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INTEGRATED SAFETY MANAGEMENT INFORMATION SYSTEM PART I: DESIGN AND ARCHITECTURE

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ABSTRACT

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This paper, presented in two parts, introduces a total safety management information system designed to accomplish two primary tasks: (1) recording and maintaining accident and safety records of a large business concern and (2) determining the optimum allocations and utilization of safety resources. Part I addresses the design principles and architecture of a safety management information system. This includes description of system files, input records, and software. Samples of the different types of system output reports are given and discussed. Part II (to be published in next issue of this journal) of the paper illustrates the potential use of ISMIS decision algorithms in dealing with safety resources problems. Examples are included to demonstrate how the system can be used in the development and implementation of optimum safety inspection plans. The potential role of the system in maintaining and improving occupational safety and health programs is outlined.

INTRODUCTION

Recent years have witnessed tightening and expansion of the regulatory grip over United States industry and business concerns. Several pieces of legislation have been enacted which practically control what goes on inside and outside every plant. Common to all regulatory laws (regardless of scope, coverage, and purpose) is an assortment of report forms to be completed and maintained for several years by industry. Examination of these forms makes obvious the startling differences among them, even when they are supposed to record the same event. Experience suggests that the designers of regulatory forms have deliberately laid out these forms in such a way as to assure that equal processing time will be spent on each form.

A case in point is that of recording and reporting occupational accidents. To record such an event, the employer has to complete OSHA forms, workmen's compensation forms, special insurance forms, and other fiscal and accounting forms; and, if the accident involved spill of toxic materials or release of harmful gases, Environmental Protection Agency and Department of

Transportation special forms may be required. Although intended to report the same event, these forms differ in design, amount of detail required, type of information to be gathered, time allowed for completion or submission of reports, retention period for reports, number of copies to be produced, feasibility of making future changes in report contents, and — above all — in the level of skill and intelligence expected from the potential form processor.

Manual accident reporting systems neither offer much in terms of establishing cause—effect relationships among accident variables nor provide an easy mechanism for evaluating safety performance in industry. To simplify and improve accident record keeping, several companies, government agencies, and practically all the military services are now using computerized safety information systems. Extensive reporting on such systems has yet to appear in the literature. A comprehensive review of several accident data systems (both manual and computerized) can be found in King (1977).

Information systems

An information system is basically a set of interrelated rules and procedures for processing data to yield information or control action concerning the status of some functions or activities. Normally the title "information system" implies the use of a computer, but that is not a necessary part of the definition. The need for a computer is determined by the nature and volume of the system. A safety information system has several data processing characteristics, some of which are:

Monitoring: recording of accident data; statistics on frequency, severity, and nature of accidents and injuries; warnings about trends and events of concern; experience ratings; hazard identification;

Data base: storing status records on people, equipment, and dollar investments; response to inquiries about status, qualifications, and history; printing of OSHA regulations, prior reports, compliance history; hazard experience; technical experience;

Management: assistance in decisions about resource utilization, such as: budget planning; changes in inspection frequency; timing of layoffs, retraining; physical examination needs; revision of methods or procedures; equipment maintenance; load balancing among inspectors; means of compliance; situation correction;

Planning: samples to determine future capabilities, including: size and skills of workforce; training programs for new employees; equipment selection; inspection policies.

Most safety information systems stress record-keeping or clerical functions, with routine statistical reporting of data. The principal gain from their use, however, derives from improved decisions on utilization of people and equipment. The latter involves processing the data for information to support management decisions regarding the (a) need for action, (b) recognition and selection among alternative courses for action, and (c) timing of decisions and actions.

Although the two words are often used interchangeably, it is important to draw a distinction between data and information. Data relates to unstructured facts that are the raw material for information processing. The product should be structured for some particular use and is perishable, in that it is time dependent. For that product to be informative, it must be: (a) relevant to a pending decision, (b) timely for the problem to be solved, (c) accurate in regard to facts, and (d) sufficient, neither lacking nor excessive in detail. Most importantly, information must contain new insight or discovery rather than a rehash of facts already known by the decisionmaker.

Design considerations

Recording of data is a straightforward process, but generating information therefrom requires significant involvement of potential users or clients in the classic phases of creating the system. These include:

Analysis: feasibility analysis, statement of user requirements;

Design: specification in terms of outputs, files, input format, system controls, and documentation;

Development: writing of procedures and programs to meet specifications, design of forms, testing of programs and system;

Implementation: training of field and processing personnel, conversion of existing files, installation of the system;

Documentation: preparation of manuals for managers of functions influenced by the system as well as operators and users of the system; and

Evaluation: determination that benefits and costs of operating the system are commensurate and meet original requirements.

A system designed to process safety data must face several specific considerations. Generally, these systems are heavily oriented toward recording facts and reporting statistics in standard formats. The usefulness of these data as a basis for decisions relative to equipment utilization, personnel assignment, hazard correction, or budget planning is limited.

The accuracy and completeness of input is a particular problem. Incidents to be recorded are generally low in frequency of occurrence for any given work unit. This suggests that clerks or safety engineers specially trained to investigate circumstances and prepare input may not be cost-justifiable. Entries must often be made by relatively untrained, decentralized supervisors who identify and classify characteristics of accidents and injuries. The forms used in most organizations require complete description of people, equipment, and circumstances, rather than assuming that certain facts, such as current employee position, are available in existing files. This requires recording of "static" data and complicates the effort to fill out forms by employees who have infrequent need to do so and thus have little opportunity to learn the process.

Safety system files usually cover substantial lists of hazards, including equipment inventory and people. These create problems in regard to number of records to be stored and updated. Changes are continually being made, resulting in additions and deletions to existing records. Back up files or reconstruction in case of loss or destruction become important issues. Rarely is the responsibility for control over content well defined. While equipment data is often a public issue, entries about individuals are normally private in nature and require security to protect confidentiality.

The data base orientation is also concerned with prompt updating and fast response to inquiry from relatively large files that are related but not directly integrated. This necessitates code compatibility and consistent formats to allow cross references among the contents of the safety data base. Typically the safety data base includes: (a) status and archival records, (b) transaction histories, (c) performance summaries and statistics, (d) environmental data, (e) tables, (f) directories, and (g) action "tickler" files. Thus, the data base is generally quite large in relation to the volume of accident or incident entries to be made, and so the size and nature of files is an important consideration. In addition, transaction activity needs to be considered in terms of both average and peak arrival rates.

File organization also depends on the pattern and density of records affected by the input transactions. Input forms are a vital concern in safety systems. The basic principle of eliminating or consolidating forms, copies, and entry items strongly suggests separating "static" reference data from "dynamic" data describing the event being reported. The former can be retrieved from data files through the use of some key identities in the report, eliminating repetitive entry of fixed data. The broader the audience exposed to the form, the greater the effort must be to ease reading, entry, and handling characteristics. The layout should aid the control user to make accurate and complete use. To assist in transcribing data from the form to the data base, the content should be generalized and standardized to structure entries and minimize write-ins that are subject to varied interpretation.

There are two principal considerations in designing safety (accident) reports: purpose and user. Differences in the purpose of forms result in differences in the type of information and level of details to be gathered. For example, some forms are used to collect data for planning purposes, while others gather data for monitoring purposes. The scope and content of these forms are different, and consequently the format also varies considerably.

With respect to the form user, there are two extremes to be taken into consideration. It may be possible merely to state the purpose of collecting the information and then to ask a competent safety professional to gather data he deems appropriate as well as essential for recording the event under consideration. Or, it may be necessary to assume that the person who will be asked to gather the information is not skilled in the task at hand, and a detailed form complete with specific entries and questions must be provided. This form in the hands of a person possessing some basic skills (e.g., familiarity with the work place) will produce a detailed, structured report that can be read and understood by others.

The approaches to designing forms for these two extremes of users are fundamentally different. On the one hand, the user is given complete control over what should be reported and how details should be entered. On the other hand, the opposite approach eliminates most of this freedom; it reduces the task of reporting to one of selecting appropriate words and phrases from a given list. Most regulatory forms are designed on the latter principle. The obvious advantage of this second approach rests with the standardization that can be exercised over safety reports completed by different individuals separated in time and in space. In practice, however, many safety data bases contain erroneous information because the user did not know how to use the form successfully, and the opportunity for guess work was overwhelming.

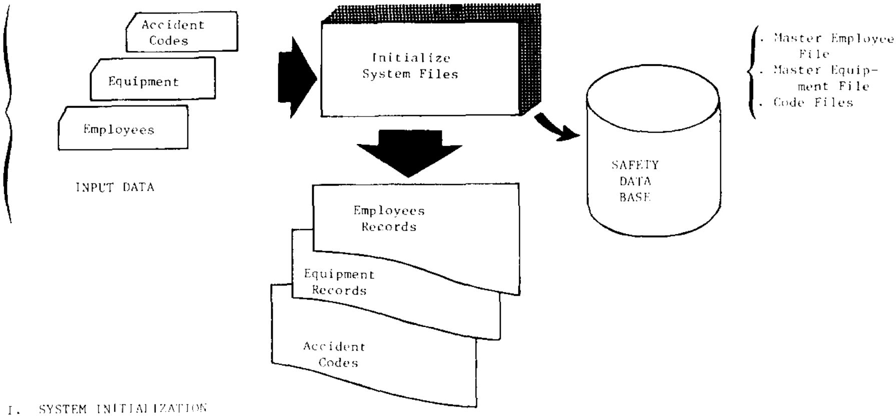
For a comprehensive review of the various design and implementation aspects of management information systems, see Hartman, Mattches, and Proeme (1972).

ISMIS OVERVIEW

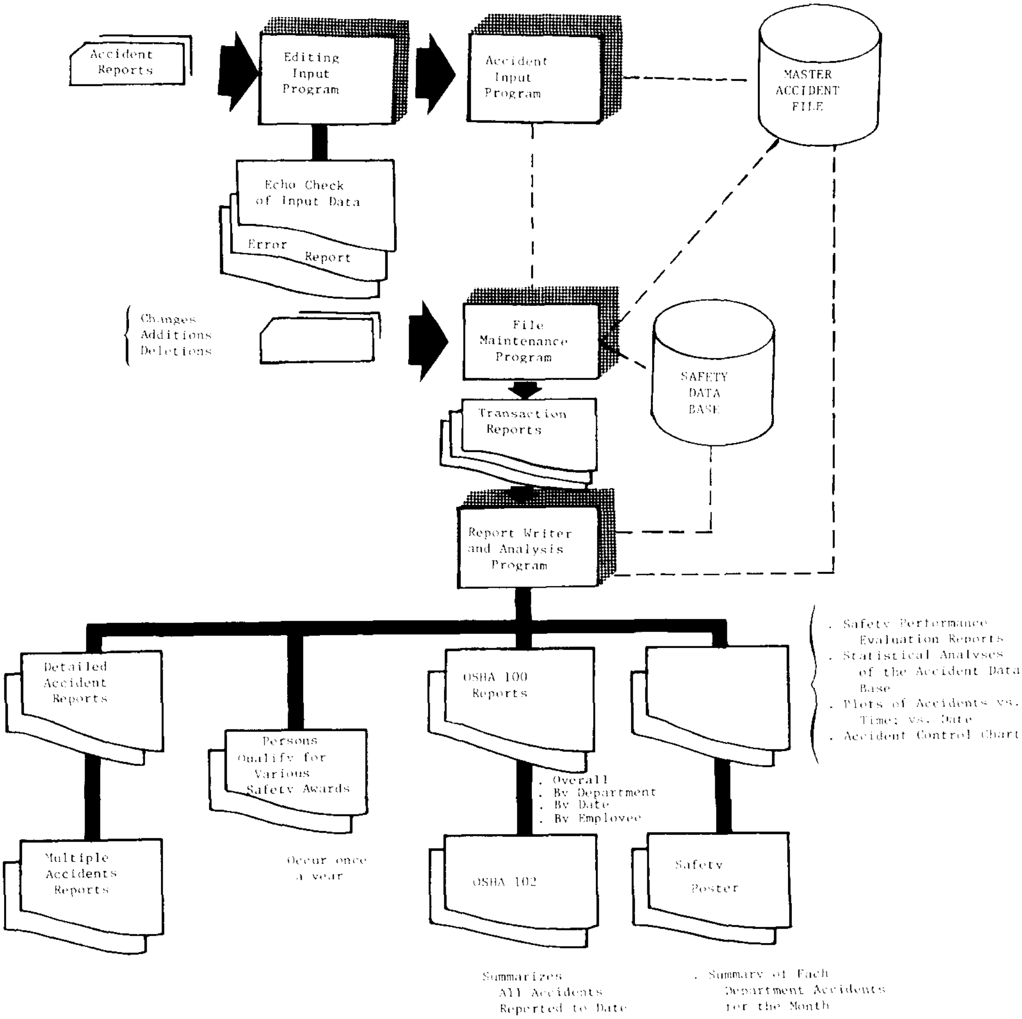
ISMIS is a comprehensive, Integrated Safety Management Information System which maintains data on injuries and illnesses as well as on the types and availability of safety resources within the organization. Input to the system (when used in the normal mode) consists of partially coded data and other related information on the various aspects of the accident experience. In addition to generating a host of standard accident reports, ISMIS provides the user with a number of quantitative tools which can be used to determine the modes for the effective utilization of safety resources, to evaluate the effects of certain policies on the overall safety performance of the organization, and to conduct various types of hazard analyses.

The philosophy behind ISMIS is centered around meeting five primary design objectives: (1) the user should be required to provide an absolute minimum of input reports; (2) the sytem should be simple to modify and/or expand at will; (3) the system should be capable of automatically performing a number of common safety management decisions which are routine to many safety programs; (4) the output modes of the system should allow for the generation of user-oriented reports typical of accident cause-effect studies; (5) the system should guard (via a comprehensive editing routine) against erroneous input data.

There are several alternatives for developing the computer software necessary for implementing a safety management information system: (a) writing the complete system software from the ground level up, using one of the higher level computer languages, such as COBOL, PL/I, or perhaps FORTRAN; or (b) adopting one or more of the already existing computer packages to piece together the necessary software that will be compatible with the system design and objectives. Both approaches have their pros and cons insofar as hardware requirements, development and testing time, reliability of the system, language of package constraints, and limitations are concerned. This paper presents a system that utilizes Statistical Analysis System, SAS (Barr, Good-



I. SYSTEM INITIALIZATION



II. DATA MANAGEMENT

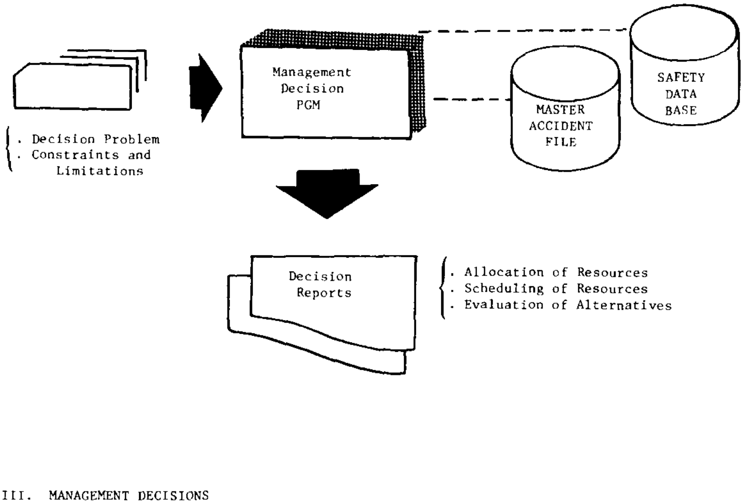


Fig. 1. System flow chart. (I) System initialization, (II) data management, (III) management decisions.

night, and Sall, 1976; Helwig, 1977), for data management and file maintenance. In addition, the system uses several FORTRAN-based algorithms to facilitate management safety decisions.

The major software components of ISMIS are data management and management decisions (see Fig. 1). These are described below.

Data management

ISMIS data management comprises the performance of four primary information handling tasks: (1) building data files, (2) updating the files (allows for adding, replacing, deleting, and/or modifying data records and fields), (3) retrieving selected records or specific data items from the files, (4) displaying file contents in several forms which may vary from detailed reports to trend charts and summary statistics. ISMIS accomplishes these four information tasks by utilizing SAS to build and maintain several data files. Data are inputted to the files via a comprehensive accident report. SAS contains a host of procedures (modules) that can be used separately or collectively for sorting, merging. updating, subsetting, and editing of files; producing detailed reports and summary charts; and performing a number of well-established statistical analyses, such as discriminant analysis, frequency and cross tabulation, analysis of variance, least square fitting, and stepwise regression.

There is no restriction on either the form or source of data to be inputted to a SAS program. The user has complete freedom in formating his input records. Further, SAS can accept data from punched cards, tapes, and disks. SAS input procedures deal with observations (records) one at a time; and, as such, manipulation of the data elements across several records is difficult, if not impossible. Also, array manipulation statements typical of many programming languages (e.g., FORTRAN and PL/I) are not possible with typical SAS procedures and statements. To overcome this limitation, SAS provides the user with a special procedure called MATRIX. Through the use of MATRIX, coupled with other SAS input procedures, a full-fledged programming language is made available. SAS offers a number of procedures for report writing, plotting (regular graphs and contour maps), insertion of appropriate titles and headings on each page of the output, and preparation of title pages using oversized prints.

Files. ISMIS maintains three master files: employee file, accident file, and equipment file. The employee file contains all employee data deemed necessary for producing required accident and safety reports and for the conduct of various types of analyses. Table 1 summarizes the data elements of a record

TABLE 1

Employee record

1. Name
2. Social Security number
3. Address
4. Sex
5. Race
6. Nationality
7. Birth date
8. Marital status
9. Number of children
10. Physical/physiological characteristics
    - —Weight
    - —Height
    - —Vision
    - —Hearing
    - —Work Capacity
11. Work restrictions
12. Education
13. Safety training
14. Special licenses or certificates
15. Job title
16. Employment date
17. Number of jobs held prior to joining the organization
18. Current salary
19. Average number of hours worked per day
20. Performance rating
21. Number of accidents to date
22. Number of days lost due to accidents
23. Number of days on sick leave
24. Number of days absent
25. Medical or treatment costs

in the employee file. Records in the file are accessed by the employee's social security number, and the file is updated continuously.

The accident file is the major master file of ISMIS, containing all the accident and safety data reported to ISMIS. Following each reporting of an accident, it automatically updates the employee and equipment files. A single accident report form (see AID input form below) provides the input to the accident file, and most of the statistical analyses of the accident data base are performed on the contents of this file. For detailed reporting of accidents, the three files are used to form a super working file that is used extensively throughout the program to produce all necessary reports and to conduct all the required statistical analyses.

The equipment file maintains records on all major pieces of equipment within the organization. Of particular importance here is the information kept on (a) special characteristics of the equipment, (b) applicable safety and health standards, and (c) the recommended safety assurance procedure after equipment utilization. Table 2 summarizes the data elements of each record of the equipment file.

In addition to the three master files. ISMIS has several small files describing various accident codes used for reporting. Table 3 gives a listing of the major

TABLE 2

Equipment record

1. Equipment identification number
2. Description
3. Function
4. Replacement cost
5. Days used/year
6. Auxiliary pieces used with the equipment
7. Skills or training required for operation
8. Hazard rating
9. Status of inspection for OSHA compliance
10. Applicable safety and health standards (subpart)
11. Safety assurance procedure
12. Total number of accidents to date

TABLE 3

Accident code files

1. Nature of injury
2. Part of body
3. Agency of accident
4. Type of accident
5. Hazardous condition
6. Unsafe act
7. OSHA injury/illness classification

categories of the codes adopted, which are those developed by ANSI and OSHA. These files are used to replace the coded information on the accident reports with appropriate descriptors. In other words, in reporting an accident, numeric codes are used to provide a full account of what actually happened. These

TABLE 4

Accident report — AID

PART A. Accident (injury/illness) data

1. Report number
2. Department
3. Location
4. Type of location
5. Supervisor's name
6. Supervisor's Social Security number
7. Date of accident
8. Time of accident
9. Day of week
10. Type of accident
11. Hazardous condition
12. Accident description

PART I. Injury/illness data; to be completed for each person involved

1. Report number
2. Name of employee
3. Employee's Social Security number
4. Job performed at time of accident if different from regular job
5. Nature of injury
6. Part of body
7. Source (agency) of injury
8. Unsafe act
9. OSHA injury/illness code
10. Safety equipment in use at time of accident
11. Date disability began
12. Date of fatality if injury or illness resulted in death
13. Lost work days
14. Days of restricted activities
15. Termination or transfer
16. New occupation or title
17. Cost of injury/illness
18. Name of physician
19. Address of physician
20. Name of hospital
21. Address of hospital

PART D. Damage data; to be completed for each piece of equipment involved

1. Report number
2. Equipment identification number
3. Description of damages
4. Name of operator
5. Social Security number of operator
6. Cost of damages

codes are then replaced by their respective descriptors or labels for producing output reports and analyses. All three master files are stored on line for easy editing and maintenance. Indeed, all of them can be edited via the use of CRT.

Input. In reporting an accident — any accident, whether it is a first aid case or results in serious multiple injuries — the data collected can be divided into two types: (1) data that describe the persons, equipment, and things involved in or contributing to the accident event, and (2) data describing the accident event itself; e.g., date, agency of accident, and unsafe act. Clearly, the first type of data can be collected and stored prior to reporting the accident. In contrast, the second type of data can not be predicted *a priori.* Accordingly, all the data have to be reported in full.

In recognition of these two types of data and in the interest of keeping the amount of input data to ISMIS to a minimum, a two-step approach is used for generating complete accident reports. First, all data concerning what actually happened, how it happened, etc. is collected. In addition, key identifiers for persons (e.g., social security numbers) and equipment are recorded. Second, using the system files and the key identifiers, full information on all persons and pieces of equipment involved in the accident is retrieved from appropriate files. Next, the retrieved and reported data are combined to produce the full accident report.

The ISMIS AID input form is designed according to the approach just described. Specifically, ISMIS operates on the data derived from a single accident/injury/damage form — AID (see Table 4). The purpose of the AID form is to provide comprehensive coverage of all accidents/incidents. This includes all personal injuries, equipment damages, tort claims, and all incidents of occupational illness. This form is designed to collect data on the *what*, *when*, *where*, *who*, *why*, etc.— all aspects of occupational accidents.

The ISMIS AID input form combines the salient features of existing accident reporting forms (Workmen's Compensation Form, OSHA 100, etc.). By using one comprehensive, yet specific, form to report all accidents, the confusion associated with describing the same event in several different ways can be avoided, and the time spent repeating the same information on at least five different forms (all required to meet state and federal regulations) can be minimized. ISMIS, using the information reported by the input form, will produce required copies of the regulatory reports and other management reports.

Management decisions

As an aid to the management decision process, several FORTRAN-based algorithms are made available to ISMIS users. These modules include several mathematical programming routines and a simulation program. The inclusion of the decision algorithms is intended to help management arrive at decisions concerning the allocation of safety resources and the development and implementation of safety policies and procedures.

In brief, the management decision algorithms of ISMIS can be used to accomplish the following:

a. An optimum allocation of safety resources (personnel, time, funds, etc.);

b. The scheduling of safety resources (e.g., determination of an optimum safety inspection) and the development of balanced safety work for field engineers; and

c. The selection among competing alternatives (e.g., determination of plans for optimum compliance with OSHA standards).

In addition, the ISMIS decision algorithms can be used to identify: (a) locations (departments) where an epidemic of accidents/incidents become evident; (b) locations (departments) which experience (chronic) numbers of accidents/incidents; (c) locations (departments) which have need of immediate attention from the Safety Department; and (d) potential problem areas based on monitoring and evaluating pre-accident performance (symptoms of accidents).

System output

Exhibits 1 through 10 provide samples of the system output and reports, based on hypothetical accidents added to the system files.

Exhibit 1 is a partial listing of the coded accident reports as inputted to the system. In other words, it is simply a mirror image of what was reported to ISMIS. Exhibit 2 shows the edited input reports, i.e., it presents a listing of the reports after all revisions (additions and deletions) have been accounted for. This output is produced as an echo check for the data transmitted to the system. In this particular case, the revisions included:

1. Additions of two reports which reference the same accident. Notice that the two reports carry the same number, 771001. This is an indication that the accident resulted in multiple injuries (see Exhibit 5).

2. The name of the supervisor on report number 12386 has been changed to read "R.G. Pearson".

3. For report number 12393, several changes have been made: (a) the list of safety equipment in use at the time of accident has been expanded to include hat, shoes, and gloves; (b) the cost reported for the injury has been reduced from $25,000 to $3,333; and (c) the injury has been reclassified as an occupational illness and, as such, given an OSHA injury/illness code of 25 instead of the 10 previously reported.

Exhibit 3 shows a sample listing of the accident reports with codes replaced by the corresponding descriptors or labels. Because of page size limitations, each report is produced in four parts. Part I details general employer data, date and time of accident. Part II covers employee data, including such things as name, social security number, and personal characteristics. Parts III and IV (not shown) fully describe the accident involvement using ANSI and OSHA codes. Missing data (information not provided or entry on the accident form not applicable) are indicated by either a period for numerical variables or left blank for character variables.

S A F E T Y M A N A G E M E N T I N F O R M A T I O N S Y S T E M

ACCIDENT REPORTS--PARTIALLY CODED

R_NUM	CITY	FUNCTION	DEPT	EMP_PREM	SUP_NAME	SUP_SSN	D_MO	D_DY	D_YR
12386	KILL DEVIL HILL	SPECIAL STUDIES	TRAFFIC RECORDS	N	R G HUGHES	526789342	1	14	75
12393	KILL DEVIL HILL	SPECIAL STUDIES	TRAFFIC RECORDS	Y	R G HUGHES	526789342	2	29	74
12345	MURFREESBORO	MAPPING:URBAN	SECONDARYROADSCOUNCI	N	J E RAY	515348725	12	12	77
12342	WILLIAMSBURG	VEHICLECLASSIFICATIO	TRAFFIC RECORDS	Y	A G GASSMAN	434669650	8	12	76
12358	WILLIAMSBURG	ADMINISTRATION	ADMINISTRATION	Y	J L LEIGH	525348245	9	16	76
12368	SEVERN	HIGHWAYSTATISTICS	FISCAL	N	L P HIGHSMITH	414367289	10	14	78
12372	ELIZABETH CITY	VEHICLE CLASSIFICATI	REGISTRATION	Y	ROGER O HOLSHAUSER	813259784	11	3	75
12348	GARYSBURG	ROAD INVENTORY	SECONDARY ROADS	N	F T HERMON	919843650	5	14	77
12346	GARYSBURG	ROAD INVENTORY	SECONDARY ROADS	Y	Z T HERMON	919843650	3	4	76

R_NUM	DAY	TIME	NAME	SOC_NUM	SEX	AGE	M_STATUS	LENG_EMP	TITLE	REG_OCC	NI_CODE	PR_CODE
12386	TUESDAY	14.26	RANDOLPH H SHORT	414632445	M	32	M	4	ENGINEER III		2	4
12393	MONDAY	14.38	DAWN L HIGGENDORF	414367842	F	22	O	2	OPERATOR	FOREMAN	3	5
12345	TUESDAY	16.24	JOHN V GUGGENHEIM	313486725	M	24	M	4	MECHANIC IV	FOREMAN	2	2
12342	FRIDAY	4.13	JULIA T WASINGER	211169115	F	28	M	4	OPERATOR		1	1
12358	SUNDAY	16.24	THOMAS A PATTERSON	141489736	M	38	M	20	OPERATOR		5	5
12368	MONDAY	14.45	LOUISE M MAKEPEACE	515489675	F	48	O	12	CLERK III		1	2
12372	MONDAY	11.22	JONATHAN F WINTERS	424778653	M	18	S	1	MECHANIC III	OPERATOR	3	4
12348	SATURDAY	3.25	GEORGE A LANGSDON	828459725	M	47	O	20	OPERATOR		4	10
12346	WEDNESDAY	10.32	CECELIA L WALSH	424678321	F	30	S	8	MAINTENANCE	ENGINEERING	7	8

R_NUM	AG_CODE	AC_CODE	HC_CODE	UA_CODE	INJ_CODE	SAF_EQU	DIS_DATE	FAT_DATE	D_LOST	D_RESTRI	NONFATAL	TER_TRAN	TRA_OCCP	COST
12386	5	3	2	4	10	NONE	01/30/75	05/15/77	100	50		X	SUPERVISOR	20000
12393	3	4	3	2	10	GLASSES		10/10/78	99	100				25000
12345	2	2	2	2	22	MASK			.	.	X	X		30
12342	1	1	1	3	10	H.SHOES	08/03/75	09/05/80	200	300				50000
12358	5	5	5	5	25	GLOVES			.	30	X	X		.
12366	3	4	3	2	10	HAT			10	.	X			200
12372	3	3	2	1	10	HARD HAT		09/09/78	10	100				30000
12348	5	5	4	3	21	NONE	12/31/73		.	.	X	X		20
12346	3	2	5	3	10	NONE			20	30				1000

Exhibit 1. Partial listing of coded accident reports.

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* S A F E T Y M A N A G E M E N T I N F O R M A T I O N S Y S T E M *

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REVISED ACCIDENT REPORTS

R_NUM	CITY	FUNCTION	DEPT	EMP_PREM	SUP_NAME	SUP_SSN	D_MO	D_DY	D_YR	DAY
12342	WILLIAMSBURG	VEHICLECLASSIFICATIO	TRAFFIC RECORDS	Y	A G GASSMAN	434669650	8	12	76	FRIDAY
12345	MURFREESBORO	MAPPING:URBAN	SECONDARYROADSCOUNCI	N	J E RAY	515348725	12	12	77	TUESDAY
12346	GARYSBURG	ROAD INVENTORY	SECONDARY ROADS	Y	Z T HERMON	919843650	3	4	76	WEDNESDAY
12348	GARYSBURG	ROAD INVENTORY	SECONDARY ROADS	N	F T HERMON	919843650	5	14	77	SATURDAY
12358	WILLIAMSBURG	ADMINISTRATION	ADMINISTRATION	Y	J L LEIGH	525348245	9	16	76	SUNDAY
12368	SEVERN	HIGHWAYSTATISTICS	FISCAL	N	L P HIGHSMITH	414387289	10	14	78	MONDAY
12372	ELIZABETH CITY	VEHICLE CLASSIFICATI	REGISTRATION	Y	ROGER D HOLSHAUSER	813259784	11	3	75	MONDAY
12386	KILL DEVIL HILL	SPECIAL STUDIES	TRAFFIC RECORDS	N	R G PEARSON	526789342	1	14	75	FRIDAY
12393	KILL DEVIL HILL	SPECIAL STUDIES	MAINTENANCE	Y	R G HUGHES	526789342	3	14	75	MONDAY
771001	RALEIGH	ENGINEERING	INDUSTRIAL ENG	Y	W A SMITH	111000	6	3	77	MONDAY
771001	RALEIGH	ENGINEERING	INDUSTRIAL ENG	Y	W A SMITH	111000	6	3	77	MONDAY

R_NUM	TIME	NAME	SOC_NUM	SEX	AGE	M_STATUS	LENG_EMP	TITLE	REG_OCC	NI_CODE	PB_CODE	AG_CODE	AC_CODE
12342	4.13	JULIA T WASINGER	211169115	F	28	M	4	OPERATOR		1	1	1	1
12345	16.24	JOHN V GUGGENHEIM	313486725	M	24	M	4	MECHANIC IV	FOREMAN	2	2	2	2
12346	10.32	CECELIA L WALSH	424678321	F	30	S	8	MAINTENANCE	ENGINEERING	7	8	3	2
12348	3.25	GEORGE A LANGSDON	828459725	M	47	D	20	OPERATOR		4	10	5	5
12358	16.24	THOMAS A PATTERSON	141489736	M	38	M	20	OPERATOR		5	5	5	5
12368	14.45	LOUISE M MAKEPEACE	515489675	F	48	D	12	CLERK III		1	2	3	4
12372	11.22	JONATHAN F WINTERS	424778653	M	18	S	1	MECHANIC III	OPERATOR	3	4	3	3
12386	9.30	RANDOLPH H SHORT	414632485	M	32	M	4	ENGINEER III		8	4	5	3
12393	14.38	DAWN L HIGGENDORF	414367842	F	22	D	2	OPERATOR	FOREMAN	3	5	3	4
771001	16.00	M.A. BOUYA	222333	F	40	D	10	TYPING		2	2	2	2
771001	16.00	M.A. AYOUB	345678923	M	40	D	10	TYPING		2	2	2	2

R_NUM	HC_CODE	UA_CODE	INJ_CODE	SAF_EQU	DIS_DATE	FAT_DATE	D_LOST	D_RESTRI	NONFATAL	TER_TRAN	TRA_OCCP	COST
12342	1	3	10	H.SHOES	08/03/75	09/05/80	200	300				50000
12345	2	2	22	MASK			.	.	X	X		30
12346	5	3	10	NONE			20	30				1000
12348	4	3	21	NONE	12/31/73		.	.	X	X		20
12358	5	5	25	GLOVES			.	30	X	X		.
12368	3	2	10	HAT			10	.	X			200
12372	2	1	10	HARD HAT		09/09/78	10	100				30000
12386	2	4	10	NONE	01/30/75	05/15/77	100	50		X	SUPERVISOR	500
12393	3	2	25	GLASSES HAT SHOES GLOVES		10/10/78	20	30				3333
771001	2	1	10	NONE	08/03/77		20	30		X		400
771001	2	1	10	NONE	08/03/77		20	30		X		400

Exhibit 2. Revised accident reports.

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SAFETY MANAGEMENT INFORMATION SYSTEM

.... DETAILED ACCIDENT REPORTS ....

*** PART I ***

CODED LABELS

R_NUM=REPORT NUMBER EMP_PREM=EMPLOYER PREMISES SUP_NAME=SUPERVISOR SUP_SSN=SOCIAL SECURITY NUMBER D_MO=MONTH D_DY=DAY D_YR=YEAR

R_NUM	CITY	FUNCTION	DEPT	EMP_PREM	SUP_NAME	SUP_SSN	D_MO	D_DY	D_YR	DAY	TIME
771001	RALEIGH	ENGINEERING	INDUSTRIAL ENG	Y	W A SMITH	111000	6	3	77	MONDAY	16,00
771001	RALEIGH	ENGINEERING	INDUSTRIAL ENG	Y	W A SMITH	111000	6	3	77	MONDAY	16,00
12372	ELIZABETH CITY	VEHICLE CLASSIFICATI	REGISTRATION	Y	ROGER D HOLSHAUSER	813259784	11	3	75	MONDAY	11,22
12345	MURFREESBURG	MAPPING:URBAN	SECONDARYROADSCOUNCI	N	J E RAY	515348725	12	12	77	TUESDAY	16,24
12368	SEVERN	HIGHWAYSTATISTICS	FISCAL	N	L P HIGHSMITH	414387289	10	14	78	MONDAY	14,45
12393	KILL DEVIL HILL	SPECIAL STUDIES	MAINTENANCE	Y	R G HUGHES	526789342	3	14	75	MONDAY	14,38
12342	WILLIAMSBURG	VEHICLECLASSIFICATIO	TRAFFIC RECORDS	Y	A G GASSMAN	434669650	8	12	76	FRIDAY	4,13
12348	GARYSBURG	ROAD INVENTORY	SECONDARY ROADS	N	F T HERMON	919843650	5	14	77	SATURDAY	3,25
12346	GARYSBURG	ROAD INVENTORY	SECONDARY ROADS	Y	Z T HERMON	919843650	5	4	76	WEDNESDAY	10,32
12386	KILL DEVIL HILL	SPECIAL STUDIES	TRAFFIC RECORDS	N	R G PEARSON	526789342	1	14	75	FRIDAY	9,30
12358	WILLIAMSBURG	ADMINISTRATION	ADMINISTRATION	Y	J L LEIGH	525348245	9	16	76	SUNDAY	16,24

*** PART II ***

---- CODED LABELS ----

R_NUM=REPORT NUMBER NAME=EMPLOYEE SOC_NUM=SOCIAL SECURITY # M_STATUS=MARITAL STATUS LENG_EMP=LENGTH OF EMPLOYMENT 7
TITLE=TASK PERFORMED REG_OCC=OCCUPATION N_INJURY=NATURE OF INJURY

R_NUM	NAME	SOC_NUM	SEX	AGE	M_STATUS	LENG_EMP	TITLE	REG_OCC	N_INJURY
771001	M.A. BOUYA	222333	F	40	O	10	TYPING		CUT
771001	M.A. AYOUB	345678923	M	40	O	10	TYPING		CUT
12372	JONATHAN F WINTERS	424778653	M	18	S	1	MECHANIC III	OPERATOR	BRUISES AND CONTUSIONS
12345	JOHN V GUGGENHEIN	313486725	M	24	M	4	MECHANIC IV	FOREMAN	CUT
12368	LOUISE M MAKEPFACE	515489675	F	48	O	12	CLERK III		FOREIGN BODY
12393	DAWN L HIGGENDORF	414367842	F	22	O	2	OPERATOR	FOREMAN	BRUISES AND CONTUSIONS
12342	JULIA T WASINGER	211169115	F	25	M	4	OPERATOR		FOREIGN BODY
12348	GEORGE A LANGSDON	828459725	M	47	O	20	OPERATOR		STRAIN AND SPRAIN
12346	CECELIA L WALSH	424676321	F	30	S	8	MAINTENANCE	ENGINEERING	AMPUTATION
12386	RANDOLPH H SHORT	414632485	M	32	M	4	ENGINEER III		HERNIA
12358	THOMAS A PATTERSON	141489736	M	39	M	20	OPERATOR		FRACTURE

Exhibit 3. Detailed accident reports — Part I and II.

Exhibit 4 lists all accidents which resulted in injuries and/or illnesses to more than one person. In the case at hand, only one such accident was reported, and it involved only injuries to two persons. The motivation behind singling out major accidents is to assure that their occurrence will be communicated to all supervisors as well as to management for their thorough investigation and analysis. Other criteria can be defined and used to flag accidents that should receive special attention.

Exhibit 5 ranks the departments according to each of the following: total number of accidents, number of illnesses, total number of fatalities, total number of days lost and total number of nonfatal accidents. For this particular example, we assumed that all departments and supervisors had identical manhours of exposure, and so no rates were used. In cases where hours of exposure vary, ranking will be based on relative frequency or severity rates (depending on the measure used) determined from the hours of exposure supplied for each supervisor and department, with each entry assigned an appropriate rank. The ranks given change from low to high; a low figure implies good performance, and a high figure means a poor performance that warrants careful evaluation and study. Supervisor's safety performance is ranked in a similar manner.

ISMIS generates plots of various accident indicators (total number of accidents, number of fatalities, number of days lost, etc.) versus time of day and day of week. These plots provide a time picture of the distribution of accidents over working hours as well as days. Careful examination of the plots can reveal the influence of certain events (holidays, adverse weather conditions, changes in work content or in the characteristics of the work force, etc.) on the overall safety performance within the organization. Exhibit 6 is a summary of the total number of accidents given on an hourly basis. A 24-hour clock is used to present time on the plot. It should be clear that the accident—time plots do not delineate the contribution of a specific variable to the causation of accidents; instead they are merely "barometer" charts which exhibit the collective effects of human, workplace, and organizational variables upon the type and number of accidents experienced by the organization.

Frequency analysis can be performed on practically all possible combinations of the variables contained in ISMIS files. This type of analysis can highlight the subset of variables which contributes the most to the causation of accidents. For instance, frequency analysis can be used to study the effects of variables such as sex, age, job type, and level of supervision upon the occurrence of accidents. Armed with this detailed information, management can define appropriate accident counter-measures that would have the potential to yield the greatest contribution to the improvement of the organization's safety performance. Exhibit 7 is a sample frequency table produced by ISMIS.

Exhibit 8 is a sample control chart on the lost-time accidents. The purpose of such a chart is to study the degree of control offered by the safety program over the accident process. A normal distribution is assumed for the accident

```
                                                          18:34 THURSDAY, OCTOBER 5, 1978   10
              * S A F E T Y   M A N A G E M E N T   I N F O R M A T I O N   S Y S T E M *
                 ACCIDENTS WHICH RESULTED IN MULTIPLE INJURIES/ILLNESSES
                                ---- CODED LABELS ----
D_MO=MONTH  D_DY=DAY  D_YR=YEAR  R_NUM=REPORT NUMBER  MUL_INJ=NUMBER OF INJURIES  MUL_ILL=NUMBER OF ILLNESSES
```

D_MO	D_DY	D_YR	R_NUM	MUL_INJ	MUL_ILL
6	3	77	771001	2	0

Exhibit 4. Accidents which resulted in multiple injuries and/or illnesses.

```
                                                          18:34 THURSDAY, OCTOBER 5, 1978   34
              * S A F E T Y   M A N A G E M E N T   I N F O R M A T I O N   S Y S T E M *
                 SAFETY PERFORMANCE EVALUATION OF THE DEPARTMENTS
NOTE: EVALUATION IS BASED ON RANKING THE DEPARTMENTS IN TERMS OF THE NUMBER OF CASES REPORTED FOR INJURY/ILLNESS
      CATEGORIES.  DEPARTMENTS ARE RANKED FROM BEST TO POOR
                                ---- CODED LABELS ----
NUM_ACC=ACCIDENTS  NUM_ILL=ILLNESSES  NUM_FAT=DEATHS  NUM_DLST=DAYS LOSTNUM_NONFA=NONFATALS  R_...,R_..., =RANKS
```

DEPT	NUM_ACC	NUM_ILLN	NUM_FAT	NUM_DLST	NUM_NONF	R_ACC	R_ILLN	R_FAT	R_DLST	R_NONF
ADMINISTRATION	0	1	0	0	1	2.0	6.5	3.0	1.5	6.5
FISCAL	1	0	0	10	1	5.0	2.5	3.0	3.5	6.5
INDUSTRIAL ENG	2	0	0	40	0	7.5	2.5	3.0	7.0	2.5
MAINTENANCE	0	1	1	20	0	2.0	6.5	6.5	5.5	2.5
REGISTRATION	1	0	1	10	0	5.0	2.5	6.5	3.5	2.5
SECONDARY ROADS	1	1	0	20	1	5.0	6.5	3.0	5.5	6.5
SECONDARYROADSCOUNCI	0	1	0	0	1	2.0	6.5	3.0	1.5	6.5
TRAFFIC RECORDS	2	0	2	300	0	7.5	2.5	8.0	8.0	2.5

Exhibit 5. Safety performance evaluation of departments. Columns headed by "Num" summarize the number of observations in each category; those headed by "R" give the corresponding ranks by department.

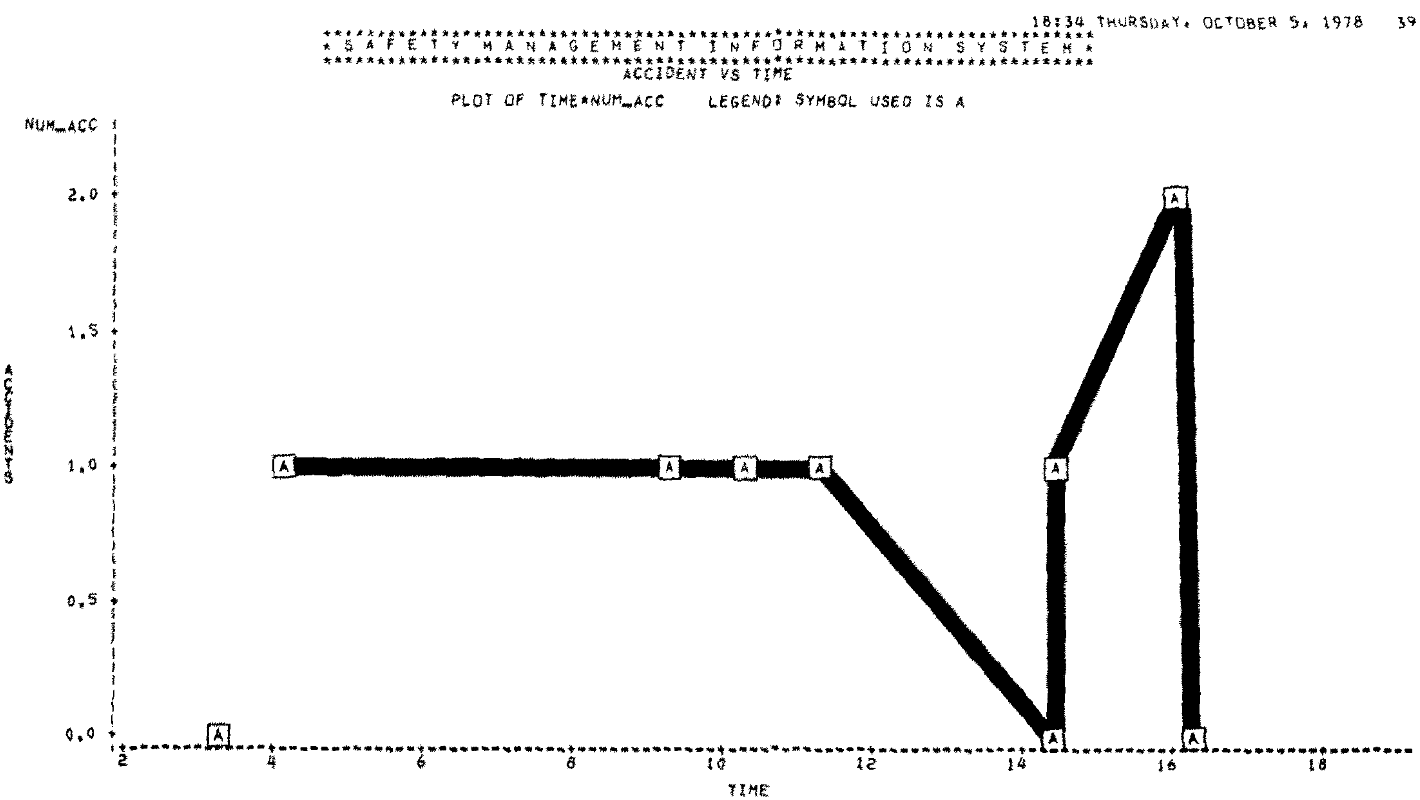

Exhibit 6. Plot of accident vs. time of day.

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* S A F E T Y M A N A G E M E N T I N F O R M A T I O N S Y S T E M *

.... FREQUENCY ANALYSIS OF INJURY/ILLNESS DATA ....

----- CODED LABELS -----

D_LOST=DAYS LOST N_INJURY=NATURE OF INJURY TER_TRAN=TERMINATION/TRANSFER P_BODY=PART OF BODY SUP_NAME=SUPERVISOR
LENG_EMP=LENGTH OF EMPLOYMENT D_MO=MONTH D_DAY=DAY

TABLE OF DEPT BY N_INJURY

DEPT / N_INJURY FREQUENCY PERCENT ROW PCT COL PCT	AMPUTATION	BRUISES AND CONT	CUT	FOREIGN BODY	FRACTURE	HERNIA	STRAIN AND SPRA	TOTAL
ADMINISTRATION	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	1 9.09 100.00 100.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	1 9.09
FISCAL	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	1 9.09 100.00 50.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	1 9.09
INDUSTRIAL ENG	0 0.00 0.00 0.00	0 0.00 0.00 0.00	2 18.18 100.00 66.67	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	2 18.18
MAINTENANCE	0 0.00 0.00 0.00	1 9.09 100.00 50.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	1 9.09
TOTAL	1 9.09	2 18.18	3 27.27	2 18.18	1 9.09	1 9.09	1 9.09	11 100.00

EXAMPLE:
Number of Observations (#)

Frequency (#/Total for all Cases)

Row Frequency (#/Row Total)

Column Frequency (#/Column Total)

Exhibit 7. Frequency analysis of department by nature of injury.

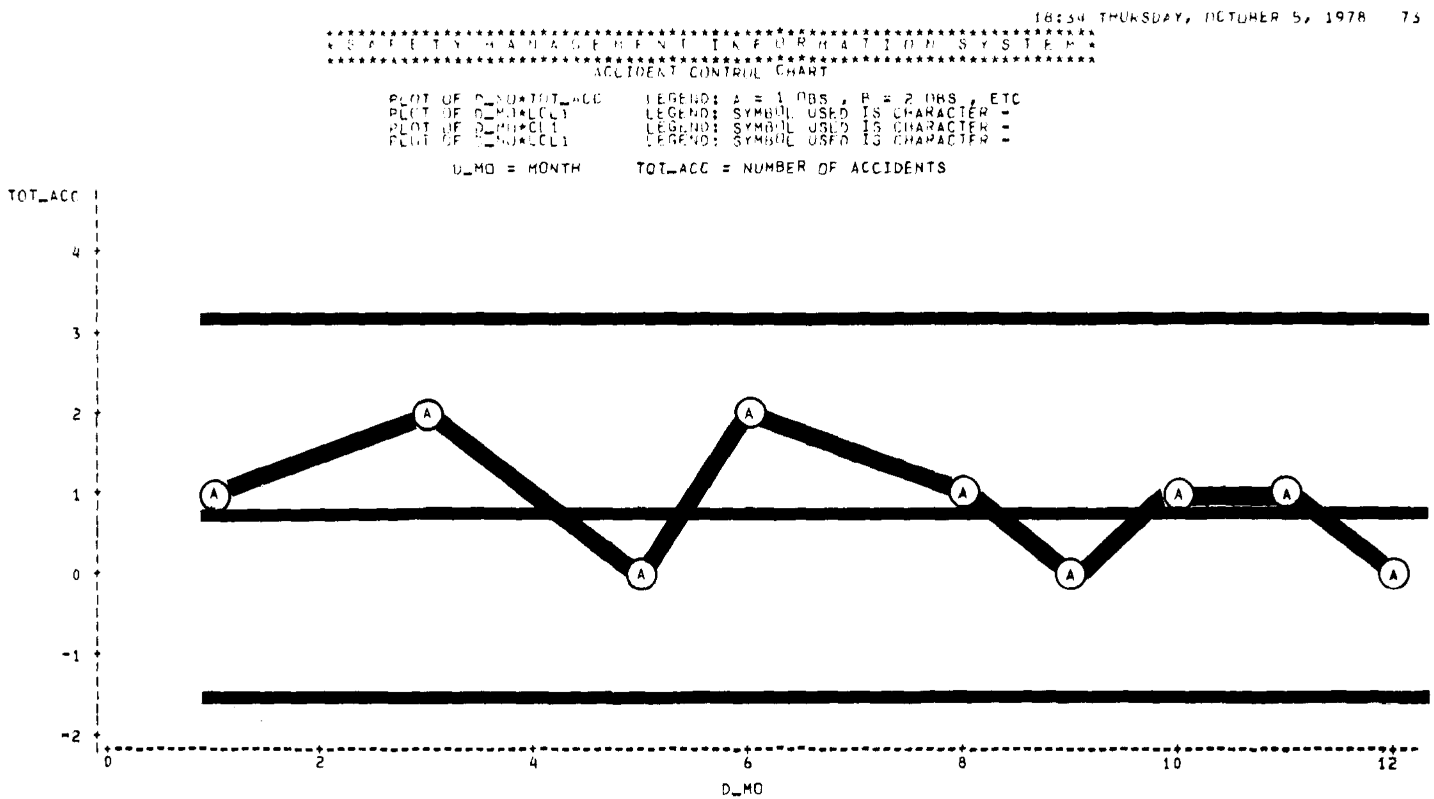

Exhibit 8. Accident control chart.

event. The upper and lower limits are computed as follows:

$UCL = u + 3\sigma$

$LCL = u - 3\sigma$

where u and σ indicate average and standard deviation, respectively. A Poisson distribution-based chart can be produced by the system if desired. The system also provides control charts on the number of nonfatal accidents and total number of serious accidents. As long as individual observations (accidents) remain within the control limits, it can be safely assumed that the reported accidents were the result of some random events and so no special corrective measures or actions should be taken. On the other hand, if the chart(s) displays a specific trend or pattern (e.g., observations are consistently falling on one side of the center line, or successive observations are continually approaching the lower or upper limits), then remedial actions should be instituted. The presence of such patterns should be viewed as an early warning that the safety program is not functioning properly. In this case, management would be justified in asking for and executing a comprehensive audit of the safety program. The actions to be instituted based on the results displayed by the control charts are left to the discretion of management. However, it is possible to program ISMIS to detect certain trends or patterns and issue appropriate messages and instructions.

Occasionally the system employee file may be scanned to determine those employees who qualify for various categories of safety awards. Based on predetermined rules, the system can produce an award report as shown in Exhibit 9.

Exhibit 10 is a sample output of the "knapsack" algorithm of the management decision component of ISMIS (see Part II of the paper). Of eight candidate departments, the system selected only four as departments which could be inspected without exceeding the allocated time of 70 man-hours. The hazard rating of each department is given by (see Exhibit 5):

Rank on Total Number of Accidents × Rank on Total Days Lost

Again, we are assuming that all departments accumulate the same number of man-hours of exposure. If this is not the case, then the hazard rating of each department should be set equal to its frequency—severity indicator; i.e., $F \times S/1{,}000$, where F and S are accident and frequency rates, respectively.

A word of caution is warranted here. All the output reports should be evaluated on the basis of their forms and the type of information they reveal. And certainly no conclusions should be drawn based on their contents, for the obvious reason that the data base used to generate them is fictitious. The purpose here is to show the form and level of detail which ISMIS reports can display.

In summary, ISMIS can generate three major types of output reports: (1) accident reports, (2) statistical analysis reports, and (3) management decision reports. Specifically, ISMIS can produce the following:

a. Monthly summary of accidents reported to ISMIS.

b. Quarterly accident cost analysis reports.

```
18:34 THURSDAY, OCTOBER 5, 1978   78
*****************************************************************
* S A F E T Y   M A N A G E M E N T   I N F O R M A T I O N   S Y S T E M *
*****************************************************************
          EMPLOYEES QUALIFY FOR TWO-YEAR-SAFETY-AWARDS
```

SOC_NUM	NAME	SUP_NAME	DEPT	YEARS
141489736	THOMAS A PATTERSON	J L LEIGH	ADMINISTRATION	2.35251
424678321	CECELIA L WALSH	Z T HERMON	SECONDARY ROADS	2.99452

Exhibit 9. Safety awards.

```
13:14 FRIDAY, JANUARY 12, 1979   1
*****************************************
* SAFETY MANAGEMENT INFORMATION SYSTEM *
*****************************************
--- S A F E T Y   I N S P E C T I O N   P L A N ---
.... OPTIMUM SELECTION OBTAINED BY USING THE KNAPSACK LOADING ALGORITHM
                                --- CODES ---
TIME=REQUIRED INSPECTION TIME   HAZARD=HAZARD RATING BASED ON PAST PERFORMANCE
```

DEPARTMT	TIME	HAZARD	INSPECT
ADMINISTRATION	4	3.0	NO
FISCAL	7	17.5	YES
INDUSTRIAL ENGI	15	22.5	YES
MAINTENANCE	20	11.0	NO
REGISTRATION	10	17.5	NO
SECONDARY ROADS	21	27.5	YES
SECONDARYROADSCONC	18	3.0	NO
TRAFFIC RECORDS	35	60.0	YES

Exhibit 10. Optimum inspection plan.

c. Complete set of OSHA reports (100, 101, 102), for each operating unit, each division, and the overall department. It should be mentioned that at the time of writing this paper OSHA has already adopted a new form in lieu of the 100 and 102 forms. Modifying the system output to conform to the new form is a simple task and should not constitute any substantial revisions in the structure of the system files.

d. Listing of all major accidents that should be communicated to all supervisors. ISMIS can also be programmed to produce safety posters which basically summarize pictorially the different personal injuries experienced by each department during a given reporting period.

e. Evaluation of safety performance of individuals, supervisors, and departments.

f. All pertinent reports needed for performing special studies relative to accident causes and effectiveness of certain safety and accident counter measures.

g. Management decision reports concerning the optimum allocation and scheduling of safety resources.

ACKNOWLEDGEMENT

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Over the last three years several of my students have — in and outside the classroom — contributed much to the formulation and the development of some of the concepts and examples presented in this paper. The list of their names is understandably long, but some names do suggest themselves: Henry Mitchell, Mustafa Pulat, Robert Hawkins, and Robert Smillie. Professor W.A. Smith, Jr. of North Carolina State University has contributed much to the preliminary definitions and concepts of Part I of the paper. To these and all others, my sincere appreciation.

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