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Occupational Injury Control Through System Safety Analysis - A Comparative Study

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OCCUPATIONAL INJURY CONTROL THROUGH SYSTEM SAFETY ANALYSIS - A COMPARATIVE STUDY

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OCCUPATIONAL INJURY CONTROL

THROUGH SYSTEM SAFETY ANALYSIS -

A COMPARATIVE STUDY

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Victor G. Aeby December 1978 40 Pages

Directed by Bruce Goodrow, David Dunn and Donald Carter

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The study was a comparative retrospective analysis to determine the effectiveness of MORT (Management Oversight and Risk Tree), a system safety method, in reducing the incidence and cost of occupational injuries occurring at the Tennessee Wheel and Rubber Company. Implementation of MORT on April 1, 1974 at the plant facility allowed for statistical comparison of accidents between the time periods April 1, 1972 through March 31, 1974 and April 1, 1974 through March 31, 1976.

Data on injury incidence were gathered by researching the company's worker compensation reports. Cost figures for injuries were drawn from computer printouts provided by the company's insurance carrier.

A reliable figure for the mean incidence of injuries occurring over the twenty-four month control period and twenty-four month experimental period was determined by calculating monthly injuries per one thousand man hours using the occupational injury rate formula:

$$\frac{\text{Total Number of Occupational Injuries Per Month}}{\text{Total Number of Man Hours Worked Per Month}} \times 1000.$$

A figure for mean occupational injury cost rate was determined by calculating annual cost of unjuries per one thousand man

hours worked for the control and experimental periods using the formula:

$$\frac{\text{Total Cost of Occupational Injuries (Year)}}{\text{Total Number of Man Hours Worked (Year)}} \times 1000.$$

Statistical analyses using a t-test at the .05 level of significance was applied to determine if MORT implementation was effective in reducing the mean incidence rate and mean cost of occupational injuries. Results showed a statistically significant reduction in the occupational injury incidence rate at the Tennessee Wheel and Rubber Company following introduction of MORT system safety. MORT implementation did not, however, result in a significant reduction in the cost of occupational injuries between the control and experimental periods.

The resultant discrepancy in findings (rejection of Ho1 and acceptance of Ho2) might be explained by: 1) the fact that no medical cost inflation factor was used when comparing injury costs between the two time periods under study, and 2) types of injuries were not differentiated in terms of severity of injuries. The findings brought forth from this research indicate a degree of uncertainty as to the application of MORT to general industry.

CHAPTER 1

INTRODUCTION

During the past several years, the number of occupational fatalities averaged 14,200 a year. From 1960 through 1970, there were over 150,000 job-related fatalities, while in 1972, more than 50 million employee days were lost because of disabling injuries. The known cost of accidents exceeded 11.5 billion dollars. These figures did not include most of the deaths and disabling illnesses from occupational disease.[1]

Employers, unions and various government agencies saw the need for developing effective programs to improve occupational safety and health. The importance of keeping employees safe and healthy received such widespread recognition that a broad and detailed national program emerged.

The testimony and documentary evidence adduced before committees of the Senate and House, during deliberations in 1969 and 1970 on Occupational Safety and Health legislation, pointed up the fact that the American work site was indeed a place of peril.[2]

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[1] U.S. Department of Labor, Occupational Safety and Health Administration, Principles and Practices of Occupational Safety and Health, Booklet I (Washington: Government Printing Office, 1971), p. 1.

[2] Employment Safety and Health Guide, Guidebook to Occupational Safety and Health (New York: Commerce Clearing House, Inc., 1973), p. 1.

The Williams-Steiger Occupational Safety and Health Act was passed by both Houses of Congress and signed into law on December 29, 1970. The purpose of the Act was to assure every working man and woman a safe and healthful place in which to work.

Coverage of the Act extended to all employers and their employees in the fifty states, the District of Columbia, Puerto Rico, the Canal Zone, and all other territories under federal jurisdiction. It applied to any employment which "affects commerce." Since its enactment, safety standards have replaced safety guidelines and requirements have replaced recommendations. Occupational health and safety had spread throughout academia, industry and government.

Prior to Worker's Compensation Legislation in 1911, all states handled industrial injuries under the "common law" concept.[3] Injured employees had to sue their employer for recompense. When management found itself in a position of having to pay for injuries on the job, it decided it would be financially better to stop injuries from happening. This decision by industry gave birth to the organized safety movement.

During the early years, the safety movement was directed towards physical hazards. This increased emphasis showed definite results. During a twenty-year period from

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[3]Daniel C. Peterson, Techniques of Safety Management (New York: McGraw-Hill, 1971), pp. 9-11.

1912 to 1933, occupational deaths were reduced from 21,000 lives per year to 14,500. The National Accident Frequency Rate per 1,000,000, according to the National Safety Council, dropped from 15.12 in 1931 to 7.68 in 1969. During that same period, the National Severity Rate per 1,000,000 dropped from 1,500 to 640.[4]

Since the late 1950s, accident rates on the job have reached a plateau. Death rates in United States manufacturing hovered at 9, 10, or 11 deaths per 100,000 workers for the years 1960 to 1971. Temporary disability rates increased by 62 percent in the same ten-year period.[5]

Companies that had developed even the best safety programs were finding that an increase in their safety effort did not necessarily mean a reduction in the frequency and severity of occupational injuries and illnesses.[6] It was soon to be realized that the development of new and better approaches to controlling occupational injuries were needed to enhance employee safety.

Improved safety methods have emerged during the decade of the 70s and the records of the aerospace, nuclear reactor, and weapons programs attest to the effectiveness of these procedures. One such method, the Management Oversight

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[4]Peterson, Techniques, p. 10.

[5]William G. Johnson, The Management Oversight and Risk Tree - MORT, Energy Research and Development Administration, No. SAN 821-2 (Washington: Government Printing Office, 1973), pp. 1-3.

[6]W. T. Parker, "Has Safety Progress Ended?", National Safety News, 23 (October 1969), 32.

and Risk Tree (MORT), is a system safety program originally developed for the Atomic Energy Commission (AEC). The method was retained by the Division of Operational Safety (DOS) - now known as the Division of Safety, Standards, and Compliance (SSC) - during the Atomic Energy Commission's transition to the Energy Research and Development Administration (ERDA). The goal of the ERDA-MORT program was to reduce the ERDA 1975 accident rates by an order of magnitude by 1986.[7]

MORT provides an analytical method for considering all elements of an individual safety program. It provides guidelines for judging the adequacy of these elements in the prevention of accidents and incidents. The Management Oversight and Risk Tree (MORT) does not represent a new and untried methodology, rather it does represent the synthesis of those safety program elements that are effective in reducing occupational injuries and illnesses.

Purpose of the Study

The purpose of this study was to compare the incidence and cost of recorded occupational injuries at the Tennessee Wheel and Rubber Company during the periods April 1, 1972 through March 31, 1974 (the control period) and April 1, 1974 through March 31, 1976 (the experimental period) as a function of system safety methods employed during the experimental period.

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[7] Robert W. Eicher, MORT Question and Answer Package, Energy Research and Development Administration (Washington, D.C., 1974), p. 3.

Statement of the Problem

The research problem in this study was to determine the effect of MORT, a system safety method, on the number and cost of injuries experienced by the Tennessee Wheel and Rubber Company.[8] The time period under consideration in this study represented insurance policy periods from April 1, 1972 through March 31, 1976.

The basic hypotheses of this study were as follows:

Ho 1 There is no significant difference in the mean incidence rates of occupational injuries between the time periods April 1, 1972 to March 31, 1974 and April 1, 1974 to March 31, 1976.

Ho 2 There is no significant difference in the mean costs of occupational injuries between the time periods April 1, 1972 to March 31, 1974 and April 1, 1974 to March 31, 1976.

Need for the Study

Various studies and authorities have failed to record the continued effectiveness of "traditionally laden" methods of controlling occupational injuries.[9] In steel and in other

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[8]The premise of a system safety method is that a simple logic or decision tree, which structures all of the presently known causal factors and/or preventive measures in an order which integrates safety concepts into a coherent whole, can assure greater control of accident variables.

[9]Lawrence Ellis, "A Review of Research on Efforts to Promote Occupational Safety," Journal of Safety Research, 5, No. 4 (December 1975), 180-187.

industries, the present accepted safety practices are job safety analysis, job instruction and training, and a safety observation plan.

The desire for improved loss prevention methods does not stem from any describable failure of old safety methods but from a desire to systematically control recognized hazards within a workplace. After some four decades of accident rate decline, a plateau, followed by a decade of slow increase in rates has been a widespread experience both in the United States and abroad. Many leading industries that have attained low occupational injury rates in the past are now seeking an even higher level of safety. It is unreasonable to conclude that these employers can make further progress by simply doing more, or better, in their present program. It becomes increasingly apparent that a different, more effective approach is needed to assure a major reduction in occupational injuries.

The trials at Aerojet Nuclear Company and their announced goal of an order of magnitude reduction in already low accident rates have served as a major impetus for this research.[10] Jack L. Clark, Systems Safety Development, Aerojet Nuclear Company, feels that as a result of numerous pilot studies over a four-year period, the Energy Research and Development Company will continue to support the development and training of personnel within Aerojet and throughout

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[10]Robert W. Eicher, MORT Package, p. 3.

the United States in the application of this method.[11]

Robert J. Nertney, Manager of Systems Safety Development Center, Aerojet Nuclear Company, feels that the preliminary results of trials at Aerojet have shown an ability to assist persons from a discipline other than safety to quickly apply and broaden their skills in accident appraisal.[12]

Outside the aerospace industry, there exists no model that can be used to evaluate the effectiveness of loss prevention programs. Even though this study is committed to the manufacturing industry, this research will serve as motivation for similar studies at other selected industrial groups.

As the duties of persons responsible for plant safety become increasingly complex, their ability to systematically work through difficult problems becomes important to their overall effectiveness. Application of the MORT system in the aerospace industry has demonstrated some degree of effectiveness and utilization potential of the MORT model. It remains now to determine if the system can be effective in the general industry environment.

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[11]Statement by Jack L. Clark, personal interview, Nashville, Tennessee, July 21, 1975.

[12]Statement by Robert Nertney, personal interview, Nashville, Tennessee, October 19, 1976.

Definitions of Terms

1. Atomic Energy Commission (AEC). A United States board formed in 1946 for the domestic control of atomic energy.

2. Employee. A person hired by another to work for wages or salary.

3. Energy Research and Development Administration (ERDA). A United States Board formed to coordinate and control the development of energy sources.

4. Insurance Policy Period. A twelve-month period of time from April 1st of each year through March 31st of the next year.

5. Management Oversight and Risk Tree (MORT). A logic or decision tree which structures causal factors and/or preventive measures in order to control losses.

6. Occupational Injury. Physical harm to a person in the course of his employment.

7. Occupational Injury Cost Rate. Dollar value of injuries occurring in a twelve-month period divided by the total man hours worked in the same period of time multiplied by one thousand.

8. Occupational Injury Rate. Number of injuries in a twelve-month period divided by the total number of man hours worked in the same period of time multiplied by one thousand.

9. Safety. The quality or condition of being free from danger, injury, or damage.

10. System Safety. A method to control certain risk factors which contribute to losses.

11. Worker's Compensation Report. Information contained in a document pertaining to an employee injury or occupational disease suffered in connection with his employment.

12. National Accident Frequency Rate. The total number of disabling injuries times one million, divided by man-hours of employment (exposure) during the period covered.

13. National Severity Rate. The total number of days lost due to disability times one million, divided by total employee man-hours of exposure.

14. Order of Magnitude. A logrithimic number given to a quantity for purposes of comparison with other quantities of the same class. For example: a reduction of accidents for one order of magnitude would be 10^3 down to 10^2.

Basic Assumptions

The following basic assumptions were considered essential for this study:

1. The workers' compensation report will supply the requisite information.

2. The responses to questionnaire items are based on the participants real or true feelings.

Limitations of the Study

1. There was no comparison group or control population for this study; therefore, conclusions resulting from this research may be generalized only to the study population involved.

2. The study was concerned with the number of worker's compensation reports. It was not concerned with any other aspects of the report.

3. The study was concerned with the annual cost of worker's compensation insurance. It was not concerned with individual costs per case.

4. The study was not concerned with the structure of a safety program or the structure of a MORT systems safety program.

Organization of the Study

Following an introductory chapter defining the purpose and need of the study, a review of literature is presented. This historical overview emphasizes factors which produce accidents and specific components of organized safety programs.

Methodology and design of the study are presented in Chapter 3. The procedure for determination of rates and the statistical technique for hypotheses testing are outlined in this chapter.

The analysis and interpretation of data are discussed next, followed by a final chapter containing conclusions from the findings as well as recommendations for further study.

CHAPTER 2

REVIEW OF LITERATURE

Introduction

At the time of this study, system safety programs were a relatively recent trend. The early 1970s might be described as a period of increasing concern over the limited usefulness of existing methods of accident prevention. During this period there grew a demand for formulation of an ideal system of controlling losses.

This review will emphasize concepts of accident prevention and the integration of system safety with present safety practices. Included will be a discussion of those factors which produce accidents (and man-hour losses) as well as organization of safety programs to date.

What Produces Accidents

As a result of Johnson's studies at Aerojet Nuclear Company, a new definition of "accident" emerged:

> An accident can be defined as an unwanted transfer of energy because of the lack of barriers and/or controls producing injury to persons, property, or process, preceded by sequences of planning and operational errors which: failed to adjust to change in physical or human factors and produced unsafe

conditions and/or unsafe acts, arising out of the risk in an activity and interrupting or degrading the activity.[1]

The basis for the Johnson definition is found in a study by Haddon suggesting that an accident is multifactorial in nature and occurs as a result of an unwanted flow of energy due to lack of barriers.[2] Nertney, Clark, and Eicher outlined these energy forms as (1) kinetic, (2) thermal, (3) electrical, (4) ionizing and non-ionizing radiation, (5) acoustic, and (6) biologic.[3]

Traditional safety concepts were based on the theory that individuals create their own accident situations due to unsafe acts. Champanis, in a 1970 address to the National Safety Council, disagreed with the traditional concept by supporting the Johnson definition. Champanis stated, "The reason errors occur in an activity is because the people involved are not able to cope with the way equipment is designed and the procedures to be followed."[4] McCormick, also de-emphasizing the traditional human error concept,

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[1] William G. Johnson, The Management Oversight and Risk Tree, Energy Research and Development Administration, No. SAN 821-2 (Washington: Government Printing Office, 1973), p. 25.

[2] William Haddon, Jr., "The Prevention of Accidents," Preventive Medicine, 11 (1966), 42.

[3] Robert J. Nertney, Jack L. Clark, and E. W. Eicher, Occupancy-Use Readiness Manual, Energy Research and Development Administration, No. 76-45-1 (Washington: Government Printing Office, 1976), 1-3.

[4] Alphonse Champanis, "The Error-Provocative Situation," Symposium on Measurement of Safety Performance, in an address to the National Safety Council at Los Angeles, California, 1970.

points to the fact that human use of virtually any man-made thing can be enhanced or conversely degraded by its design.[5]

T. M. Khalil, in writing about the relationship of man and machine, postulated that whenever man's physical or psychological limitations are extended beyond their capabilities, the cost is inevitable whether in terms of economic cost or loss of human resources.[6] Taylor wrote of the role of psychology in designing machines which require less of man yet exploit his special abilities. He felt that engineering aims first at building a better system and only second at improving the operator.[7]

Johnson's theory, that errors in an activity stem from one or more planning or design stages at a higher level, promoted the philosophy that the best way to minimize errors is by a continual, systematic awareness of human factors in the planning, design, installation, and maintenance of equipment.[8] Berberich supports this supposition in writing, "Injury control can be achieved through a team effort in which all

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[5]Ernest J. McCormick, Human Factors Engineering (New York: McGraw-Hill, 1976), pp. 3-15.

[6]T. M. Khalil, "Design Tools and Machines to Fit the Man," Journal of Industrial Engineering, 4 (January, 1972), 32.

[7]F. V. Taylor, "Psychology and the Design of Machines," The American Psychologist, 12 (1957), 249-258.

[8]Johnson, MORT, p. 25.

members contribute their expertise towards the solution of problems.[9]

Russell Miller, Director of Safety at the Monsanto Company, approaches the problem of error reduction by starting with top management policies and continuing through engineering start-up and yearly audits by corporate staff.[10] This systematic managerial approach to error reduction was promoted by Peters, when describing the Defense Department's objective of safety based on consistency of effort in all divisions of the Department, he stated, "the degree of error reduction depends directly upon management emphasis during and throughout the life cycle of an activity."[11] The DuPont Company's philosophy of accident prevention is similar: "Since management, which includes all levels through foreman, has the responsibility for every operational activity of the company, each supervisor has the responsibility of preventing personal injuries."[12]

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[9]N. J. Berberich, Jr., "Occupational Injury Control," Occupational Health and Safety Symposia, U.S. Department of Health, Education, and Welfare, No. 76-136 (Washington: Government Printing Office, 1976), 81-182.

[10]Russell L. Miller, "The Changing Challenge of Loss Control in the Chemical Industry," Proceedings of the Second International System Safety Conference, Systems Safety Society Series (July 1975), pp. 130-139.

[11]George A. Peters, "System Safety Management," Hazard Prevention, 14, No. 1 (September 1977), 11-17.

[12]E. I. DuPont and Company, Inc., Safety and Fire Protection Reference Guide for Company Units (1967), pp. 1-7.

Throughout the literature, writers are quick to note the important intervening factor of change. New employees, transfers, new projects, and adjustments can have an adverse impact on even the soundest safety methods. As Johnson suggests, "each change is believed to create the potential of human error."[13] Kepner and Tregoe identified characteristics of change in relation to accident prevention:

> (1) The sensitivity to impending or probable change is a key quality of a good manager or safety coordinator, (2) the significance of change is that jobs such as construction are continually changing, (3) sensitivity to change situations such as transfers, new operations, and new materials is essential and (4) necessary to augment the essential feedback to detect changes that could contribute to an accident.[14]

Knox and Eicher suggested that the practice of change analysis gives the analyst the ability to determine whether changes are needed in a stable operational system or a changing operational system requires safety-related counter changes.[15] Kepner and Tregoe supported the Knox and Eicher development of change analysis by stating, "When hunting for the cause of a problem, the kind of change that could produce this certain kind of

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[13] Johnson, MORT, p. 25.

[14] Charles H. Kepner and Benjamin B. Tregoe, The Rational Manager (New York: McGraw-Hill, 1965), p. 5.

[15] N. W. Knox and E. W. Eicher, MORT Users Manual, Energy Research and Development Administration, No. 76145-A (Virginia: National Technical Information Service, 1976), pp. 1-8.

result must be determined. A problem must be identified before a solution can be determined."[16]

The real cause of a problem, according to Crowe and Douglas, is some change that occurs in the process as it moves toward the expected purpose or outcome.[17] This theory is based on an earlier theory - Heinrich's Domino Theory - suggesting that loss is a result of factors occurring in a sequence. If the series of events is interrupted by the elimination of one of the factors making up the series, the loss cannot occur. Each element in the chain of events is a result of chance.[18]

Heinrich's theory was a subject of criticism in the writings of some safety analysts however. In differing with the Domino theory, Brenner postulated that a loss occurs because factors, conditions, and events (changes) interface through different chains and at different times.[19] Peterson went so far as to say that, "the narrow-mindedness of the Heinrich theory has severely limited our ability to find and deal with multiple causes of a loss.[20]

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[16]Charles H. Kepner and Benjamin B. Tregoe, Analytic Trouble Shooting (New York: McGraw-Hill, 1966), pp. 10-17.

[17]Joan M. Crowe and Hugh M. Douglas, Effective Loss Prevention (Boston: Houghton Mifflin, 1976), pp. 43-92.

[18]H. W. Heinrich, Industrial Accident Prevention (New York: McGraw-Hill, 1959), pp. 3-20.

[19]Ludwig Brenner, Hazardous Materials Emergencies (Lufrin Industries Publication, 1976), p. 25.

[20]Daniel C. Peterson, Techniques of Safety Management (New York: McGraw-Hill, 1971), p. 13.

Surrey utilized an epidemiological model to describe and determine the cause of specific problems.[21] He felt that the use of a series of questions was needed to fully expose the areas contributing to the problem. Mausner and Bahn furthered this concept by stating "a basic tenet of epidemiology is that an ecological or multi-factorial approach is necessary to explain the occurrence of disease. Disease cannot be attributed to the operation of any one factor."[22] In a September, 1975 National Institute of Occupational Safety and Health Symposia held in Cincinnati, Ohio, Bahn made note of the functional use of epidemiological models utilizing the same 'question' concept brought forth by Kepner and Tregoe.[23]

In summary, whether it be a disease or an accident, one organism or one event is not sufficient to account for the problem; other factors must be considered. And any analysis of such a problem must take into account the potentiality of change for affecting a safety system.

The following section will be devoted to the components of a safety program. The literature cited will focus upon attempts to organize an effective safety program in an effort to control losses.

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[21] J. Surrey, Industrial Accident Research - A Human Engineering Appraisal (Toronto: University of Toronto Press, 1968), pp. 12-24.

[22] Judith S. Mausner and Anita K. Bahn, Epidemiology - An Introductory Text (St. Louis: W. B. Saunders Company, 1974), pp. 21-40.

[23] Anita K. Bahn, "Epidemiology for the Part-time Occupational Physician," Occupational Safety and Health Symposium, U.S. Department of Health, Education, and Welfare (Washington: Government Printing Office, 1976), pp. 1-24.

Safety Program Organization

The value of a well-organized safety program in preserving property and life has been debated. In a review of occupational safety research, Ellis writes:

> Safety experts generally can be divided into two schools of thought - those who see accident reduction as largely an engineering problem and those who consider it a matter of human motivation and education.[24]

Knaff saw the importance of proper engineering techniques in safety program organization. He wrote, "In considering man-machine, the major design freedoms lie with the machine-related or equipment-related factors. It is far easier to alter the characteristics of a machine than to alter the characteristics of a man."[25] In other safety literature, Ayob and Bowen also suggest designing the machine to fit the man.[26]

A number of studies illustrate the difficulty man encounters operating the machine. In an earlier writing, Holding noted variations that occur between men in their

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[24]Lawrence Ellis, "A Review of Research on Efforts to Promote Occupational Safety," Journal of Safety Research, 5, No. 4 (December 1975), 180-187.

[25]Robert P. Knaff, "Man-Machine Compatability: A Highway Safety Essential," Proceedings of the Second International System Safety Conference, System Safety Society Series (July 1975), pp. 242-251.

[26]M. M. Ayob, "Sitting Down on the Job (Properly)," Industrial Design (April 1972), pp. 1-3; H. M. Bowen, "The Imp in the System," Economics, 10 (1967), 112-119.

tendencies to operate display controls.[27] In researching the effects of noise on human performance, Jerison showed a relationship between noise levels and changes in human performance in related tasks.[28] Similar performance variations to machine tasks have been studied in relation to differences in lighting. Khalil, in a summary of research regarding performance changes due to certain extrinsic factors, theorized the following:

> In order to obtain the optimal results in the design of man-machine systems, there are four basic decision rules in which to follow. These rules are (1) man is the center of design, (2) utilize principles of kinesiology, (3) observe physiological capacity, and (4) apply psychological principles.[29]

The benefits of and techniques for human motivation and safety education have been brought forth in the writing of several safety analysts, most notably Hammer and Bush.[30] Also attesting to the value of organized safety programs are the National Safety Council and the American Society of Safety Engineers. Neither of the organizations, although both publish information concerning safety organization, are specific as to the best type of organized system safety

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[27] D. H. Holding, "Direction of Motion Relationships Between Control and Displays in Different Planes," Journal of Applied Psychology, 41 (January 1957), 93-97.

[28] H. F. Jerison, "Effects of Noise on Human Performance," Journal of Applied Psychology, 43 (May 1959), 96-101.

[29] Khalil, "Design Tools and Machines," p. 32.

[30] Willie Hammer, Occupational Safety Management and Engineering (Chicago: Prentice-Hall, Inc., 1976), pp. 144-154; Vincent G. Bush, Safety in the Construction Industry: OSHA (Reston Publishing Company, 1975), pp. 1-34.

methods. Opinions differ widely concerning the necessary components of such programs.

Covert felt an important component of any safety program is the use of committees within each industry to serve as a monitor for safety organization. Covert suggested the establishment of a "Hazard Committee" to review and approve new materials in the plant.[31] Drawing from a 1974 fire prevention study, Belles outlined the need for another component of a sound safety program--that of a "plant emergency organization plan" and the training of all employees in the use of fire suppression equipment.[32] Similarly, this education component was recommended by Aeby in a 1976 study dealing with worker motivation and safety education.[33] This concept of safety motivation and education first gained attention in the writing of Heinrich.[34] Interestingly, Heinrich described the concept as "used by man to reduce injury since the beginning of time."[35]

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[31]Roy J. Covert, "An Occupational Health Study of a Selected Memphis Tennessee Chemical Plant," (consultant's report, 1975). Report on file at company office: 114 Trail East, Hendersonville, Tennessee.

[32]Donald Belles, "Fire Prevention Study - Tennessee Wheel and Rubber Company" (consultant's report, 1974). Report on file at company office: 114 Trail East, Hendersonville, Tennessee.

[33]Victor G. Aeby, "Loss Prevention Study for a Selected Rockford Illinois Manufacturing Plant" (consultant's report, 1976). Report on file at company office: 114 Trail East, Hendersonville, Tennessee.

[34]H. W. Heinrich, Industrial Accident Prevention (New York: McGraw-Hill, 1959), pp. 8-24.

[35]Ibid., p. 10.

Ellis identified five basic components of a safety program that should be used by government and industry for reducing work injuries and man-hour losses. Those components, quite general in nature, are 1) industrial safety laws and inspections, 2) employee safety training, 3) transmittal of accident statistics to company officials, 4) management-sponsored safety programs, and 5) economic sanctions.[36] Ellis's safety elements seemed to be consistent with the earlier, widely-read views of W. G. Johnson who wrote:

> The basic elements of a safety program should consist of 1) management implementation of a sound safety policy, 2) a defined hazard analysis process to minimize errors and oversights, 3) work situations which provide the environment and direction to enable people to perform capably and safely, 4) an information system which provides monitoring to promptly detect risks and deviations from safety plans, knowledge of hazards and correcting measures, and prompt feedback on safety performance, and 5) opportunity for all members of the organization to participate.[37]

One might conclude from the literature cited that there is no exact remedy, no one set of components of a safety program that can assure control of losses. Johnson's elements of safety organization, though thought to be a comprehensive approach, still largely are theoretical in nature and remain untested. Perhaps Chelius best sums up past efforts to

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[36] L. Ellis, "A Review of Research," p. 18.

[37] Johnson, MORT, pp. 131-132.

control losses by stating:

> We are at a point where further anecdotes and even theoretical developments are of limited value. Only by empirical analysis can we hope to develop programs which are based on more than just good intentions.[38]

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[38] J. R. Chelius, "The Control of Industrial Accidents: Economic Theory and Empirical Evidence," Law and Contemporary Problems (1974), pp. 38-40.

CHAPTER 3

METHOD AND DESIGN

Type of Research

This research was a comparative retrospective study of the number and cost of occupational injuries occurring at the Tennessee Wheel and Rubber Company from fiscal periods April 1, 1972 through March 31, 1974 and April 1, 1974 through March 31, 1976. Implementation of a MORT system safety method in April, 1974 allowed for statistical analysis of losses by using a basic comparative design. For the purposes of this research design, April 1, 1972 through March 31, 1974 served as the control period (pre-MORT period) and April 1, 1974 through March 31, 1976 served as the experimental period (post-MORT period).

Data Source

The data were hand collated by researching the Tennessee Wheel and Rubber Company's worker compensation reports for the pre-MORT and post-MORT time periods. Annual cost figures for occupational injuries were drawn from computer printout analyses provided by the company's insurance carrier, Reliance Insurance Company of Nashville, Tennessee.

Permission for using the Tennessee Wheel and Rubber Company's worker compensation reports and company insurance expense records was secured verbally from company president, James Hutton.

Method of Determining Occupational Injury Rate

In order to determine a reliable figure for the incidence of occupational injuries incurred for the twenty-four month pre-MORT and twenty-four month post-MORT periods, the calculations of injuries per one thousand man hours were needed. These values were obtained as follows:

$$\text{Occupational Injury Rate} = \frac{\text{Total Number of Occupational Injuries Per Month}}{\text{Total Number of Man Hours Worked Per Month}} \times 1000$$

An example of the procedure for calculating occupational injury is shown below:

(A) 6 recorded occupational injuries in March, 1973

(B) 3891 recorded total man hours worked in March, 1973

(C) $\frac{6}{3891} = .00154 \times 1000 = 1.54202$ per 1000 man hours

The mean scores for the pre-MORT and post-MORT periods were determined by summing the monthly rates over the twenty-four month control and the twenty-four month experimental periods.

Method of Determining Occupational Injury Cost Rate

Reliable figures for occupational injury cost rates for the pre-MORT and post-MORT periods were determined by calculating the annual cost of occupational injuries per one thousand man hours worked. These yearly cost values were obtained by utilizing the following formula:

$$\text{Occupational Injury Cost Rate} = \frac{\text{Total Cost of Occupational Injuries (Year)}}{\text{Total Number of Man Hours Worked (Year)}} \times 1000$$

An example of the procedure for calculating the occupational injury cost rate is as follows:

(A) \$12,550 total cost recorded for occupational injuries in 1973

(B) 119,500 recorded total man hours worked in 1973

(C) $\frac{\$12,550}{119,500}$ = .10502 x 1000 = \$105.02 per 1000 man hours

The mean occupational injury cost rates for the pre-MORT and post-MORT periods were then determined by summing the annual cost rates over the two-year experimental period and the two-year control period.

Statistical Technique

The use of a t-test was employed at the .05 level of significance to determine 1) whether there was a significant difference in the mean incidence rate of occupational injuries between the pre-MORT time period April 1, 1972 through March 31, 1974 and the post-MORT period April 1, 1974 through March 31, 1976; and, 2) whether there was a significant difference in the mean cost of occupational injuries between the pre-MORT and post-MORT periods at the Tennessee Wheel and

Rubber Company. The null hypotheses tested were,
1) Ho1 - there is no significant difference in the mean incidence rate of occupational injuries at the Tennessee Wheel and Rubber Company between the periods April 1, 1972 through March 31, 1974 and April 1, 1974 through March 31, 1976.
2) Ho2 - there is no significant difference in the mean cost of occupational injuries at the Tennessee Wheel and Rubber Company between the periods April 1, 1972 through March 31, 1974 and April 1, 1974 through March 31, 1976.

Summary

The research was a comparative study of the difference in the mean incidence rates and mean costs of occupational injuries at the Tennessee Wheel and Rubber Company between the periods April 1, 1972 through March 31, 1974 and April 1, 1974 through March 31, 1976. Using a t-test at the .05 level of significance, the null hypotheses were tested and the effectiveness of MORT implementation in terms of injury incidence reduction and cost reduction was determined.

CHAPTER 4

DATA ANALYSIS AND INTERPRETATION

The first hypothesis considered after data analysis was the hypothesis that stated: there is no significant difference in the mean incidence rate of occupational injuries at the Tennessee Wheel and Rubber Company between the periods April 1, 1972 through March 31, 1974 and April 1, 1974 through March 31, 1976. Table 1 presents the frequency of occupational injury, total man hours worked, and the occupational injury rate per one thousand man hours worked for the pre-MORT period.

Prior to computation of statistical differences between means, the occupational injury data for the post-MORT period had to be determined. The results are illustrated in Table 2.

The mean occupational injury rate per 1000 for the pre-MORT period was .553255 with a standard deviation of .29616. The mean occupational injury rate per 1000 for the post-MORT period was .372212 with a standard deviation of .22138. Upon determining these intermediate values for the pre-MORT and post-MORT periods, the t-test procedure was applied to determine if a significant statistical difference resulted in the mean occupational injury rates between the pre-MORT and post-MORT periods. The t-value was computed as follows:

Table 1

Occupational Injury Rate Per 1000 Man Hours Worked
by Month, Pre-MORT Years 1972-74

Month	Number of Injuries	Man Hours Worked	Injury Rate Per 1000 Man Hours
April '72	4	9,511	.42057
May	4	9,890	.40445
June	8	10,679	.74913
July	5	10,379	.48174
August	8	11,155	.71717
September	12	11,185	1.07287
October	5	11,487	.43539
November	3	11,509	.26067
December	10	9,261	1.07980
January '73	5	8,065	.61996
February	2	9,953	.20094
March	6	9,207	.65168
April	8	10,021	.79832
May	5	8,364	.59780
June	8	9,392	.85179
July	3	10,121	.29641
August	5	8,598	.58153
September	5	9,285	.53850
October	6	10,221	.58703
November	8	10,542	.75887
December	2	11,232	.17806
January '74	0	10,750	.0
February	0	10,560	.0
March	1	10,478	.99544
Total	123	241,844	13.27812

Table 2

Occupational Injury Rate Per 1000 Man Hours Worked by Month, Post-MORT Years 1974-76

Month	Number of Injuries	Man Hours Worked	Injury Rate Per 1000 Man Hours
April '74	6	10,202	.58812
May	5	10,123	.49392
June	4	10,200	.39216
July	5	10,532	.47474
August	5	10,386	.48142
September	5	9,880	.50607
October	4	9,950	.40201
November	5	11,159	.44807
December	4	8,120	.48900
January '75	4	5,467	.73166
February	1	5,467	.18292
March	2	5,475	.36530
April	5	5,533	.90367
May	3	6,308	.47559
June	1	10,046	.09954
July	3	9,872	.30389
August	3	10,066	.02998
September	5	11,283	.44314
October	6	10,927	.54910
November	1	11,554	.09655
December	1	8,472	.11804
January '76	2	8,128	.24606
February	0	8,237	.0
March	1	8,186	.12216
Total	81	215,573	8.93311

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{(n_1-1)(s^2 1) + (n_2-1)(s^2 2)}{(n_1 + n_2) - 2} \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

The resulting analysis yielded the following:

$$\frac{.55326 - .37221}{\sqrt{\frac{(23)(.29616)^2 + (23)(.22138)^2}{46} \left(\frac{1}{24} + \frac{1}{24}\right)}}$$

The calculations revealed a t-value of 2.398. This calculated t-value exceeded the critical value of 2.069 which resulted in the rejection of Ho^1. Therefore, the reduction in the mean occupational injury rate following MORT implementation is statistically significant at the .05 level.

The second hypothesis considered after data analysis was the hypothesis that stated: there is no significant difference in the mean cost of occupational injuries at the Tennessee Wheel and Rubber Company between the periods April 1, 1972 through March 31, 1974 and April 1, 1974 through March 31, 1976. The total cost of occupational injuries per year, the total man hours worked per year, and calculations of occupational injury cost per 1000 man hours worked for the pre-MORT years are presented in Table 3.

Occupational injury cost data in Table 4 presents the total cost of injuries, total man hours worked and the cost of injuries per 1000 man hours worked for the post-MORT years April 1, 1974 through March 31, 1976.

Table 3

Cost Per Year of Occupational Injuries
Per 1000 Man Hours Worked, Pre-MORT Years 1972-74

Total Cost Per Year	Man Hours Worked Per Year	Cost Per 1000 Man Hours Worked
$11,729.00	122,281	$ 95.92
$12,498.00	119,564	$104.53

Table 4

Cost Per Year of Occupational Injuries
Per 1000 Man Hours Worked, Post-MORT Years 1974-76

Total Cost Per Year	Man Hours Worked Per Year	Cost Per 1000 Man Hours Worked
$13,911.00	106,961	$130.06
$11,627.00	108,612	$107.05

Computation of mean occupational injury cost for the pre-MORT years yielded a mean value of $100.23, with a standard deviation of 4.3049. The mean occupational injury cost rate for the pre-MORT years was found to be $118.56, with a standard deviation of 11.5050. To determine whether a significant difference existed for the mean cost of occupational injuries between the pre-MORT and post-MORT years, the following t-test procedure was utilized:

$$t = \frac{x_1 - x_2}{\sqrt{\frac{(n_1-1)(s^2{}_1) + (n_2-1)(s^2{}_2)}{(n_1 + n_2) -2} (\frac{1}{n_1} + \frac{1}{n_2})}}$$

Statistical analysis of t is shown by the following:

$$\frac{100.22 - 118.56}{\sqrt{\frac{(1)(18.5322) + (1)(132.3650)}{2} (\frac{1}{2} + \frac{1}{2})}}$$

The resulting analysis determined a t-value of -2.1141. The calculated t-value was found to be less than the critical value of 12.706. Therefore, Ho^2 was not rejected and the difference in the mean cost of occupational injuries between the control and experimental years was found not to be significant.

Summary

In determining the statistical difference in mean occupational injury rates between the pre-MORT control period and the post-MORT experimental period, the calculated t-value of 2.398 was found to exceed the critical value of 2.069, thus rejecting Ho^1. Therefore, the mean occupational injury rate reduction following implementation of a MORT system safety method was statistically significant ($p > .05$).

Data analysis of the difference in mean cost of occupational injuries between the pre-MORT and post-MORT periods showed a t-value of -2.1141 compared to the critical value of 12.706, thus Ho2 was not rejected at the .05 level of confidence. Implementation of the MORT system safety method, therefore, was found not to be statistically significant in terms of the reduction in mean cost of occupational injuries between the control and experimental periods.

CHAPTER 5

CONCLUSIONS, RECOMMENDATIONS, AND SUMMARY

Conclusions

The statistical evidence brought forth from this research lends itself to several general conclusions. The most noteworthy of these conclusions is the implementation of a MORT system safety program at the Tennessee Wheel and Rubber Company on April 1, 1974 resulting in a statistically significant reduction in occupational injury incidence rate at that facility for the experimental period under study. Such a reduction in the incidence rate of occupational injuries could theoretically have a positive impact on total production, worker efficiency, and ultimately, company profits.

The statistical analyses has also led to the general conclusion that MORT implementation at the Tennessee Wheel and Rubber Company on April 1, 1974 did not reduce the cost of occupational injuries for the experimental period studied. The notable discrepancy in the findings of this research indicating a resultant reduction in incidence but not cost of occupational injuries following the introduction of a system safety program, deserves further consideration. This inconsistency in findings might be explained by the fact that is calculating the mean differences in the cost of injuries between the pre-MORT and post-MORT years, no adjustment factor was used to account for medical care cost inflation variance between the experimental years, 1972-1974, and the control years, 1974-1976.

Another explanation for the inconsistency in findings might be that since no differentiation of injury types was described in this research design, one cannot conclude that the severity of injuries in the pre-MORT period was to the same degree as in the post-MORT period. Even though the reported incidence of injuries was significantly reduced in the experimental period, the injuries that took place in the experimental period may have been more severe in nature, thus accounting for higher injury cost rates.

Recommendations

The conclusions derived from the research presented give rise to the following recommendations:

1. Any occupational health study designed to determine the effectiveness of a system safety program in reducing costs for injuries should concern itself with exact types of injuries incurred. Comparison of the severity of injuries between the research periods being studied will yield a more representative view of occupational injury costs.

2. Further research in system safety program effectiveness should take into account inflation variances for the years in study.

3. Management Oversight and Risk Tree (MORT) is a system safety method for analyzing various elements of safety

programs and provides certain guidelines for judging the effectiveness of safety program components within an industry. MORT does not, however, detail specific system safety techniques for reducing losses. For this reason, the safety techniques used within a particular industry will continue to vary from other industries despite introduction of a MORT system.

It is recommended that future research address the actual structure of the system safety program. This way any deficiencies of the safety program in the industry or industries being studied can be weighed against man hour losses in those industries. Analyzing each component of the safety program being researched would minimize the threats to the internal validity of the study that might result from industries that are grossly negligent in one or more facets of their safety programs.

Summary

The purpose of this study was to determine the effect of a MORT system safety program on the incidence and cost of occupational injuries at the Tennessee Wheel and Rubber Company. The time periods considered in this research were April 1, 1972 through March 31, 1974 (the control period) and April 1, 1974 through March 31, 1976 (the experimental period). Ho1, which stated: there is no significant difference in the mean incidence rate of occupational injuries between the pre-MORT and post-MORT periods, was rejected at the .05 level of significance. The statistical analysis (using a t-test) found the reduction in the mean occupational injury rate following MORT implementation to be statistically significant. Ho2 which stated: there is a significant difference in the mean cost of occupational injuries between the pre-MORT and post-MORT periods, was accepted by the use of a t-test at the .05 level of significance. Statistical analysis found the reduction in the mean cost of occupational injuries at the Tennessee Wheel and Rubber Company following MORT implementation not to be statistically significant.

The findings of this research are supportive of only a handful of studies attesting to the effectiveness of system safety in reducing occupational losses. Even in the aerospace industry where the MORT technique has gained the acceptance of top-level management, pilot study results have shown little more than an ability to assist persons from a discipline other than safety to quickly apply and broaden their skill in accident appraisal. Clearly, important gaps remain in knowledge of the efficacy of MORT system safety. Its application to general industry remains uncertain.

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