P can be obtained from the analysis of a one-year accident data. Once priorities are determined, the information will be refined by task and categories of employment; both categorizations will be discussed in the following sections. The relative effectiveness of alternatives can be calculated if input for degree of correction (DC) and cost factor (CF) are fed into the processor. Both values are obtained by value judgements exercised by the management group and their safety experts. Table 1 summarizes the information required by the decision models.

Model description	Information required
Robinson model, calculates total accident costs.	Part of body injured Nature of injury Whether injury results in lost time Robinson matrix
Fine model Priorities calculation:	Consequences using Robinson model Exposure and probabilities from one-year accident data
Alternative assessment:	Degree of correction Cost factor Both estimated by management group and safety experts.

Table 1: The Decision Models and Their Required Information

As was mentioned previously, there is a need to categorize task and duration of employment. Task was previously defined as the smallest unit of work to be executed which still has meaning for the managers. In the oil-well drilling industry, most of the tasks to be done require teamwork among the crew members (NIOSH, 1982). An observer on a well site, however, will immediately notice that even if the crew works as a team, each one of them has a specific task to do which would normally not be done by others. It might therefore be feasible to classify tasks based on the job descriptions of the crew. Hence, seven categories of tasks will be used in this MIS:

(1) The task of a toolpusher is to supervise the rig and the overall drilling operations, to direct the actual operations of the drilling rig and the work performed by the drilling crew, to authorize the employment of drillers and crewmen, and to coordinate the affairs of the operating company and the drilling contractor.

(2) The task of a driller is to supervise the actual drilling operations, to operate the drilling machinery on the rig floor, and to give the actual instructions to the other crew members concerning work on the rig floor.

(3) The task of a derrickman is to work on the monkeyboard, a small platform located up in the derrick at a level of the upper end of a stand of drill pipe (about 90 ft). During tripping, he handles the upper end of the stands, guiding it to and from the special equipment used to run pipe in and out of the hole. When drilling is going on, he is responsible for maintaining the drilling fluid and maintaining or repairing the pumps and other circulating equipment.

(4) The task of a motorman is to keep the engines provid-

ing the power for the drilling equipment on the rig in good working order. He is responsible for the engines, engine fuel, air compressor, water pumps, and accessories. He checks the lubricating oil and makes minor adjustments on the engines.

(5) The task of a floorman, known as the rotary helper or roughneck is to handle the lower end of the drill pipe when it is being tripped in or out of the hole, to handle tongs when making up or breaking out pipe, to maintain equipment by keeping it clean and painted, and to keep the rig in good working order.

(6) The task of a maintenance man is to keep equipment in good working order. He makes minor repairs on engines, small pumps, and various machinery on and around the rig (mechanic). Another maintenance man is the rig electrician who repairs and maintains the electrical generating and distribution system on the rig. He may make minor repairs on generators or electric motors, inspect and maintain the rig's electrical wiring, and maintain the rig's lighting and other electrical appliances.

(7) The task of others not directly related to the drilling operations, such as truck driving, rigging up and/or down.

(Baker, 1979)

Duration of employment can be categorized based on Siskind's study (1982). He found that duration of employment rather than age is the factor that determines the frequency of injury incurred by workers. The results of his study showed that there was a steady decline in risk as length of employment increased, as shown in Table 2.

Length of Employment	Percent Distribution of Injury and Illness Cases* (1)	All Workers** (2)	Incidence Ratio (1)/(2)
1 - 3 months	20.1	11.6	1.73
4 - 6 months	10.6	9.0	1.18
7 -12 months	14.4	9.8	1.47
2 - 3 years	20.9	20.7	1.01
4 - 5 years	9.9	12.3	.80
6 -10 years	12.5	15.7	.80
11 -25 years	9.9	16.0	.61
26 -35 years	1.4	3.9	.36
36 or more years	.2	1.1	.18

* Data was taken from detailed injury and illnesses information from the Workers Compensation System, covering 23% of US Employment.

** Data was taken from unpublished tables for the January 1978 Current Population Survey and relate to all workers age 16 and over, cover the same jurisdiction, except the Virgin Islands.

Table 2: Relative Injury Experience by Length of Employment. Source: Siskind,1982.

Although it was not mentioned how the class-interval of employment duration was determined, it seemed that the categorization was based on the prevalence of injuries incurred. If the number of injuries were about equal, they were then grouped into the same class-interval. Thus far, Siskind's research is the only study available in the literature which provides employment categorizations and their associated incidence ratio (see Table 2) important to this MIS for the normalization of the calculated risk scores. For an individual company, where data of total workers by their respective length of employment is available, the incidence ratio can be determined specifically using the same method as shown in Table 2. In cases where the total workers data is not available, the Siskind ratios can be adopted because of the relatively good sample (23% of US employment) used in this study.

The calculated risk scores (RS) need to be normalized so that the RS become comparable to each other and can be explained in the following way. By the categorization in Table 2, an injured employee who has worked for two months can be classified as category number one, and those already employed for five months when injured, fall into category two, etc. From Table 2 it can be seen that workers in category one incurred more injuries than any other workers in the rest of the category. In the processing of accident data, whereby only injury cases are used, category one employees will be found more often than any other category. If their risk scores are compared by length of employment, category one employees will have the highest number of risk scores. Thus, the risk scores are only reflecting the risk faced by the injured employees, which is not what was intended in this study. To show the risk faced by all workers in each category of employment, the risk scores should be normalized by multiplying them with their respective incidence ratios. Hence, the input collected should be appropriately categorized by the above task and employment category.

3.4.1.2. Information Required from Prospective Activities

Prospective accident prevention is mostly accomplished by performing what is known as continuous "hazards inspections" (NSC, 1978). This type of inspection is actually a procedure used to identify safety problems and are usually done by the toolpushers on a daily basis. If any problem is identified, its hazard should be assessed based on the existing standards, laws, and ordinances. If a safety problem is found to violate any of the standard or ordinance, a hazard is known to exist. In case a hazard is identified, the MCP will be notified so that corrective action can be taken. These "hazards inspections" are routine procedures required by OSHA (Petersen, 1979). Hence, it is being performed in most companies, including the oil-well drilling industry.

The input required by the processor from these prospective activities includes records containing the rig number, the date, the description of what constitutes a hazard, and the location of the hazard. From this data, the rig number, the task number, the unsafe act code number, and the respective risk scores for the hazard can then be assigned. The risk scores of these identified hazards could then be included in the process of priority determination.

3.4.2. Information Required for the Presentation of Accident Causations

The processor component is also meant to present the accident causations to all levels of management, mainly to give feedback to their own safety performance. However, these reports can also be used as basis to analyze and improve safety policies. This information can be collected with the use of 4x4 problem-solving technique, the principles of which have been discussed in Chapter 2. The continuous use of this technique in each accident investigation will reveal the underlying causes of all accidents, which at the same time denote the corrective steps to be taken at each level in the organization. These underlying causes should then be recorded in addition to the form used to record accidents (see OSHA 101 Form item 13, in Appendix C). It should be noted that to be able to use the 4x4 Problem-Solving Technique, the toolpushers must have special training. Some oil-well drilling companies, such as the Delta Drilling Company, have been using this technique as part of the occupational injury data research project conducted by the Texas Safety Association (Texas Safety Assoc, 1980). However, this technique can be used as a routine accident investigation procedure to reveal the underlying causes of accidents.

3.5. Subsystems and Their Interrelationships

Subsystems are separate parts of a system. They perform some specific useful purpose, but are not by themselves of sufficient scope to be considered a system. Thus, a system is a collection of interrelated subsystems, which are unified by design to obtain one or more objectives (Luchsinger and Dock, 1977). Therefore, the identification of the subsystems and their interrelationships will lead to the identification of the whole system. The procedure of identification of the subsystems will follow the three main components of the system, namely the input, the processor, and the output components. As was mentioned before, the subsystems of this MIS will show "what" as well as "how" something is being done.

3.5.1. Subsystems of the Input Component

The input component should collect, store, retrieve, and transmit the information required by the processor. This input component is basically a file containing the needed data, which should be easily retrieved and transmitted. There are two groups of information needed by the processor component: (1) information about accidents and (2) information about hazards.

Information about accidents that should be collected are basically included in the OSHA 101 Form or any Workers' Compensation Claim forms, as shown in Appendix C. This information includes the date of accident, the rig number, the task of the injured, the date the injured started working, the nature of the injury, the part of the body injured, whether the injury resulted in lost time, the unsafe act, and the unsafe condition. One other piece of information that is normally not recorded is the underlying cause accident, which in this case needs to be enclosed.

Information about hazards includes the date the hazard was identified, the description of the hazard, the rig number, and the task in which the hazard was found. This information is usually recorded in the hazard inspection sheet.

Thus, the input component contains three subsystems, namely, the hazard inspection and the accident investigation subsystem which investigates hazards and accidents, the records and reports subsystem, and the filing system subsystem which files the reports and records. The reports and records should also be used to notify the MCP so that any possible corrections can be made immediately. At this time, the corrections taken are routine in nature, i.e., they do not constitute major changes. The MCP consists of the safety personnel, toolpushers, and other crew members. At this stage, there is no way of finding out which accident or hazard resulted in the largest risk of loss. Severity of an injury might be impressive, but again, severity is not the only variable that determines priority. Hence, the input subsystems and their interrelationships can be illustrated as follows:

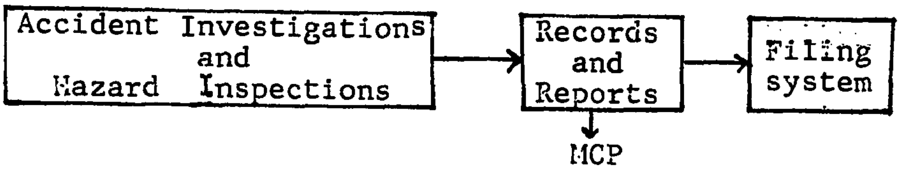


Figure 23: Input Subsystems and Their Interrelationships

3.5.2. Subsystems in the Processor Component

The processor component aids management in making decisions concerning poorly understood problems. It receives information from the input component, processes, arranges, and reports the results to different levels of management. These reports are used mainly to support decisions upon which action plans can be made to implement major changes. The major functions of this processor element as related to the input and the output components are illustrated in Figure 24.

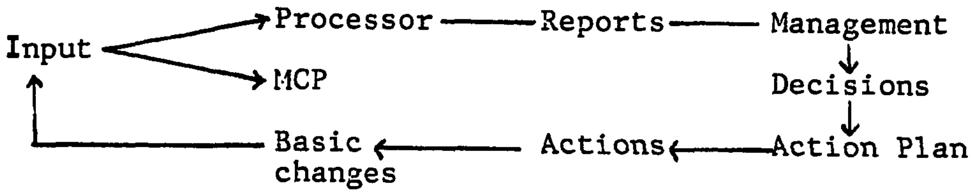


Figure 24: Main Functions of the Processor as Related to its Output

The subsystems which should be contained in the processor component depends on the processes necessary to produce the required output:

(1) Reports on total accident costs (see Figure 13).

(2) Reports on accident causations (see Figures 14, 15, and 16).

(3) Reports on priority rigs (see Figures 17, 18, 19).

(4) Reports on relative effectiveness of the alternatives (see Figure 20).

To be able to present this output, the processor component will need several subsystems:

(1) A subsystem to present accident causations.

(2) A subsystem to calculate and report the total accident costs.

(3) A subsystem to calculate risk scores and present priorities for corrections.

(4) A subsystem where alternatives are enumerated and have their respective degrees of correction (DC) and cost factors (CF) estimated.

(5) A subsystem to calculate the relative effectiveness of each alternative using the "J" factor and to choose the best alternative.

The processor's subsystems and their interrelationships are illustrated in Figure 25.

Subsystem 1 in Figure 25 receives information about accident causations, arranges, and presents reports to all three levels of management.

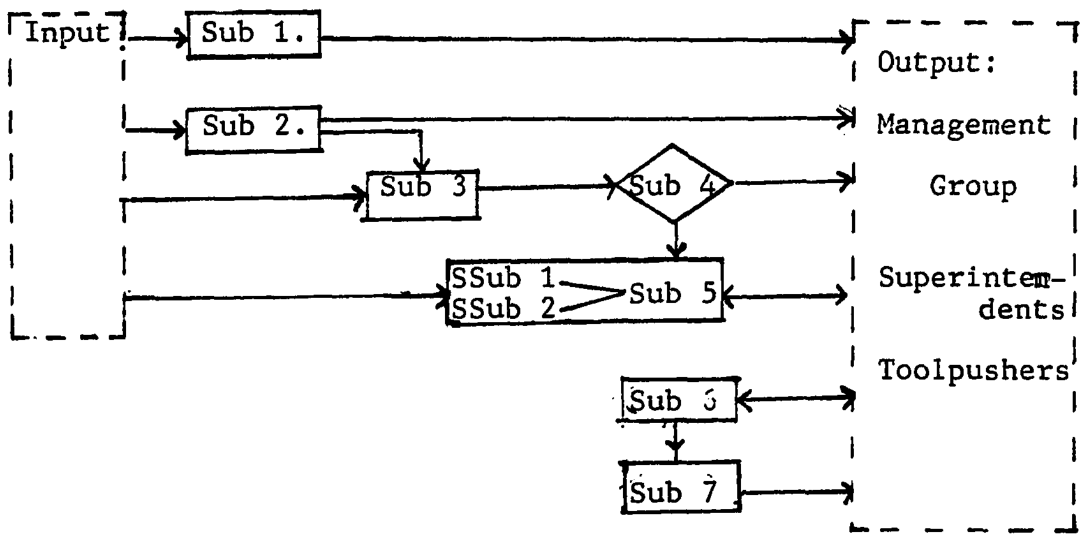


Figure 25: Processor Subsystems and Their Interrelationships

Subsystem 2 receives accident records containing injury variables, calculates the total accident costs, and present the reports to all three levels of management.

Subsystem 3 receives information about at least a one-year accident data set from the input component as well as the total accident costs from Subsystem 2. Based on this information, Subsystem 3 can calculate the risk scores for each accident.

Subsystem 4 receives risk scores from Subsystem 3, uses them to determine the total risk scores for each rig, ranks the rigs by their respective scores, and presents the report to the management group.

Subsystem 5 consists of two subsubsystems, namely, the SSub 1 and the SSub 2. SSub 1 receives information from Subsystem 4 about priorities and with the help of the files, refines these priorities by task and length of employment categories and reports them to the management group. SSub 2 receives feedback from the management group on the rig number, task number, and length of employment category that should further be refined by case numbers. Again, this task can be accomplished with the help of the files. Based on this latest refinement, the management group, together with their safety experts, enumerate alternatives for corrections and at the same time also estimate their respective DC and CF values. These activities are performed by Subsystem 6. These alternatives, with their respective DC's and CF's, are fed into Subsystem 7.

Subsystem 7 receives information from Subsystem 6 and processes it to provide the relative effectiveness of each alternative. The results of these calculations are then reported back to the management group so that the best alternative can be chosen.

3.5.3. The Subsystems in the Output Component

The output produced by the processor becomes the input for the output component. This output is essentially feedback to the implementation of the management safety policies, as shown in Figure 26.

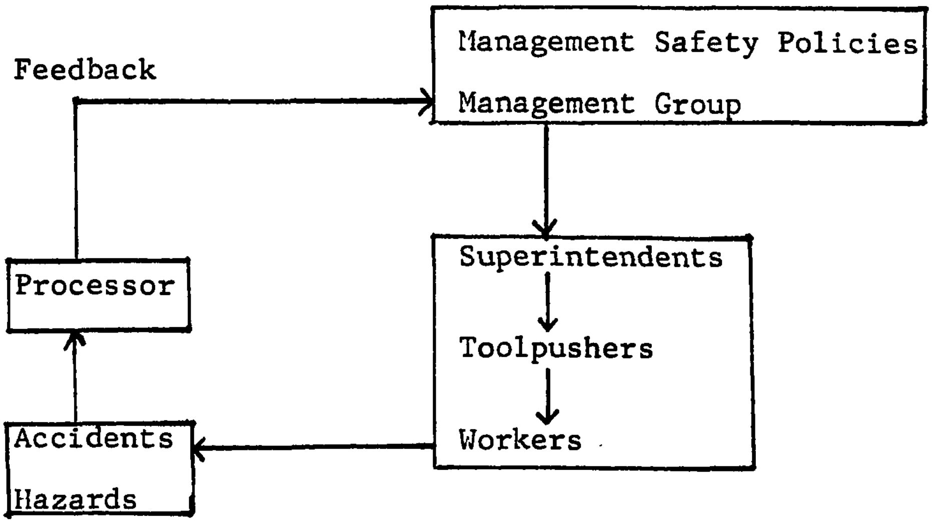


Figure 26: Feedback to the Implementation of the Management Safety Policies

The management group designs and controls the implementation of the management safety policy. The superintendents, toolpushers, and workers implement the safety policy. Accidents and hazards occur because of the imperfections existing in the policy and its implementation. Data on accidents and hazards are collected for monitoring purposes. They are then fed back into the processor to be converted into other parameters and presented as reports addressed to the management group. These reports actually provide information of how well the mangement safety policy is functioning and how well it is being implemented by their personnel.

The subsystems in this output component consist of those subsystems receiving reports from the processor component.

Since these reports are meant to support decisions, the subsystems are then the existing management levels: the management group, the superintendents, and the toolpushers. The rest of this component comprises the decisions made to improve the management safety policies and the implementation thereof. The subsystems and their interrelationships are shown in Figure 27.

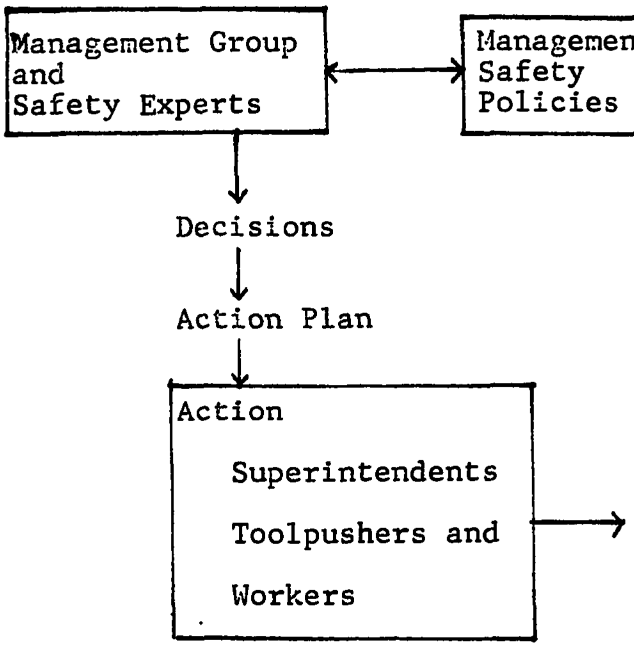


Figure 27: Output Subsystems and Their Interrelationships

The management group receives reports from the processor concerning the underlying causes, total accident costs, priorities by rig, priorities by tasks and duration of employment, and relative effectiveness of alternatives. Based on these reports, the management group can make decisions to improve the existing Management Safety Policy. The decisions are then followed by the preparation of the plans of action to be implemented. Given the actual plans, the superintendents will put them into action by providing schedules to the tool-pushers who implement the required action.

Finally, to complete the cycle of the total system, Figure 28 shows the relationship between the output and the input components.

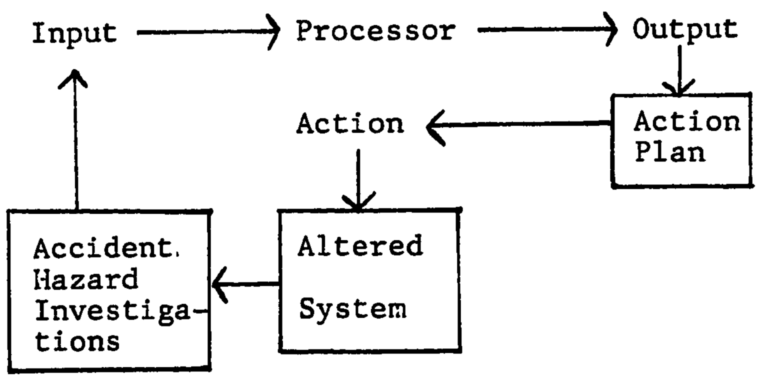


Figure 28: Relationship Between the Output and the Input Components

As was discussed previously, the management group present plan of action to improve the safety performance of the company which is then implemented. These actions will result in an improved or altered system. The altered system, however, is not quite foolproof and should be monitored through continuous inspections and accident investigations. The process and results of these investigation are part of the input component. Thus, the total system is completed by the one subsystem which contains the altered system.

3.6. MIS Model on Paper

The subsystems discussed under each component will now be presented as a whole system, the Management Information System for Accident Prevention.

Figure 29 shows the whole MIS, drawn as effectively as possible to show all subsystems in each component previously described. However, Subsystem 10 has been added to decide on the effectiveness of alternatives. There is a possibility that none of the alternatives will be considered worthwhile, that is, if the values of the "J" factors are all unacceptable. In such cases, a re-evaluation is warranted because the urgency for corrections has been previously determined. Also, the MCP is included to show the routine maintenance procedure. The management group and the management safety policies subsystems are included into one large subsystem with the consideration that only the management group can alter the safety policies. The MIS as a total system consists of a total of 18 subsystems.

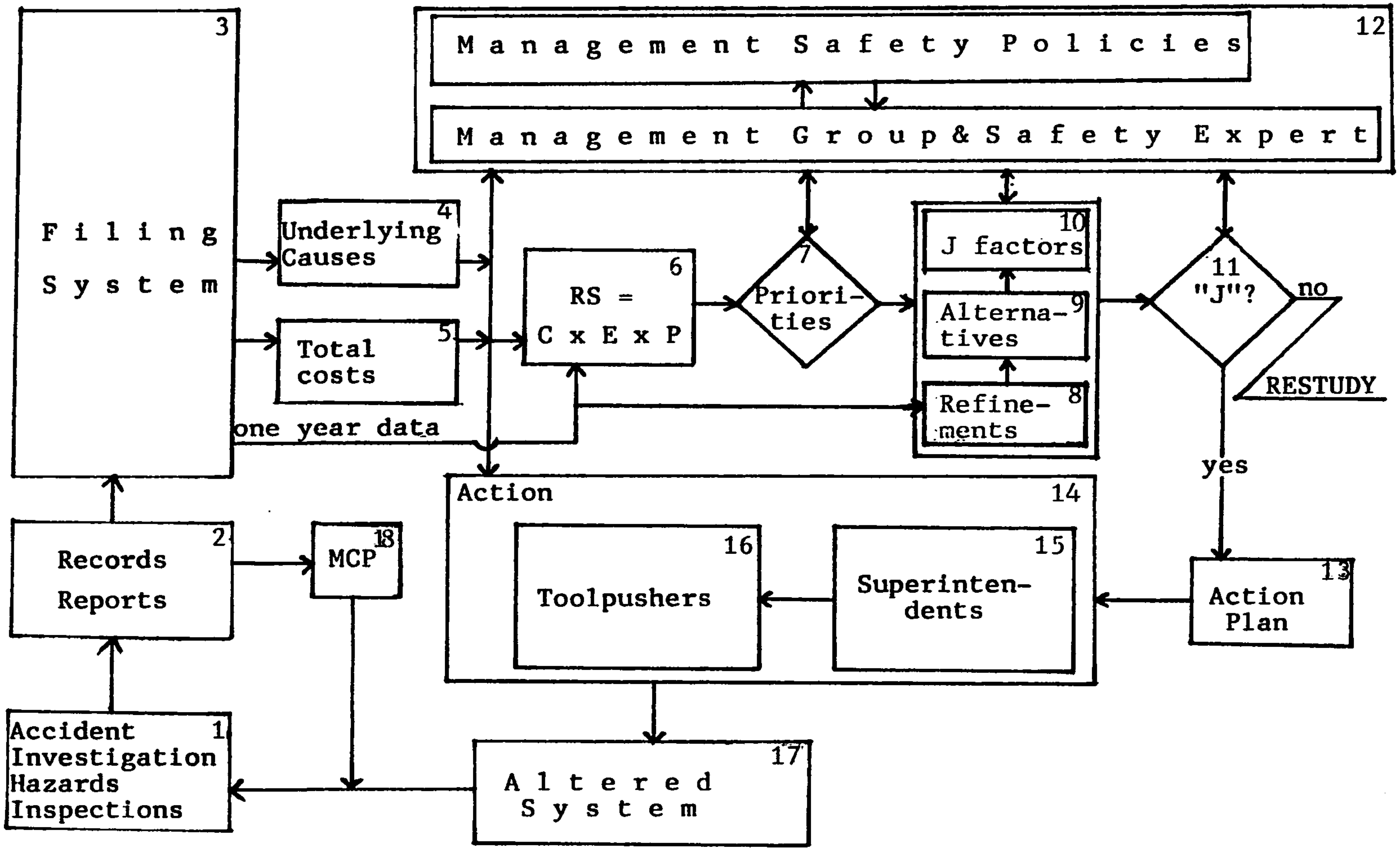


Figure 29: The MIS as a total system.

Chapter 4

TESTING OF THE MIS

In this chapter, an attempt is made to test the MIS model shown in Figure 29. The test is divided into two parts:

(1) Test using a hypothetical data set.

(2) Test using a real accident data set.

The hypothetical data set is designed to fulfill the exact input required by the MIS, while the actual accident data set represents accident data existing in an oil-well drilling company.

The use of these two data sets in the test is based on the following rationale:

(1) It is of the utmost importance to test a model to see whether it can indeed perform its expected functions:

  (i) Motivating and involving managers in safety activities.

  (ii) Converting data into information to support management decisions for accident prevention.

  Both capabilities are expressed in the contents of the following reports:

  (i) The total accident cost reports.

(ii) The accident causation reports.

(iii) The report on rigs having priorities for corrections.

(iv) The reports on the refinement of information for each priority rig.

(v) The report on the relative effectiveness ("J" factor) for each alternative.

(2) The availability of a one-year actual accident data set can be very useful, to a certain extent, in supporting the test with the hypothetical data set.

(3) The use of these two data sets may also reveal other important aspects of accident prevention with the use of the existing information system in the real world.

The description of the tests using both data sets will cover three basic areas for discussion:

(1) The data set itself.

(2) The procedures used in the tests.

(3) The results of the tests.

4.1. Test Using the Hypothetical Data Set

4.1.1. Hypothetical Data Set

Hypothetical data is the value of variables which are designed to serve as the required input to the MIS model. This data set consists of both accident and hazard records. Each accident record contains the following variables:

(1) The case number, which is the year, the month, and the running number of accidents occurring in that month.

(2) The rig number, assuming that there are 30 rigs in operation, and that each superintendent supervises 3 rigs.

(3) The task number.

(4) The nature of the injury incurred.

(5) The part of the body injured.

(6) The unsafe act, if applicable.

(7) The unsafe condition, if applicable.

(8) The underlying causes.

(9) Whether the injury resulted in lost time.

(10) The employment category of the injured.

Each hazard record contains only four variables; they are mentioned under (1), (2), (3), and (4) of the accident record.

The values assigned to the above variables are numerical with the exception of the underlying causes, which are expressed in the form used by the 4x4 accident investigation technique (see Appendix B). The case numbers assigned consist of the two last digits of the year, the month, and the running number of the accident occurring in that month. For example, Case Number 820105 implies that the accident or hazard occurred in 1982, January, and it was the fifth accident/hazard occurring within the month of January. The rig number is the actual number assigned to each rig. The task number is the code number of the task in which the accident occurred and is assigned arbitrarily from one to seven (see Appendix E). The nature of injury, and the part of the body injured are coded in accordance with the numbers of rows and columns of the Robinson matrix respectively, which is 17 by 14 (see Appendix A). The unsafe acts and the unsafe conditions are coded by the ANSI classification (ANSI, 1969). The lost time variable is coded arbitrarily; it is assigned a value of one if there was no lost time and a value of two if there was lost time. The length of employment categories are also arbitrarily coded from one to four as shown in Appendix E.

The accident and hazard cases contained in this data set are not exactly contrived, but are taken from reports describing accident cases (NIOSH, 1982 and NSC, 1979). The cases include both severe and minor cases. Based on the examples found in the reports, more accident cases were made up. Some minor cases were assigned to one rig while one severe accident was assigned to another rig, and still other rigs were assigned combinations of severe and minor cases. The data set contains a two-month record consisting of 50 and 40 accidents and hazards for each month respectively. This hypothetical data set can be found in Appendix F.1.

4.1.2. Test Procedures

As was discussed in Chapter 2, the procedures used in the processor component of this MIS are computerized. Hence, these test procedures will also be computerized. The step-by-step manipulation will be explained by using algorithms which formulate the given problems in a list of manipulation to be performed (Friedman and Koffman, 1979). These algorithms will further be elaborated into flow diagrams to show detailed operational procedures. The language used in the programs is Fortran 77 (Wagener, 1980); all the programs used in these tests can be found in Appendix D.

The test procedures will also be described in accordance with the required output of the MIS in the following order:

(1) The total cost report.

(2) The accident causation report.

(3) The report on priority rigs.

(4) The report on the refinement of information of the priority rigs.

(5) The report on the relative effectiveness of each alternative.

4.1.2.1. Total Accident Cost Report

4.1.2.1.1. Data Set

To be able to prepare the total accident cost reports with the use of the Robinson model, the data fed into the program should consist of the retrospective data or the accident data only. The new data set required is formed by copying all accident data into a new file followed by a deletion of all the hazards cases.

4.1.2.1.2. Procedure

The sequence of manipulations to prepare the total accident cost report is shown in the following algorithm:

Step 1. Read in the Robinson matrix into the matrix SM (17,14) and the accident records into the following arrays:
CS(N) for case numbers, NI(N) for nature of injury, RG(N) for rig numbers, PB(N) for part of body injured, TK(N) for task numbers, UACT(N) for unsafe act code numbers, UCON(N) for unsafe condition code numbers, ULC(N) for underlying causes, LOT(N) for lost time code numbers, LEM(N) for employment category code numbers. Assign N = the number of cases.

Step 2. Look at the nature of injury, part of body, and lost time values of each record and find the total cost value in the SM matrix in accordance with the values of the above variables and store it in the array C(N).

Step 3. Sum the total costs of the records having the same rig number and store in the array CRG(30).

Step 4. Print CRG array by superintendent and by rig number.

The above algorithm is further elaborated in the flow diagrams illustrated in Figures 30 and 31. The actual program used to

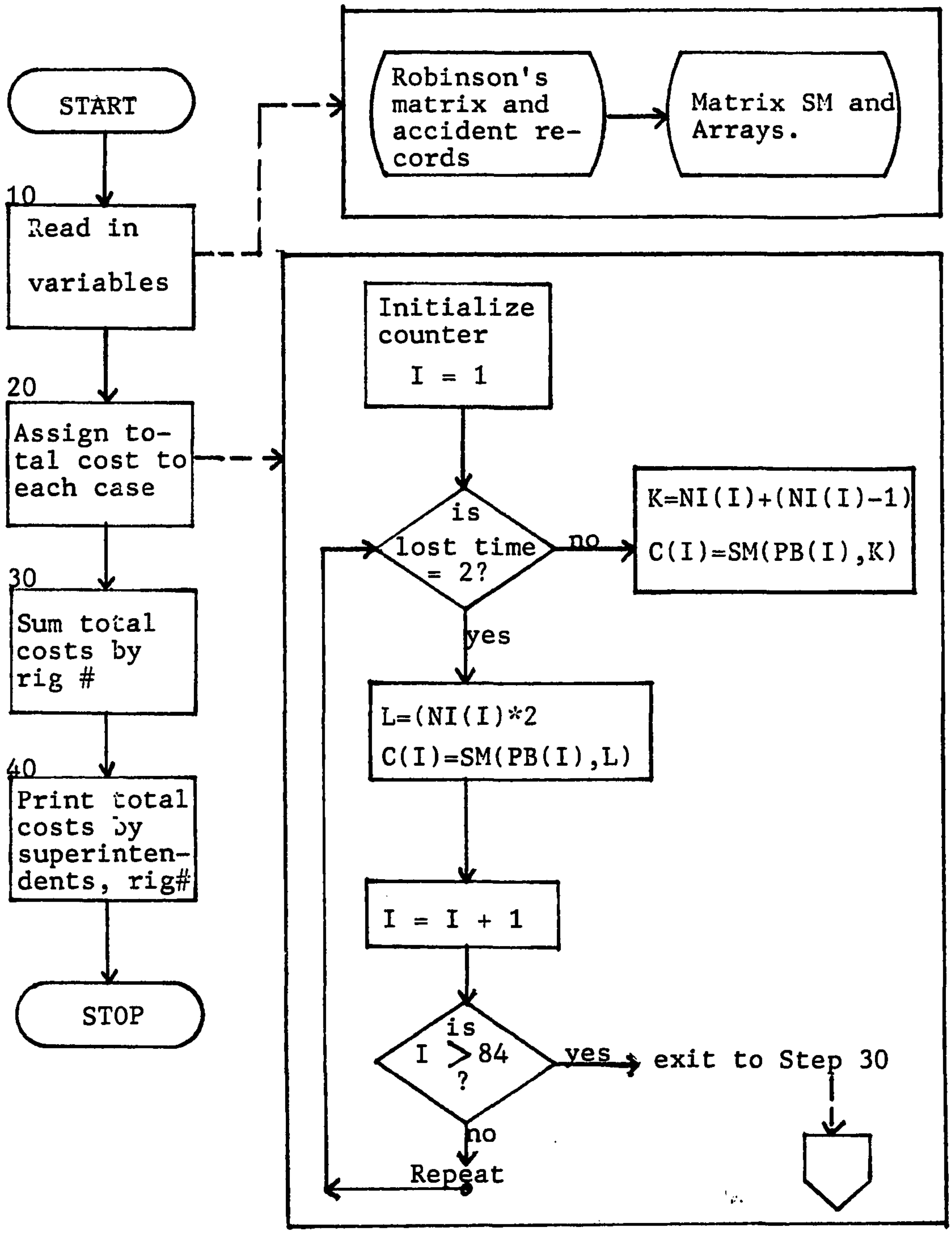


Figure 30: Flow Diagram for Total Accident Cost Report

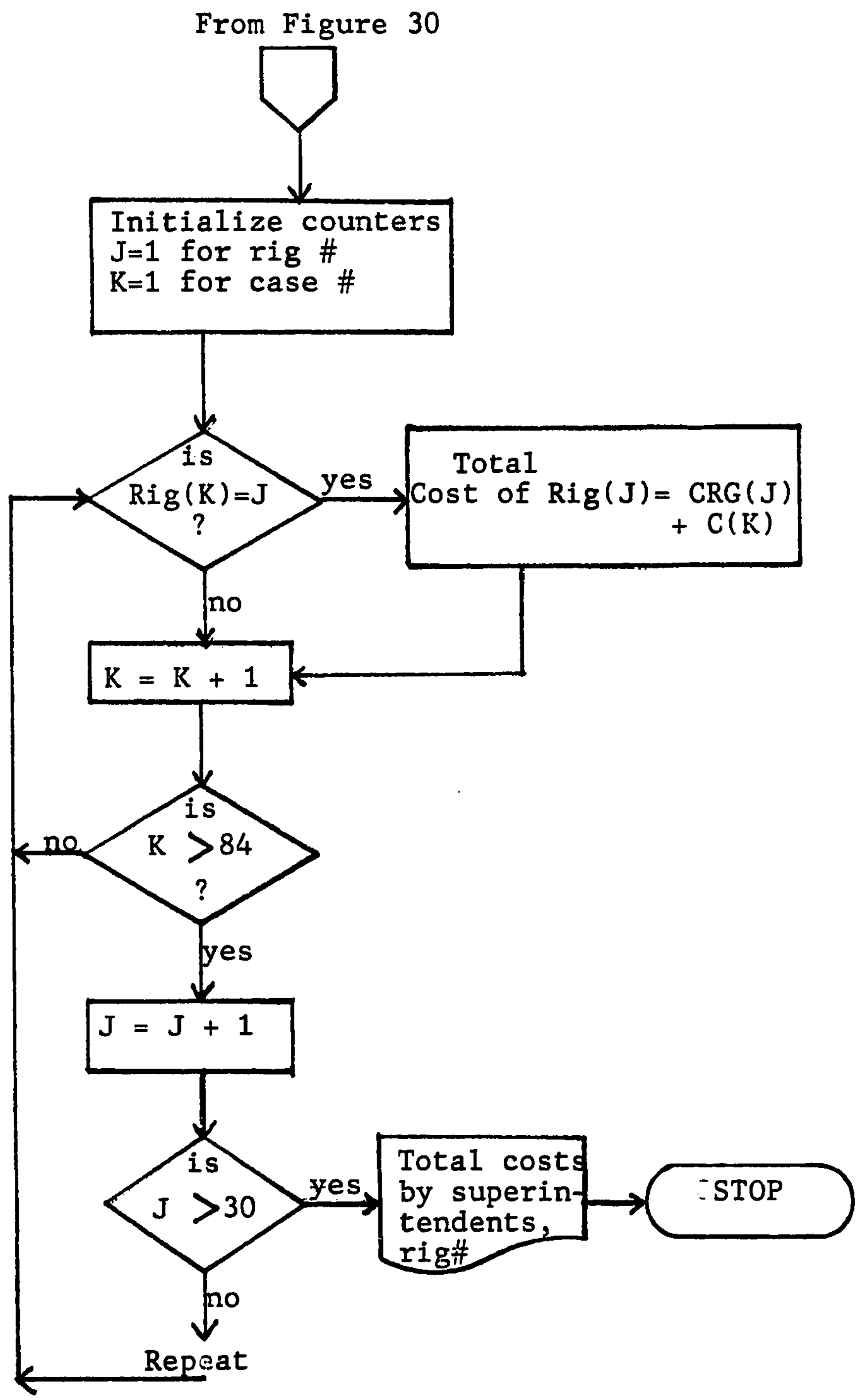


Figure 31: Flow Diagram for Total Cost Report (cont.)

present this cost report can be found in Appendix D.1.

4.1.2.1.3. <u>Results</u>

The results of this test are shown in Figure 32, which is an example of the monthly total accident cost reports managers will receive. The report expresses the total costs in man-hours lost so that the costs become comparable among all rigs. This report also shows several facts about accident costs:

(1) The magnitude of the costs incurred vary by rig and by month. Since these costs are reported together and expressed as man-hours lost, comparisons can be made among all rigs. Safety performance of different types of rigs can also be evaluated.

(2) The variation of these costs by month show that there are trends which indicate the superintendent's as well as the toolpusher's efforts to prevent accidents; hence, these are also safety performance trends.

(3) By multiplying the numbers of man-hours lost by the average wage per hour, the man-hours can be converted into dollar values. These dollar values can then be used to charge the respective projects in the process of predicting whether a project will make a profit so that necessary actions can be taken to ensure this.

XYZ DRILLING CO., ACCIDENT REPORT IN MANHOURS LOST,BY MONTH,   1982

SUPERINTENDENT	RIG NUMBER	JAN	FEB	MCH	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
SUPERINTENDENT 1														
	RIG# 1	320	0											320
	RIG# 2	265	300											565
	RIG# 3	320	25											345
SUPERINTENDENT 2														
	RIG# 4	455	240											695
	RIG# 5	75	50											125
	RIG# 6	20	0											20
SUPERINTENDENT 3														
	RIG# 7	40	70											110
	RIG# 8	450	20											470
	RIG# 9	2480	2420											4900
SUPERINTENDENT 4														
	RIG# 10	380	0											380
	RIG# 11	150	0											150
	RIG# 12	6635	0											6635
SUPERINTENDENT 5														
	RIG# 13	300	415											715
	RIG# 14	18000	25											18025
	RIG# 15	300	0											300
SUPERINTENDENT 6														
	RIG# 16	45	380											425
	RIG# 17	20	75											95
	RIG# 18	380	300											680
SUPERINTENDENT 7														
	RIG# 19	6600	75											6675
	RIG# 20	530	0											530
	RIG# 21	14000	0											14000
SUPERINTENDENT 8														
	RIG# 22	320	0											320
	RIG# 23	770	0											770
	RIG# 24	380	25											405
SUPERINTENDENT 9														
	RIG# 25	720	400											1120
	RIG# 26	25	20											45
	RIG# 27	150	0											150
SUPERINTENDENT 10														
	RIG# 28	405	20											425
	RIG# 29	300	0											300
	RIG# 30	220	225											445
	TOTAL :	55055	5085											60140

Figure 32: Total Accident Cost Report

The situation created by the communication of this report will motivate managers to prevent accidents provided that: (i) all superintendents and toolpushers are informed that their safety performance is being evaluated through these reports, and (ii) that these accident costs are being charged to their respective projects.

The report in Figure 32 also shows that in January, the two highest losses were incurred by Rigs 14 and 21. These high losses seemed to be due to one severe accident occurring in each rig and are not a regular phenomena as shown by the losses incurred in the next month by the same rigs, which are much lower compared to the month January.

Rig 9 on the other hand, shows a somewhat consistent losses for both months. This phenomena should be noticed because even if the losses are not impressive, the consistency of losses by month result in a greater total loss in the long run.

4.1.2.2. Accident Causation Report

4.1.2.2.1. Data Set

The accident causation report is a monthly report presenting the underlying causes for each accident occurring during one month. The causes will be presented by rig , by superintendent, and by case number. The data set needed to present this report is then a one-month retrospective data set containing case numbers, rig numbers, and their respective underlying causes. This data set can be obtained by taking out a particular month's data from the file and deleting all other variables except the case numbers, the rig numbers, and the underlying causes (see Appendix F.2).

4.1.2.2.2. Procedure

The procedure to present the underlying causes by rig and by superintendent are illustrated in general in the following algorithm:

Step 1. Read in variables: case numbers into array CS, rig numbers into array RG, underlying causes into arrays M1, M2, M3, S1, S2, S3, W1, W2, W3.

Step 2. Print out headings.

Step 3. For each rig number, print out the case number and its associated cause in the right column.

The above algorithm is then refined into a more detailed flow diagram as shown in Figure 33, which is self-evident.

The reports for the superintendents and the management group are made at the same time using the same program because the report for the management group actually contains the sum of the causes occurring under each superintendent. The program for the above report is shown in Appendix D.2.

The report intended for the toolpushers, however, is made with another program because only the causes related to their own and their workers' levels are printed. The algorithm and the flow diagram are the same as those used in the

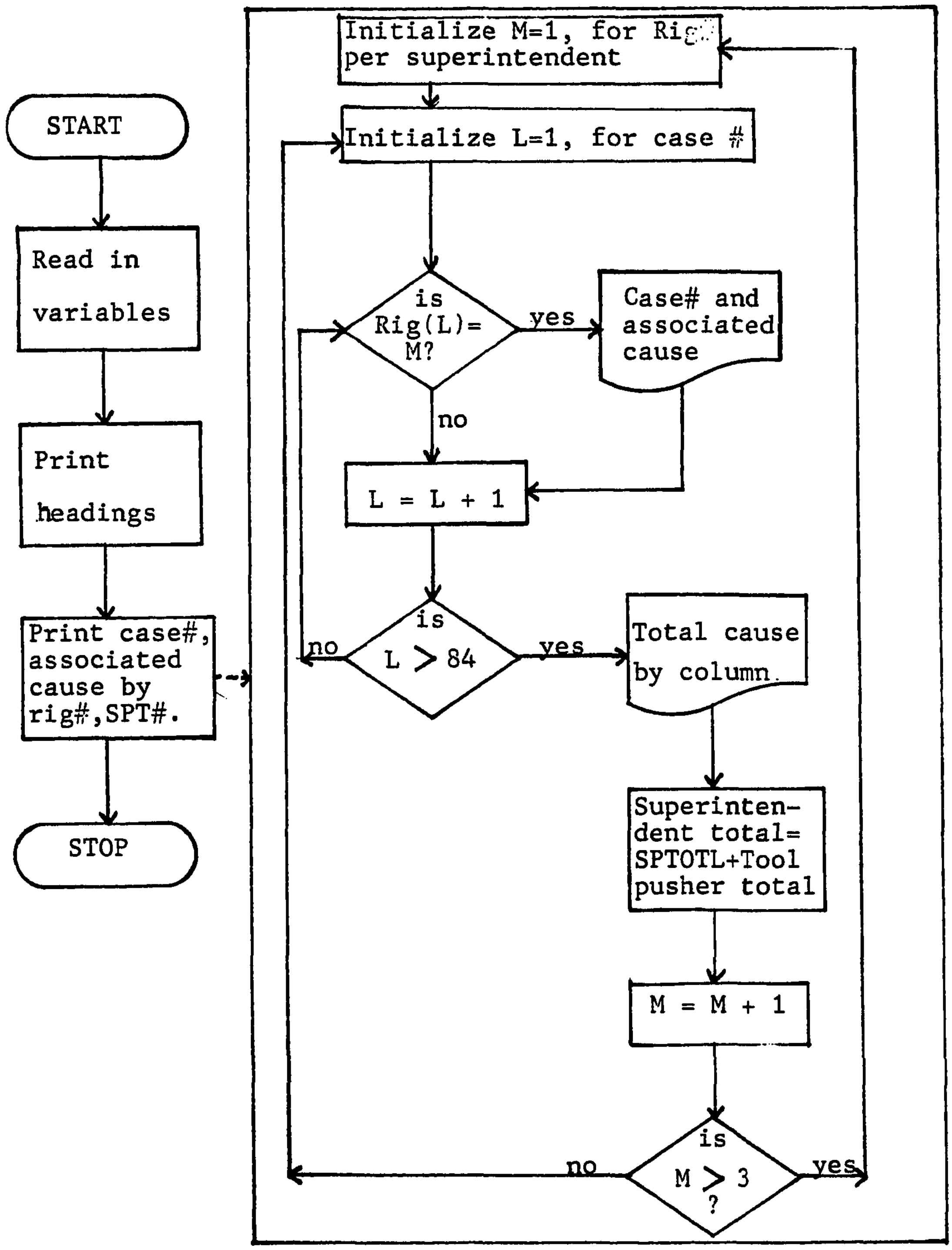


Figure 33: Flow Diagram for Accident Causation Report

previous program. The program for this toolpusher's report can be found in Appendix D.3.

4.1.2.2.3. Results

The results of this test are shown in Figures 34 and 35. Figure 34 consists of four examples of reports. Figure 34a, 34b, and 34c show reports addressed to superintendents number three, five, and seven, respectively. These reports are selected because they contain Rig 9, 14, and 21 discussed previously under the total cost report. These reports for superintendents show the number of cases occurring in each rig and their associated causes. Figures 34b and 34c show that Rigs 14 and 21 contain only one accident per month, but as was mentioned previously, they incurred the highest losses for that month. Hence, the one accident must be a major accident, i.e., one resulting in severe injury. On the contrary, Rig 9 contains several accidents for the same month but did not show high total costs, therefore, they must be minor accident cases. The underlying causes and their respective corrective steps to be taken are also different. Rigs 14 and 21 require corrective steps at the toolpusher's and the workers' levels only, while Rig 9 reaches the superintendent's level also (see case 820137).

Figure 34d shows a sample report for the management group. It consists of the sum of the underlying causes existing at each superintendent level. This report shows several impor-

TO :SUPERINTENDENT # 3
FROM :THE SAFETY DEPARTMENT
SUBJECT:ACCIDENT CAUSATION REPORT
PERIOD :JANUARY,1983

TOOLPUSHER # 7 UNDERLYING CAUSES AT LEVELS OF CORRECTION

CASE #	M	M -S	M -S -W	M -W	S	S -W	W
820120			M30-S20-W20				
820139							W30
TOTAL	0	0 - 0	1 - 1 - 1	0 - 0	0	0 - 0	1

TOOLPUSHER # 8 UNDERLYING CAUSES AT LEVELS OF CORRECTION

CASE #	M	M -S	M -S -W	M -W	S	S -W	W
820105		M20-S20					
TOTAL	0	1 - 1	0 - 0 - 0	0 - 0	0	0 - 0	0

TOOLPUSHER # 9 UNDERLYING CAUSES AT LEVELS OF CORRECTION

CASE #	M	M -S	M -S -W	M -W	S	S -W	W
820108					S40		
820121							W34
820137		M30-S40					
820143							W30
820146							W30
820148						S40-W30	
820149					S40		
TOTAL	0	1 - 1	0 - 0 - 0	0 - 0	2	1 - 1	4

Figure 34a: Accident Causation Report for Superintendent 3

TO :SUPERINTENDENT # 5
FROM :THE SAFETY DEPARTMENT
SUBJECT:ACCIDENT CAUSATION REPORT
PERIOD :JANUARY,1983

TOOLPUSHER # 13 UNDERLYING CAUSES AT LEVELS OF CORRECTION

CASE #	M	M -S	M -S -W	M -W	S	S -W	W
820112							W43
TOTAL	0	0 - 0	0 - 0 - 0	0 - 0	0	0 - 0	2

TOOLPUSHER # 14 UNDERLYING CAUSES AT LEVELS OF CORRECTION

CASE #	M	M -S	M -S -W	M -W	S	S -W	W
820123					S40		
TOTAL	0	0 - 0	0 - 0 - 0	0 - 0	1	0 - 0	0

TOOLPUSHER # 15 UNDERLYING CAUSES AT LEVELS OF CORRECTION

CASE #	M	M -S	M -S -W	M -W	S	S -W	W
820113							W40
TOTAL	0	0 - 0	0 - 0 - 0	0 - 0	0	0 - 0	1

Figure 34b: Accident Causation Report for Superintendent 5

TO :SUPERINTENDENT # 7
FROM :THE SAFETY DEPARTMENT
SUBJECT:ACCIDENT CAUSATION REPORT
PERIOD :JANUARY,1983

TOOLPUSHER # 19 UNDERLYING CAUSES AT LEVELS OF CORRECTION

CASE #	M	M -S	M -S -W	M -W	S	S -W	W
820104			M20-S20-W30				
TOTAL	0	0 - 0	1 - 1 - 1	0 - 0	0	0 - 0	0

TOOLPUSHER # 20 UNDERLYING CAUSES AT LEVELS OF CORRECTION

CASE #	M	M -S	M -S -W	M -W	S	S -W	W
820127	M10						
820135							W10
TOTAL	1	0 - 0	0 - 0 - 0	0 - 0	0	0 - 0	1

TOOLPUSHER # 21 UNDERLYING CAUSES AT LEVELS OF CORRECTION

CASE #	M	M -S	M -S -W	M -W	S	S -W	W
820116						S43-W10	
TOTAL	0	0 - 0	0 - 0 - 0	0 - 0	0	2 - 1	0

Figure 34c: Accident Causation Report for Superintendent 7

TO   :THE MANAGEMENT GROUP
FROM   : THE SAFETY DEPARTMENT
SUBJECT:ACCIDENT CAUSATIONS REPORT
PERIOD :JANUARY,1983

SUPERINTENDENT	UNDERLYING CAUSES AT LEVELS OF CORRECTION						
	M	M -S	M -S -W	M -W	S	S -W	W
1	0	0 - 0	1 - 1 - 1	0 - 0	1	2 - 2	2
2	0	0 - 0	0 - 0 - 0	0 - 0	0	2 - 2	2
3	0	2 - 2	1 - 1 - 1	0 - 0	2	1 - 1	5
4	0	0 - 0	3 - 3 - 3	0 - 0	0	1 - 1	0
5	0	0 - 0	0 - 0 - 0	0 - 0	1	0 - 0	3
6	0	3 - 3	0 - 0 - 0	0 - 0	0	1 - 1	0
7	1	0 - 0	1 - 1 - 1	0 - 0	0	2 - 1	1
8	0	0 - 0	0 - 0 - 0	0 - 0	1	5 - 4	0
9	0	0 - 0	0 - 0 - 0	0 - 0	0	5 - 6	2
10	0	1 - 1	0 - 0 - 0	0 - 0	0	1 - 1	2
TOTAL	1	6- 6	6- 6 - 6	0 - 0	5	20 -19	17

Figure 34d: Accident Causation Report for the Management Group

tant facts about the underlying causes of accidents for this particular month:

(1) Under the supervision of Superintendent 3 the largest number of managerial errors occurred resulting in accidents.

(2) The underlying causes are mostly related to the toolpusher's and the workers' safety performance.

In general, this type of report can help management in locating problems, identifying problems, and evaluating safety performance. This report can also give insights to the solution of the problems identified.

Figure 35 is an example of a report to be sent to Toolpusher 9, which shows the underlying causes and the corrective steps to be taken at this toolpusher's and his workers' levels only. By simply looking at this report, this toolpusher will know what problems exist at these two levels and what actions should be taken to prevent similar accidents from occurring in the future.

4.1.2.3. Priority Determination

4.1.2.3.1. Data Set

Two data sets are needed in the priority determination: (1) the retrospective data set consisting of accident accident records for both months and (2) the complete data set consisting of both the accident and the hazard records.

The retrospective data set will be used to calculate the

TOOLPUSHER # 9 UNDERLYING CAUSES AT LEVELS OF CORRECTION

CASE #	M	M	-S	M	-S	-W	M	-W	S	S	-W	W
820108									S40			
820121												W34
820137			-S40									
820143												W30
820146												W30
820148										S40	-W30	
820149									S40			
TOTAL			- 1		- 0	- 0		- 0	2	1	- 1	4

Figure 35: Example of an Accident Causation Report for Toolpushers

risk scores for each accident case and to calculate the average risk scores for each rig by task. The average risk scores are calculated so that each hazard identified within a task and rig can be assigned a number which represents the magnitude of risk imposed by the hazard. The complete data set will be used to actually determine the priorities for corrections so that both accidents and hazards are taken into account.

4.1.2.3.2. Procedure

The following algorithm illustrates the sequence of steps to be taken to determine the priority for corrections by the Fine model:

Step 1. Determine the risk scores for each accident case and store them.

Step 2. Determine the average risk scores for each rig by task.

Step 3. Sum up the risk scores by rig number.

Step 4. Rank the rigs according to their risk scores.

Step 5. Print out the list of rank, the associated rig number and risk scores.

The flow diagram for the above algorithm is shown in Figure 36. Each of the steps shown in the flow diagram will be discussed separately because of the complexity of the process involved in each of these steps, except for Step 5 which will be described with Step 4.

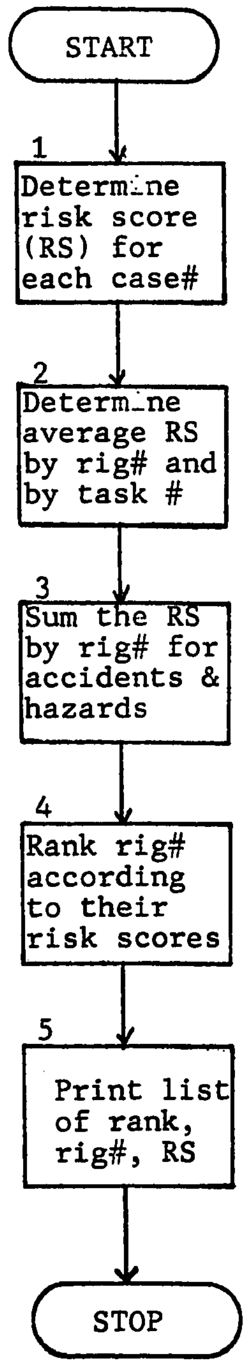


Figure 36: Flow Diagram of the Main Steps for Priority Determination

4.1.2.3.2.1. Determination of Risk Scores

Step 1 of the flow diagram shown in Figure 36 is the step that determines the risk score for each accident case. It is further refined into four other steps shown in Figure 37. Step 1.1 of this flow diagram contains exactly the same manipulation procedures as shown in Figure 30, so it will not be discussed again in this section. Step 1.2 is divided again into two substeps. Substep 1.2.1 is elaborated to show the principal procedure of computing the frequency of exposure to the same agent for each accident case, E(I). The value for E(I) can be obtained by adding all cases having the same direct causes, i.e., the same unsafe conditions and unsafe acts. Once the value of E(I) is found, all other cases having the same unsafe condition and unsafe act as case(I) should be assigned the same value of E(I) for their E(K), which is the procedure contained in Substep 1.2.2, illustrated in Figure 38.

The next Step 1.3 is the step whereby the probability that similar accidents will occur is computed. This step is used to find cases having the same unsafe condition (UCON) and the same unsafe act (UACT) which resulted in the same consequences (C). These cases are then counted (SUMP) and the probability (P) is then defined as the total number of cases divided by the number of all accident cases (SUMP/84). The procedure is diagrammed in Figure 39. This Step 1.3 is actually divided into two substeps as is the case with E(I), but is not shown in Figure 39 because the same procedure is

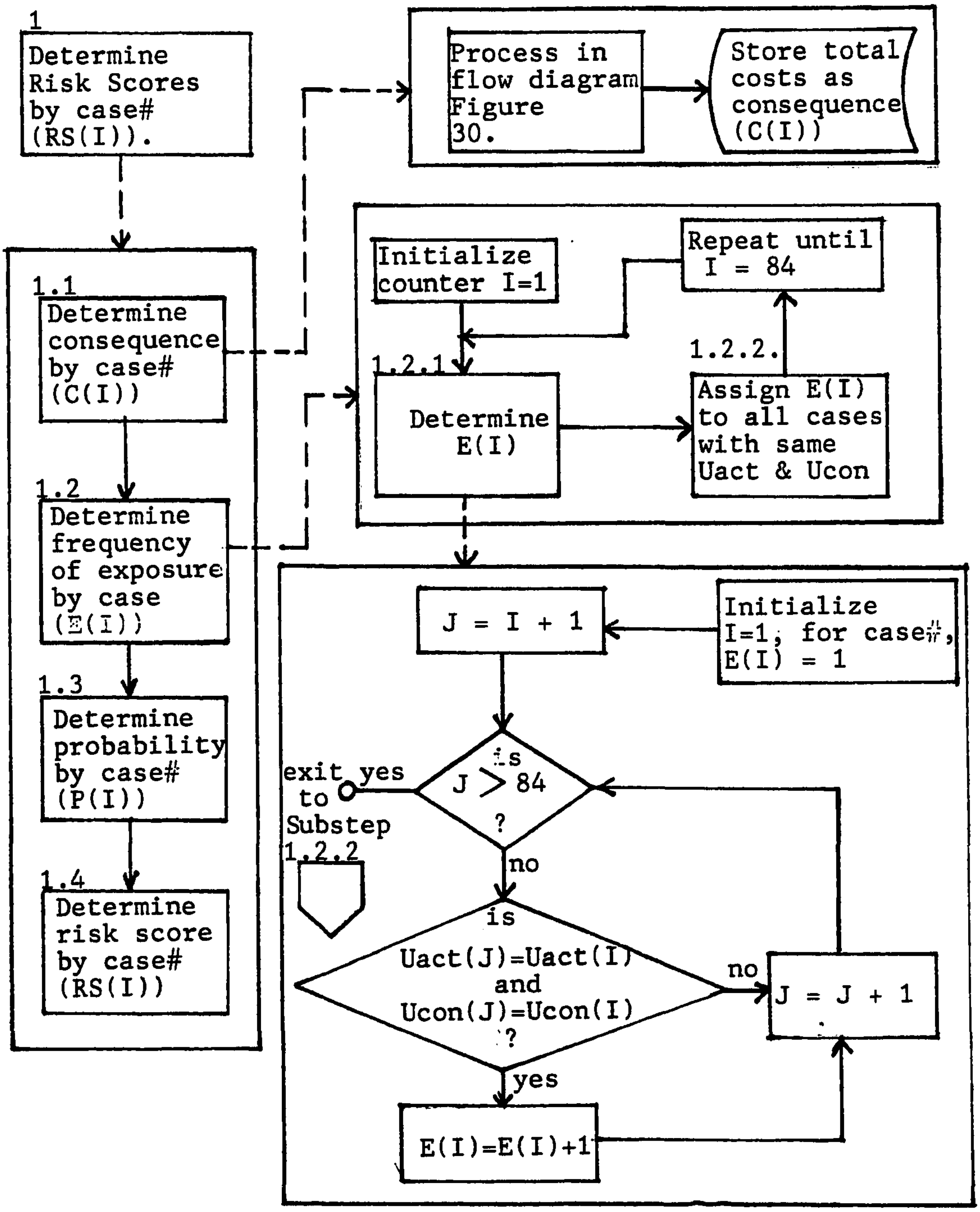


Figure 37: Flow Diagram for the Determination of Frequency of Exposure, Substep 1.2.1

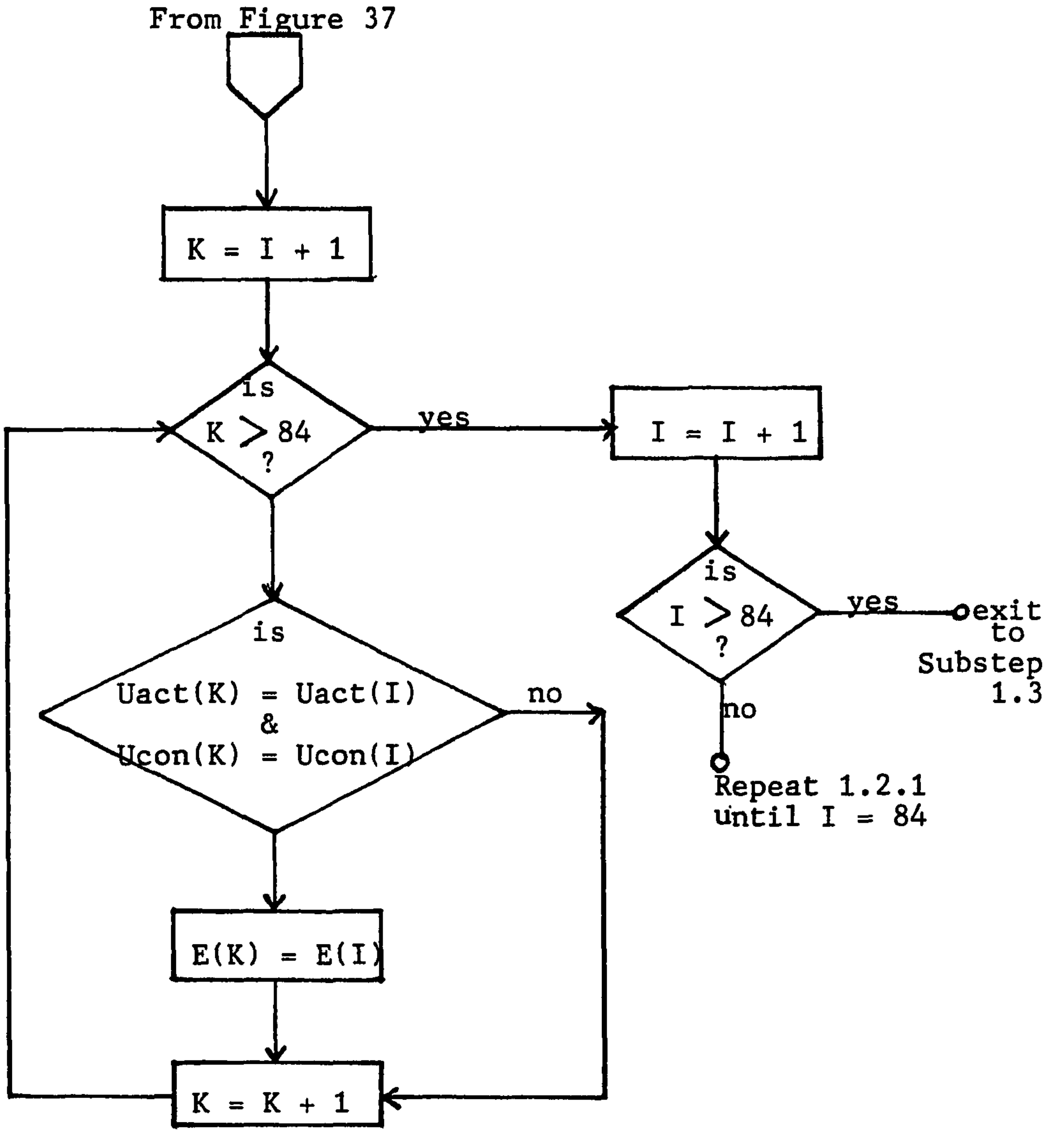


Figure 38: Flow Diagram for the Determination of the Frequency of Exposure, Substep 1.2.2

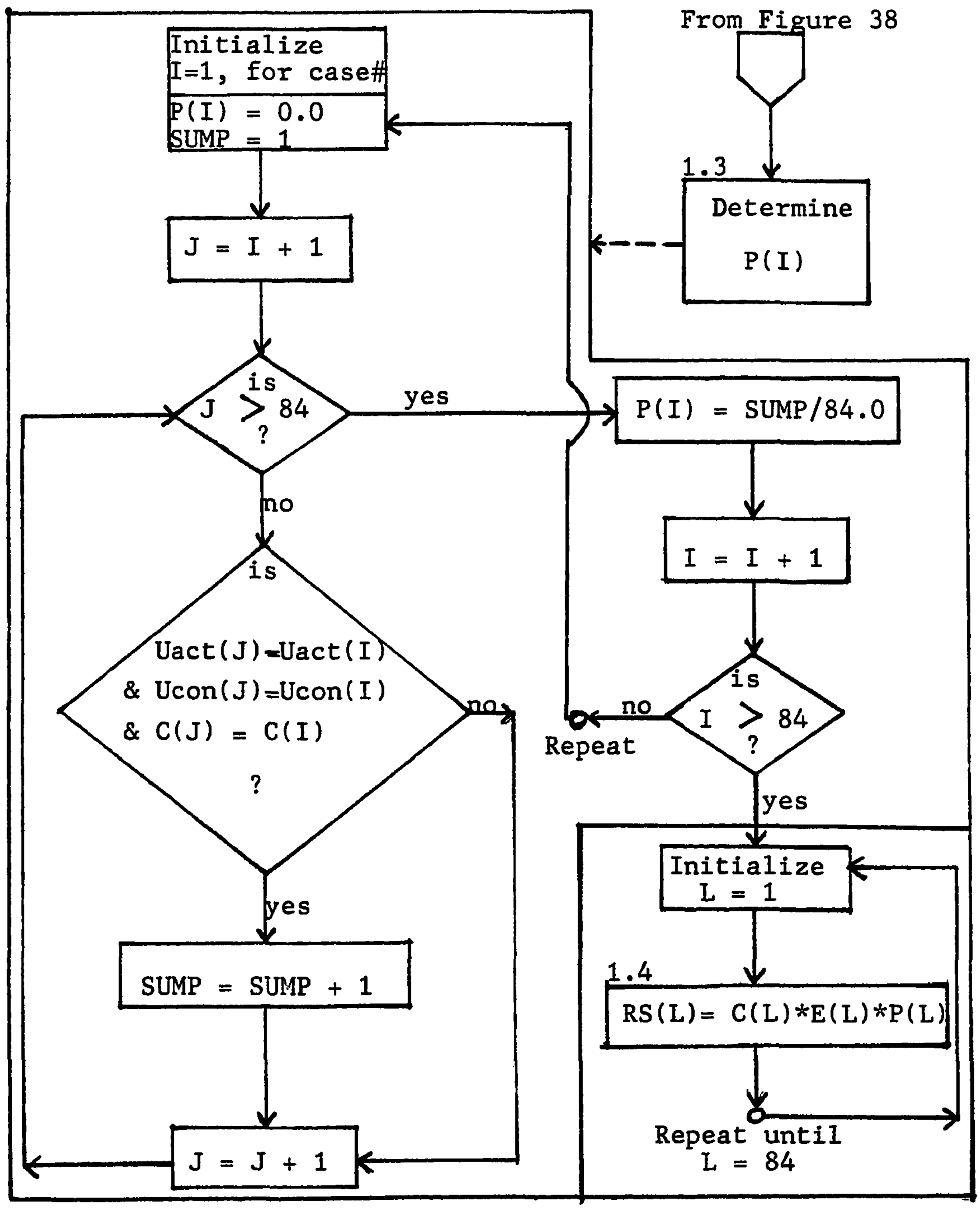


Figure 39: Flow Diagram for the Determination of the Probability, P and the Risk Score, RS

used for P(I) as is shown for E(I). At the end of Step 1.3 each case already has a consequence value C(I), a frequency value E(I), and a probability value P(I). Hence, the risk score value can easily be computed as follows:

RS(I) = C(I) x E(I) x P(I), which is also shown in Figure 39. All of these values of C(I), E(I), P(I), and RS(I) are stored on line to be used further in the following Steps 2, 3, 4, and 5 of Figure 36, to determine the priorities by rig numbers.

4.1.2.3.2.2. Determination of the Average Risk Scores by Rig and by Task

The average risk score for each task is defined as the sum of all the risk scores existing in that task divided by the number of cases occurring within that task. As was discussed in Chapter 3, there are seven tasks in each rig and the risk scores should be weighted before being totalled to make them comparable to each other.

The procedure to compute this average risk score by task is illustrated in the flow diagram of Figure 40, which is self-explanatory. The actual program used for this purpose is shown in Appendix D.4.

The result of executing Step 2 of the priority determination can be found in Figure 41, which is a table of 30 by 7, representing the 30 rigs and their respective seven tasks. The calculation of the average risk score is based on a two-month data, which might not be considered reliable in the real world. This table is presented here as an example of

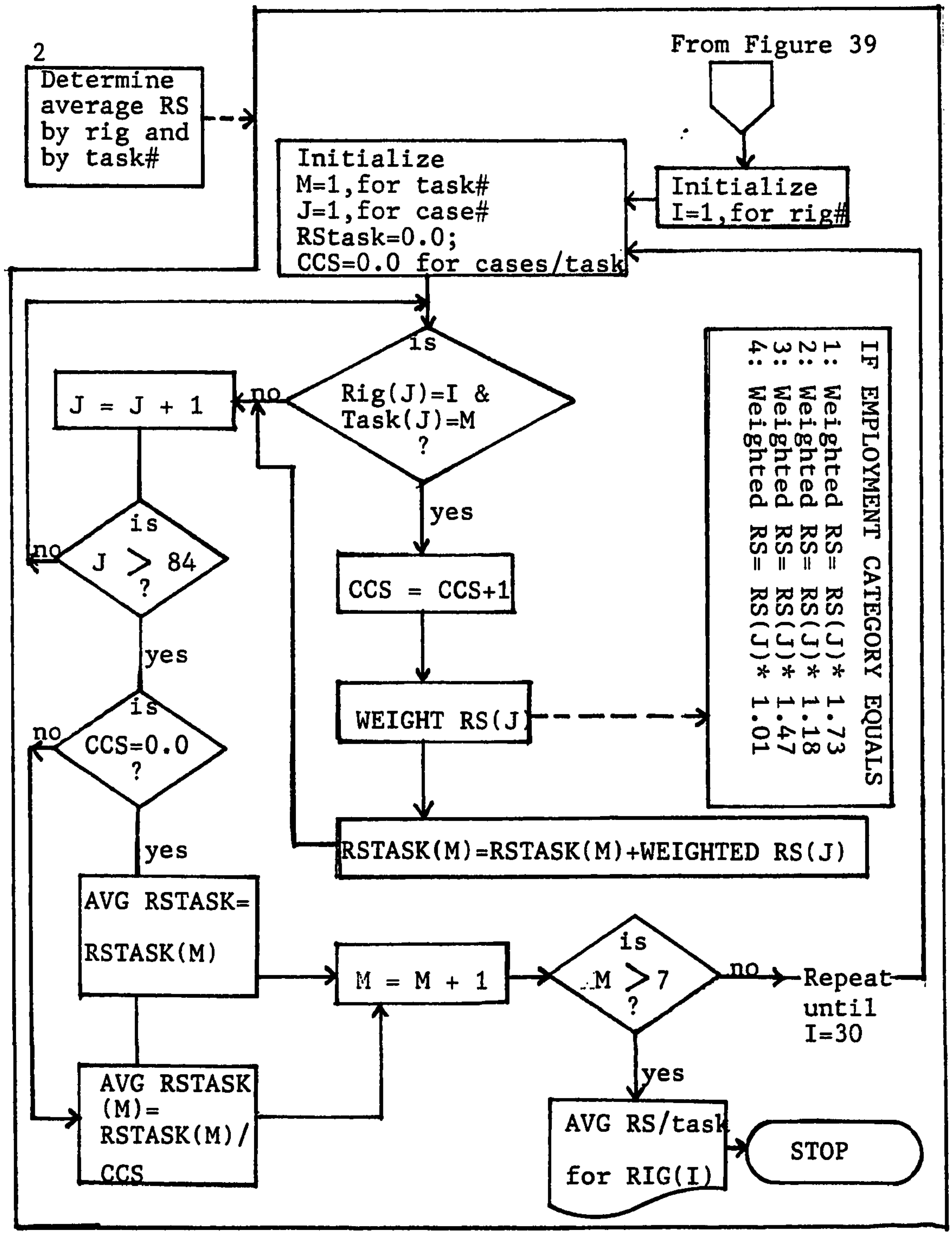


Figure 40: Flow Diagram for the Determination of the Average Risk Scores by Rig and by Task

AVERAGE RISK SCORES BY RIG AND BY TASK

TASK NUMBER:

RIG#	1	2	3	4	5	6	7
1	.00	.41	43.25	.00	.00	.00	.00
2	2.88	.00	.00	34.24	.00	.00	39.68
3	.00	.00	.00	.00	6.18	23.43	.00
4	.00	.00	.00	23.48	27.47	.00	.00
5	2.11	.00	.00	7.93	.00	.31	.00
6	.00	.00	.00	.00	4.21	.00	.00
7	.00	3.60	.00	7.93	.00	.62	.00
8	.00	18.54	.00	.00	6.18	.00	.00
9	.00	.00	12.64	42.86	73.24	.00	.00
10	.00	7.83	.00	.00	.00	.00	.00
11	.00	.00	.00	33.98	.00	.00	.00
12	.98	271.86	.00	.00	.00	.00	.00
13	.00	.00	.00	62.85	.00	.00	.00
14	.00	.00	.00	185.87	.00	.00	.00
15	.00	.00	.00	63.21	.00	.00	.00
16	.00	.00	.00	.51	117.39	.00	.82
17	7.37	.00	.00	.00	6.18	.00	.00
18	.00	.00	10.68	67.96	.00	.00	.00
19	.00	271.86	.00	23.17	.00	.00	.00
20	6.18	.00	.00	.00	117.39	.00	.00
21	.00	288.33	.00	.00	.00	.00	.00
22	.00	.00	.00	15.75	6.18	.00	.00
23	.00	.00	.00	10.74	.00	.00	.00
24	.00	.00	.00	7.72	117.39	.00	.00
25	4.21	.00	117.39	35.71	10.81	.00	.00
26	.00	.00	.00	.00	6.18	.00	.00
27	.00	.00	.00	.00	.00	9.27	.00
28	.00	7.83	6.56	.00	6.18	.00	.00
29	.00	.00	.00	.00	.00	18.54	.00
30	.00	13.59	2.67	7.93	.00	.00	.00

Figure 41: Table of Average Risk Scores by Rig and by Task

the chart that can be used as reference to assign risk scores to each identified hazard. For example, if a hazard was identified in Rig 1 and Task 3, then the risk score that should be assigned to that hazard equals 43.25, as found in Column 3, Row 1 of this table. This table also shows many zero values due to lack of data for that particular task and rig number. It is therefore desirable to have a data set representing a one-year operating data for each rig so that if a zero value appears in the result, it can be said that the zero value truly represents a low risk score value for that particular task and rig.

For the purpose of this testing procedure, the table in Figure 41 will be used as reference to assign risk scores to the identified hazards. These hazard cases are then added into the file of the restospective data to form the complete hypothetical data set.

4.1.2.3.2.3. Summation of Risk Scores by Rig Number

Step 3 in the priority determination is the summation of the risk scores by rig. To be able to execute this third step, the flow diagrams to compute risk scores for each case (see Figures 37, 38, 39) should be connected to the flow diagram shown in Figure 42. As shown, the risk scores are again weighted because their magnitude will be compared to each other. The rest of the manipulation procedure describes a simple summation by rig which is self-explanatory.

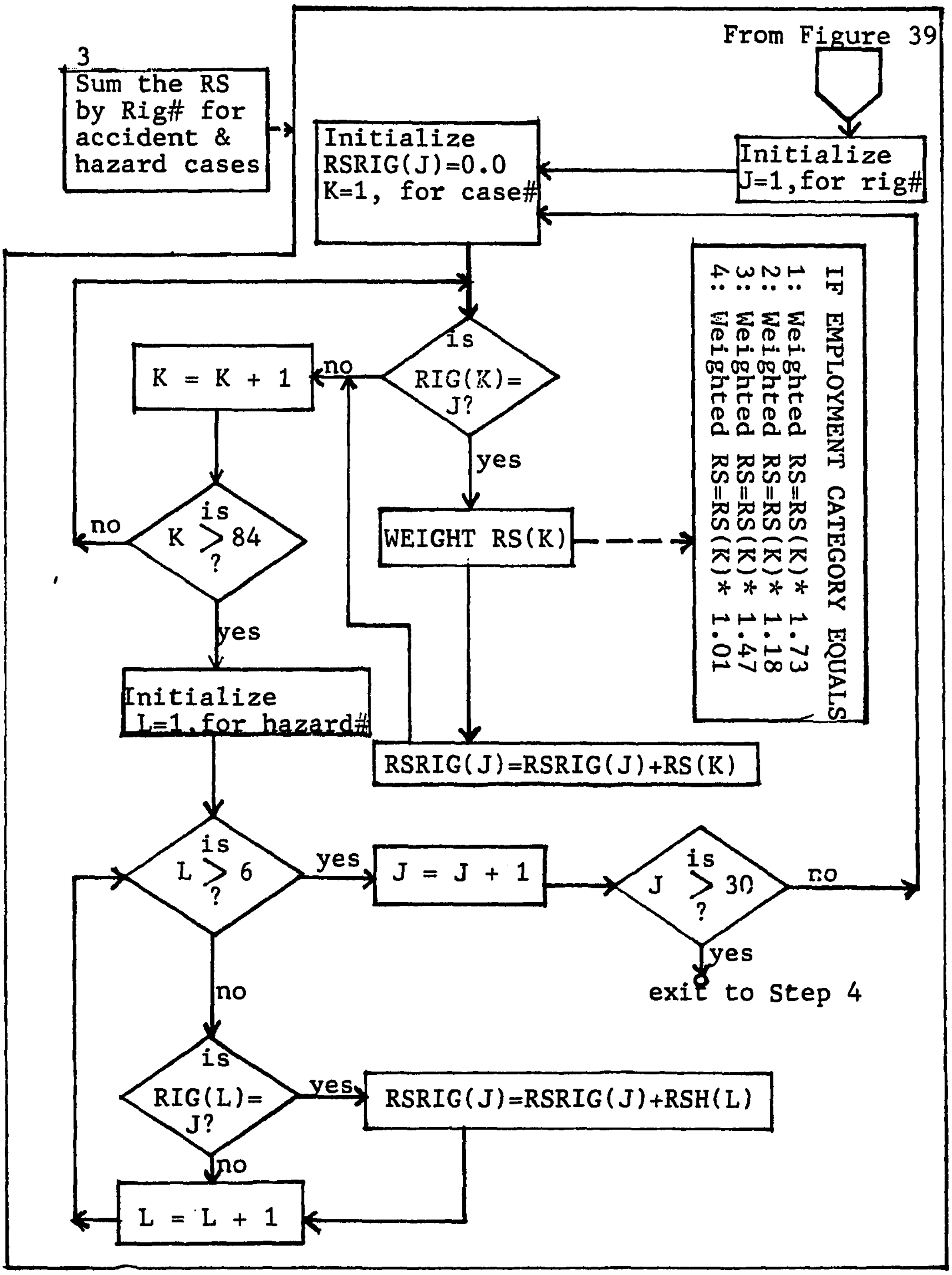


Figure 42: Flow Diagram for the Summation of RS by Rig for Accidents and Hazards

4.1.2.3.2.4. Ranking of the Rigs by Their Risk Scores

The last steps to be executed are Steps 4 and 5 which are the ranking of the rigs based on the magnitude of their respective risk scores, and the printing steps. The detailed operational procedure for both steps is illustrated in Figure 43, which is a continuation of the flow diagram shown in Figure 42. Both diagrams are then made into one program which is contained in Appendix D.5.

4.1.2.3.3. Results

The results of the test for the determination of priorities is shown in Figure 44; it shows a list of rigs ranked according to their respective risk scores. It shows that the five highest ranks are taken by Rig 9, 25, 13, 24, and 20. Also, Rig 9 has a significantly high risk score value as compared to the rest of the rigs. The magnitude of the risk scores of Rig 13 and 25 are somewhat comparable and so are Rigs 24, 20, and 16. As shown in the total cost report (Figure 31), Rig 9 did not incur high total losses for either month, but now has the highest priority for correction. On the other hand, Rigs 14 and 21 which show high total losses, only place tenth and twelfth at the rank list. These discrepancies again show that the so-called major accidents are not automatically prioritized for correction.

The severity of the consequences of a major accident can be very dramatic and provides a psychological force to perform an accident investigation. On the contrary, minor acci-

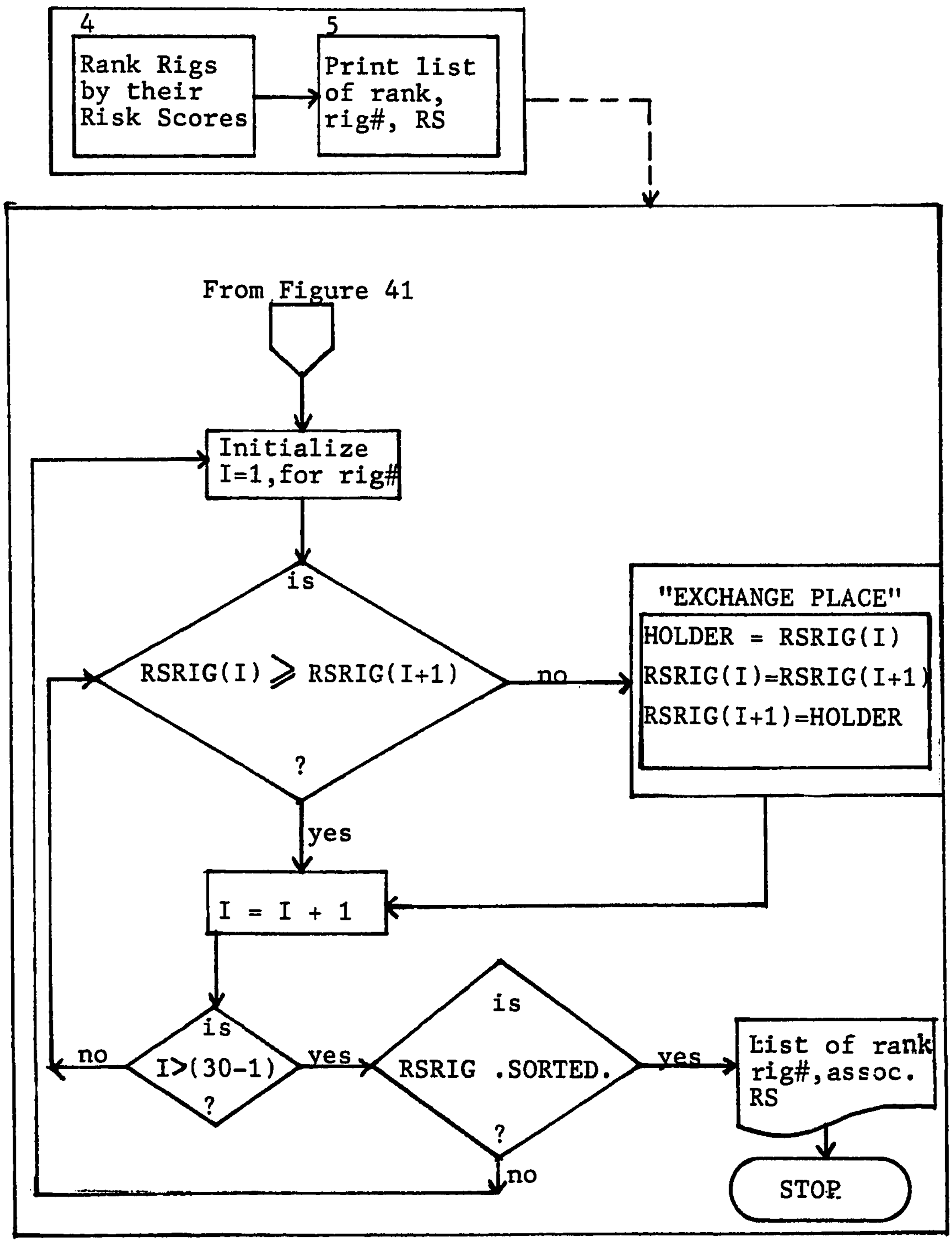


Figure 43: Flow Diagram for the Ranking and Printing of the Rigs According to Their Risk Scores

PRIORITY RANK	RIG NUMBER	RISK SCORE
1	9	4696.5923
2	25	1670.7656
3	13	1302.7893
4	24	970.0358
5	20	945.3215
6	16	940.4816
7	19	566.8839
8	12	544.6976
9	2	419.3833
10	14	371.7440
11	15	316.0714
12	21	288.3333
13	4	226.1996
14	18	214.5691
15	3	143.1383
16	7	102.9762
17	1	87.3219
18	28	77.3262
19	26	74.1429
20	30	63.8369
21	8	61.7857
22	22	59.0000
23	5	49.9911
24	17	40.6607
25	11	33.9821
26	6	29.5000
27	23	21.4833
28	29	18.5357
29	27	9.2679
30	10	7.8262

Figure 44: List of Rigs Ranked According to Their Risk Scores

dents are often neglected for the opposite reasons. With the use of the Fine model, however, priorities are determined rationally based on the concept of loss control. It does not intend to eliminate the urge to investigate major accidents, in fact, the Fine model reveals that all types of accidents deserve equal attention and should therefore be investigated thoroughly as a regular procedure. Routinely, all unsafe acts and unsafe conditions occurring in each accident might already have been taken care of by the Maintenance and Control Program (MCP). Also, the underlying causes reported to all levels of management already help managers to better enforce or improve the management safety policies. The main value of this part of the MIS, however, is to point out that actions beyond the routine procedures are called for to actually improve loss control and the management safety policies.

4.1.2.4. Refinement of the Information of the Priority Rigs

To be able to improve the existing system by using the previous priority determination, information about the priority rigs needs to be refined to reveal the existing problems and to formulate plans of action for improvement. The refinement procedure consists of two major steps:

(1) The refinement of the information by task, by category of employment, and hazards. This step is necessary to obtain the information about the task and the employment category that are causing prob-

lems, and thus have the priority to be corrected. Tasks and category of employments are chosen as the variables into which the information should be refined, based on the previous discussion in Chapter 3 (see pp. 82-83).

(2) The refinement of the priority rig, priority task, and priority employment category by case numbers, unsafe acts, unsafe conditions, and underlying causes.

4.1.2.4.1. Refinement of information by Task and Category of Employment

4.1.2.4.1.1. Data Set

The data set used in this procedure of testing is the complete hypothetical data set, i.e., consisting of both the retrospective and the prospective data.

4.1.2.4.1.2. Procedure

The manipulation procedure of this first step of information refinement is quite simple; it consists of the presentation of the existing file by the preferred variables. An algorithm for this procedure is therefore unnecessary. The manipulation is directly illustrated as a flow diagram in Figure 45. It is a continuation of the one shown in Figure 39 which calculates risk scores for each case. The risk scores are again weighted by category of employment so that they become comparable to each other. Finally, the actual program used for this purpose is shown in Appendix D.6.

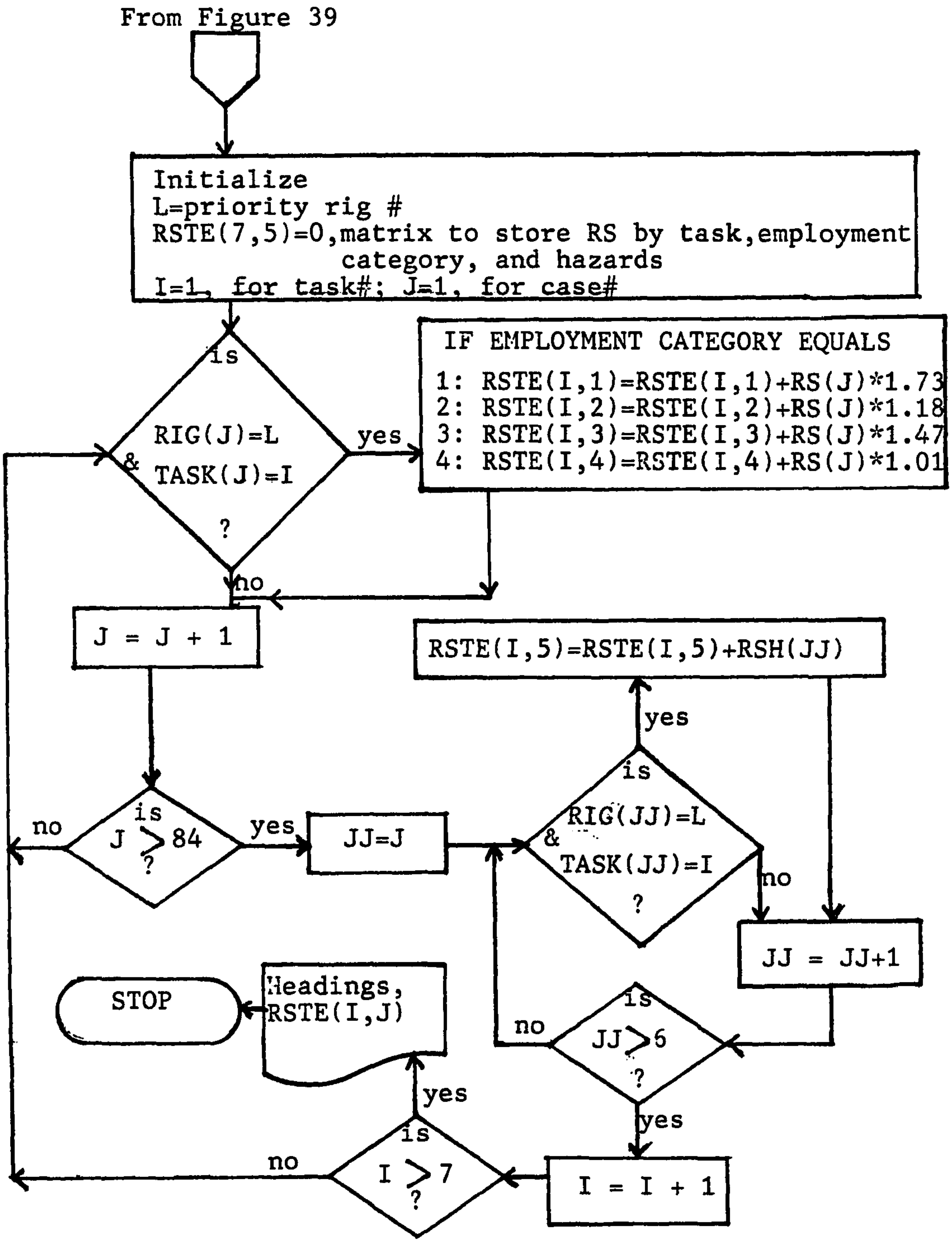


Figure 45: Flow Diagram for the Refinement of Information of Priority Rigs by Tasks, Employment Categories, and Hazards

4.1.2.4.1.3. Results

The results of this test can be seen in Figure 46. These results show that hazards do not play an important role in this priority determination. The risk scores which contribute the most to this priority come from the first category of employment (LE 1) and from Tasks 3, 4, and 5. These findings are somewhat consistent for all five priority rigs. These priority tasks (Tasks 3, 4, 5) and LE 1 then, will further be refined in the next procedure.

4.1.2.4.2. Refinement of Information by Case Numbers, Unsafe Acts, Unsafe Conditions, and Underlying Causes

4.1.2.4.2.1. Data Set

As was the case with the previous elaboration of information, this second step of refinement will also use the complete hypothetical data set.

4.1.2.4.2.2. Procedure

The procedure in this step is to take the selected category of employment, task number, and rig number and feed them into a program which will print out the required variables associated with the above priority rig, task, and category of employment. An algorithm for this procedure is also unnecessary and the flow diagram is illustrated in Figure 47; the actual program used in this test can be found in Appendix D.7.

Figure 46: Risk Scores of the Prioritized Rigs by Task and Category of Employment

FOR PRIORITY RIG # 9

RISK SCORES BY TASK AND LENGTH OF EMPLOYMENT

	LENGTH OF EMPLOYMENT CATEGORY				HAZARD
TASK#	1	2	3	4	
1	.00	.00	.00	.00	.00
2	.00	.00	.00	.00	.00
3	.00	12.64	.00	.00	12.64
4	1802.80	.00	.00	.00	.00
5	2868.51	.00	.00	.00	.00
6	.00	.00	.00	.00	.00
7	.00	.00	.00	.00	.00

Figure 46 (cont.)

FOR PRIORITY RIG # 25

RISK SCORES BY TASK AND LENGTH OF EMPLOYMENT

	LENGTH OF EMPLOYMENT CATEGORY				HAZARD
TASK#	1	2	3	4	
1	.00	12.64	.00	.00	.00
2	.00	.00	.00	.00	.00
3	939.14	.00	.00	.00	.00
4	686.54	.00	.00	.00	.00
5	32.44	.00	.00	.00	.00
6	.00	.00	.00	.00	.00
7	.00	.00	.00	.00	.00

Figure 46 (cont.)

FOR PRIORITY RIG # 13

RISK SCORES BY TASK AND LENGTH OF EMPLOYMENT

	LENGTH OF EMPLOYMENT CATEGORY				HAZARD
TASK#	1	2	3	4	
1	.00	.00	.00	.00	.00
2	.00	.00	.00	.00	.00
3	.00	.00	.00	.00	.00
4	986.72	316.07	.00	.00	.00
5	.00	.00	.00	.00	.00
6	.00	.00	.00	.00	.00
7	.00	.00	.00	.00	.00

Figure 46 (cont.)

FOR PRIORITY RIG # 24

RISK SCORES BY TASK AND LENGTH OF EMPLOYMENT

	LENGTH OF EMPLOYMENT CATEGORY				HAZARD
TASK#	1	2	3	4	
1	.00	.00	.00	.00	.00
2	.00	.00	.00	.00	.00
3	.00	.00	.00	.00	.00
4	30.89	.00	.00	.00	.00
5	939.14	.00	.00	.00	.00
6	.00	.00	.00	.00	.00
7	.00	.00	.00	.00	.00

Figure 46 (cont.)

FOR PRIORITY RIG # 20

RISK SCORES BY TASK AND LENGTH OF EMPLOYMENT

	LENGTH OF EMPLOYMENT CATEGORY				HAZARD
TASK#	1	2	3	4	
1	6.18	.00	.00	.00	.00
2	.00	.00	.00	.00	.00
3	.00	.00	.00	.00	.00
4	.00	.00	.00	.00	.00
5	939.14	.00	.00	.00	.00
6	.00	.00	.00	.00	.00
7	.00	.00	.00	.00	.00

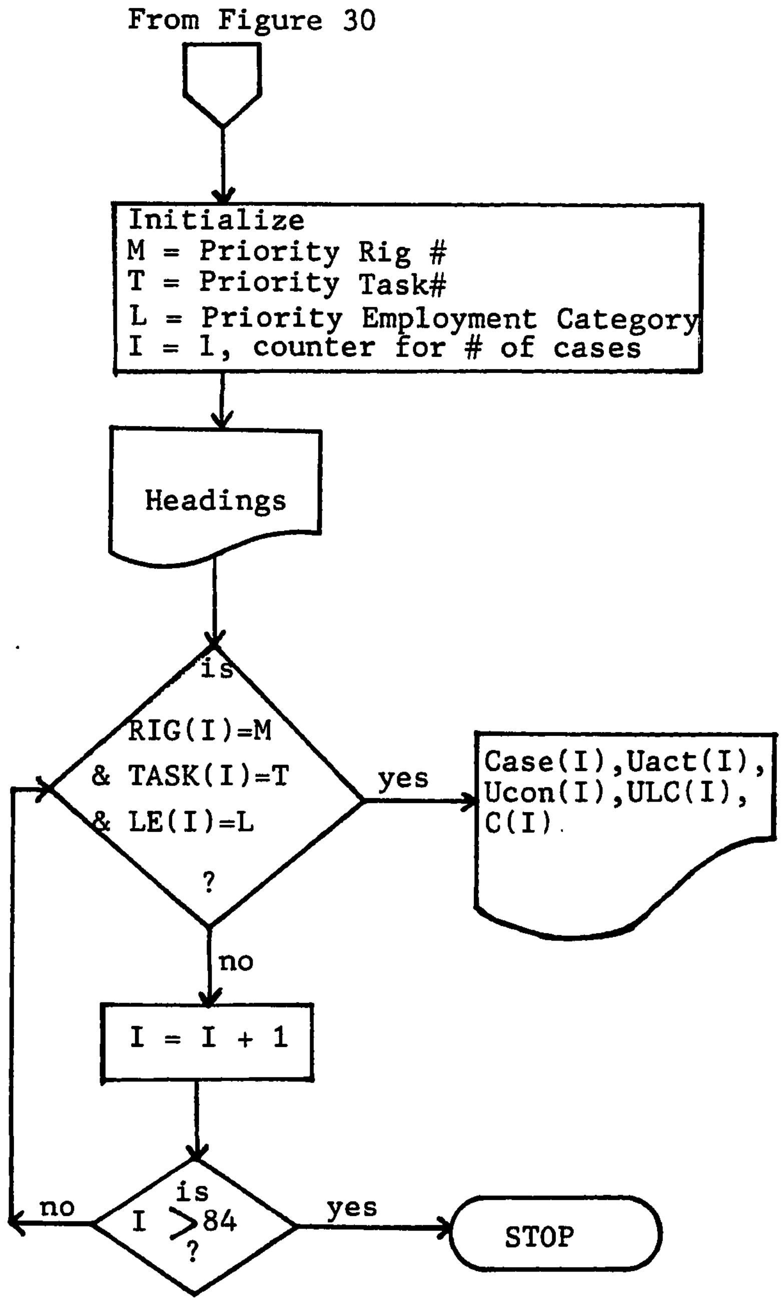


Figure 47: Flow Diagram for the Refinement of Information of the Priority Rig, Task, Employment Category, by Case Numbers and Their Associated Causes

4.1.2.4.2.3. Results

The results of this test are shown in Figure 48. To be able to interpret the numbers shown on this report, the management group to whom this report is sent, is provided with a sheet containing the code numbers and their respective meanings. An example of such a decoding sheet can be found in Appendix E. Based on this report, the management group and their safety experts are expected to confer and develop some solutions for the existing problems shown in the report.

To this report is added a column of the total costs of cases to confirm the previous findings that the risk scores for Rig 9 are mostly attributed to minor but frequent accidents, as shown by the small man-hour values for each case. The unsafe act and unsafe condition codes shown in this report aid management in searching for alternatives for corrections.
At this time, the MIS is awaiting further input from the management group to do the next step, i.e., the alternative assessment. It should be noted also that Figure 48 only represents Rig 9 and serves as an example of this refinement procedure.

4.1.2.5. Alternative Assessment

The discussion on alternative assessment will only be limited to one example, namely, the problem shown in Figure 48. Rig 9 is chosen as an example because it contains enough cases which enable analysis to be performed, thereby describing the principal procedure required by the MIS.

Figure 48: Priority Rig, Task, and Category of Employment by Case Numbers and Causes

FOR PRIORITY RIG# 9
FOR TASK# 5
LENGTH OF EMPLOYMENT CATEGORY 1

WITH RISK SCORE OF 2868.51

CASE#	UNSAFE ACT CODE#	UNSAFE CONDITION CODE#	LEVEL OF CORRECTION	MANHOURS LOST
82 148	100	399	S4W3	380
82 215	100	399	M4S2W4	380
82 227	100	399	M4S2W4	20
82 233	100	399	M4S2W4	380
82 234	100	999	M4S2W4	380

FOR PRIORITY RIG# 9
FOR TASK# 4
LENGTH OF EMPLOYMENT CATEGORY 1

WITH RISK SCORE OF 1802.80

CASE#	UNSAFE ACT CODE#	UNSAFE CONDITION CODE#	LEVEL OF CORRECTION	MANHOURS LOST
82 121	355	399	W3	750
82 143	350	999	W3	300
82 146	350	999	W3	300
82 149	993	520	S4	300
82 2 1	993	520	S4	300
82 2 2	993	520	S4	25
82 2 3	993	520	S4	300
82 2 4	400	30	W4	300
82 221	350	999	M4W3	35
82 232	993	520	S4	300

4.1.2.5.1. Data Set

The data set for this procedure of testing consists of input from the management group. The input should contain the alternatives enumerated and their respective degree of correction and cost factor. The cost factors can be expressed as dollar values or rated values. The degree of correction can also be expressed in percent or rated values.

This input can be obtained by analyzing the report shown in Figure 48, especially the column which contains the underlying causes of accident cases. For Rig 9, the underlying causes are mostly cited as M4, S24, and W34. These notations can be translated as follows (see Appendix B):

M4 : enforce policy/procedure based upon procedural monitoring.

S2 : assure means to comply.

S4 : be consistent in enforcement.

W3 : train/motivate/enforce.

W4 : recognize/reward improved performance.

All of these underlying causes generally point out to the need for better enforcement, motivation, and training of the new employees (LE 1). Based on the above information, alternatives can be enumerated. The following alternatives can be used as an example:

Alternative 1 : Training of the newly-hired workers.

Alternative 2 : Better enforcement and motivation.

Alternative 3 : The combination of both alternative one and two.

The cost factor and the degree of correction for each alternative can be obtained by the following means:

Alternative 1 : The training of the new employees, irrespective of their experience, may already be a routine procedure in a company, in which case the training need only be intensified. In cases where training of the newly-hired workers are not yet established, a new procedural requirement should be implemented. In the latter case, some additional man-hours might be needed to set up a new procedure. In general, however, this alternative requires almost no expense.

The degree of correction accomplished through this alternative might be quite significant. Levitt (1975) reported that training of the newly-hired workers can reduce accident rates by 25% in the first six months of employment, which exactly meets the need to reduce accidents within the first category of employment.

Alternative 2 : To be able to better enforce the existing safety policy and to motivate superintendents, toolpushers, and workers, may require some expense if a bonus and incentive plan is to be used. A bonus is an award of substantial monetary value (greater than one month's salary) made privately. An incentive, on the other hand, is of small monetary value and is given publicly. An incentive may also carry some prestige or status value. Levitt (1975) again reported that incentives given on any day a worker or foreman does not have accidents requiring first aid, medical attention, or near misses can improve safety. Also, if bonuses are given to superintendents for their overall performance during that year, which includes safety performance, then safety will improve. If a bonus and incentive plan is used in the second alternative, then this alternative will be significantly more expensive than the first alternative.

The degree of correction attained by this alternative is reported as ranging from 50% to 55% (Levitt, 1975). Hence, compared to the first alternative, the second alternative is about twice as powerful in terms of the degree of correction.

Alternative 3 : This third alternative, consisting of both the first and the second alternatives, will be the most expensive of the three alternatives. The degree of correction for this alternative would also be the best compared to the other alternatives (both CF and DC assumed to be additive).

The resulting cost factors and degree of corrections for all three alternatives can then be rated as small (S), medium (M), and high (H), as follows:

Alternative #	Cost Factor	Degree of Correction
1	S(1)	S(6)
2	M(4)	M(4)
3	H(6)	H(3)

The rating in the S, M, and H values can then be converted into numerical values between 0 and 10 (shown in parenthesis behind S, M, H). The numerical rating is necessary so that the relative effectiveness or the "J" factor for each alternative can be computed. The converted rating values for Alternative 1, 2, and 3 can be like 1, 4, and 6 for cost factor, and 6, 4, and 3 for the degree of correction respectively (see rating system suggested by Fine in Chapter 3). This conversion can be effected by the management group and their safety experts or by the MIS in accordance with a predetermined standard. The resulting rates and alternatives are then fed back into the MIS so that the report on the relative effectiveness of each alternative can be presented.

4.1.2.5.2. Procedure

The procedure to present a report on the relative effectiveness of each alternative is quite simple and is directly illustrated as a flow diagram in Figure 49. It calculates the "J" factor for each alternative and prints out the results in a report format. As discussed previously, J = RS/(DC x CF). The actual program used can be found in Appendix D.8.

4.1.2.5.3. Results

The results of this test are shown in Figure 50. It presents all the input given and the resulting "J" factor. The purpose of this report is to help management in the evaluation and selection of the best alternative. The numbers representing "J" may not be meaningful to those who have never

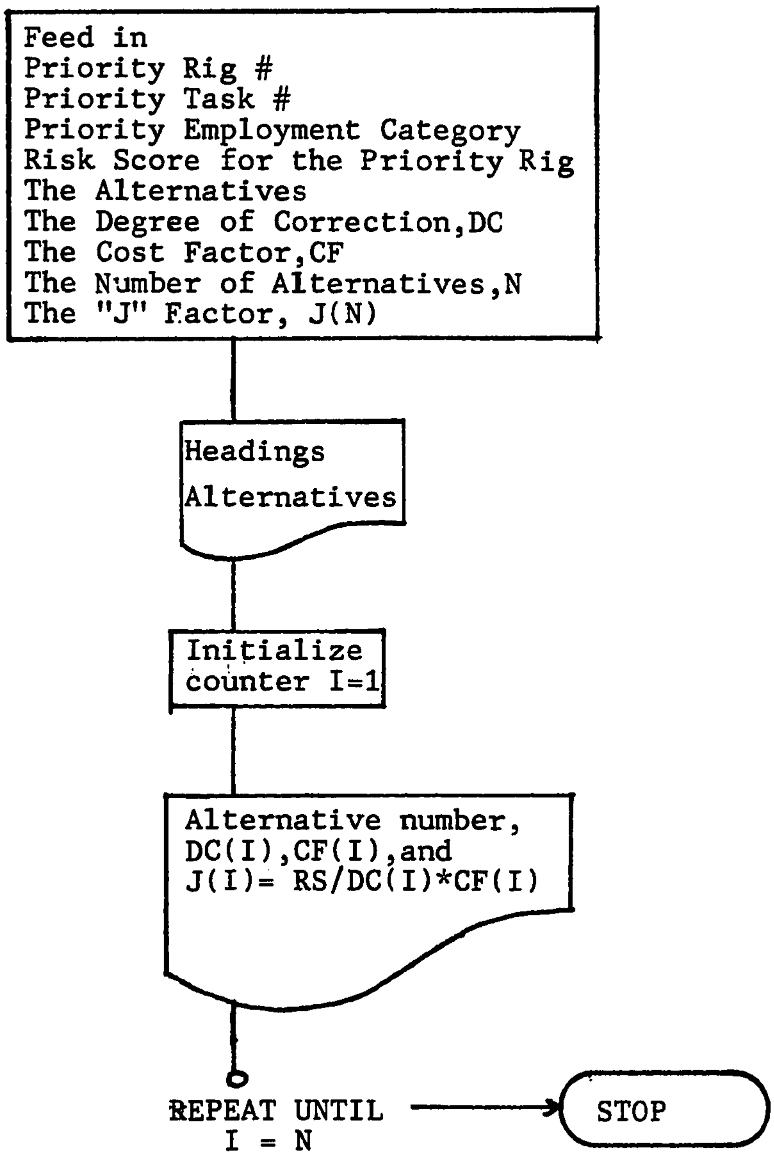


Figure 49: Flow Diagram to Present the Alternatives with Their Associated "J" Factor for Management Decision

```
FOR PRIORITY RIG#       :  9
FOR PRIORITY TASK#      :  4
FOR EMPLOYMENT CATEGORY:   1


THE ALTERNATIVES FOR CORRECTION ARE:
  1       TRAINING OF NEW HIRES
  2       ENFORCE AND MOTIVATE
  3       BOTH ONE AND TWO

ALTERNATIVE   DEGREE OF CORRECTION   COST FACTOR   ECONOMIC JUSTIFICATION

      1                  6.00             1.00                782.7650
      2                  4.00             4.00                293.5369
      3                  3.00             6.00                260.9217

FOR J=   782.76  C WILL BE REDUCED BY         :   612.50 MONTHLY

FOR J=   293.54  C WILL BE REDUCED BY         :    612.50 TO  1225.00 MONTHLY

FOR J=   260.92  C WILL BE REDUCED BY         :  1225.00 TO  1837.50 MONTHLY
```

Figure 50: Relative Effectiveness of the Enumerated Alternatives

used this method before. For this reason, additional information is added within the report that can help management in the selection of the best alternative, i.e., the monthly reduction of the man-hours lost as related to each "J" factor. Depending on the situation of the company, the management group can then decide which alternative would be the best for the present condition. Once the alternative is decided upon, a plan to implement the alternative should then be made. The implementation of the plan of action should further be monitored to see its effectiveness and whether changes are necessary. In this way, the company will accumulate experiences and the decisions made by the management group may become more effective over time.

4.2. Test Using the Real Data Set

4.2.1. Real Data Set

The real data set used in this testing procedure is a one-year accident record of a well-drilling company, whose name will be kept confidential. The accident record is kept as Workers' Compensation Claim Forms; it therefore consists of all accident cases requiring medical costs. These forms were obviously completed with the objective of obtaining payments on medical costs incurred and disability benefits. They were certainly not intended to be used as input to the MIS; hence, for the purpose of testing, this data becomes limited in several ways:

(1) They consist of retrospective data only.

(2) There is no recording on the causes of accidents.

These limitations caused testing restrictions which will be discussed later.

As a whole, the data set consists of 475 cases and each form contains the following variables: the case number, the rig number, the task number, the nature of injury, the part of the body injured, the lost time, and the length of employment. At the time the accident cases were collected, this oil-well drilling company possessed 30 operational rigs, but not every rig was active throughout the year. The codes used to assign numerical values to the above variables are exactly the same as those used in the hypothetical data set. This actual data set can be found in Appendix F.3.

4.2.2. Test Procedures

Because of the limitations found in this real data set, the test procedure was restricted to those tests which did not require the presentation of the causes of accidents, but the tests were performed to the point of maximum possibility. These tests include the following:

(1) The presentation of the total accident cost report.

(2) The presentation of a chart showing the average risk scores by rig and by task.

(3) The determination of priority rigs based on retrospective data only.

(4) The presentation of refined information of the priority rig by task and length of employment.

(5) The presentation of refined information of the priority rig, task, and length of employment by case numbers.

The manipulation procedures took almost the same course as discussed previously when using the hypothetical data set. Some modifications, however, were necessary because of the absence of the accident causes. However, as discussed in Chapter 3, the causes can be categorized by tasks so that in cases where causes were to be compared in the following procedures, the tasks were compared instead. The exact modifications will be discussed as necessary under the specific test procedures. The data set needed to perform the above tests remained the same at all times, hence there will be no more discussion of the data set used in each test.

4.2.2.1. Total Accident Cost Report

4.2.2.1.1. Procedure

The sequence of steps taken to present the total accident report with the use of the Robinson model are exactly the same as shown in the flow diagram of Figure 30. In the actual program, however, the number of cases should be changed from 84 to 475; this program is attached as Appendix D.9.

4.2.2.1.2. Results

The results of this test can be seen in Figure 51, which shows that Rigs 2 and 12 incurred the highest losses for that year. These high losses were apparantly due to a major accident occurring in each rig in the month of March and January respectively. Consistent losses incurred by Rig 5, however, indicate the existence of safety problems.

The zero values for Rigs 25 - 30, starting from the first month to the sixth month or tenth month, cannot be explained. The numbers can reflect a real zero value, meaning that there was not a single accident occurring during those periods or that the rigs were not in operation. Unfortunately, the actual circumstances cannot be verified. In the actual situation, however, these zero values would not pose any problem since the company would know exactly which rigs were not in operation at a certain time period.

The total estimated loss due to accidents for this particular year was 131,710 man-hours. If the average man-hours wage equals $10.00, then the loss for that year was about $1,317,100.00. This figure represents the very lowest estimate of loss because the Robinson matrix uses a very conservative ratio of 1:2 for the ratio between the direct and the indirect costs (total cost = 3 x direct cost). Heinrich (1980) estimated this ratio to be about 1:4 for the average industry (total cost = 5 x direct cost). When this estimate is used, the total loss for that year would be about 5/3 x $1,317,100 =

XYZ DRILLING CO., ACCIDENT REPORT IN MANHOURS LOST,BY MONTH, 1981

SUPERINTENDENT	RIG NUMBER	JAN	FEB	MCH	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
SUPERINTENDENT 1														
	RIG# 1	0	850	620	30	0	0	0	520	75	0	220	380	2695
	RIG# 2	0	0	8000	190	520	35	380	1130	410	0	240	675	12080
	RIG# 3	0	0	0	190	0	0	0	0	0	380	220	0	790
SUPERINTENDENT 2														
	RIG# 4	0	20	0	1130	820	1280	30	0	220	1095	245	95	4935
	RIG# 5	300	30	450	750	380	960	395	240	190	360	710	630	5395
	RIG# 6	0	440	0	0	190	0	0	30	0	0	750	220	1630
SUPERINTENDENT 3														
	RIG# 7	220	0	0	0	240	20	0	0	300	0	0	410	1190
	RIG# 8	980	0	75	220	0	0	785	380	220	190	930	0	3780
	RIG# 9	0	20	570	0	750	0	0	520	560	0	380	1360	4160
SUPERINTENDENT 4														
	RIG# 10	20	660	940	300	740	380	190	0	640	20	100	750	4740
	RIG# 11	0	0	0	220	0	1720	110	440	990	1050	265	300	5095
	RIG# 12	0	600	0	190	440	0	455	0	300	645	440	1100	4170
SUPERINTENDENT 5														
	RIG# 13	440	0	520	20	190	190	0	0	380	0	0	15	1755
	RIG# 14	0	0	1265	0	0	1210	0	0	400	0	190	260	3325
	RIG# 15	0	0	0	0	0	0	0	20	0	0	0	0	20
SUPERINTENDENT 6														
	RIG# 16	0	0	220	0	0	0	20	0	820	0	220	380	1660
	RIG# 17	0	190	240	220	640	0	1050	0	0	0	760	1620	4720
	RIG# 18	0	0	0	0	55	0	0	220	70	0	775	380	1500
SUPERINTENDENT 7														
	RIG# 19	0	0	0	190	190	0	0	220	0	0	410	810	1820
	RIG# 20	215	300	25	170	0	0	0	0	1005	825	0	300	2840
	RIG# 21	380	25	220	190	465	220	220	220	220	0	0	0	2160
SUPERINTENDENT 8														
	RIG# 22	6655	20	520	0	30	1120	210	75	410	1230	740	380	11390
	RIG# 23	0	0	0	190	790	20	490	600	190	0	0	450	2730
	RIG# 24	490	0	305	75	600	0	0	600	1280	740	0	220	4310
SUPERINTENDENT 9														
	RIG# 25	0	0	0	0	0	0	325	70	0	1140	220	0	1755
	RIG# 26	0	0	0	0	0	0	0	0	0	0	0	20	20
	RIG# 27	0	0	0	0	0	0	0	300	0	0	0	0	300
SUPERINTENDENT 10														
	RIG# 28	0	0	0	0	0	0	0	0	0	0	190	0	190
	RIG# 29	0	0	0	0	0	0	0	0	0	0	0	0	0
	RIG# 30	0	0	0	0	0	0	0	0	0	0	1135	415	1550
	FOR THE NA RIG NUMBER:	2280	1445	1795	2690	2360	3310	4500	3605	5905	5035	4655	1425	39005
	TOTAL :	11980	4600	15765	6965	9400	10465	9160	9190	14585	12710	14295	12595	131710

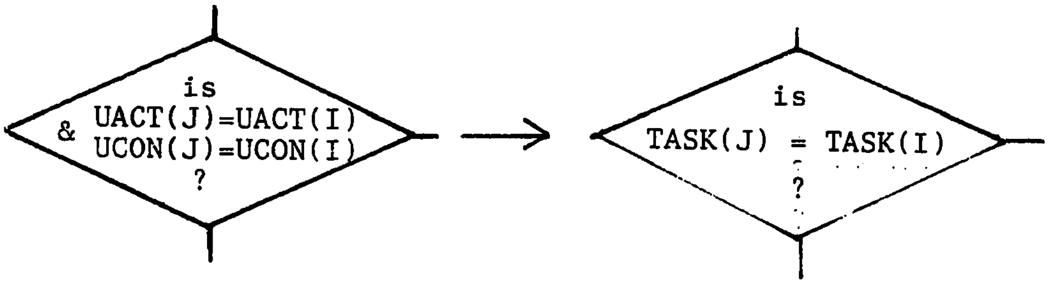
Figure 51: Total Accident Cost Report Based on the Real Data Set

$2,195,166.67. The highest ratio found by Robinson was about 1:13 in a construction company, a high-hazard industry (total cost = 14 x direct cost). When this estimate is used, the total loss would be about 14/3 x $1,317,100 = $6,146,466.67. Which of these estimates applies to this particular company is very difficult to say. But since the oil-well drilling industry is classified as one of the most hazardous industries in the United States, the estimated cost would be more likely between $2,195,166.67 and $6,146,466.67. It should be noted that this loss estimate does not include the losses due to first aid cases and all other cases which did not require medical attention.

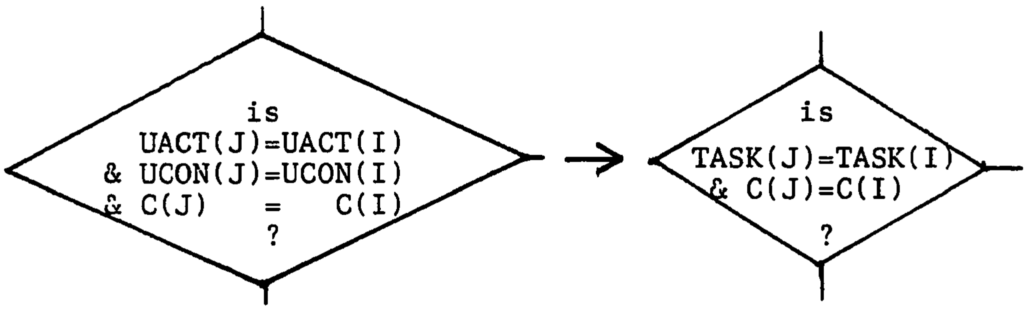
4.2.2.2. Average Risk Scores by Rig and by Task

4.2.2.2.1. Procedure

The manipulations required to compute the risk scores by rig and by task are almost the same as those shown in Figures 36 and 40. The differences lie in the decision steps of Figures 36 and 37 whereby the unsafe act (UACT) and the unsafe condition (UCON) variables were used in the process. In the present procedure, instead of the unsafe act and the unsafe condition, the task variable will be used in the decision steps as follows:



From Figure 36



From Figure 37

Again, the total number of cases should be changed from 84 to 475. The detailed program used in this test can be found in Appendix D.10.

4.2.2.2.2. <u>Results</u>

The results of this test are shown in Figure 52, which again shows some zero values in each rig for all rigs. These zero values can again be attributed either to no accidents occurring during that period or the idleness of the rigs. Which of these reasons was true, again could not be verified. For the purpose of assigning risk scores to the identified hazards,

AVERAGE RISK SCORES BY RIG AND BY TASK

TASK NUMBER:

RIG#	1	2	3	4	5	6	7
1	191.94	113.44	741.79	2308.51	.00	.00	2.79
2	278.62	468.43	558.33	1826.93	3288.09	119.75	.00
3	.00	.00	707.22	1640.20	1141.41	.00	.00
4	80.83	430.22	626.13	1880.04	.00	232.70	.00
5	99.28	282.00	897.77	1339.35	.00	.00	.00
6	.00	550.68	15.95	.00	.00	174.30	.00
7	.00	424.55	.00	1284.85	.00	.00	26.22
8	329.39	675.74	541.27	2654.45	7429.31	.00	.00
9	.00	714.74	21.27	1906.88	423.29	.00	15.31
10	34.48	562.73	.00	1963.80	.00	5.83	1.75
11	137.46	370.57	941.30	1300.23	.00	398.59	19.14
12	151.46	420.66	.00	2177.79	1141.41	.00	.00
13	.00	741.13	898.65	2158.66	.00	.00	1.75
14	30.87	469.52	757.74	1556.05	.00	.00	18.50
15	.00	27.53	.00	.00	.00	.00	.00
16	.00	510.48	837.82	1857.95	.00	139.91	.00
17	252.28	689.06	465.50	1071.86	.00	89.13	.00
18	.00	325.52	188.05	124.66	.00	.00	.00
19	.00	380.61	1009.94	2550.19	.00	.00	.00
20	.00	353.71	353.61	821.84	.00	7.43	15.31
21	.00	424.55	824.94	2455.77	.00	.00	.00
22	7.43	736.37	431.49	1544.07	.00	.00	.00
23	99.96	318.32	61.47	1557.85	.00	.00	.00
24	164.67	284.23	677.98	1884.76	.00	.00	.00
25	.00	741.13	757.74	1264.05	.00	.00	.00
26	.00	.00	.00	.00	78.80	.00	.00
27	.00	.00	.00	.00	622.59	.00	.00
28	.00	.00	757.74	.00	.00	.00	.00
29	.00	.00	.00	.00	.00	.00	.00
30	37.15	.00	707.22	1323.01	7429.31	.00	.00
FOR THE NA RIG NUMBER							
31	55.90	.00	530.93	1278.29	3020.03	151.24	16.25

Figure 52: Average Risk Scores by Rig and by Task Based on the Real Data Set

it would be desirable to use a data set that covers at least one-year operational data for each rig rather than one-calendar-year data. In this way, if zero values are found, one could be certain that it is due to the non-occurrence of accidents.

As a whole, Figure 52 shows consistently large risk score values for Task 4 for all rigs, which is the task assigned to the floorhands. This indicates that this task is the most injurious in well-drilling operations.

It should be noted that the claim forms used in this data set were not completely filled out. Some of the rig numbers are missing. For these cases, the rig number was labeled as number 31 and the rig shows high risk scores for Task 5, which is a task assigned to the maintenance crew.

4.2.2.3. Priority Determination

4.2.2.3.1. Procedure

The manipulation steps used in this priority determination are the same as those shown in Figures 36, 37, 38, 39, 42, and 43, with the same exceptions for the unsafe acts and conditions which are replaced by tasks variables. Also the number of cases are changed from 84 to 475. The actual program is attached as Appendix D.11.

4.2.2.3.2. Results

The results of this test are shown in Figure 53 which in-

PRIORITY RANK	RIG NUMBER	RISK SCORE
1	31	345635.9063
2	5	25830.8027
3	4	24601.4160
4	10	23929.2676
5	12	22457.9180
6	2	21382.2246
7	8	20321.1582
8	21	18058.5430
9	19	16542.0020
10	13	14232.1455
11	9	14177.1982
12	24	14080.5068
13	22	13570.7070
14	11	13075.0820
15	30	12142.7061
16	25	11611.2695
17	17	10347.6719
18	23	8648.7910
19	14	7599.5493
20	20	7429.3364
21	16	6225.0737
22	7	6014.7310
23	1	5374.3105
24	3	3488.8306
25	6	2392.9802
26	18	1525.7903
27	28	757.7400
28	27	622.5852
29	26	78.7992
30	15	27.5343
31	29	.0000

Figure 53: Ranked Rigs Based on the Real Data Set

dicates that Rigs 5, 4, 10, 12, and 2 have the five highest ranks for correction. Rig 31 cannot be considered as having priority because in reality it does not exist. Rigs 2 and 22 which show large losses in the total costs report place fifth and twelfth in the rank list. This fact again proves that severe accidents are not automatically prioritized for corrections.

4.2.2.4. Refinement of Information of the Priority Rig by Task and by Length of Employment

4.2.2.4.1. Procedure

The manipulation sequence to present this report on the priority rigs is the same as that used when hypothetical data was used, with the same exception described under 4.2.2.3. The actual program is attached as Appendix D.12.

4.2.2.4.2. Results

The results of this test can be seen in Figure 54 which shows a general trend of large risk score values in the first category of employment for Task 4 for all priority rigs. Thus, the employees within the first employment category doing Task 4 are the high risk population in well-drilling operations. It appears that Task 4 is especially hazardous as seen from the risk scores in Rigs 12 and 2 where workers in the third and second categories of employment still incur high risk scores.

Figure 54: Refined Information of the Prioritized Rigs by Task and by Employment Category

FOR PRIORITY RIG# 5

RISK SCORES BY TASK AND LENGTH OF EMPLOYMENT

LENGTH OF EMPLOYMENT CATEGORY

TASK#	1	2	3	4
1	117.64	80.24	99.96	.00
2	1409.99	.00	.00	.00
3	2693.30	.00	.00	.00
4	21429.67	.00	.00	.00
5	.00	.00	.00	.00
6	.00	.00	.00	.00
7	.00	.00	.00	.00

Figure 54 (cont.)

FOR PRIORITY RIG# 4

RISK SCORES BY TASK AND LENGTH OF EMPLOYMENT

LENGTH OF EMPLOYMENT CATEGORY

TASK#	1	2	3	4
1	318.25	5.07	.00	.00
2	860.45	.00	.00	.00
3	2504.53	.00	.00	.00
4	20680.42	.00	.00	.00
5	.00	.00	.00	.00
6	.00	.00	.00	232.70
7	.00	.00	.00	.00

Figure 54 (cont.)

FOR PRIORITY RIG# 10

RISK SCORES BY TASK AND LENGTH OF EMPLOYMENT

LENGTH OF EMPLOYMENT CATEGORY

TASK#	1	2	3	4
1	37.15	.00	.00	31.81
2	2250.93	.00	.00	.00
3	.00	.00	.00	.00
4	21601.80	.00	.00	.00
5	.00	.00	.00	.00
6	5.83	.00	.00	.00
7	1.75	.00	.00	.00

Figure 54 .(cont.)

FOR PRIORITY RIG# 12

RISK SCORES BY TASK AND LENGTH OF EMPLOYMENT

LENGTH OF EMPLOYMENT CATEGORY

TASK#	1	2	3	4
1	366.54	87.84	.00	.00
2	1261.99	.00	.00	.00
3	.00	.00	.00	.00
4	17556.84	.00	2043.30	.00
5	.00	.00	.00	1141.41
6	.00	.00	.00	.00
7	.00	.00	.00	.00

Figure 54 (cont.)

FOR PRIORITY RIG# 2

RISK SCORES BY TASK AND LENGTH OF EMPLOYMENT

	LENGTH OF EMPLOYMENT CATEGORY			
TASK#	1	2	3	4
1	278.62	.00	.00	.00
2	775.55	.00	629.75	.00
3	1675.00	.00	.00	.00
4	12975.26	1640.20	.00	.00
5	3288.09	.00	.00	.00
6	.00	.00	.00	119.75
7	.00	.00	.00	.00

4.2.2.5. Refinement of Information of the Priority Rig, Task, and Category of Employment by Case Numbers

4.2.2.5.1. Procedure

The sequence of steps taken to present the refinement of the information of the priority rig, task, and category of employment selected from the previous report (see Figure 54) are almost the same as those depicted in the flow diagram in Figure 47. The difference lies in the request of information to be printed. In this program, the request to print the causes of the cases is being omitted. The actual program used is attached as Appendix D.13.

4.2.2.5.2. Results

The results of this second refinement step are shown in Figure 55 which is a sample representing the refinement of Rigs 5 and 2. These examples are taken to show that this test, using an actual accident data set, supports the previous findings when using the hypothetical data set. Rig 5 containing minor but frequent accidents ranks first in the priority list. On the other hand, Rig 2 which has one major accident with a total cost of 7400 man-hours as well as other minor accidents, only places fifth at the rank list. Also, this major accident is not the major contributor of the high risk score of Rig 2 (RS = 3288.09). In fact, the minor accidents in Task 4 contribute the most to the high risk score (RS = 12975.26) in this rig.

Figure 55: Prioritized Rigs, Tasks, and Employment Categories by Case Numbers

FOR PRIORITY RIG# 5
FOR TASK# 4
LENGTH OF EMPLOYMENT CATEGORY 1

WITH RISK SCORE OF 21429.67

CASE#	MANHOURS LOST
81 1 6	300
81 2 3	30
81 318	260
81 337	190
81 429	260
81 430	300
81 615	190
81 618	300
81 619	380
81 634	35
81 635	35
81 8 3	20
81 820	220
811026	150
811129	520
811211	220

FOR PRIORITY RIG# 5
FOR TASK# 3
LENGTH OF EMPLOYMENT CATEGORY 1

WITH RISK SCORE OF 2693.30

CASE#	MANHOURS LOST
81 529	380
8111 7	190
811216	220

Figure 55 (cont.)

```
FOR PRIORITY RIG#                   2
FOR TASK#                           4
LENGTH OF EMPLOYMENT CATEGORY       1

WITH RISK SCORE OF           12975.26

CASE#          MANHOURS LOST

81 4 5              190

81 5 9              520

81 626               35

81 7 5              190

81 833              380

81 945              220

8111 5              550

FOR PRIORITY RIG#                   2
FOR TASK#                           5
LENGTH OF EMPLOYMENT CATEGORY       1

WITH RISK SCORE OF            3288.09

CASE#          MANHOURS LOST

81 327             7400

FOR PRIORITY RIG#                   2
FOR TASK#                           3
LENGTH OF EMPLOYMENT CATEGORY       1

WITH RISK SCORE OF            1675.00

CASE#          MANHOURS LOST

81 329              600

81 725              190

81 9 9              190

FOR PRIORITY RIG#                   2
FOR TASK#                           4
LENGTH OF EMPLOYMENT CATEGORY       2

WITH RISK SCORE OF            1640.20

CASE#          MANHOURS LOST

8111 6              190
```

CHAPTER 5

CONCLUSIONS

This conclusion chapter will be divided into two sections:

(1) A general section which discusses conclusions deduced from literature.

(2) A specific section which recapitulates the qualities and the results of testing the MIS.

5.1. General

The oil-well drilling industry is presently categorized into the high-hazard classification due to the consistently high accident rates incurred. It was therefore concluded that the safety activities practiced thus far could no longer reduce the present accident rates. Hence, the oil-well drilling industry needs to have a model which is better than the traditional safety practices if the accident rates are to be reduced.

An improved model should be based on the system and the management causation models, the two best and most acceptable causation models at this time. Both causation models are considered suitable to the oil-well drilling industry. It is the management causation model that can provide the "people" approach to accident prevention, which is exactly what is needed by this industry. According to the management causation model, inferior management practices are the underlying causes of accidents. To reduce or eliminate those underlying causes, management needs to monitor and control the implementation of the existing management safety policy (MSP). The monitoring procedure can be accomplished by also adopting the system causation model to provide the necessary feedback mechanism. The adoption of the management causation model is also supported by Levitt's findings (1975) which suggest that top managers in high-hazard industries should be knowledgeable about the safety aspects of the company and involve safety in their management duties. To assure the usefulness of feedback information, accident data must be presented as parameters which can be related to the managers' previous knowledge, such as costs and risk scores. In this way, the model supports management in making and carrying out safety decisions.

To ensure the functioning of the model, another source of motivation, in addition to the existing legal requirements, should be used as the foundation of the model. Accident costs were taken to be the most acceptable among the other existing sources of motivation. The drilling industry is too large to use humanitarian concern as a source of motivation. The company's safety image as a source of motivation is inadequate for accident prevention. The total accident costs, therefore, seems to be the most suitable; it was reported to be successfully applied in the construction industry which, like oil-well drilling, is also classified as a high-hazard industry.

The model is then called the Management Information System (MIS) because besides having causation models and motivation sources as its basis, it also has the special ability of transforming accident data into pertinent information to aid management in making, carrying out, and controlling safety decisions. The emphasis in the development of the MIS is to be only on the processor element which contains decision models. The incorporation of the models into this MIS is meant to be used for the transformation of data into information which assists management in the decision processes associated with poorly understood problems only.

It is also concluded that the MIS should be flexible as well as adaptable. An MIS is considered flexible if it can provide the required information to different levels of management. Because of the constant advancement of technology in the field of oil-well drilling safety, it is desirable to have a MIS that is adaptive to the progress of safety technology.

5.2. Specific

The specific discussions of the conclusions will be covered in the following two sections:

(1) Conclusions on the basic qualities of the MIS.

(2) Conclusions drawn from the results of the tests.

5.2.1. Basic Qualities of the MIS

(1) The MIS dictates the need to continuously inspect the system for hazard identification and investigate accidents, produce feedback, and therefore is based on a system causation model.

(2) The conclusion that this MIS is based on the management causation model can be drawn from the following reports and procedures:

(i) The monthly accident causation reports presenting the underlying causes (faulty management practices) by accident case and by month is a report that helps management monitor, evaluate, control, and improve the management safety policies. Without these reports, the management group will not be able to discern the causes of accidents; hence, no improvement of the existing safety conditions can be made.

(ii) The procedure of revealing the underlying causes of accidents is found in the prioritized rigs. It is a process which consists of two steps. The first step discloses the direct causes of accidents and the second reveals the underlying causes of each accident case. These steps are taken in accordance with the accident theorems or accident sequence (see Chapter 2).

(iii) The procedure of prioritizing rigs for correction, as based on the magnitude of their risk scores, shows that it is the safety performance of the managers that is being investigated, rather than the causes of the accidents per se. The accidents and the hazards contributing to the high risk scores in the priority rigs might or might not be the same as those occurring in the other rigs. In the prioritized rigs, however, accidents occur consistently over time and their frequency may also be high. Hence, the difference between the prioritized and the non-prioritized rigs must lie in the safety performance of the managers associated to the rigs. And since the underlying causes of accidents are defined as inferior management practices, the prioritized rigs must be managed by those managers which perform poorly in safety. It can therefore be concluded that this procedure uses the basic principles of the management causation model in the prioritization of rigs for correction.

(3) The conclusion that this MIS uses legal requirements as a source of motivation can be drawn from the fact that evaluations of safety problems are based on existing legal requirements.

(4) The use of the total accident cost as another source of motivation in this MIS can be concluded from the fact that total accident cost report is included in the monthly

costs report and used in accident costs accounting.

(5) The transformation of accident data into operational information is another basic quality this MIS should contain. The quality of data transformation into information and its resulting effects are reflected in the following reports produced by the MIS for different levels of management:

(i) The total accident cost reports, which are used for accident costs accounting and managers motivation, are prepared from injury data. This data would normally not reflect costs of accidents to any reader, especially if presented as individual accident records or forms.

(ii) The report on priority rigs is a report that is prepared by transforming accident and hazard data into risk scores. The priorities are then determined in accordance with the magnitude of the total risk scores existing in the individual rigs. If these accident and hazard records were presented to any reader, they would not reflect the need for correction. But this MIS can transform this data into risk score figures which are further used to determine priorities.

5.2.2. Conclusions of the Tests Results

(1) The tests using both the hypothetical and the real acci-

dent data sets, as presented in the total accident cost reports in Figure 32 and 51, show two important findings:

(i) The major accidents which create large total accident costs do not occur frequently and are therefore important only as a short-term loss.

(ii) The minor but consistent accidents create small total costs, but in the long run they will produce large losses for the company. The large losses produced by these type of accidents can later be shown in the priority determination reports (see Figures 44 and 54).

Hence, it can be concluded that all types of accidents must be given equal attention and should be investigated thoroughly.

(2) The total accident cost report as shown in Figure 51, which was prepared from the real accident data set, may or may not reflect the real estimated costs incurred by the oil-well drilling company from which this data set was taken. Discrepancies that may have occurred can unfortunately not be verified at this time due to the existing time constraints. But if differences are found at a later time, the following two reasons are now offered for their solution:

(i) The direct to the indirect costs ratio used in the computation of 1:2 might be too conservative for this particular drilling company.

(ii) The Robinson matrix used in these tests was designed for the construction industry which may or may not apply to this drilling company, even if both the construction and the drilling industries are in the same high-hazard classification.

Hence, a matter of future research would be to determine a matrix for the oil-well drilling industry like the one developed by Robinson for the construction industry. Such a matrix can become a powerful tool in the estimation of the total accident costs incurred as well as the motivation of managers to prevent accidents in the drilling industry.

(3) The accident causation report can help locate problem areas and their possible solutions. An example of this is the report shown in Figure 34d which indicates that Superintendent 3 has been most frequently involved in the occurence of accidents and that most of the poor safety practices are concentrated at the toolpusher's and the workers' levels. The same results are revealed in a later report of the refinement of priority rigs. Thus, this accident causation report can be used as a warning of future problems, prompting the need for change, and improvement.

On the other hand, the real data set does not contain such underlying causes of accidents; therefore, the above report cannot be made with this data set. However, if one looks carefully at the forms provided by OSHA or other forms used by individual companies to record accidents (see examples of forms in Appendix C), one can see that entries are available to document direct causes as well as to describe how the accident occurred. Unfortunately, these forms are never completely filled out. Not all data related to the causes of accidents exists. Hence, it can be concluded that companies, as the providers of data, will only record that data which will benefit the company, i.e., in the case of this data set, to obtain Workers' Compensation benefits.

(4) The test using the actual data set indicates consistently high risk scores for Task 4 and Length of Employment (LE) 1. These findings can be seen in Figures 52 and 55, which show the average risk scores by task and by rig for all rigs, and the refinement of information of the priority rigs respectively. Task is defined to represent condition of work (see Chapter 3), hence, the above finding implies that Task 4, which is the task assigned to floorhands, is the most unsafe condition found in this drilling company. LE is defined to represent the human factor in the interaction with tasks (see Chapter 3), hence, LE 1 is the most hazardous category of workers found in this drilling company. This test result supports Siskind's

findings which state that workers incur the most injuries within their first few months on the job. If Task 4 and LE 1 are combined, the risk scores become significantly higher compared to the other LE categories (see Figure 55). The hazardousness of Task 4 can be seen also in Figure 54 which shows that it is still dangerous for workers categorized as LE 2 and LE 3.

Routine on-the-job training for all new employees, irrespective of their experience, may reduce the risk of accidents for the workers within LE 1 and constant management attention to this group of workers may reduce these risks. As for the importance of Task 4 in accident occurrence, further research may be needed to eliminate the problem. Finally, the above findings can be considered an example of an additional advantage this MIS can provide, i.e., helping management find problem areas for further investigation or study.

(5) The tests using both the hypothetical and the real data sets indicate that frequency of accidents plays a very large role in the determination of priorities for corrections. The priorities which are determined based on the total risk scores existing in a rig is, in turn, dependent upon the consequences (C), the frequency of exposure to the direct causes (E), and the probability that similar accidents will occur (P) for each individual ac-

cident. Thus, for the minor but frequently occurring accidents, the P is high and so is the E; depending on the magnitude of the C, the risk scores for these accidents together may be very high. For a major injury case, the C is certainly high, but since it seldom occurs, the P is small and so is the E. Hence, major accidents will generally not generate a high risk score and are therefore of short-term importance only. For the above reasons it can be concluded that priority determination in this MIS is a measure of risk which predicts long-term effects of the present managerial safety performance. Since the consequences of a priority determination require that changes in the MSP be made, these prioritizing activities should only be done periodically.

Another conclusion that can be drawn from the process of priority determination is that all types of accidents (major, minor, first-aid, near misses) deserve equal attention from the managers and the safety experts; they should all be thoroughly investigated.

Finally, it can also be concluded that the changes made as a result of this priority determination and the consequent alternative assessment will benefit the company because this assessment is based on cost-effectiveness.

(6) The tests reveal that various reports required by the

different levels of the organization can be produced by using simple routine procedures (see Appendix D). The management group is presented with the total accident cost reports (Figures 32 and 51), a summary of the accident causation report (Figure 34d), a report on prioritized rigs (Figures 44 and 53), reports on refinement of information (Figures 46, 48, 54, and 55), and reports on alternative assessment (Figure 50). The superintendents receive the same total accident cost reports (Figures 32 and 51), accident causation reports related to their own rig operations (Figures 34a, 34b, and 34c). Like the superintendents, the toolpushers receive the total accident cost reports (Figures 32 and 51) and reports on accident causation which contain feedback to their own and their workers' safety performance (Figure 35). The above reports then show the flexibility of the MIS.

(7) This MIS is adaptable to the advancement of technology. The decision models (Robinson, Jones, and Fine) adopted in this MIS can be changed and improved without altering the basic concept of the MIS. Hence, this model is flexible; it can accomodate variables that management perceives important and maybe used on a relative basis (as the risk scores and the J factors are currently) to measure performance. The sequence of collecting accident and hazard data, transforming it into useful information, and presenting it in reports can be maintained. The

change will affect only the process by which the data is collected, transformed, and presented. The same principles apply to the categorizations of the direct causes used in this MIS.

(8) This MIS offers opportunities to achieve significant reduction of accident costs. This will be directly measurable through the reduced Workers' Compensation insurance premium.

(9) Other findings resulting from the tests.

(i) From the quality differences existing between the hypothetical and the real data sets, the following conclusions can be drawn:

- Data should be collected only to fulfill certain purposes or objectives so that their high quality can be guaranteed.
- Since resources are necessary for the collection of data, the providers should also be the users of data so that the benefits of the information received justifies the costs of collecting the data which, in turn, will again maintain the high quality of the data assembled.

(ii) Safety reports which are sent to the different levels of management should contain only data which can be received as useful information. Managers should therefore not be presented with raw accident data or rates. This raw data should be converted into parameters such as costs and risk scores which can assist management in the process of decision-making.

(iii) The continuous execution of this MIS will result in the accumulation of experience; hence, it is also a learning process. For example, managers can learn to evaluate the acceptability of risk scores, "J" factors, the effects of accident costs accounting, training, and bonus granting for accident prevention.

(iv) Inspite of all the above advantages, the execution of this MIS needs to be supported by the development of a data base management subsystem and the utilization of the 4x4 Problem-Solving Technique (Jones, 1980) which can reveal the underlying causes of accidents.

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APPENDICES

APPENDIX A

TOTAL ACCIDENT COST ESTIMATION

A method to estimate the total accident cost by a matrix was developed by Robinson (1979) for the construction industry. It has been tested and applied in several industries with succesful results. Its principal method of development, the resulting matrix, and an example of its use are discussed below.[1]

Method of Development

Basically, the matrix was developed based on the direct costs of accidents, and to get to the total costs, these direct costs were multiplied by a factor of three, i.e., a ratio of two between the direct and the indirect costs was decided upon. The matrix was developed in the following procedure:

(1) The direct costs of several thousands accidents resulting from various types of works in different parts of the country over a three year period were collected.

(2) These direct costs were then classified on the basis of

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[1]Michal R. Robinson, Accident Cost Accounting as a Means of Improving Safety in Construction (California: Stanford University, 1979), pp. 26-32.

the three following variables, namely

- the parts of the body injured (ANSI, 1969 classification)
- the nature of injury (ANSI, 1969 classification)
- whether or not the injury resulted in a lost time (OSHA definition).

(3) Adjustments for inflation were made so that all costs were in the 1979 dollars.

(4) The three variables were arranged in a matrix schedule as shown on page 33.

(5) The direct cost data for each cell of the matrix were arranged in accordance to the above schedule and the mean values were calculated.

(6) The mean values were then multiplied by three.

(7) Finally, these total costs were converted into their equivalent labor hours so that the matrix became universally useful.

ACCIDENT COST SCHEDULE, LABOR HOURS

Numbers on the left side are for no-lost-time accidents; numbers to right are for lost-time accidents; NA - Not Applicable. All costs are in equivalent labor hours; to obtain a dollar value, multiply by job labor rate including fringe benefits; then round off totals.

Body Part \ Injury Type	Amputation	Strain Sprain Crush, Mash Smash		Fracture		Cut Puncture Laceration		Burn		Bruise Abrasion		Other	
Head, Face	NA	NA		50	600	20	220	25	550	20	75	25	450
Eye (s)	3,300 (1) 18,000 (2)	NA		NA		20	220	15	380	20	75	20	380
Neck and Shoulder	NA	25	520	110	600	20	220	25	380	20	150	20	520
Arm (s) and Elbow (s)	14,000 (1) 18,000 (2)	25	300	75	450	20	220	20	380	20	220	20	450
Wrist (s) and Hand	3,800 (1) 18,000 (2)	20	190	50	650	20	220	25	380	20	300	25	450
Thumb (s) and Finger (s)	600 ea. up to 2,800	20	190	25	380	20	220	15	380	15	220	15	380
Back	NA	150	750	NA	7,400	20	220	25	550	25	380	25	750
Chest and Lower Trunk	NA	35	300	NA		20	600	25	380	20	220	20	680
Ribs	NA	25	75	35	300	NA		25	380	25	220	20	680
Hip	NA	NA	260	35	900	15	220	25	380	25	380	35	300
Leg (s) and Knees	6,600 (1) 21,000 (2)	30	300	35	1,100	20	220	25	380	20	220	20	600
Foot (feet) Ankle (s)	3,300 (1) 6,600 (2)	20	190	35	650	15	190	20	220	20	75	25	150
Toe (s)	520 ea. up to 3,000	20	110	15	190	20	220	25	150	15	75	20	150
Hernia Rupture												15	600
Heart Attack													2,200
Hearing Loss													750
Death													6,600

An Example Of Using the Matrix

To illustrate the use of the matrix, consider a worker whose hand is injured by a piece of lumber dropped from a scaffold. The worker is unable to work the next day (therefore, it is a lost-time accident) and it is on the second day that the safety engineer learns that the hand was broken. At this time, without waiting for a report from the insurance carrier, the cost of the accident can be assessed by using the matrix. Referring to the matrix, the safety engineer reads down at the left "hand" and across to the right to "fracture", to find the "cost on the right side of the column (for lost-time accident) of 650 hours. In most cases this should be converted to a dollar cost by multiplying the hourly labor cost. If it were $10.00 per hour, for example, the resulting total dollar cost assigned to the accident would be $6500.00.

APPENDIX B

4x4 PROBLEM-SOLVING TECHNIQUE

The flowchart indicating the step by step procedure, the rules, and the definitions of terms used in this technique are all cited from Jones (1981).[1]

Rules for the Application of the 4x4 Technique

RULE 1

"Start at the end-result and keep asking why until you have established corrective opportunity at the worker, supervisor, and management level- or have eliminated one or more of these with your answer."

RULE 2

"Your answers must tend to raise the level of generating responsibility."

RULE 3

"Your answers at each sequential step must include only those generating and permitting influences necessary for the occurrence of that step."

RULE 4

"If your question requires more than one answer, each must be taken through the why sequence seperately."

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[1]Charles W. Jones, 4x4 Problem Solving Technique, (Austin: Texas Safety Association, 1981), pp. 3, 11-14.

END-RESULT
LOSS/PRELOSS

STANDARD OPERATING PROCEDURE
4x4 INVESTIGATION

GENERATING/PERMITTING
INTERNAL CAUSAL INFLUENCES

ORGANIZATIONAL
CORRECTIVE LEVELS

APPROPRIATE
CORRECTIVE STEP/ACTION

MANAGEMENT

1. Establish and communicate policy/procedure.
2. Apply policy/procedure consistently where applicable.
3. Establish and communicate procedural monitoring.
4. Enforce policy/procedure based upon procedural monitoring.

SUPERVISOR

1. Communicate what is wanted.
2. Assure means to comply.
3. Be consistent in good example.
4. Be consistent in enforcement.

WORKER

1. Remove obstacle to proper performance
2. Communicate what is wanted.
3. Train/motivate/enforce.
4. Recognize/reward improved performance.

DATA ANALYSIS

PREVENTION PLANNING

Definition of Terms

End-result is a hyphenated word with a special meaning. It is any selected point along a sequential flow of causal influences.

Corrective opportunity level refers to the lowest organizational level with the ability and authority to correct the internal causal influence.

Generating responsibility is the agent or agency with the internal capability to prevent factors which produced the causal influence.

Generating influence is an active causal factor which pushes along the sequence toward an end-result. These influences are associated with a causal event at one point in time. Generating influences are avenues to prevention.

Permitting influence is a passive causal factor which allows or acts as the medium for the event sequence to evolve toward an end-result.

Acceptable performance is an activity within the organization which has not endangered disciplinary process.

Corrective steps are the specific activities necessary at each organizational level to produce sustaining control effectiveness.

Occupational accident is an organizationally unacceptable end-result.

APPENDIX C

EXAMPLES OF FORMS USED TO RECORD ACCIDENTS

OSHA No. 101
Case or File No. ....

Form approved
OMB No. 44R 1453

Supplementary Record of Occupational Injuries and Illnesses

EMPLOYER

1. Name ....
2. Mail address .... (No. and street) (City or town) (State)
3. Location, if different from mail address ....

INJURED OR ILL EMPLOYEE

4. Name .... (First name) (Middle name) (Last name) Social Security No. ....
5. Home address .... (No. and street) (City or town) (State)
6. Age .... 7. Sex: Male.......... Female.......... (Check one)
8. Occupation .... (Enter regular job title, *not* the specific activity he was performing at time of injury.)
9. Department .... (Enter name of department or division in which the injured person is regularly employed, even though he may have been temporarily working in another department at the time of injury.)

THE ACCIDENT OR EXPOSURE TO OCCUPATIONAL ILLNESS

10. Place of accident or exposure .... (No. and street) (City or town) (State)
    If accident or exposure occurred on employer's premises, give address of plant or establishment in which it occurred. Do not indicate department or division within the plant or establishment. If accident occurred outside employer's premises at an identifiable address, give that address. If it occurred on a public highway or at any other place which cannot be identified by number and street, please provide place references locating the place of injury as accurately as possible.
11. Was place of accident or exposure on employer's premises? .... (Yes or No)
12. What was the employee doing when injured? .... (Be specific. If he was using tools or equipment or handling material, name them and tell what he was doing with them.)
13. How did the accident occur? .... (Describe fully the events which resulted in the injury or occupational illness. Tell what happened and how it happened. Name any objects or substances involved and tell how they were involved. Give full details on all factors which led or contributed to the accident. Use separate sheet for additional space.)

OCCUPATIONAL INJURY OR OCCUPATIONAL ILLNESS

14. Describe the injury or illness in detail and indicate the part of body affected. .... (e.g.: amputation of right index finger at second joint; fracture of ribs; lead poisoning; dermatitis of left hand, etc.)
15. Name the object or substance which directly injured the employee. (For example, the machine or thing he struck against or which struck him; the vapor or poison he inhaled or swallowed; the chemical or radiation which irritated his skin; or in cases of strains, hernias, etc., the thing he was lifting, pulling, etc.)
    ....
16. Date of injury or initial diagnosis of occupational illness .... (Date)
17. Did employee die? .... (Yes or No)

OTHER

18. Name and address of physician ....
19. If hospitalized, name and address of hospital ....

Date of report .... Prepared by ....
Official position ....

EMPLOYER'S FIRST NOTICE OF INJURY

Form No. 2

To: WORKERS' COMPENSATION COURT
JIM THORPE BUILDING
OKLAHOMA CITY, OK 73105

Send copies to:
1 to W.C. Court
1 to Insurance Carrier

We have been informed that one of our employees contends that he was injured on the job as the result of an accidental injury or occupational disease. The information regarding this alleged injury as reported to us is as follows:

EMPLOYEE

Name ______ (Last / First / Middle) Social Security # ______ (Must be filled out)

Address ______ (Number & Street / City / State / Zip code)

Telephone ______ Age ______ Sex ______ Length of employment or service ______ (With present employer)

Occupation or job description ______ (Enter regular job title — not the activity he was performing when injured)

Average weekly wage $ ______ (See reverse side #1) Was employment agreement made in Oklahoma? ______

INJURY

Date of accident (or last hazardous exposure) ______ Time ______ (To nearest hour)

Place of accident: City ______ County ______ State ______

Date employee reported injury to employer ______

Is the employee likely to lose more than 3 calendar days? ______

Last date employee worked ______ Time his work shift began ______

Was employee paid full wages for that last day? ______

Has employee returned to work? No If so, on what date? ______

Did employee die? ______ If so, on what date? ______

Treating physician ______ (Name / Address)

Nature of injury ______ (Example: burn, cut, sprain or amputation)

List parts of body injured ______ (Example: eye, finger, arm or back)

How did the accident occur ______ (Describe fully the events which resulted in the injury or illness. Tell what happened and how it occurred)

Name object or substance which directly injured employee Improper footing (Be specific. Example: hammer, saw, box, floor or desk)

Is validity of accident in doubt? No If so, indicate reasons ______

EMPLOYER

Name ______ Telephone ______

Address ______

Type of business ______ SIC Number ______ (See reverse side #)

Type of ownership: Private ______ State Govt. ______ County ______ or Local ______

Insurance Carrier (NOT YOUR AGENT) ______ (Workers' compensation carrier — not liability carrier)

Policy Number ______ Carrier Number ______ (See reverse side #)

I hereby declare under penalty of perjury that I have examined this notice, and all statements contained herein, and to the best of my knowledge and belief, they are true, correct and complete.

Signed this ______ day of ______, 19 ______

Prepared by ______ Title ______

SUBMISSION OF THIS FORM IS NOT AN ADMISSION OF LIABILITY

APPENDIX D

ACTUAL PROGRAMS USED IN THE TEST PROCEDURES

D.1. Program for the Monthly Total Accident Cost Report Using the Hypothetical Data Set

```
c program reports monthly manhours lost due to accidents by
c superintendents and rig number.
c input:  stanford matrix and injury records
c injury records in this order:case#,rig#,task#, nature of
c injury code#,part of the body code#,unsafe act code#, unsafe
c condition code#,level of correction,length of employment
c category, losttime code#,
      INTEGER CSY(84),CSM(84),CSN(84),RG(84),TK(84),NI(84),
     :PB(84),UACT(84),UCON(84),LEM(84),LOT(84),C(84),SM(17,
     :14), CRG(30),TCRG,CM(30,2),TCM(2)
      CHARACTER*6 ULC(84)
      N=84
      DO 10 I=1,N
         C(I)=0
   10 CONTINUE
      DO 15 I=1,17
       READ*,(SM(I,J),J=1,14)
   15 CONTINUE
      DO 20 I=1,N
      READ*,CSY(I),CSM(I),CSN(I),RG(I),TK(I),NI(I),PB(I),
     :UACT(I),UCON(I),ULC(I),LEM(I),LOT(I)
   20 CONTINUE
      DO 30 I=1,N
      IF(LOT(I).EQ.2)THEN
         L=(NI(I)*2)
         C(I)=C(I)+SM(PB(I),L)
      ENDIF
      IF(LOT(I).NE.2) THEN
         K=NI(I)+(NI(I)-1)
         C(I)=C(I)+SM(PB(I),K)
      ENDIF
   30 CONTINUE
      K=1
      DO 95 I=1,N
   85 IF(CSM(I).EQ.K) THEN
      J=1
   88 IF(RG(I).EQ.J) THEN
      CM(J,K)=CM(J,K)+C(I)
      ENDIF
      J=J+1
      IF(J.GT.30) GOTO 95
```

```
      GOTO 88
      ELSE
      K=K+1
      IF(K.GT.2) GOTO 96
      GOTO 85
      ENDIF
   95 CONTINUE
   96 DO 98 K=1,2
      DO 97 L=1,30
      TCM(K)=TCM(K)+CM(L,K)
   97 CONTINUE
   98 CONTINUE
      PRINT*,(TCM*K),K=1,2)
      TCRG=0
      DO 100 I=1,2
      TCRG=TCRG+TCM(I)
  100 CONTINUE
      DO 120 J=1,30
      CRG(J)=0
      DO 110 K=1,2
      CRG(J)=CRG(J)+CM(J,K)
  110 CONTINUE
  120 CONTINUE
      PRINT'(//T2,A//T2,A,T25,A,T50,A/)',
     :'XYZ DRILLING CO., ACCIDENT REPORT IN MANHOURS LOST,
     :BY MONTH,1982',
     :'SUPERINTENDENT',' RIG NUMBER ','JAN FEB MCH APR MAY
     :JUN JUL AUG SEP OCT NOV DEC TOTAL'
      L=1
      DO 200 I=1,10
      PRINT'(T2,A,I3)','SUPERINTENDENT',I
      DO 150 J=1,3
      PRINT'(T30,A,I3,T47,2(I6,)60X,I7)','RIG#',L,(CM(L,K),
     :K=1,2),CRG(L)
      L=L+1
      IF(L.GT.30) GOTO 200
  150 CONTINUE
  200 CONTINUE
      PRINT'(//T39,A,2(I6,),60X,I7)','TOTAL   :',(TCM(K),
     :K=1,2),TCRG
      STOP
      END
```

D.2. Program for the Accident Causation Report by Superintendents, Toolpushers, and Case Numbers

```
c program presents reports on accident causations by super-
c intendents, toolpushers, and by case numbers.
c input:  one month injury records: case#,rig#,underlying
c causes.
      INTEGER CS(50), RG(50),M2(50),M3(50),S2(50),S3(50),
     :W2(50),W3(50,TOTL(3,12),SPTOTL(10,12),COTOTL(12),SUBTL
      CHARACTER M1(50),S1(50),W1(50)
      DO 10 I=1,10
      DO 5 J=1,12
      SPTOTL(I,J)=0
    5 CONTINUE
   10 CONTINUE
      DO 11 K=1,12
      COTOTL(K)=0
   11 CONTINUE
      SUBTL=0
      SO 15 I=1,50
      READ*, CS(I),RG(I),M1(I),M2(I),M3(I),S1(I),S2(I),
     :S3(I),W1(I),W2(I),W3(I)
   15 CONTINUE
      M=1
      DO 200 I=1,10
      PRINT'(//T2,A,I3,3(/T2,A))',
     :'/f TO     :SUPERINTENDENT #',I,
     :'FROM   :THE SAFETY DEPARTMENT',
     :'SUBJECT:ACCIDENT CAUSATION REPORT',
     :'PERIOD :JANUARY,1983'
      DO 19 II=1,3
      DO 17 IJ=1,12
      TOTL(II,IJ)=0
   17 CONTINUE
   19 CONTINUE
      DO 150 J= 1,3
      PRINT'(///T2,A,I3, A//T2,A)',
     :'TOOLPUSHER #',M,'          UNDERLYING CAUSES AT LEVELS
     :OF CORRECTION',
     :'    CASE #     M    M  -S   M  -S  -W   M  -W   S   S
     :-W   W    '
      L=1
   20 IF(RG(L).EQ.M) THEN
```

```
      LL=CS(L)
      IF((M1(L).EQ." ").AND.(S1(L).WQ." ")) GOTO 80
      IF((M1(L).EQ." ").AND.(S1(L).NE." ").AND.(W1(L).NE.
     :" ")) GOTO 81
      IF((M1(L).WQ." ").AND.(S1(L).NE." ").AND.(W1(L).EQ.
     :" ")) GOTO 82
      IF((M1(L).NE." ").AND.(S1(L).EQ." ").AND.(W1(L).NE.
     :" ")) GOTO 83
      IF((M1(L).NE." ").AND.(S1(L).NE." ").AND.(W1(L).NE.
     :" ")) GOTO 84
      IF((M1(L).NE." ").AND.(S1(L).NE." ").AND.(W1(L).EQ.
     :" ")) GOTO 85
      IF((S1(L).EQ." ").AND.(W1(L).EQ." ")) GOTO 86
   80 PRINT'(T6,I6,63X,A,2I/)',LL,W1(L),W2(L),W3(L)
      K=W3(L)
      CALL TTL(K,TOTL(J,12))
      GOTO 90
   81 PRINT'(T6,I6,52X,A,2I,2A,2I/)',LL,S1(L),S2(L),S3(L),
     :'-',W1(L),W2(L),W3(L)
      K=W3(L)
      CALL TTL(K,TOTL(J,11))
      K=S3(L)
      CALL TTL(K,TOTL(J,10))
      GOTO 90
   82 PRINT'(T6,I6,46X,A,2I/)',LL,S1(L),S2(L),S3(L)
      K=S3(L)
      CALL TTL(K,TOTL(J,9))
      GOTO 90
   83 PRINT'(T6,I6,36X,A,2I,2A,2I/)',LL,M1(L),M2(L),M3(L),
     :'-',W1(L),W2(L),W3(L)
      K=W3(L)
      CALL TTL(K,TOTL(J,8))
      K=M3(L)
      CALL TTL(K,TOTL(J,7))
      GOTO 90
   84 PRINT'(T6,I6,22X,A,2I,2A,2I,2A,2I/)',LL,M1(L),M2(L),
     :M3(L),'-',S1(L),S2(L),S3(L),'-',W1(L),W2(L),W3(L)
      K=W3(L)
      CALL TTL(K,TOTL(J,6))
      K=S3(L)
      CALL TTL(K,TOTL(J,5))
      K=M3(L)
      CALL TTL(K,TOTL(J,4))
      GOTO 90
   85 PRINT'(T6,I6,12X,A,2I,2A,2I/)',LL,M1(L),M2(L),M3(L),
     :'-',S1(L),s2(L),S3(L)
      K=S3(L)
      CALL TTL(K,TOTL(J,3))
      K=M3(L)
      CALL TTL(K,TOTL(J,2))
      GOTO 90
```

```
 86 PRINT'(T6,I6,6X,A,2I/)',LL,M1(L),M2(L),M3(L)
    K=M3(L)
    CALL TTL(K,TOTL(J,1))
 90 ENDIF
    L=L+1
    IF(L.GT.50) GOTO 99
    GOTO 20
 99 DO 100 L=1,12
    SPTOTL(I,L)=SPTOTL(I,L)+TOTL(J,L)
100 CONTINUE
    PRINT'(/T2,A,7X,I2,2(4X,I2,1X,A,I2),1X,A,
   :I2,4X,I2,1X,A,I2,2(4X,I2),1X,A,I2,4X,I2)',' TOTAL',
   :TOTL(J,1),TOTL(J,2),'-',TOTL(J,3),TOTL(J,4),'-',TOTL
   :(J,5),'-',TOTL(J,6),TOTL(J,7),'-',TOTL(J,8),TOTL(J,9),
   :TOTL(J,10),'-',TOTL(J,11),TOTL(J,12)
    M=M+1
150 CONTINUE
200 CONTINUE
    DO 220 II=1,12
    DO 210 JJ=1,10
    COTOTL(II)=COTOTL(II)+SPTOTL(JJ,II)
210 CONTINUE
220 CONTINUE
    PRINT"(4(/T2,A)/)',
   :'/f TO     :THE MANAGEMENT GROUP',
   :'FROM   : THE SAFETY DEPARTMENT',
   :'SUBJECT:ACCIDENT CAUSATIONS REPORT',
   :'PERIOD :JANUARY,1983'
    PRINT'(//T2,A//T20,A//)',
   :'SUPERINTENDENT          UNDERLYING CAUSES AT LEVELS
   :'OF CORRECTION,
   :'M   M  -S   M  -S  -W   M  -W   S   S  -W   W  '
    DO 300 I=1,10
    PRINT'(T7,I2,11X,2(I2,4X,I2,1X,A),2(I2,1X,A,I2,4X),I2,
   :4X,I2,1X,A,I2,4X,I2/)',I,SPTOTL(I,1),SPTOTL(I,2),'-',
   :SPTOTL(I,3),SPTOTL(I,4),'-',SPTOTL(I,5),'-',SPTOTL(I,
   :6),SPTOTL(I,7),'-',SPTOTL(I,8),SPTOTL(I,9),SPTOTL(I,1
   :0),'-',SPTOTL(I,11),SPTOTL(I,12)
300 CONTINUE
    PRINT'(/T2,A,9X,I2,2(5X,I2,A,I2),1X,A,I2,4X,I2,1X,A,I
   :2,2(4X,I2),1X,A,I2,4X,I2)',
   :'    TOTAL',COTOTL(1),COTOTL(2),'-',COTOTL(3),COTOTL
   :(4),'-',COTOTL(5),'-',COTOTL(6),COTOTL(7),'-',COTOTL
   :(8),COTOTL(9),COTOTL(10),'-',COTOTL(11),COTOTL(12)
    STOP
    END
    SUBROUTINE TTL(L,SUBTL)
    INTEGER L,SUBTL
    IF(L.EQ.0) THEN
    SUBTL=SUBTL+1
    ELSE
```

```
SUBTL=SUBTL+2
ENDIF
RETURN
END
```

D.3. Program for the Accident Causation Report by Toolpushers and by Case Numbers

```
c program presents reports on accident causations by toolpush-
c ers, and by case numbers.
c input:  one month injury records: case#,rig#,underlying
c causes.
       INTEGER CS(50),RG(50),M2(50),M3(50),S2(50),S3(50),W2
      :(50),W3(50),TOTL(30,12),SUBTL
       CHARACTER M1(50),S1(50),W1(50)
       SUBTL=0
       DO 14 I=1,50
       READ*,CS(I),RG(I),M1(I),M2(I),M3(I),S1(I),S2(I),S3(I),
      :W1(I),W2(I),W3(I)
    15 CONTINUE
       M=1
       DO 19 II=1,30
       DO 17 IJ=1,12
       TOTL(II,IJ)=0
    17 CONTINUE
    19 CONTINUE
       DO 150 J=1,30
       PRINT'(///T2,A,I3, A//T2,A)',
      :'/f TOOLPUSHER #',M,'       UNDERLYING CAUSES AT LEVELS
      :OF CORRECTION',
      :'      CASE #      M    M  -S    m  -S  -W    M  -W    S
      :S  -W    W  '
       L=1
    20 IF(RG(L).EQ.M) THEN
       LL=CS(L)
       IF((M1(L).EQ." ").AND.(S1(L).EQ." ")) GOTO 80
       IF((M1(L).EQ." ").AND.(S1(L).NE." ").AND.(W1(L).NE.
      :" ")) GOTO 81
       IF((M1(L).EQ." ").AND.(S1(L).NE." ").AND.(W1(L).EQ.
      :" ")) GOTO 82
       IF((M1(L).NE." ").AND.(S1(L).EQ." ").AND.(W1(L).NE.
      :" ")) GOTO 83
       IF ((M1(L).NE." ").AND.(S1(L).NE." ").AND.(W1(L).NE.
      :" ")) GOTO 84
       IF((M1(L).NE." ").AND.(S1(L).NE." ").AND.(W1(L).EQ.
      :" ")) GOTO 85
       IF((S1(L).EQ." ").AND.(W1(L).EQ." ")) GOTO 90
    80 PRINT'(T6,I6,62X,A,2I/)',LLW1(L),W2(L),W3(L)
       K=W3(L)
       CALL TTL(K,TOTL(J,12))
```

```
      GOTO 90
   81 PRINT'(T6,I5,52X,A,2I,2A,2I/)',LL,S1(L),S2(L),S3(L),
     :'-',W1(L),W2(L),W3(L)
      K=W3(L)
      CALL TTL(K,TOTL(J,11))
      K=S3(L)
      CALL TTL(K,TOTL(J,10))
      GOTO 90
   82 PRINT'(T6,I6,46X,A,2I/)',LL,S1(L),S2(L),S3(L)
      K=S3(L)
      CALL TTL(K,TOTL(J,9))
      GOTO 90
   83 PRINT'(T6,I6,39X,2A,2I/)',LL,'-',W1(L),
     :W2(L),W3(L)
      K=W3(L)
      CALL TTL(K,TOTL(J,8))
      GOTO 90
   84 PRINT'(T6,I6,25X,2A,2I,2A,2I/)',LL,'-',
     :S1(L),S2(L),S3(L),'-',W1(L),W2(L),W3(L)
      K=W3(L)
      CALL TTL(K,TOTL(J,6))
      K=S3(L)
      CALL TTL(K,TOTL(J,5))
      GOTO 90
   85 PRINT'(T6,I6,15X,2A,2I/)',LL,'-',
      :S1(L),S2(L),S3(L)
      K=S3(L)
      CALL TTL(K,TOTL(J,3))
      GOTO 90
   90 ENDIF
      L=L+1
      IF(L.GT.50) GOTO 99
      GOTO 20
   99 PRINT'(/T2,A,16X,A,I2,8X,A,
     :I2,A,I2,7X,A,I2,2(4X,I2),A,I2,4X,I2)','     TOTAL',
     :'-',TOTL(J,3),'-',TOTL(J,5),'-',
     :TOTL(J,6),'-',TOTL(J,8),TOTL(J,9),TOTL(J,10),'-',
     :TOTL(J,11),TOTL(J,12)
      M=M+1
  150 CONTINUE
      STOP
      END
      SUBROUTINE TTL(L,SUBTL)
      INTEGER L,SUBTL
      IF(L.EQ.O) THEN
      SUBTL=SUBTL+1
      ELSE
      SUBTL=SUBTL+2
      ENDIF
      RETURN
      END
```

D.4. Program for the Average Risk Scores by Rig and by Task Using the Hypothetical Data set

```
c program calculates risk scores prospectively
c prints out risk scores by rig# and by task
c input:  stanford matrix and injury records
      INTEGER CSY(84),CSM(84),CSN(84),RG(84),TK(84),NI(84),
     :PB(84),UACT(84),UCON(84),LEM(84),LOT(84),C(84),SM(17,
     :14),E(84)
      REAL P(84),RS(84),RSTK(1),MRSTK(31,7),SUMP,CCS
      CHARACTER*6 ULC(84)
      N=84
      DO 10 I=1,N
         C(I)=0
         E(I)=1
         P(I)=0.0
   10 CONTINUE
      DO 15 I=1,17
       READ*,(SM(I,J),J=1,14)
   15 CONTINUE
      DO 20 I=1,N
      READ*,CSY(I),CSM(I),CSN(I),RG(I),TK(I),NI(I),PB(I),
     :UACT(I),UCON(I),ULC(I),LEM(I),LOT(I)
   20 CONTINUE
      DO 30 I=1,N
      IF(LOT(I).EQ.2)THEN
         L=(NI(I)*2)
         C(I)=C(I)+SM(PB(I),L)
      ENDIF
      IF(LOT(I).NE.2) THEN
         K=NI(I)+(NI(I)-1)
         C(I)=C(I)+SM(PB(I),K)
      ENDIF
   30 CONTINUE
      DO 40 I=1,N
      IF(E(I).GT.1) GOTO 40
      J=I+1
      IF(J.GT.N) GOTO 32
   31 CONTINUE
      IF((UACT(J).EQ.UACT(I)).AND.(UCON(J).EQ.UCON(I))) THEN
        E(I)=E(I)+1
      ENDIF
      J=J+1
```

```
      IF(J.GT.N) GOTO 32
      GOTO 31
   32 K=I+1
      IF(K.GT.N) GOTO 40
   33 IF((UACT(K).EQ.UACT(I)).AND.(UCON(K).EQ.UCON(I))) THEN
        E(K)=E(I)
      ENDIF
      K=K+1
      IF(K.GT.N) GOTO 40
      GOTO 33
   40 CONTINUE
      J=0
      DO 60 I=1,N
      SUMP=1.0
      IF(P(I).GT.0.0) GOTO 60
      J=I+1
      IF(J.GT.N) GOTO49
   45 IF((UACT(K).EQ.UACT(I)).AND.(UCON(K).EQ.UCON(I)).AND.
     :(C(K).EQ.C(I))) THEN
      SUMP=SUMP+1
      ENDIF
      J=J+1
      IF(J.GT.N)GOTO 49
      GOTO 45
   49 Z=SUMP/84.0
      P(I)=P(I)+Z
      K=I+1
      IF(K.GT.N) GOTO 60
   50 CONTINUE
      IF((UACT(K).EQ.UACT(I)).AND.(UCON(K).EQ.UCON(I)).AND.
     :(C(K).EQ.C(I))) THEN
        P(K)=P(I)
      ENDIF
      K=K+1
      IF(K.GT.N) GOTO 60
      GOTO 50
   60 CONTINUE
      DO 80 I=1,N
        RS(I)=C(I)*E(I)*P(I)
   80 CONTINUE
      DO 100 I=1,31
      M=1
   83 RSTK(M)=0.0
      CCS=0.0
      J=1
   85 IF((RG(J).EQ.I).AND.(TK(J).EQ.M)) THEN
      CCS=CCS+1.0
      L=LEM(J)
      GOTO(86,87,88,89),L
   86 RSTK(M)=RSTK(M)+RS(J)*1.73
      GOTO 90
```

```
 87 RSTK(M)=RSTK(M)+RS(J)*1.18
    GOTO 90
 88 RSTK(M)=RSTK(M)+RS(J)*1.47
    GOTO 90
 89 RSTK(M)=RSTK(M)+RS(J)*1.01
 90 ENDIF
    J=J+1
    IF(J.GT.N) GOTO 91
    GOTO 85
 91 IF(CCS.EQ.0.0) THEN
    MRSTK(I,M)=RSTK(M)
    ELSE
    MRSTK(I,M)=RSTK(M)/CCS
    ENDIF
    M=M+1
    IF(M.GT.7) GOTO 100
    GOTO 83
100 CONTINUE
    PRINT'(////T20,A/)','AVERAGE RISK SCORES BY RIG AND BY
   :TASK'
    PRINT'(/T30,A/)','TASK NUMBER:'
    PRINT'(T2,A,2X,7(2X,I3,5X)/)','RIG#',1,2,3,4,5,6,7
    PRINT'(T2,A/)','_______________________________________________
   :_______________________'
    DO 200 I=1,30
    PRINT'(T2,I3,1X,7(1X,F8.2,1X)/)',I,(MRSTK(I,J),J=1,7)
200 CONTINUE
    STOP
    END
```

D.5. Program for the Priority Determination of Rigs Using the Hypothetical Data Set

```
c program calculates c,e,p, and rs=cxexp retrospectively
c program prints out risk scores by rig number
c input:  stanford matrix and injury records
c injury record in this order:case#,rig#,task#,nature of in-
c jury code#,part,of the body code#,unsafe act code#,unsafe
c condition code#, level of correction,length of employment,
c category,lost time code#.
      INTEGER CSY(90),CSM(90),CSN(90),RG(90),TK(90),NI(90),
     :PB(90),UACT(90),UCON(90),LEM(90),LOT(90),C(84),SM(17,
     :14),E(84),PNT(30)
      REAL P(84),RS(84),SUMP,RSRG(30),RSH(90)
      CHARACTER*6 ULC(90)
      N=84
      DO 10 I=1,N
         C(I)=0
         E(I)=1
         P(I)=0.0
   10 CONTINUE
      DO 15 I=1,17
       READ*,(SM(I,J),J=1,14)
   15 CONTINUE
      DO 20 I=1,90
      READ*,CSY(I),CSM(I),CSN(I),RG(I),TK(I),NI(I),PB(I),
     :UACT(I),UCON(I),ULC(I),LEM(I),LOT(I),RSH(I)
   20 CONTINUE
      DO 30 I=1,N
      IF(LOT(I).EQ.2)THEN
         L=(NI(I)*2)
         C(I)=C(I)+SM(PB(I),L)
      ENDIF
      IF(LOT(I).NE.2) THEN
         K=NI(I)+(NI(I)-1)
         C(I)=C(I)+SM(PB(I),K)
      ENDIF
   30 CONTINUE
      DO 40 I=1,N
      IF(E(I).GT.1) GOTO 40
      J=I+1
      IF(J.GT.N) GOTO 32
   31 CONTINUE
      IF((UACT(J).EQ.UACT(I)).AND.(UCON(J).EQ.UCON(I))) THEN
```

```
      E(I)=E(I)+1
    ENDIF
    J=J+1
    IF(J.GT.N) GOTO 32
    GOTO 31
 32 K=I+1
    IF(K.GT.N) GOTO 40
 33 IF((UACT(K).EQ.UACT(I)),AND.(UCON(K).EQ.UCON(I))) THEN
      E(K)=E(I)
    ENDIF
    K=K+1
    IF(K.GT.N) GOTO 40
    GOTO 33
 40 CONTINUE
    J=0
    DO 60 I=1,N
    SUMP=1.0
    IF(P(I).GT.0.0) GOTO 60
    J=I+1
    IF(J.GT.N) GOTO 49
 45 IF((UACT(J).EQ.UACT(I)).AND.(UCON(J).EQ.UCON(I)).AND.
   :(C(J).EQ.C(I))) THEN
    SUMP=SUMP+1
    ENDIF
    J=J+1
    IF(J.GT.N)GOTO 49
    GOTO 45
 49 Z=SUMP/84.0
    P(I)=P(I)+Z
    K=I+1
    IF(K.GT.N) GOTO 60
 50 CONTINUE
    IF((UACT(K).EQ.UACT(I)).AND.(UCON(K).EQ.UCON(I)).AND.
   :(C(K).EQ.C(I))) THEN
       P(K)=P(I)
    ENDIF
    K=K+1
    IF(K.GT.N) GOTO 60
    GOTO 50
 60 CONTINUE
    DO 80 I=1,N
      RS(I)=C(I)*E(I)*P(I)
 80 CONTINUE
    DO 89 J=1,30
    PNT(J)=J
    K=1
    RSRG(J)=0.0
 81 IF(RG(K).EQ.J) THEN
    M=LEM(K)
    GOTO(82,83,84,85),M
 82 RSRG(J)=RSRG(J)+RS(K)*1.73
    GOTO 86
```

```
83 RSRG(J)=RSRG(J)+RS(K)*1.18
   GOTO 86
84 RSRG(J)=RSRG(J)+RS(K)*1.47
   GOTO 86
85 RSRG(J)=RSRG(J)+RS(K)*1.01
   ENDIF
86 K=K+1
   IF(K.GT.N) GOTO 87
   GOTO 81
87 MM=K
   DO 88 II=1,6
   IF(RG(MM).EQ.J)THEN
   RSRG(J)=RSRG(J)+RSH(MM)
   ENDIF
   MM=MM+1
88 CONTINUE
89 CONTINUE
   CALL SORT(PNT,30,RSRG)
   PRINT'(////T2,A,I5///2(T2,A,T20,A/))',
  :'RISK SCORES BY RIG NUMBER  ', 1982,
  :'  RIG NUMBER  ','  RISK SCORES  ',
  :'______________','________________'
   DO 90 I=1,30
   PRINT'(T2,I5,T20,F12.4)',I,RSRG(I)
90 CONTINUE
   PRINT'(//T2,A/)','/f PRIORITY RANK   RIG NUMBER
  :RISK SCORE'
   DO 95 J=1,30
   PRINT'(T2,I10,12X,I3,7X,F12.4)',J,PNT(J),RSRG(PNT(J))
95 CONTINUE
   STOP
   END
   SUBROUTINE SORT(P,N,RRG)
   INTEGER P(N),HOLDER
   LOGICAL SORTED
   REAL RRG(N)
   K=N
 3 SORTED =.TRUE.
   K=K-1
   DO 5 I=1,K
   IF(RRG(P(I)).GE.RRG(P(I+1))) GOTO 5
   HOLDER=P(I)
   P(I)=P(I+1)
   P(I+1)=HOLDER
   SORTED=.FALSE.
 5 CONTINUE
   IF(.NOT. SORTED) GOTO 3
   RETURN
   END
```

D.6. Program for the Refinement of Information of the Priority Rigs by Task and by Length of Employment

```
c program calculates c,e,p, and rs=cxexp retrospectively
c program prints out risk scores by task and length of employ-
c ment for each priority rig#.
c input:  stanford matrix and injury records
c injury record in this order:case#,rig#,task#,nature of
c injury code#,part of the body code#,unsafe act #,unsafe
c condition #,level of correction, length of employment code#,
c lost time code#.
      INTEGER CSY(90),CSM(90),CSN(90),RG(90),TK(90),NI(90),
     :PB(90),UACT(90),UCON(90),LEM(90),LOT(90),C(84),E(84),
     :SM(17,14)
      REAL P(84),RS(84),SUMP,RSTL(7,5),RSH(90)
      CHARACTER*6 ULC(90)
      N=84
      DO 10 I=1,N
         C(I)=0
         E(I)=1
         P(I)=0.0
   10 CONTINUE
      DO 15 I=1,17
       READ*,(SM(I,J),J=1,14)
   15 CONTINUE
      DO 20 I=1,90
      READ*,CSY(I),CSM(I),CSN(I),RG(I),TK(I),NI(I),PB(I),
     :UACT(I),UCON(I),ULC(I),LEM(I),LOT(I),RSH(I)
   20 CONTINUE
      DO 30 I=1,N
      IF(LOT(I).EQ.2)THEN
         L=(NI(I)*2)
         C(I)=C(I)+SM(PB(I),L)
      ENDIF
      IF(LOT(I).NE.2) THEN
         K=NI(I)+(NI(I)-1)
         C(I)=C(I)+SM(PB(I),K)
      ENDIF
   30 CONTINUE
      DO 40 I=1,N
      IF(E(I).GT.1) GOTO 40
      J=I+1
      IF(J.GT.N) GOTO 32
```

```
 31 CONTINUE
    IF(UACT(J).EQ.UACT(I).AND.UCON(J).EQ.UCON(I)) THEN
      E(I)=E(I)+1
    ENDIF
    J=J+1
    IF(J.GT.N) GOTO 32
    GOTO 31
 32 K=I+1
    IF(K.GT.N) GOTO 40
 33 IF(UACT(K).EQ.UACT(I).AND.UCON(K).EQ.UCON(I)) THEN
      E(K)=E(I)
    ENDIF
    K=K+1
    IF(K.GT.N) GOTO 40
    GOTO 33
 40 CONTINUE
    J=0
    DO 60 I=1,N
    SUMP=1.0
    IF(P(I).GT.0.0) GOTO 60
    J=I+1
    IF(J.GT.N) GOTO 49
 45 IF((UACT(J).EQ.UACT(I)).AND.(UCON(J).EQ.UCON(I)).AND.
   :(C(J).EQ.C(I))) THEN
    SUMP=SUMP+1
    ENDIF
    J=J+1
    IF(J.GT.N)GOTO 49
    GOTO 45
 49 Z=SUMP/84.0
    P(I)=P(I)+Z
    K=I+1
    IF(K.GT.N) GOTO 60
 50 CONTINUE
    IF((UACT(K).EQ.UACT(I)).AND.(UCON(K).EQ.UCON(I)).AND.
   :(C(K).EQ.C(I))) THEN
       P(K)=P(I)
    ENDIF
    K=K+1
    IF(K.GT.N) GOTO 60
    GOTO 50
 60 CONTINUE
    DO 80 I=1,N
      RS(I)=C(I)*E(I)*P(I)
 80 CONTINUE
    M=9
    CALL RSTLPR(RG,TK,LEM,84,M,RS,RSTL,RSH)
    M=25
    CALL RSTLPR(RG,TK,LEM,84,M,RS,RSTL,RSH)
    M=13
    CALL RSTLPR(RG,TK,LEM,84,M,RS,RSTL,RSH)
```

```
      M=24
      CALL RSTLPR(RG,TK,LEM,84,M,RS,RSTL,RSH)
      M=20
      CALL RSTLPR(RG,TK,LEM,84,M,RS,RSTL,RSH)
      M=16
      CALL RSTLPR(RG,TK,LEM,84,M,RS,RSTL,RSH)
      M=19
      CALL RSTLPR(RG,TK,LEM,84,M,RS,RSTL,RSH)
      M=12
      CALL RSTLPR(RG,TK,LEM,84,M,RS,RSTL,RSH)
      M=2
      CALL RSTLPR(RG,TK,LEM,84,M,RS,RSTL,RSH)
      M=14
      CALL RSTLPR(RG,TK,LEM,84,M,RS,RSTL,RSH)
      STOP
      END
      SUBROUTINE RSTLPR(RI,TS,LP,N,M,RR,RST,RH)
      INTEGER RI(N),TS(N),LP(N)
      REAL RR(N),RST(7,5),RH(90)
      L=M
      K=N
      DO 50 I=1,7
      DO 40 J=1,5
      RST(I,J)=0.0
   40 CONTINUE
   50 CONTINUE
      DO 120 I=1,7
      J=1
   85 IF((RI(J).EQ.L).AND.(TS(J).EQ.I)) THEN
      M=LP(J)
      GOTO(86,87,88,89),M
   86 RST(I,1)=RST(I,1)+RR(J)*1.73
      GOTO 90
   87 RST(I,2)=RST(I,2)+RR(J)*1.18
      GOTO 90
   88 RST(I,3)=RST(I,3)+RR(J)*1.47
      GOTO 90
   89 RST(I,4_=RST(I,4)+RR(J)*1.01
   90 ENDIF
      J=J+1
      IF(J.GT.K) GOTO 100
      GOTO 85
  100 JJ=J
      DO 110 II=1,6
      IF((RI(JJ).EQ.L).AND.(TS(JJ).EQ.I)) THEN
      RST(I,5)=RST(I,5)+RH(JJ)
      ENDIF
      JJ=JJ+1
  110 CONTINUE
  120 CONTINUE
      PRINT'(///T2,A,I3/)','/f FOR PRIORITY RIG # ',L
```

```
      PRINT'(/T2,A/)','RISK SCORES BY TASK AND LENGTH OF
     :EMPLOYMENT'
      PRINT'(/T15,A/)','LENGTH OF EMPLOYMENT CATEGORY HAZARD'
      PRINT'(/T2,A,6X,I3,6X,I3,6X,I3,6X,I3/)','TASK# ',1,2,
     :3,4
      PRINT'(A/)','__________________________________________
     :___'
      DO 200 I=1,7
      PRINT'(/T3,I5,F8.2,4(1X,F8.2)//)',I,(RST(I,J),J=1,5)
  200 CONTINUE
      RETURN
      END
```

D.7. Program for the Refinement of the Priority Rig, Task, Length of Employment by Case Numbers

```
c program calculates c,e,p, and rs=cxexp retrospectively
c program prints out UACT,UCON,ULC for each task by each
c pririty rig.
c input:  stanford matrix and injury records
c injury record in this order:case#,rig#,task#,nature of in-
c jury code#,part of the body code#,unsafe act code#,unsafe
c condition code#, level of correction code#,length of employ-
c ment code#,lost time code#
      INTEGER CSY(84),CSM(84),CSN(84),RG(84),TK(84),NI(84),
     :PB(84),UACT(84),UCON(84),LEM(84),LOT(84),SM(17,14),
     :C(84)
      CHARACTER*6 ULC(84)
      N=84
      DO 10 I=1,N
      C(I)=0
   10 CONTINUE
      DO 15 I=1,17
       READ*,(SM(I,J),J=1,14)
   15 CONTINUE
      DO 20 I=1,N
      READ*,CSY(I),CSM(I),CSN(I),RG(I),TK(I),NI(I),PB(I),UA
     :CT(I),UCON(I),ULC(I),LEM(I),LOT(I)
   20 CONTINUE
      DO 30 I=1,N
      IF(LOT(I).EQ.1) THEN
      L=(NI(I)*2)
      C(I)=C(I)+SM(PB(I),L)
      ELSE
      K=NI(I)+(NI(I)-1)
      C(I)=C(I)+SM(PB(I),K)
      ENDIF
   30 CONTINUE
      MRG=9
      RSRG=2868.51
      MTK=5
      LEMP=1
      CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,UACT,UCON,ULC,
     :CSY,CSM,CSN,N,C)
      MRG=9
      RSRG=1802.80
```

```
 MTK=4
 LEMP=1
 CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,UACT,UCON,ULC,
:CSY,CSM,CSN,N,C)
 MRG=25
 RSRG=939.14
 MTK=3
 LEMP=1
 CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,UACT,UCON,ULC,
:CSY,CSM,CSN,N,C)
 MRG=25
 RSRG=686.54
 MTK=4
 LEMP=1
 CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,UACT,UCON,ULC,
:CSY,CSM,CSN,N,C)
 MRG=13
 RSRG=986.72
 MTK=4
 LEMP=1
 CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,UACT,UCON,ULC,
:CSY,CSM,CSN,N,C)
 MRG=13
 RSRG=316.07
 MTK=4
 LEMP=2
 CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,UACT,UCON,ULC,
:CSY,CSM,CSN,N,C)
 MRG=24
 RSRG=939.14
 MTK=5
 LEMP=1
 CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,UACT,UCON,ULC,
:CSY,CSM,CSN,N,C)
 MRG=20
 RSRG=939.14
 MTK=5
 LEMP=1
 CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,UACT,UCON,ULC,
:CSY,CSM,CSN,N,C)
 MRG=16
 RSRG=939.14
 MTK=5
 LEMP=1
 CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,UACT,UCON,ULC,
:CSY,CSM,CSN,N,C)
 MRG=19
 RSRG=543.71
 MTK=2
 LEMP=1
 CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,UACT,UCON,ULC,
:CSY,CSM,CSN,N,C)
```

```
      MRG=12
      MTK=2
      RSRG=543.71
      CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,UACT,UCON,ULC,
     :CSY,CSM,CSN,N,C)
      MRG=2
      RSRG=337.14
      MTK=4
      LEMP=2
      CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,UACT,UCON,ULC,
     :CSY,CSM,CSN,N,C)
      MRG=14
      RSRG=371.74
      MTK=4
      LEMP=1
      CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,UACT,UCON,ULC,
     :CSY,CSM,CSN,N,C)
      STOP
      END
      SUBROUTINE PUACUL (MR,MT,LEP,RSR,RI,TS,LM,UAC,UCO,UL,
     :CASY,CASM,CASN,N,CC)
      INTEGER MR,MT,LEP,RI(N),TS(N),LM(N),UAC(N),UCO(N),CA
     :SY(N),CASM(N),CASN(N),CC(N)
      REAL RSR
      CHARACTER*6 UL(N)
      PRINT'(/3(T2,A,I3/))',
     :'FOR PRIORITY RIG#             ',MR,
     :'FOR TASK#                     ',MT,
     :'LENGTH OF EMPLOYMENT CATEGORY',LEP
      PRINT'(T2,A,F8.2)',
     :'WITH RISK SCORE OF            ',RSR
      PRINT'(//T2,A,A,A,A/)','CASE# ',' UNSAFE ACT CODE# ',
     :' UNSAFE CONDITION CODE# ',' LEVEL OF CORRECTION  MAN
     :HOURS LOST'
      DO 90 I=1,84
      IF((RI(I).EQ.MR).AND.(TS(I).EQ.MT).AND.(LM(I).EQ.LEP))
     :THEN
      PRINT'(/T1,3(I2,)I13,I23,17X,A,12X,I4/)',CASY(I),CASM
     :(I),CASN(I),UAC(I),UCO(I),UL(I),CC(I)
      ENDIF
   90 CONTINUE
      RETURN
      END
```

D.8. Program for the Presentation of the Relative Effectiveness of Alternatives

```
c program calculates economic justification for each alterna-
c tive for correction (j).
c input:rig#,task#,length of employment category,risk score.
c for each rig#, alternatives are specified & printed
c for each alternative degree of correction and cost factor
c are specified; j=rs/dcxcf,
      REAL RS,COF(3),ECJ(3),DEC(3),MC
      CHARACTER*25 AL(3)
      MRI=9
      MTK=4
      MLEP=1
      DEC(1)=6.0
      DEC(2)=4.0
      DEC(3)=3.0
      RS=4696.59
      COF(1)=1.0
      COF(2)=4.0
      COF(3)=6.0
      MC=.5*4900
      AL(1)=' TRAINING OF NEW HIRES '
      AL(2)=' ENFORCE AND MOTIVATE'
      AL(3)=' BOTH ONE AND TWO       '
      PRINT'(/3(T2,A,I3/))',
     :'FOR PRIORITY RIG#       :',MRI,
     :'FOR PRIORITY TASK#      :',MTK,
     :'FOR EMPLOYMENT CATEGORY:',MLEP
      PRINT'(/T2,A)','THE ALTERNATIVES FOR CORRECTION ARE:'
      DO 3 I=1,3
      PRINT'(T2,I3,5X,A)',I,AL(I)
    3 CONTINUE
      DO 5 I=1,3
      ECJ(I)=RS/(DEC(I)*COF(I))
    5 CONTINUE
      PRINT'(T2,A/)','ALTERNATIVE   DEGREE OF CORRECTION
     :COST FACT OR ECONOMIC JUSTIFICATION'
      DO 7 I=1,3
      PRINT'(I9,15X,F5.2,13X,F5.2,10X,F12.4)',I,DEC(I),COF
     :(I),ECJ(I)
    7 CONTINUE
      PRINT'(/T2,A,F8.2,2X,A,F8.2,A)','FOR J= ',ECJ(1),
     :'C WILL BE REDUCED BY        : ',.25*MC,' MONTHLY'
```

```
 PRINT'(/T2,A,F8.2,2X,A,2(F8.2,A))','FOR J= ',ECJ(2),
:'C WILL BE REDUCED BY          :  ',.25*MC,' TO',.5*MC,
:' MONTHLY'
 PRINT'(/T2,A,F8.2,2X,A,2(F8.2,A))','FOR J= ',ECJ(3),
:'C WILL BE REDUCED BY          : ',.5*MC,' TO ',.75*MC,
:' MONTHLY'
 STOP
 END
```

D.9. Program for the Monthly Total Accident Cost Report Using the Real Data Set

```
c program reports monthly manhours lost due to accidents by
c superintendents and rig number.
c input: stanford matrix and injury records
c injury records in this order:case#,rig#,task#nature of in-
c jury code#,part of the body code#,length of employment,lost
c time code#.
      INTEGER CSY(475),CSM(475),CSN(475),RG(475),TK(475),NI
     :(475),PB(475),LEM(475),LOT(475),C(475),SM(17,14),CRG(3
     :1),TCRG,CM(31,12),TCM(12)
      N=475
      DO 10 I=1,N
         C(I)=0
   10 CONTINUE
      DO 15 I=1,17
       READ*,(SM(I,J),J=1,14)
   15 CONTINUE
      DO 20 I=1,N
       READ*,CSY(I),CSM(I),CSN(I),RG(I),TK(I),NI(I),PB(I),
     :LEM(I),LOT(I)
   20 CONTINUE
      DO 30 I=1,N
      IF(LOT(I).EQ.2)THEN
         L=(NI(I)*2)
         C(I)=C(I)+SM(PB(I),L)
      ENDIF
      IF(LOT(I).NE.2) THEN
         K=NI(I)+(NI(I)-1)
         C(I)=C(I)+SM(PB(I),K)
      ENDIF
   30 CONTINUE
      K=1
      DO 95 I=1,N
   85 IF (CSM(I).EQ.K) THEN
      J=1
   88 IF(RG(I).EQ.J) THEN
      CM(J,K)=CM(J,K)+C(I)
      ENDIF
      J=J+!
      IF(J.GT.31) GOTO 95
      GOTO 88
      ELSE
```

```
    K=K+1
    IF(K.GT.12) GOTO 96
    GOTO 85
    ENDIF
 95 CONTINUE
 96 DO 98 K=1,12
    TCM(K)=0
    DO 97 L=1,31
    TCM(K)=TCM(K)+CM(L,K)
 97 CONTINUE
 98 CONTINUE
    TCRG=0
    DO 100 I=1,12
    TCRG=TCRG+TCM(I)
100 CONTINUE
    DO 120 J=1,31
    CRG(J)=0
    DO 110 K=1,12
    CRG(J)=CRG(J)+CM(J,K)
110 CONTINUE
120 CONTINUE
    PRINT'(//T2,A//T2,A,T25,A,T50,A/)',
   :'XYZ DRILLING CO., ACCIDENT REPORT IN MANHOURS LOST,BY
   :MONTH,1981',
   :'SUPERINTENDENT',' RIG NUMBER ','JAN   FEB   MCH   APR
   :MAY   JUN   JUL   AUG   SEP   OCT   NOV   DEC   TOTAL'
    L=1
    DO 200 I=1,10
    PRINT'(T2,A,I3)','SUPERINTENDENT',I
    DO 150 J=1,3
    PRINT'(T30,A,I3,T47,12(I6,)I7)','RIG# ',L,(CM(L,K),K=
   :1,12),CRG(L)
    L=L+1
    IF(L.GT.30) GOTO 200
150 CONTINUE
200 CONTINUE
    PRINT'(//T25,A,12(I6,)I7)','FOR THE NA RIG NUMBER:',
   :(CM(31,K),K=1,12),CRG(31)
    PRINT'(//T39,A,12(I6,)I7)','TOTAL  :',(TCM(K),K=1,12),
   :TCRG
    STOP
    END
```

D.10. Program for the Average Risk Scores by Rig and by Task Using the Real Data Set

```
c program calculates risk scores prospectively
c prints out risk scores by rig# and by task
c input: stanford matrix and injury records
c injury record in this order:case#,rig#,task#,nature of in-
c jury code#,part of the body code#,length of employment
c category,lost time code#
      INTEGER CSY(475),CSM(475),CSN(475),RG(475),TK(475),NI
     :(475),PB(475),LEM(475),LOT(475),C(475),SM(17,14),E(475)
      REAL P(475),RS(475),RSTK(1),MRSTK(31,7),SUMP,CCS
      N=475
      DO 10 I=1,N
         C(I)=0
         E(I)=1
         P(I)=0.0
   10 CONTINUE
      DO 15 I=1,17
       READ*,(SM(I,J),J=1,14)
   15 CONTINUE
      DO 20 I=1,N
      READ*,CSY(I),CSM(I),CSN(I),RG(I),TK(I),NI(I),PB(I),LEM
     :(I),LOT(I)
   20 CONTINUE
      DO 30 I=1,N
      IF (LOT(I).EQ.2)THEN
          L=(NI(I)*2)
          C(I)=C(I)+SM(PB(I),L)
      ENDIF
      IF(LOT(I).NE.2) THEN
         K=NI(I)+(NI(I)-1)
         C(I)=C(I)+SM(PB(I),K)
      ENDIF
   30 CONTINUE
      DO 40 I=1,N
      IF(E(I).GT.1) GOTO 40
      J=I+1
      IF(J.GT.N) GOTO 32
   31 CONTINUE
      IF(TK(J).EQ.TK(I)) THEN
        E(I)=E(I)+1
      ENDIF
      J=J+1
```

```
      IF(J.GT.N) GOTO 32
      GOTO 31
   32 K=I+1
      IF(K.GT.N) GOTO 40
   33 IF(TK(K).EQ.TK(I)) THEN
        E(K)=E(I)
      ENDIF
      K=K+1
      IF(K.GT.N) GOTO 40
      GOTO 33
   40 CONTINUE
      J=0
      DO 60 I=1,N
      SUMP=1.0
      IF(P(I).GT.0.0) GOTO 60
      J=I+1
      IF(J.GT.N) GOTO 49
   45 IF((TK(J).EQ.TK(I)).AND.(C(J).EQ.C(I))) THEN
      SUMP=SUMP+1
      ENDIF
      J=J+1
      IF(J.GT.N)GOTO 49
      GOTO 45
   49 Z=SUMP/475.0
      P(I)=P(I)+Z
      K=I+1
      IF(K.GT.N) GOTO 60
   50 CONTINUE
      IF((TK(K).EQ.TK(I)).AND.(C(K).EQ.C(I))) THEN
         P(K)=P(I)
      ENDIF
      K=K+1
      IF(K.GT.N) GOTO 60
      GOTO 50
   60 CONTINUE
      DO 80 I=1,N
        RS(I)=C(I)*E(I)*P(I)
   80 CONTINUE
      DO 100 I=1,31
      M=1
   83 RSTK(M)=0.0
      CCS=0.0
      J=1
   85 IF((RG(J).EQ.I).AND.(TK(J).EQ.M)) THEN
      CCS=CCS+1.0
      L=LEM(J)
      GOTO(86,87,88,89),L
   86 RSTK(M)=RSTK(M)+RS(J)*1.73
      GOTO 90
   87 RSTK(M)=RSTK(M)+RS(J)*1.18
      GOTO 90
```

```
 88 RSTK(M)=RSTK(M)+RS(J)*1.47
    GOTO 90
 89 RSTK(M)=RSTK(M)+RS(J)*1.01
 90 ENDIF
    J=J+1
    IF(J.GT.N) GOTO 91
    GOTO 85
 91 IF(CCS.EQ.0.0) THEN
    MRSTK(I,M)=RSTK(M)
    ELSE
    MRSTK(I,M)=RSTK(M)/CCS
    ENDIF
    M=M+1
    IF(M.GT.7) GOTO 100
    GOTO 83
100 CONTINUE
    PRINT'(////T20,A/)','AVERAGE RISK SCORES BY RIG AND BY
   :TASK'
    PRINT'(/T30,A/)','TASK NUMBER:'
    PRINT'(T2,A,2X,7(2X,I3,5X)/)','RIG#',1,2,3,4,5,6,7
    PRINT'(T2,A/)','_____________________________________________
   :______________________________'
    DO 200 I=1,30
    PRINT'(T2,I3,1X,7(1X,F8.2,1X)/)',I,(MRSTK(I,J),J=1,7)
200 CONTINUE
    PRINT'(//T2,A/)','FOR THE NA RIG NUMBER'
    PRINT'(T2,I3,1X,7(1X,F8.2,1X))',31,(MRSTK(31,J),J=1,7)
    STOP
    END
```

D.11. Program for the Priority Determination of Rigs Using the Real Data Set

```
c program calculates c,e,p, and rs=cxexp retrospectively
c program prints out risk scores by rig number
c input: stanford matrix and injury records
c injury record in this order:case#,rig#,task#,nature of in-
c jury code#,part of the body code#,length of employment
c category,lost time code#.
      INTEGER CSY(475),CSM(475),CSN(475),RG(475),TK(475),NI
     :(475),PB(475),LEM(475),LOT(475),C(475),SM(17,14),E(475
     :),PNT(31)
      REAL P(475),RS(475),RSRG(31),SUMP
      N=475
      DO 10 I=1,N
         C(I)=0
         E(I)=1
         P(I)=0.0
   10 CONTINUE
      DO 15 I=1,17
       READ*,(SM(I,J),J=1,14)
   15 CONTINUE
      DO 20 I=1,N
       READ*,CSY(I),CSM(I),CSN(I),RG(I),TK(I),NI(I),PB(I),
     :LEM(I),LOT(I)
   20 CONTINUE
      DO 30 I=1,N
      IF(LOT(I).EQ.2)THEN
         L=(NI(I)*2)
         C(I)=C(I)+SM(PB(I),L)
      ENDIF
      IF(LOT(I).NE.2) THEN
         K=NI(I)+(NI(I)-1)
         C(I)=C(I)+SM(PB(I),K)
      ENDIF
   30 CONTINUE
      DO 40 I=1,N
      IF(E(I).GT.1) GOTO 40
      J=I+1
      IF(J.GT.N) GOTO 32
   31 CONTINUE
      IF(TK(J).EQ.TK(I)) THEN
        E(I)=E(I)+1
      ENDIF
```

```
      J=J+1
      IF(J.GT.N) GOTO 32
      GOTO 31
   32 K=I+1
      IF(K.GT.N) GOTO 40
   33 IF(TK(K).EQ.TK(I)) THEN
        E(K)=E(I)
      ENDIF
      K=K+1
      IF(K.GT.N) GOTO 40
      GOTO 33
   40 CONTINUE
      J=0
      DO 60 I=1,N
      SUMP=1.0
      IF(P(I).GT.0.0) GOTO 60
      J=I+1
      IF(J.GT.N) GOTO 49
   45 IF((TK(J).EQ.TK(I)).AND.(C(J).EQ.C(I))) THEN
      SUMP=SUMP+1
      ENDIF
      J=J+1
      IF(J.GT.N)GOTO 49
      GOTO 45
   49 Z=SUMP/475.0
      P(I)=P(I)+Z
      K=I+1
      IF(K.GT.N) GOTO 60
   50 CONTINUE
      IF((TK(K).EQ.TK(I)).AND.(C(K).EQ.C(I))) THEN
         P(K)=P(I)
      ENDIF
      K=K+1
      IF(K.GT.N) GOTO 60
      GOTO 50
   60 CONTINUE
      DO 80 I=1,N
        RS(I)=C(I)*E(I)*P(I)
   80 CONTINUE
      DO 90 J=1,31
      PNT(J)=J
      K=1
      RSRG(J)=0.0
   81 IF(RG(K).EQ.J) THEN
      M=LEM(K)
      GOTO (82,83,84,85),M
   82 RSRG(J)=RSRG(J)+RS(K)*1.73
      GOTO 86
   83 RSRG(J)=RSRG(J)+RS(K)*1.18
      GOTO 86
   84 RSRG(J)=RSRG(J)+RS(K)*1.47
```

```
      GOTO 86
   85 RSRG(J)=RSRG(J)+RS(K)*1.01
      ENDIF
   86 K=K+1
      IF(K.GT.N) GOTO 90
      GOTO 81
   90 CONTINUE
      CALL SORT(PNT,31,RSRG)
      PRINT'(////T2,A,I5///2(T2,A,T20,A/))',
     :'RISK SCORES BY RIG NUMBER  ', 1981,
     :'  RIG NUMBER  ',' RISK SCORES  ',
     :'____________','_____________'
      DO 100 I=1,30
      PRINT"(T2,I5,T20,F12,4)',I,RSRG(I)
  100 CONTINUE
      PRINT'(//T2,A,F12.4)','FOR THE NA RIG NUMBER, THE RISK
     :SCORE= ',RSRG(31)
      PRINT'(//T2,A/)','/f PRIORITY RANK     RIG NUMBER
     :RISK SCORE'
      DO 95 J=1,31
      PRINT'(T2,I10,12X,I3,7X,F12.4)',J,PNT(J),RSRG(PNT(J))
   95 CONTINUE
      STOP
      END
      SUBROUTINE SORT(P,N,RRG)
        INTEGER P(N),HOLDER
        LOGICAL SORTED
        REAL RRG(N)
      K=N
    3 SORTED=.TRUE.
      K=K-1
      DO 5 I=1,K
      IF(RRG(P(I)).GE.RRG(P(I+1))) GOTO 5
      HOLDER=P(I)
      P(I)=P(I+1)
      P(I+1)=HOLDER
      SORTED=.FALSE.
    5 CONTINUE
      IF(.NOT.SORTED) GOTO 3
      RETURN
      END
```

D.12. Program for the Refinement of Information of the Priority Rigs by Task and by Length of Employment

```
c program calculates c,e,p, and rs=cxexp retrospectively
c program print out risk scores by task and length of employ-
c ment for each priority rig#.
c input: stanford matrix and injury records
c injury record in this order:case#,rig#,task#,nature of in-
c jury code#, part of the body code#,length of employment
c category,lost time code.
      INTEGER CSY(475),CSM(475),CSN(475),RG(475),TK(475),NI
     :(475),PB(475),LEM(475),LOT(475),C(475),SM(17,14),E(475)
      REAL P(475),RS(475),SUMP,RSTL(7,4)
      N=475
      DO 10 I=1,N
         C(I)=0
         E(I)=1
         P(I)=0j0
   10 CONTINUE
      DO 15 I=1,17
       READ*,(SM(I,J),J=1,14)
   15 CONTINUE
      DO 20 I=1,N
      READ*,CSY(I),CSM(I),CSN(I),RG(I),TK(I),NI(I),PB(I),
     :LEM(I),LOT(I)
   20 CONTINUE
      DO 30 I=1,N
      IF(LOT(I).EQ.2)THEN
         L=(NI(I)*2)
         C(I)=C(I)+SM(PB(I),L)
      ENDIF
      IF(LOT(I).NE.1) THEN
         K=NI(I)+(NI(I)-1)
         C(I)=C(I)+SM(PB(I),K)
      ENDIF
   30 CONTINUE
      DO 40 I=1,N
      IF(E(I).GT.1) GOTO 40
      J=I+1
      IF(J.GT.N) GOTO 32
   31 CONTINUE
      IF(TK(J).EQ.TK(I)) THEN
        E(I)=E(I)+1
      ENDIF
```

```
      J=J+1
      IF(J.GT.N) GOTO 32
      GOTO 31
   32 K=I+1
      IF(K.GT.N) GOTO 40
   33 IF(TK(K).EQ.TK(I)) THEN
        E(K)=E(I)
      ENDIF
      K=K+1
      IF(K.GT.N) GOTO 40
      GOTO 33
   40 CONTINUE
      J=0
      DO 60 I=1,N
      SUMP=1.0
      IF(P(I).GT.0.0) GOTO 60
      J=I+1
      IF(J.GT.N) GOTO 49
   45 IF((TK(J).EQ.TK(I)).AND.(C(J).EQ.C(I))) THEN
      SUMP=SUMP+1
      ENDIF
      J=J+1
      IF(J.GT.N)GOTO 49
      GOTO 45
   49 Z=SUMP/475.0
      P(I)=P(I)+Z
      K=I+1
      IF(K.GT.N) GOTO 60
   50 CONTINUE
      IF((TK(K).EQ.TK(I)).AND.(C(K).EQ.C(I))) THEN
         P(K)=P(I)
      ENDIF
      K=K+1
      IF(K.GT.N) GOTO 60
      GOTO 50
   60 CONTINUE
      DO 80 I=1,N
        RS(I)=C(I)*E(I)*P(I)
   80 CONTINUE
      M=31
      CALL RSTLPR(RG,TK,LEM,475,M,RS,RSTL)
      M=5
      CALL RSTLPR(RG,TK,LEM,475,M,RS,RSTL)
      M=4
      CALL RSTLPR(RG,TK,LEM,475,M,RS,RSTL)
      M=10
      CALL RSTLPR(RG,TK,LEM,475,M,RS,RSTL)
      M=12
      CALL RSTLPR(RG,TK,LEM,475,M,RS,RSTL)
      M=2
      CALL RSTLPR(RG,TK,LEM,475,M,RS,RSTL)
```

```
      M=8
      CALL RSTLPR(RG,TK,LEM,475,M,RS,RSTL)
      M=21
      CALL RSTLPR(RG,TK,LEM,475,M,RS,RSTL)
      M=19
      CALL RSTLPR(RG,TK,LEM,475,M,RS,RSTL)
      M=13
      CALL RSTLPR(RG,TK,LEM,475,M,RS,RSTL)
      STOP
      END
      SUBROUTINE RSTLPR(RI,TS,LP,N,M,RR,RST)
      INTEGER RI(N),TS(N),LP(N)
      REAL RR(N),RST(7,4)
      K=N
      L=M
      DO 12 I=1,7
      DO 11 J=1,4
      RST(I,J)=0.0
   11 CONTINUE
   12 CONTINUE
      DO 100 I=1,7
      J=1
   85 IF((RI(J).EQ.L).AND.(TS(J).EQ.I)) THEN
      M=LP(J)
      GOTO(86,87,88,89),M
   86 RST(I,1)+RST(I,1)+RR(J)*1,73
      GOTO 90
   87 RST(I,2)=RST(I,2)+RR(J)*1.18
      GOTO 90
   88 RST(I,3)=RST(I,3)+RR(J)*1.47
      GOTO 90
   89 RST(I,4)=RST(I,4)+RR(J)*1.01
   90 ENDIF
      J=J+1
      IF(J.GT.K) GOTO 100
      GOTO 85
  100 CONTINUE
      PRINT'(///T2,A,I3/)','/f FOR PRIORITY RIG# ',L
      PRINT'(/T2,A/)','RISK SCORES BY TASK AND LENGTH OF
     :EMPLOYMENT'
      PRINT'(/T15,A/)','LENGTH OF EMPLOYMENT CATEGORY'
      PRINT'(/T2,A,9X,I3,9X,I3,9X,I3,9X,I3/)','TASK# ',1,2,3,4
      PRINT'(A/)','____________________________________________
     :________'
      DO 200 I=1,7
      PRINT'(/T2,I5,F12.2,1X,F12.2,1X,F12.2,1X,F12.2//)',I,
     :(RST(I,J),J=1,4)
  200 CONTINUE
      RETURN
      END
```

D.13. Program for the Refinement of the Priority Rig,Task, and Length of Employment by Case Numbers

```
c program calculates c,e,p, and rs=cxexp retrospectively
c program prints out case numbers for each priority rig and
c task
c input:  stanford matrix and injury records
c injury record in this order:case#,rig#,task#,nature of in-
c jury code#,part of the body code#,length of employment code#,
c lost time code#
      INTEGER CSY(475),CSM(475),CSN(475),RG(475),TK(475),NI
     :(475),PB(475),LEM(475),LOT(475),SM(17,14),C(475)
      N=475
      DO 10 I=1,N
      C(I)=0
   10 CONTINUE
      DO 15 I=1,17
       READ*,(SM(I,J),J=1,14)
   15 CONTINUE
      DO 20 I=1,N
      READ*,CSY(I),CSM(I),CSN(I),RG(I),TK(I),NI(I),PB(I),
     :LEM(I),LOT(I)
   20 CONTINUE
      DO 30 I=1,N
      IF(LOT(I).EQ.2) THEN
      L=(NI(I)*2)
      C(I)=C(I)+SM(PB(I).L)
      ELSE
      K=NI(I)+NI(I)-1)
      C(I)=C(I)+SM(PB(I),K)
      ENDIF
   30 CONTINUE
      MRG=5
      RSRG=21429.67
      MTK=4
      LEMP=1
      CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,CSY,CSM,
     :CSN,N,C)
      MRG=5
      RSRG=2693.30
      MTK=3
      LEMP=1
      CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,CSY,CSM,
     :CSN,N,C)
      MRG=4
      RSRG=20680.42
      MTK=
```

```
 MRG=4
 RSRG=20680.42
 MTK=4
 LEMP=1
 CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,CSY,CSM,
:CSN,N,C)
 MRG=4
 RSRG=2504.53
 MTK=3
 LEMP=1
 CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,CSY,CSM,
:CSN,N,C)
 MRG=10
 RSRG=21601.80
 MTK=4
 LEMP=1
 CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,CSY,CSM,
:CSN,N,C)
 MRG=10
 RSRG+2250.93
 MTK=2
 LEMP=1
 CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,CSY,CSM,
:CSN,N,C)
 MRG=12
 RSRG=17556.84
 MTK=4
 LEMP=1
 CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,CSY,CSM,
:CSN,N,C)
 MRG=12
 RSRG=2043.30
 MTK=4
 LEMP=3
 CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,CSY,CSM,
:CSN,N,C)
 MRG=2
 RSRG=12975.26
 MTK=4
 LEMP=1
 CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,CSY,CSM,
:CSN,N,C)
 MRG=2
 RSRG=3288.09
 MTK=5
 LEMP=1
 CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,CSY,CSM,
:CSN,N,C)
 MRG=2
 MTK=3
 RSRG=1675.00
```

```
      LEMP=1
      CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,CSY,CSM,
     :CSN,N,C)
      MRG=2
      RSRG=1640.20
      MTK=4
      LEMP=2
      CALL PUACUL(MRG,MTK,LEMP,RSRG,RG,TK,LEM,CSY,CSM,
     :CSN,N,C)
      STOP
      END
      SUBROUTINE PUACUL(MR,TM,LEP,RSR,RI,TS,LM,CASY,CASM,
     :CASN,N,CC)
      INTEGER MR,MT,LEP,RI(N),TS(N),LM(N),CASY(N),
     :CASM(N),CASN(N),CC(N)
      REAL RSR
      PRINT'(/3(T2,A,I3/))',
     :'FOR PRIORITY RIG#              ',MR,
     :'FOR TASK#                      ',MT,
     :'LENGTH OF EMPLOYMENT CATEGORY',LEP
      PRINT'(T2,A,F8.2)',
     :'WITH RISK SCORE OF             ',RSR
      PRINT'(//T2,A/)','CASE#           MANHOURS LOST'
      DO 90 I=1,N
      IF ((RI(I).EQ.MR).AND.(TS(I).EQ.MT).AND.(LM(I).EQ.LEP))
     :THEN
      PRINT'(/T1,3(I2,)10X,I8/)',CASY(I),CASM(I),CASN(I),
     :CC(I)
      ENDIF
   90 CONTINUE
      RETURN
      END
```

APPENDIX E

EXAMPLE OF A DECODING SHEET

TASKS
task 1=task of a driller
task 2=task of a motorman
task 3=task of a derrickman
task 4=task of a floorhand
task 5=task of maintenance men: welders, mechanics, electricians
task 6=task of others not directly related:truck drivers, yard workers
task 7=task of a toolpusher

LENGTH OF EMPLOYMENT CATEGORY
1 = one to three month
2 = four to six months
3 = seven to twelve months
4 = more than one year

UNSAFE ACTS CODES

100 = failure to use available personal protective equipment
350 = improper use of hands and body parts
355 = taking wrong hold of objects
400 = inattention to footings and surroundings
500 = operating or working at unsafe speed
558 = unnecessary exposure to moving materials or equipments
993 = no unsafe act

UNSAFE CONDITION

30 = slippery
399 = hazardous methods or procedures
520 = inadequately guarded (mechanical/physical)
999 = no hazardous condition

LEVEL OF CORRECTION

M1 = establish and communicate policy or procedure
M2 = apply policy or procedure consistently where applicable
M3 = establish and communicate procedural monitoring
M4 = enforce policy or procedure based upon procedural monitoring

S1 = communicate what is wanted
S2 = assure means to comply
S3 = be consistent in setting a good example
S4 = be consistent in enforcement

W1 = remove obstacles to proper performance
W2 = communicate what is wanted
W3 = train / motivate / enforce
W4 = recognize /reward improved performance

DEGREE OF CORRECTION

%	rating
100	1
>75	2
50-75	3
25-50	4
<25	6

COST FACTOR

$	rating
>50.000	10
25-50.000	6
10-25.000	4
1-10.000	2
100-1000	1
<100	0.5

APPENDIX F

DATA SETS USED IN THE TEST PROCEDURES

F.1. Hypothetical Data Set

```
0,0,0,0,50,600,20,220,25,550,20,65,25,450
3300,18000,0,0,0,0,20,220,15,380,20,75,20,380
0,0,25,520,110,600,20,220,25,380,20,150,20,520
14000,18000,25,200,75,450,20,220,20,380,20,220,20,450
3800,18000,20,190,50,650,20,220,25,380,20,200,25,450
600,2800,20,190,25,280,20,220,15,380,15,220,15,380
0,0,150,750,0,7400,20,220,25,550,25,380,25,750
0,0,35,300,0,0,20,600,25,380,20,220,20,680
0,0,25,75,35,300,0,0,25,380,25,220,20,680
0,0,0,260,35,900,15,220,25,380,25,380,25,380,35,300
6600,21000,30,300,35,1100,20,220,25,380,20,220,20,600
3300,6600,20,190,35,650,15,190,20,220,20,75,25,150
520,3000,20,110,15,190,20,220,25,150,15,75,20,150
0,0,0,0,0,0,0,0,0,0,0,0,15,600
0,0,0,0,0,0,0,0,0,0,0,0,0,2200
0,0,0,0,0,0,0,0,0,0,0,0,0,750
0,0,0,0,0,0,0,0,0,0,0,0,0,6600
82,1,1,1,3,2,4,353,30,'W1    ',1,2,0.00
82,1,2,30,2,4,3,502,999,'W2    ',1,2,0.00
82,1,3,12,2,7,17,448,999,'M2A4W3',1,2,0.00
82,1,4,19,2,7,17,558,999,'M2S2W3',1,2,0.00
82,1,5,8,2,3,4,100,320,'M2S2  ',1,2,0.00
82,1,6,4,4,5,2,500,30,'S4W3  ',1,2,0.00
82,1,7,5,1,6,1,205,999,'W1    ',2,2,0.00
82,1,8,2,7,4,4,400,30,'S2W3  ',4,2,0.00
82,1,9,3,6,2,4,353,30,'S2W3  ',1,2,0.00
82,1,10,1,2,4,3,353,510,'M4S4W3',1,1,0.00
82,1,11,10,2,5,2,353,100,'M4S4W3',1,2,0.00
82,1,12,13,4,3,4,400,30,'W4    ',2,2,0.00
82,1,13,15,4,2,4,400,30,'W4    ',2,2,0.00
82,1,14,11,4,6,3,350,999,'S4W3  ',1,2,0.00
82,1,15,25,3,5,4,100,399,'S2W3  ',1,2,0.00
82,1,16,21,2,1,4,205,205,'S4W1  ',1,1,0.00
82,1,17,22,4,2,4,500,30,'S4W1  ',3,2,0.00
82,1,18,25,4,4,6,600,30,'S4W3  ',1,1,0.00
82,1,19,6,5,7,2,100,399,'S4W3  ',2,1,0.00
82,1,20,7,6,4,12,356,620,'M3S2W2',1,1,0.00
82,1,21,9,4,2,7,355,399,'W3    ',1,2,0.00
82,1,22,12,1,7,10,356,620,'M3S2W2',2,1,0.00
82,1,23,14,4,1,4,205,299,'S4    ',1,2,0.00
82,1,24,16,7,7,4,100,35,'M3S4  ',1,1,0.00
```

```
82,1,25,28,3,7,2,100,320,'M2S2  ',2,2,0.00
82,1,26,17,5,4,4,400,30,'S2W3  ',1,1,0.00
82,1,27,20,5,7,2,100,299,'M1    ',1,2,0.00
82,1,28,23,4,2,12,999,520,'S4    ',1,1,0.00
82,1,29,27,6,6,3,502,000,'S4W3  ',1,2,0.00
82,1,30,24,5,7,2,100,300,'S4W3  ',1,2,0.00
82,1,31,26,8,7,1,400,30,'W4    ',1,1,0.00
82,1,32,29,6,3,9,502,999,'W1    ',1,2,0.00
82,1,33,28,3,6,7,400,30,'S2W3  ',3,1,0.00
82,1,34,38,3,5,8,993,399,'M3S2  ',1,2,0.00
82,1,35,20,1,2,7,355,340,'W1    ',1,1,0.00
82,1,36,2,1,2,12,993,520,'S4    ',1,1,0.00
82,1,37,9,3,7,4,100,35,'M3S4  ',2,2,0.00
82,1,38,4,5,6,2,353,30,'W3    ',3,2,0.00
82,1,39,7,2,2,4,353,30,'W3    ',1,1,0.00
82,1,40,16,4,2,3,993,410,'M3S3  ',1,1,0.00
82,1,41,23,4,2,7,355,340,'S4W3  ',2,2,0.00
82,1,42,22,5,7,2,100,399,'S2W3  ',1,1,0.00
82,1,43,9,4,2,4,350,999,'W3    ',1,2,0.00
82,1,44,2,4,2,4,400,30,'W4    ',2,1,0.00
82,1,45,3,5,7,2,100,399,'S4W3  ',1,1,0.00
82,1,46,9,4,2,4,350,999,'W3    ',1,2,0.00
82,1,47,25,4,2,4,400,30,'W4    ',1,2,0.00
82,1,48,9,5,7,2,100,399,'S4W3  ',1,2,0.00
82,1,49,9,4,3,4,993,520,'S4    ',1,2,0.00
82,1,50,25,1,6,4,400,30,'W34   ',2,1,0.00
82,2,1,9,4,2,4,993,520,'S4    ',1,2,0.00
82,2,2,9,4,2,4,993,520,'S4    ',1,1,0.00
82,2,3,9,4,3,4,993,520,'S4    ',1,2,0.00
82,2,4,9,4,2,8,400,30,'W4    ',1,2,0.00
82,2,5,2,4,2,8,400,30,'W4    ',2,2,0.00
82,2,6,4,5,6,11,400,30,'W34   ',3,1,0.00
82,2,7,5,6,6,6,355,30,'W34   ',1,1,0.00
82,2,8,13,4,7,2,100,399,'S4W3 ',1,2,0.00
82,2,9,19,4,6,2,400,30,'W34   ',1,2,0.00
82,2,10,17,1,6,2,353,30,'W34   ',2,2,0.00
82,2,11,30,3,2,5,993,350,'W3    ',2,2,0.00
82,2,12,4,5,6,11,400,30,'W34   ',1,2,0.00
82,2,13,25,4,2,4,993,420,'S4    ',1,2,0.00
82,2,14,8,5,7,2,100,399,'S4W3 ',1,1,0.00
82,2,15,9,4,7,2,100,399,'M4S2W4',1,2,0.00
82,2,16,25,5,6,2,353,30,'W3    ',1,2,0.00
82,2,17,14,4,2,4,205,999,'S4    ',1,1,0.00
82,2,18,16,5,7,2,100,399,'W3    ',1,2,0.00
82,2,19,18,4,2,4,350,999,'M4W3  ',1,2,0.00
82,2,20,25,4,2,4,350,999,'M4W3  ',1,1,0.00
82,2,21,9,4,2,8,350,999,'M4W3  ',1,1,0.00
82,2,22,24,4,2,4,400,30,'W4    ',1,1,0.00
82,2,23,26,5,7,2,100,399,'M4S2W4',1,1,0.00
82,2,24,28,5,7,2,100,299,'M2S2W3',1,1,0.00
82,2,25,30,4,2,8,350,999,'M4W3  ',1,1,0.00
```

```
82,2,26,7,4,2,8,350,999,'M4W3  ',1,1,0.00
82,2,27,9,5,7,2,100,399,'M4S2W4',1,1,0.00
82,2,28,13,4,2,8,350,999,'M4W3  ',1,1,0.00
82,2,29,7,4,2,8,350,999,'M4W3  ',1,1,0.00
82,2,30,5,4,2,8,350,999,'M4W3  ',1,1,0.00
82,2,31,3,6,2,4,353,30,'S2W3  ',1,1,0.00
82,2,32,9,4,2,4,993,520,'S4    ',1,2,0.00
82,2,33,9,5,7,2,100,399,'M4S2W4',1,2,0.00
82,2,34,9,4,7,2,100,999,'M4S2W4',1,2,0.00
82,2,35,9,3,0,0,0,520,'      ',0,0,12.64
82,2,36,1,4,0,0,0,520,'      ',0,0,00.00
82,2,37,2,3,0,0,0,30,'      ',0,0,00.00
82,2,38,3,5,0,0,0,100,'      ',0,0,6.18
82,2,39,4,4,0,0,0,30,'      ',0,0,23.48
82,2,40,1,2,0,0,0,520,'      ',0,0,.41
```

F.2. Data Set for Accident Causation Report

```
820101,1,' ',0,0,' ',0,0,'W',1,0
820102,30,' ',0,0,' ',0,0,'W',2,0
820103,12,'M',2,0,'S',4,0,'W',3,0
820104,29,'M',2,0,'S',2,0,'W',3,0
820105,8,'M',2,0,'S',2,0,' ',0,0
820106,4,' ',0,0,'S',4,0,'W',3,0
820107,5,' ',0,0,' ',0,0,'W',1,0
820108,9,' ',0,0,'S',4,0,' ',0,0
820109,3,' ',0,0,'S',2,0,'W',3,0
820110,1,'M',4,0,'S',4,0,'W',3,0
820111,10,'M',4,0,'S',4,0,'W',3,0
820112,13,' ',0,0,' ',0,0,'W',4,3
820113,15,' ',0,0,' ',0,0,'W',4,0
820114,11,' ',0,0,'S',4,0,'W',3,0
820115,25,' ',0,0,'S',2,0,'W',3,0
820116,21,' ',0,0,'S',4,3,'W',1,0
820117,22,' ',0,0,'S',3,4,'W',1,0
820118,25,' ',0,0,'S',3,4,'W',3,4
820119,6,' ',0,0,'S',4,0,'W',3,0
820120,7,'M',3,0,'S',2,0,'W',2,0
820121,9,' ',0,0,' ',0,0,'W',3,4
820122,12,'M',3,0,'S',2,0,'W',2,0
820123,14,' ',0,0,'S',4,0,' ',0,0
820124,16,'M',3,0,'S',4,0,' ',0,0
820125,18,'M',2,0,'S',2,0,' ',0,0
820126,17,' ',0,0,'S',2,0,'W',3,0
820127,20,'M',1,0,' ',0,0,' ',0,0
820128,23,' ',0,0,'S',4,0,' ',0,0
820129,27,' ',0,0,'S',4,0,'W',3,0
820130,24,' ',0,0,'S',4,0,'W',3,0
820131,26,' ',0,0,' ',0,0,'W',4,0
820132,29,' ',0,0,' ',0,0,'W',1,0
820133,28,' ',0,0,'S',2,0,'W',3,0
820134,28,'M',3,0,'S',2,0,' ',0,0
820135,20,' ',0,0,' ',0,0,'W',1,0
820136,2,' ',0,0,'S',4,0,' ',0,0
820137,9,'M',3,0,'S',4,0,' ',0,0
820138,4,' ',0,0,' ',0,0,'W',3,0
820139,7,' ',0,0,' ',0,0,'W',3,0
820140,16,'M',3,0,'S',3,0,' ',0,0
820141,23,' ',0,0,'S',4,0,'W',3,0
820142,22,' ',0,0,'S',2,0,'W',3,0
```

```
820142,9,' ',0,0,' ',0,0,'W',3,0
820144,2,' ',0,0,' ',0,0,'W',4,0
820145,3,' ',0,0,'S',4,0,'W',3,0
820146,9,' ',0,0,' ',0,0,'W',3,0
820147,25,' ',0,0,' ',0,0,'W',4,0
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F.3. Actual Data Set

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GLOSSARY*

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*Most of the definitions of terms are compiled from the following publications:

1. Ron Baker. A Primer of Oil Well Drilling (Austin: Texas University Press, 1969)

2. Petroleum Extension Service and IADC. The Rotary Rig and its Components. Unit I, LessonI. 3rd ed. (Austin: Texas University Press, 1980)

Accident n: is an unplanned not necessarily injurious or damaging event, that interrupts the completion of an activity and is invariably preceeded by an unsafe act and or an unsafe condition or some combination of unsafe acts and/ or unsafe conditions (Tarrant, 1980).

Accumulator n: is a storage device for nitrogen-pressurized hydrolic fluid, which is used in closing the blowout preventers.

Back off v: to unscrew one threaded piece (as a section of pipe) from another.

Back up v: to hold one section of an object (as pipe) while another is being screwed into or out of it.

Bail n: a cylindrical steel bar (similar to the handle or bail of a bucket, only much larger) that supports the swivel and connects it to the hook. Sometimes, the two cylindrical bars that support the elevators and attach them to the hook are called bails. v: to recover bottomhole fluids, samples, or drill cuttings by lowering a cylindrical vessel called a bailer to the bottom of a well, filling it, and retrieving it.

Belt n: a flexible band or cord connecting and passing about each of two or more pulleys to transmit power or impart motion.

Bit n: the cutting or boring element used in drilling oil and gas wells. The bit consits of the cutting element and the circulating element. The circulating element permits the passage of drilling fluid and utilizes the hydrolic force of the fluid stream to improve drilling rates. In a rotary drilling, several drill collars are joined to the bottom end of the drill pipe column. The bit is attached to the drill collar. Most bits used in rotary drilling are roller cone bits.

Block n: any assembly of pulleys on a common framework; in mechanics, one or more pulleys, or sheaves, mounted to rotate on a common axis. The crown block is an assembly of sheaves mounted on beams at the top of the derrick. The drilling line is reeved over the sheaves of the crown block alternately with the sheaves of the traveling block, which is hoisted and lowered in the derrick by the drilling line. When elevators are attached to a hook on a traveling block, and when drill pipe is latched to the elevators, the pipe can be raised or lowered in the derrick or mast.

Blowout n: an uncontrolled flow of gas, oil, or other well fluids into the atmosphere. A blowout, or gusher, occurs when a formation pressure exceeds the pressure applied to it by the column of drilling fluid. A kick warns of an impending blowout.

BOP abbr: blowout preventer.

Borehole n: the wellbore; the hole made by drilling or boring.

Bottomhole n: the lowest or deepest part of a well. adj: pertaining to the bottom of the wellbore.

Break out v: 1. to unscrew one section of pipe from another section, especially drill pipe while it is being withdrawn from the wellbore. During this operation, the tongs are used to start the unscrewing operation. 2. to separate, as gas from liquid.

Breakout tongs n: tongs that are used to start unscrewing one section of pipe from another section, especially drill pipe coming out of a hole. Also called lead tongs.

Buck up v: to tighten up a threaded connection (as two joints of drill pipe).

Cable n: a rope or wire, hemp, or other strong fibers.

Cathead n: a spool-shaped attachement on a winch around which rope for hoisting and pulling is wound.

Catline n: a hoisting or pulling line powered by the cathead and used to lift heavy equipment on the rig.

Chain drive n: a drive system using a chain and chain gears to transmit power. Power transmissions use a roller chain, in which each link is made of side bars, transverse pins, and rollers on the pins. A double roller chain is made of two connected rows of kinks, a triple roller chain of three,etc.

Chain tongs n: a tool consisting of a handle and releasable chain used for turning pipe or fittings of a diameter larger than that which a pipe wrench would fit. The chain is looped and tightened around the pipe or fitting, and the handle is used to turn the tool so that the pipe or fitting can be tightened or loosened.

Choke manifold n: the arrangement of piping and special valves, called chokes, through which drilling mud is circulated when the blowout preventers are closed to control the pressures encountered during a kick.

Circulation n: the movement of drilling fluid out of the mud pits, down the drill stem, up the annulus, and back to the pits.

Come out of the hole v: to pull the drill stem out of the wellbore. This withdrawal is necessary to change the bit, run electric logs, prepare for a drill stem test, run casing,

Crown block n: an assembly of sheaves or pulleys mounted on beams at the top of a derrick over which the drilling line is reeved.

Damage n: is the severity of an injury or the physical, functional, or monetary loss that could result if control of a hazard is lost (hammer, 1972).

Danger n: expresses a relative exposure to a hazard. A hazard may be present, but there is little danger because of the precautions taken. A person working on a very high structure is subject to the hazard that he could fall to his death. When he wears an anchored safety harness, the danger is reduced but is still present since the harness break (Hammer, 1972).

Deadline n: the drilling line for the crown block sheave to the anchor, so called because it does not move.

Degasser n: the equipment used to remove unwanted gas from a liquid, especially from drilling fluid.

Derrick n: a large load-bearing structure, usually of bolted construction. In drilling, a standard derrick has four legs standing at the corners of the substructures and reaching to the crown block. The substructure is an assembly of heavy beams used to elevate the derrick and provide space to install blowout preventers, casingheads, and so forth. Because the standard derrick must be assembled piece by piece, it has largely been replaced by a mast, which can be lowered and raised without assembly.

Desander n: a centrifugal device for removing sand from drilling fluid to prevent abrasion of the pumps. It may be operated mechanically or by a fast moving stream of fluid inside a special cone-shaped vessel, in which case it is sometimes called a hydrocyclone.

Desilter n: a centrifugal device for removing very fine particles, or silt, from drilling fluid to keep the amount of solids in the fluid to the lowest possible point. Usually, the lower the solid content of the mud, the faster the rate of penetration. It works on the same principles as a desander.

Doghouse n: a small enclosure on the rig floor used as an office for the driller or as a storehouse for small objects.

Drawworks n: the hoisting mechanism on a drilling rig. It is essentially a large winch that spools off or takes in the drilling line and thus raises or lowers the drill stem and bit.

Drill collar n: a heavy, thick walled tube, usually steel, used between the drill pipe and the bit in the drill stem. Drill collars are used to put weight on the bit so that the bit can drill.

Drilling fluid n: circulating fluid, one function of which is to force cuttings out of the wellbore and to the surface. While a mixture of clay water, and other chemical additives is the most common drilling fluid, wells can also be drilled using air, gas, or water as the drilling fluid. Also called circulating fluid.

Drill stem n: all members in the assembly used for drilling by the rotary method from the swivel to the bit, including the kelly, drill pipe and tool joints, drill collars, stabilizers, and various subsequent items.

Drill string n: the column or string of drill pipe with attached tooljoints that transmits fluid and rotational power from the kelly to the drill collars and bit. Often, especially in the oil patch, the term is loosely applied to include both drill pipes and drill collars.

Elevator n: a set of clamps that grips a stand, or column of casing, tubing, or drill pipe so that the stand can be raised or lowered into the hole.

Fingerboard n: a rack that supports the tops of the stands of pipes being stacked in the derrick or mast. It has several steel finger-like projections that form a series of slots into which the derrickman can set a stand of drill pipe as it is pulled out of the hole.

Hazard n: is a condition with the potential of causing injury to personnel, damage to equipment or structure, loss of material, or lessening the ability to perform a prescribed function. When a hazard is present, the possibility of adverse effects occurring exists (Hammer, 1972).

Hoist n: an arrangement of pulleys and wire rope or chain used for lifting heavy objects; a winch or similar device; the drawworks.

Hook n: a large hook-shaped device from which the swivel is suspended. It is designed to carry maximum loads ranging from 100 to 650 tons and turns on bearings in its supporting housing. A strong spring within the assembly cushions the weight of a stand (90 ft) of drill pipe, thus permitting the pipe to be made up and broken out with less damage to the tool joint threads. Smaller hooks without the spring are used for handling tubing and sucker rods.

Information n: meaningful data; it is the aggregate of facts or data organized into knowledge or intelligence (O'Brien, 1970, Bedford and Onsi, 1966).

Joint n: a single length (about 30 ft) of drill pipe or of drill collar, casing, or tubing, that has threaded connections at both ends. Several joints screwed together constitute a stand of pipe.

Kelly n: the heavy steel member, four-or six-sided, suspended from the swivel through the rotary table and connected to the topmost joint of drill pipe to turn the drill stem as the rotary table turns. It has a bored passageway that permits fluid to be circulated into the drill stem and up the annulus, or vice versa.

Kelly bushing n: a special device, that when fitted into the master bushing, transmits torque to the kelly and simultaneously permits vertical movement of the kelly to make the hole. It may be shaped to fit the rotary opening or have pins for transmitting torque. Also called the drive bushing.

Kick n: an entry of water, gas, oil, or other formation fluid into the wellbore. It occurs because the pressure exerted by the column of the drilling fluid is not great enough to overcome the pressure exerted by the fluids in the formation drilled. If prompt action is not taken to control the kick or kill the well, a blowout will occur.

Latch on v: to attach elevators to a section of pipe to pull it out of or run it into the hole.

Lead tongs n: the pipe tongs suspended in the derrick or mast operated by a wireline connected to the breakout cathead. Also called breakout tongs.

Make a connection v: to attach a joint of drill pipe onto the drill stem suspended in the wellbore to permit deepening of the wellbore.

Make a trip v: to hoist the drill stem out of the wellbore to perform one or a number of operations, such as changing the bits, taking a core, and so forth, and then return the the drill stem to the wellbore.

Make up a joint v: to screw a length of pipe into another length of pipe.

Management n: the planning and control of the physical and personnel resources of the company in order to reach the company's objectives (Kanter, 1977).

Mast n: a portable derrick capable of being erected as a unit as distinguished from a standard derrick that can not be raised to a working position as a unit. For transporting by land, the mast can be divided into two or more sections to avoid excessive length extending from the truck beds on the highway.

Master bushing n: a device that fits into the rotary table. It accomodates the slips and drives the kelly bushing so that the rotating motion of the rotary table can be transmitted to the kelly. Also called rotary bushing.

Mechanical rig n: a drilling rig in which the source of power is one or more internal-combustion engines and in which the power is distributed to the rig component through mechanical devices (as chains, sprockets, clutches, and shafts). It is also called a power rig.

Monkeyboard n: the derrickman's working platform. As pipe or tubing is run into or out of the hole, the derrickman must handle the top end of the pipe, which may be as high as 90 ft in the derrick or mast. The monkeyboard provides a small platform to raise him to the proper height to be able to handle the top of the pipe.

Mousehole n: an opening through the rig floor, usually lined with the pipe, into which a length of drill pipe is placed temporarily for later connection to the drill string.

Mud n: the liquid circulated through the wellbore during rotary drilling operations. In addition to its functions of bringing cuttings to the surface, drilling mud cools and lubricates the bit and the drill stem, protects against blowouts by holding back subsurface pressures, and deposits a mud cake on the wall of the borehole to prevent loss of fluids to the formation. Although it originally was a suspensions of earth solids (especially clays) in water, the mud used in modern drilling operations is a more complex three phased mixture of liquids, reactive solids, and inert solids. The liquid phase may be fresh water, diesel oil, or crude oil and may contain one or more conditioners.

Mud pit n: a series of open tanks, usually made of steel plates, through which the drilling mud is cycled to allow sands a and sediments to settle out. Additives are mixed with the mud in the pit, and the fluid is temporarily stored there before being pumped back into the well. Modern rotary drilling rigs are generally provided with three or more pits, usually fabricated steel tanks fitted with built-in pipings, valves, and mud agitators. Mud pits are also called shaker pits, settling pits, and suction pits, depending on their main purpose.

Mud pump n: a large, reciprocating pumps used to circulate mud on a drilling rig. A typical mud pump is a single or double acting, two- or three- cylinder piston pump whose pistons travel in replaceable liners and are driven by a crankshaft actuated by an engine or motor. Also called a slush pump.

Mud return line n: a through or pipe placed between the surface connections at the wellbore and the shale shaker, through which drilling mud flows upon its return to the surface from the hole.

Mud screen n: see shale shaker.

Processor n: is that element in a system which involves a transformation or conversion process which modifies the input into the output format (Luchsinger and Dock, 1975).

Pump n: a device that increases the pressure on a fluid or raises it to a higher level. Various types of pumps include the reciprocating pump, centrifugal pump, rotary pump, jet pump, hydraulic pump, mud pump, submersible pump, and bottom hole pump.

Rathole n: 1. a hole in the rig floor 30 to 35 feet deep, lined with casing that projects above the floor, into which the kelly and swivel are placed when hoisting operations are in progress. 2. a hole of a diameter smaller than the main hole that is drilled in the bottom of the main hole. v: to reduce the size of the wellbore and drill ahead.

Reserve pit n: 1. a mud pit in which a supply of drilling fluid was stored. 2. a waste pit, usually an excavated, earthen walled pit. It may be lined with plastic to prevent contamination of the soil.

Rig n: the derrick or mast, drawworks, and attendant surface equipment of a drilling unit.

Rig down v: to dismantle the drilling rig and auxiliary equipment following the completion of drilling operations; also called tear down.

Rig up v: to prepare the drilling rig for making a hole; to install tools and machinery before drilling is started.

Risk n: an expression of possible loss over a specific period of time or number of operational cycles (Hammer, 1972).

Rotary bushing n: see master bushing.

Rotary drilling n: a drilling method in which a hole is drilled by a rotary bit to which downward force is applied. The bit is fastened to and rotated by the drill stem, which also provides a passageway through which the drilling fluid is circulated. Additional joints of drill pipe are added as drilling progresses.

Rotary hose n: a reinforced, flexible tube on a rotary drilling rig that conducts the drilling fluid from the mud pump and stand pipe to the swivel and kelly; also called the mud hose or the kelly hose.

Rotary table n: the principal component of the rotary or machine, used to turn the drill stem and support the drilling assembly. It has a beveled gear arrangement to create the rotational motion and an opening into which bushings are fitted to drive and support the drilling assembly.

Round trip n: the action of pulling out and subsequently running back into the hole a string of drill pipe or tubing. It is also called tripping.

Run in v: to go into the hole with tubing, drill pipe, and so forth.

Safety n: the absence of errors that interrupt business. It is the result of doing things the right way (Jones, 1981).

Shaker n: shortened form of shale shaker.

Shale shaker n: a series of trays with sieves that vibrate to remove cutting from the circulating fluid in rotary drilling operations. The size of the openings in the sieves are carefully selected to match the size of the solids in the drilling fluid and the anticipated size of the cuttings. Also called a shaker or mud screen.

Slips n: pl: wedge shaped pieces of metal with teeth or other gripping elements that are used to prevent pipes from slipping down into the hole or to hold the pipe in place. Rotary slips fit around the drill pipe and wedge against the master bushing to support the pipe. wer slips are pneumatically or hydraulically actuated devices that allow the crew to dispense with the manual handling of slips when making a connection. Packers and other downhole equipment are secured in position by slips that engage the pipe by action directed at the surface.

Spinning cathead n: a spooling attachment on the makeup cathead to permit use of a spinning chain to spin up or make up drill pipe.

Spinning chain n: a Y-shaped chain used to spin up (tighten) one joint of drill pipe into another. In use, one end of the chain is attached to the tongs, another end to the spinning cathead, and the third end is free. The free end is wrapped around the tool joint, and the cathead pulls the chain off the joint, causing the joint to spin (turn) rapidly and tightened up. After the chain is pulled off the joint, the tongs are secured in the same spot, and the cathead continues to pull on the chain (and thus the tongs) making up the joint to the final tightness.

Spud in v: to begin drilling; to start a hole.

Stab v: to guide the end of the pipe into a coupling or tool joint when making up a connection.

Stand n: the connected joints of pipe racked in the derrick or mast when making a trip. On a rig, the usual stand is 90 feet long (three lengths of pipe screwed together) or a thribble.

String n: the entire length of casing, tubing, or drill pipe run into a hole; the casing string.

Subsystems n: a separate parts of the total system which perform some specific useful purposes, but are not themselves of sufficient scope to be considered a system in the context of the total system (Methlie, 1968).

Swivel n: a rotary tool that is hung from the rotary hook and traveling block to suspend and permit free rotation of the drill stem. It also provides a connection for the rotary hose and a passageway for the drilling fluid into the drill stem.

System n: a collection of interrelated parts which is unifeid by design to obtain one or more objectives (Luchsinger and Dock, 1977).

Throw the chain v: to flip the spinning chain up from a tool joint box so that the chain wraps around the tool joint pin after it is stabbed into the box. The stand or joint of drill pipe is turned or spun by a pull on the spinning chain from the cathead on the drawworks.

Tongs n pl: the large wrenches used for turning when making up or breaking out drill pipe; variously called casing tongs, rotary tongs, and so forth, according to their specific use.

Tool joint n: a heavy coupling element for drill pipe made of special alloy steel. Tool joints have coarse, tapered threads and seating shoulders designed to sustain the weight of the drill stem, withstand the strain of frequent coupling, and provide a leakproof seal. The male section of the joint, or the pin, is attached to one end of a length of drill pipe, and the female section or box, is attached to the other end. The tool joint may be welded to the end of the pipe or screwed on or both. A hard metal facing is often applied in a band around the outside of the tool joint to enable it to resist abrasion from the walls of the borehole.

Torque n: the turning force that is applied to a shaft or other rotary mechanism to cause it to rotate or tend to do so. Torque is measured in foot pounds, joules, meter-kilograms, etc.

Tour n: (pronounced "tower") an 8-hour shift worked by a drilling crew or other oil field workers. Sometimes, 12-hour tours are used, especially on offshore rigs. The most common division of tours are daylight, evening, and graveyard, if 8-hour tours are employed.

Traveling Block n: an arrangement of pulleys, or sheaves, through which drilling cable is reeved and moves up and down in the derrick or mast.

Trip n: the operation of hoisting the drill stem from and returning it to the wellbore.

Wellbore n: a borehole; the hole drilled by the bit.

Wellhead n: the equipment installed at the surface of the wellbore. A wellhead includes such equipment as the casinghead and the tubing head.

Wireline n: a slender, rod-like or thread-like piece of metal usually small in diameter, that is used for lowering special tools (such as logging sondes, perforating guns, and so forth) into the well.

Wire rope n: a cable composed of steel wires twisted around a central core of hemp or other fiber to create a rope of great strength and considerable flexibility. Wire rope is used as drilling line, core line, servicing line, winch line, and so on. It is often called cable or wireline; however, wireline is a single slender metal rod, usually very flexible.