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HUMAN FACTORS IN RAILROAD OPERATIONS: ACTIVITIES IN FISCAL YEAR 1973

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FEBRUARY 1974

TECHNICAL REPORT

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16. Abstract

This is an interim report covering human factors services rendered by TSC to the FRA under the project: "Human Factors in Railroad Operations," during fiscal year 1973. It reviews all activities briefly and contains more detailed reports on a research plan for use with a locomotive cab simulator, a training survey, studies of train handling, and fault-tree analysis of railroad accident data.

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PREFACE

"Human Factors in Railroad Operations" is a continuing program of consulting and research conducted by the Human Factors Branch of the Transportation Systems Center under the sponsorship of the Office of Research, Development and Demonstrations, Federal Railroad Administration (FRA). The purpose of the project is to provide technical knowledge related to human behavior in support of FRA activities in the interest of improved safety and efficiency in railroad operations.

This report is an interim report on project activities conducted during Fiscal Year 1973 under Project Plan Agreement RR309. The report serves three purposes: to summarize all aspects of the project for FY 73 (Section 2.0); to report in some detail the progress on uncompleted tasks (Sections 4.0 and 5.0), and to present final reports of subtasks, the results of which do not warrant individual publication (Sections 3.0 and 6.0).

In addition to the authors, TSC staff members Dr. H.P. Bishop, Dr. Anne W. Story and Dr. C.N. Abernethy made significant contributions to the project.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT.)

TABLE OF CONTENTS (CONT.)

LIST OF ILLUSTRATIONS

LIST OF TABLES

1. INTRODUCTION

1.1 PURPOSE AND SCOPE

The Department of Transportation's Transportation Systems Center (TSC) is conducting a continuing program of consultation and research in human factors for the Federal Railroad Administration (FRA), entitled: "Human Factors in Railroad Operations". The purpose of this program is to provide technical skills and knowledge in the areas related to human behavior needed by the FRA in support of their efforts to promote safety in railroad operations. This report summarizes the work accomplished in Fiscal Year 1973 on this project.

1.2 BACKGROUND

1.2.1 Requirements of Federal Railroad Safety Act

Public Law 91-458; 84 Stat. 971, "The Federal Railroad Safety Act of 1970", provides in part that, in order to promote safety in all areas of railroad operations, the Secretary of Transportation shall:

> ....(1) prescribe, as necessary, appropriate rules, regulations, orders, and standards for all areas of railroad safety supplementing provisions of law and regulations in effect on the date of enactment of this title, and (2) conduct, as necessary, research, development, testing, evaluation, and training for all areas of railroad safety.

The Federal Railroad Administration was delegated the responsibility for implementing this act. Recognizing that in an industry employing over half a million personnel, human performance must be a significant contributory factor in operational safety, the FRA sought professional guidance on human factors. Essentially, what the FRA required was the answers to such questions as:

a. How can human error contribute to railroad accidents?

b. What are the minimum criteria of physical and mental fitness and job skills consonant with safety?

c. What is the minimum training required to achieve these criteria?

d. How can posession of these criteria be measured?

1.2.2 Goals and Structure of Program

The goals of the project are to analyze what is known of railroad operations; to determine and evaluate minimum criteria for physical and mental fitness, for job knowledge, job skills and training; to develop appropriate methods for identification and measurement of these criteria; to evaluate the reliability, validity, and efficacy of these criteria and tests; and to conduct research in areas where additional knowledge is needed.

The general structure of the program involves development and evaluation of criteria, pursuit of research, and consultation as required. In many job areas, it has been necessary to conduct intensive job analyses and general surveys to provide a data base for deriving criteria. In areas where more information is needed, research is planned and conducted; where appropriate, research is undertaken in cooperation with other programs having related goals. Table 1-1 summarizes the principal efforts of the program, past, present and projected. The activities in the first column (FY72) were reported on in detail in an interim report (Devoe, et al, 1972). The activities in the second column (FY73) are the subject of this report.

TABLE 1-1 PROGRAM STRUCTURE

	Fiscal Year 1972	Fiscal Year 1973	Fiscal Year 1974	FY 1975 and Beyond
CRITERIA				
Physical Fitness	Study-All Personnel	Recommend-All Pers.	Evaluate	
Use of Drugs and Alcohol	Study-All Personnel	Recommend-All Pers.	Evaluate	
Operating Rules		Study, Recommend	Recommend	Evaluate
Job Knowledge, Job Skills, Training	Study-Engineer	Study-Dispatcher Conductor Brakemen	Recommend- Engineer, Dispatcher, Conductor, Brakemen	Evaluate
Proficiency Tests			Study- Engineer, Dispatcher, Conductor, Brakemen	Recommend, Evaluate
Psychological Fitness				Study, Recommend, Evaluate
RESEARCH				
Train Handling	Study, Develop Techniques	Develop Techniques, Start Experiments	Continue Experiments, Evaluate	
Cab Safety	Study	Study, Plan Experiments	Monitor Experiments, Evaluate	
Cab Vigilance			Develop Techniques, Start Experiments	Continue Experiments, Evaluate
Simulation	Study, Recommend	Plan Experiments	Aid in Procurement	Conduct Studies
Accident Causes	Study	Evaluate		
Vandalism	Study, Recommend			
Human Engineering of Equipment				Study, Evaluate, Recommend

2 PRINCIPAL TASKS OF FY73

2.1 INTRODUCTION

The principal tasks of FY73 will be reviewed briefly. Advisory memoranda and reports deriving form these tasks and submitted separately to the FRA will be cited. Reports not previously submitted will be added as sections of this report.

2.2 JOB ANALYSES

2.2.1 General

To generate a data base from which criteria can be derived for job knowledge, skills and training consonant with operational safety, detailed analyses of jobs and tasks have been undertaken for the engineer, conductor, brakemen, and train dispatcher. Portions of these analyses constituted a major activity in the work of FY73.

2.2.2 Locomotive Engineer

In FY72, the job of the locomotive engineer, particularly as his performance affects safety, was studied in detail for road-freight operations. A summary of the nature of the job was included in the first interim report (Devoe et al., 1972), and a more detailed breakdown of tasks was performed under contract and reported separately (McDonnell Douglas, 1972). In FY73, the only additional effort in this area was the distribution of the McDonnell Douglas report to sixteen selected carriers for evaluation. Comments were solicited on the basic accuracy of the report and on whether it, and other reports like it, might have some general value to the industry in addition to providing working data for derivation of job criteria. Table 2-1 shows the form of the questionnaire that accompained the report, including a summary of the responses on the seven questionnaires that were returned.

TABLE 2-1 RETURNS ON QUESTIONNAIRE ON MCDONNELL DOUGLAS REPORT

Sent: 16
Returned: 7

1. In what way can this task analysis be useful to you?

   3 As a basis for operating rules modifications
   4 As support to safety manual/procedures
   3 As a training aid
   1 Other Handbook for Shop Crew
   1 Not useful

2. If the report does not accurately reflect your operating procedures, what changes would your recommend? (Include corrections, deletions, additions, particularly with regard to emergency procedures. Use additional sheets as necessary.)

   1. Correct but misleading - discipline, reliability, attitudes make locomotive engineer - disagree with relative ratings of freight passenger, and yard service.
   2. Term "engineman" should be "locomotive engineer".

3. Could you use similar analyses of other operating crew functions? YES 2 NO 5

4. If YES, what additional jobs would you like to see analyzed? (Put 1 before your first choice, 2 before your second, etc.)

1 Engineman (Yard and Hump)	___ Yard Crewman
2,2 Fireman	___ Ways and Structures Foreman
___ Brakeman/Flagman	___ Ways and Structures Crewman
___ Conductor	1,5 Dispatcher/Operator
3,3 Road Foreman	___ Switchman
___ Yard Foreman	4 Other Engine House Foreman

Mail in Attached Self Addressed Envelope

The respondents noted no serious errors of fact in the report. Two respondents commented at some length, one on the report's inapplicability as a training manual or rating device, the other on its length and detail, which seemed excessive to him. Four respondents felt that the report might be useful as a reference for preparing safety and procedural manuals; three each saw utility in support of modifying operating rules and training; one felt it would make a good handbook for a shop crew, and one could see no use of it for his needs. Five respondents were not interested in receiving similar documents for other crew functions. The rankings of the additional jobs that the other two respondents would like to see analyzed were remarkably similar (see Table 2-1).

The principal conclusions to be drawn from this small survey are: (1) The McDonnell Douglas report is accurate in its description of the locomotive engineer, and (2) there is little point in distributing such reports widely within the industry, since their content and format are not directly related to felt needs in the industry.

2.2.3 Train Dispatcher

A principal effort of the FY73 program was the detailed analysis of the job of train dispatcher. An exhaustive study was made of the duties of one position on one railroad, including observations for entire working shifts, photography of the work position, and collection and study of samples of all documentation prepared by the dispatcher. Summary charts of the tasks of this position were prepared detailing step by step the actions and decisions involved in six major job functions. Field trips were made to dispatching offices of six other carriers. Operations were observed, tape recorded and photographed; dispatchers and supervisors were interviewed, and samples of relevant documents were obtained. The original analyses were modified as required by the field data to produce a job description representative of train dispatching operations throughout the country. A draft of the full report of this effort has been submitted to the FRA, entitled: "An Analysis of the Job of Railroad Train Dispatcher."

2.2.4 Train Crew

Detailed job analyses were also required for the members of the train crew other than engineer, namely: conductor, front end brakeman and rear end brakeman (flagman). In February 1973, funds were transferred to Crane Naval Ammunition Deport, Crane, Indiana, to cover the accomplishment of these analyses by Crane human factors personnel. The work is currently in progress. Observations have been made by Crane personnel on freight runs with several carriers, riding both the locomotive and caboose. This job is scheduled for completion in the first quarter of FY74.

2.3 SIMULATOR PROGRAM

In FY72, the utility of a computer-run locomotive and cab simulator for human factors research was evaluated, and it was recommended that the FRA procure such a facility. Performance specifications for such a simulator were prepared, and a discussion of its value for research on railroad safety was included in the first interim report (Hill, in Devoe et al., 1972). A final decision as to whether to procure a simulator is still pending.

In FY73, a task was established to do initial planning of experiments that might be run on such a simulator. A research plan was prepared detailing general guidelines for research on the simulator, guidelines for preparation of scenarios, design of validation studies, design of four research sequences, and preparation of four specific problem packages. This material constitutes Section 3 of this report.

2.4 PHYSICAL FITNESS, DRUGS AND ALCOHOL

Recommendations of criteria for physical fitness for all railroad jobs and/or standards for the control of the use of drugs and alcohol were programmed to be derived in FY73 from studies made in FY72. At the request of the Office of Standards, FRA, these recommendations were submitted in August, 1972, ahead of schedule.

The specification of criteria for the regulation of certain physical disabilities was particularly difficult for several reasons: the disabilities are difficult to diagnose; their impact on the safe performance of railroad jobs is unclear or controversial; or they present special problems in the assurance of compliance. Through a contract with the Lahey Clinic, Boston, Massachusetts, a series of interviews was conducted with specialists in the individual areas. Tape recordings of these interviews were analyzed, and a report was prepared summarizing conclusions and recommendations, reviewed by the Lahey specialists, submitted to the Office of Safety, FRA, in May 4, 1973, for comments, and is being prepared for publication under the title: "Recommendations to the FRA Concerning Critical Factors in Railroad Employee Medical Standards."

2.5 OPERATING RULES

It has long been recognized that some railroad operating rules are confusing, conflicting, ambiguous, hard to understand, hard to obey and hard to enforce and that these difficulties can lead to railroad accidents (NTSB,1971;NTSB,1972). To improve this situation, the FRA has undertaken a program "...looking toward the development of specific operating requirements through a future rule-making proceeding," announced in the Federal Register, Vol. 38, No. 92, May 14, 1973.

In anticipation of this program, TSC was requested to study the content of current codes of operating rules, to develop techniques for rules analysis, to identify problems, and generally to prepare to assist the FRA in future efforts to assure intelligibility of standard codes of rules.

In FY73, several efforts with regard to operating rules were undertaken, including: a keyword analysis of the contents of the AAR Standard Code of Operating Rules, a comparison of the contents and organization of the rule books of different carriers, a functional classification of the AAR rules, and attendance at meetings of the Operating Rules Association. The results of these efforts were reported to the FRA, Office of Safety, (RA 622) in a memorandum dated December 21, 1972.

As a result of these analyses, techniques were developed that may be applied in the future evaluation of the rules of rail carriers. In addition, the principal factors contributing to confusion, ambiguity and lack of intelligibility of rules were identified. As an aid to avoidance of such problems in future rule-writing, a set of guidelines for writing intelligible rules was prepared and published as a Technical Report (Devoe and Story, 1973).

2.6 ACCIDENT DATA

In FY72, the utility of railroad accident statistics for identifying human factors in accident causation was evaluated and reported (Feehrer, in Devoe et al., 1972). The use of a fault-tree technique for data analysis was recommended as a means for gaining additional insight into the interrelationships in the chains of events leading to railroad accidents.

In FY73, the fault-tree technique was adapted for application to railroad accident data and evaluated on data from the Office of Safety's annual Accident Bulletins. Although the technique showed promise, the available data were not detailed enough to permit in-depth analysis with a potentially useful yield. Therefore, it was recommended that no further study be conducted along these lines until such time as changes in the reporting of railroad accidents may provide a suitable data base. A detailed description of the technique and the evaluation constitutes Section 6 of this report.

2.7 CAB HAZARDS

2.7.1 Introduction

Train collisions in which a steel caboose rose from its wheels, overrode the heavy underframe of a colliding locomotive and crushed the cab, killing or seriously injuring the occupants, have occured frequently enough, even at low speeds, to be a matter of serious concern to the industry. In 1971, an ad hoc group, the

Locomotive Control Compartment Committee (LCCC), was formed to attack this and related problems. The LCCC is composed of members from the FRA, the Association of American Railroads, the Brotherhood of Locomotive Engineers and the United Transportation Union. Several other agencies provide regular advisory and consultation services to the LCCC, and TSC, under the present project, has assisted the committee in matters relating to human factors.

In FY73, a TSC staff member attended most of the LCCC meetings in an advisory capacity. Under the technical guidance of this project, a survey of human engineering factors in locomotive cabs was released (Jankovich, 1972). The recommendations of this report were given serious consideration by the committee, and several projects were initiated in response to them and to other data provided the committee.

2.7.2 LCCC Activities

Two classes of cab hazards were identified in the LCCC studies. First, the severe damage to cabs experienced in collisons (as noted above) results in death or severe injury to crew members. Although relatively few in number, these casualties are of great concern, because some collisions occur at speeds only a little above coupling speeds, and coupling operations occur frequently as part of the every day operations of railroads. The second class of casualties involves injuries received in minor accidents and mishaps which, although less serious in nature, occur much more frequently (Kurz, 1972).

2.7.2.1 Collision Hazards - The LCCC has focussed on anti-collision posts, deflecting pilots ("snowplows"), energy-absorbing devices and general strengthening of the cab structure as possible methods for increasing the survivability of train collisions. The committee consulted with the principal locomotive manufacturers and maintained close contact with the Canadian National Railways (CNR). The CNR studied cab design from the point of view of safety and habitality, adopted a standard for cab design in 1972, and specified that standard for a fleet of new locomotives now entering the active inventory. The LCCC visited the CNR in 1972, received briefings on the cab design and inspected a cab mockup.

In spite of progress in the industry, the LCCC became convinced that not enough is yet known about the dynamics of train collisions at and immediately after impact to permit new standards of design to be adopted with assurance that survivability will be enchanced. It was therefore proposed that studies be undertaken in which measurements and photographs would be made during experimentally controlled collisions of surplus locomotives. The CNR proposed a set of specifications for locomotive crash tests in March 1973, and the committee, with the help of special studies by the AAR, has been engaged in modifying these specifications and planning the actual tests.

As a part of its consulting function, TSC, under the present project, submitted a memorandum to the FRA (RA 612) on May 10, 1973, recommending that dummies be placed in some of the cabs and photographed during the tests to acquire more information on accelerations imparted to the human body at impact, motion of the body after impact, collision of the body with fixed objects and surfaces in the cab, and collision of the body with moving objects in the cab. Initial reaction of the committee has been favorable, and TSC expects to take an active part in the crash tests through its services to the LCCC.

2.7.2.2 Other Causes of Cab Injuries - A study of accident data (Kurz, 1972) commissioned by the committee showed a variety of sources of injuries to personnel in locomotive cabs, including cases of failure of defective equipment (especially seats), injuries related to operation of equipment (especially jamming fingers in doors and windows), and cases of slipping and falling against equipment and surfaces. Fumes, smoke and gas in the cab, electrical shock and fires, and eye injuries were also noted.

The general approach by the LCCC to this miscellany of problems has been to undertake an effort aimed at the design of a "clean" cab... one so designed as to minimize sharp edges, protruding objects, slippery surfaces, breakable material, hazardous controls and the like as sources of injuries. Through the AAR, each of the two principal locomotive manufactureres has been commissioned to prepare a cab mock-up suitable for hazard evaluation. TSC anticipates an active role in such studies.

Other areas of concern to the committee included noise, visibility and ventilation in the cab. Two areas have received special attention by the committee: seating and fumes.

2.7.2.3 Seating - The Jankovich report (1972) highlighted the lack of support and adjustability of seats in American locomotives as compared to European locomotives, and the Kurz report (1972) showed a high incidence of injuries due to seat failures. The LCCC therefore has undertaken an effort to review seating technology and to prepare one or more specifications for locomotive cab seat design that might be adopted as standards by the AAR. TSC is conducting this study (under PPA RR414) with the cooperation of the Human Factors Branch.

2.7.2.4 Fumes - In some train accidents, cab crews complained of loss of consciousness due to fumes in the cab, yet subsequent investigation showed no leakage from the engine room. However, the engine exhaust contain high concentrations of lethal and toxic gases (Southern Pacific, 1972), and the circulation of the exhaust around the cab under various environmental conditions is not known. Some controlled studies of fumes in the cab in a tunnel (Thompson, 1973) have yielded no evidence of a hazard in this regard, but the conditions and types of locomotives sampled were very limited. The possibility of sudden influxes of concentrated exhaust gases through the cab window will continue to be a matter of concern of this project.

2.8 SKILL ACQUISITION

One factor in the assurance that railroad personnel have the basic job knowledge and skills needed to perform their jobs safely is the specification of minimum requirements for training on those jobs. As preparation for consultation with the FRA on criteria for adequacy of training, TSC undertook in FY73 a survey of current practices and trends in the industry with regard to training of train crew members and train dispatchers. This survey is currently under way. A report on its objectives and progress is given below as Section 4 of this report.

2.9 TRAIN HANDLING

Early in this project, the desirability of recording the events within a locomotive cab during normal operations was recognized. In FY72, equipment was developed and pretested that would record physiological behavior of the engineer while operating a locomotive (Sussman, in Devoe et al., 1972). Continuation of this work to expand the instrumentation capabilities to the recording of correlated cab events and to collect field data was initially provided for as a subtask of the human factors project.

A joint FRA-AAR-RPI program of research on track/train dynamics was started in 1973. The in-cab measurement techniques developed by TSC were recognized as being directly applicable to measurement requirements of the dyanmics study, and plans were made for TSC to participate in that program on a cooperative basis. For this purpose, the subtask on physiological measures was expanded in January, 1973, to a full task: "Train Handling". Additional equipment was developed and pretested, and in June 1973, field data were taken on an instrumented train of the Southern Pacific Railroad. Data reduction from this run is now in progress.

Section 5 of this report gives details on the activities and progress of the train handling task.

2.10 SPECIAL SERVICES

As consultants to the FRA on matters involving human behavior, project staff members are frequently asked for assistance in areas not specifically covered by the project tasks. In FY73, some of the special services rendered the FRA by this project were:

a. Attendance at the week of NTSB hearings in Chicago in December, 1972, on causes of the ICG collision of October 30, 1972.

b. Assistance in evaluating the use of certain drugs not on the BNDD "Controlled Substances Inventory List," provided in a memorandum to RA 622, dated February 7, 1973.

c. Assistance in evaluating proposed additions to accident-cause categories used by the Office of Safety. With the help of W.H. Holland, consultant, a critique of the proposed terms was submitted to RA 6231 in a memorandum dated May 8, 1973.

3. RESEARCH PLAN FOR USE WITH LOCOMOTIVE CAB SIMULATOR

3.1 SCOPE

3.1.1 Introduction[1]

The FRA is engaged in a program of research and development to increase the safety and effectiveness of railroad operations. This program requires extensive information on human performance in the operation of locomotives and trains. Of particular and immediate interest are studies focussed on the performance of the railroad locomotive engineer, a key figure in the safety and effectiveness of railroad operations. Since most of the critical experiments cannot be carried out under actual operating conditions with railroad equipment because of the danger, cost or time required, a railroad locomotive and train simulator designed specifically for research is required for this effort.

3.1.2 Research Program

The locomotive and train simulator will be used to conduct research studies in four main areas of human performance in railroad operations.

a. Tests and evaluation of new control designs and layouts and control procedures and systems for potential human performance and safety problems before implementation of the hardware requirements.

b. Studies of the performance of the railroad engineer as affected by physical and physiological factors such as fatigue, work-rest cycles, cab environment, alcohol, drugs, medicines and age.

c. Study, reconstruction and analysis of events and conditions which have led up to accidents.

---

[1]Sections 3.1.1 and 3.1.2 from "Specification for a Locomotive and Train Simulator for Research", FRA, March 15, 1972.

d. Research, development and evaluation of the skill level requirements for the establishment of standards and qualifications (initial, recurrent and transitional) and new skill acquisition methods and procedures for the railroad engineer.

3.1.3 Research Plan

In order that maximum utility be realized with the simulator recently specified, it is necessary that a detailed experimental plan for the use of such a device be formulated. The completion of such a plan prior to the time at which the simulator becomes available for use in the program will help insure the earliest possible accumulation of data which support the research goals of the FRA. This document is intended to aid the eventual formulation of a highly detailed plan.

The assumptions are made here that an initial series of validation experiments will have to be run and that the conclusions reached on the basis of these experiments will bear heavily on the future utility of the simulator. Accordingly, a major concern of the plan is with the form and content of the validation series.

It is further assumed that, after completion of the validation series, demand for the simulator may occur within the contexts of long-term and short-term requirements of the Administration. Thus it may be necessary temporarily to suspend research on, say, the general aspects of train handling in order to determine the probable utility of a new information display or a prospective change in rules relating to use of dynamic brake. To accomodate such a likelihood, the experimental packages comprising the plan have been developed in modular form with defined beginnings and ends. Such organization allows for maximum freedom in the utilization of the simulator while, at the same time, assuring validity and reliability of results.

3.2 OVERVIEW OF EXPERIMENTAL DESIGN

3.2.1 Sources of Variation

Before turning to a discussion of individual research packages, it is well to reflect briefly on the fact that, whatever their differences, all experimental designs included in this document have the same basic goal: to establish, at a given level of confidence, the "potency" of each experimental condition defined in the study. As a result, statements concerning observed "potency" are statistical statements. They may or may not be statements concerning operational (i.e., real-world) significance. Conclusions regarding operational significance grow largely out of judicious choice of the experimental variables in a given study and from the perspective provided by a series of related studies.

It is reasonable to expect that requirements on the precision of results and the conclusions drawn on the basis of those results will vary. Some studies may be accomplished simply for the purpose of generating new directions in the solution of specific problems. Some other efforts may take the form of demonstrations rather than of well-controlled experiments. The remainder may receive the full treatment associated with rigorous scientific study.

The various categories of study alluded to above differ primarily in the extent to which the variation in effect associated with each condition and with interactions among conditions is controlled. An example of the possible sources of variation in a nominal experiment concerned with evaluating the differences between, say, three different displays is presented in Figure 3-1. Here the total variation is divided among "enginemen", "vehicles", and "conditions" ("displays") and "measurement error", (three) first-order interactions and second-order interaction. The total variation in each of the major sources is further divided among the sets of repeated measurements (trials).

The major observation to be made here is that the sources of variation identified in the figure would, in principle, be present in any study -- formal or informal -- carried on for the

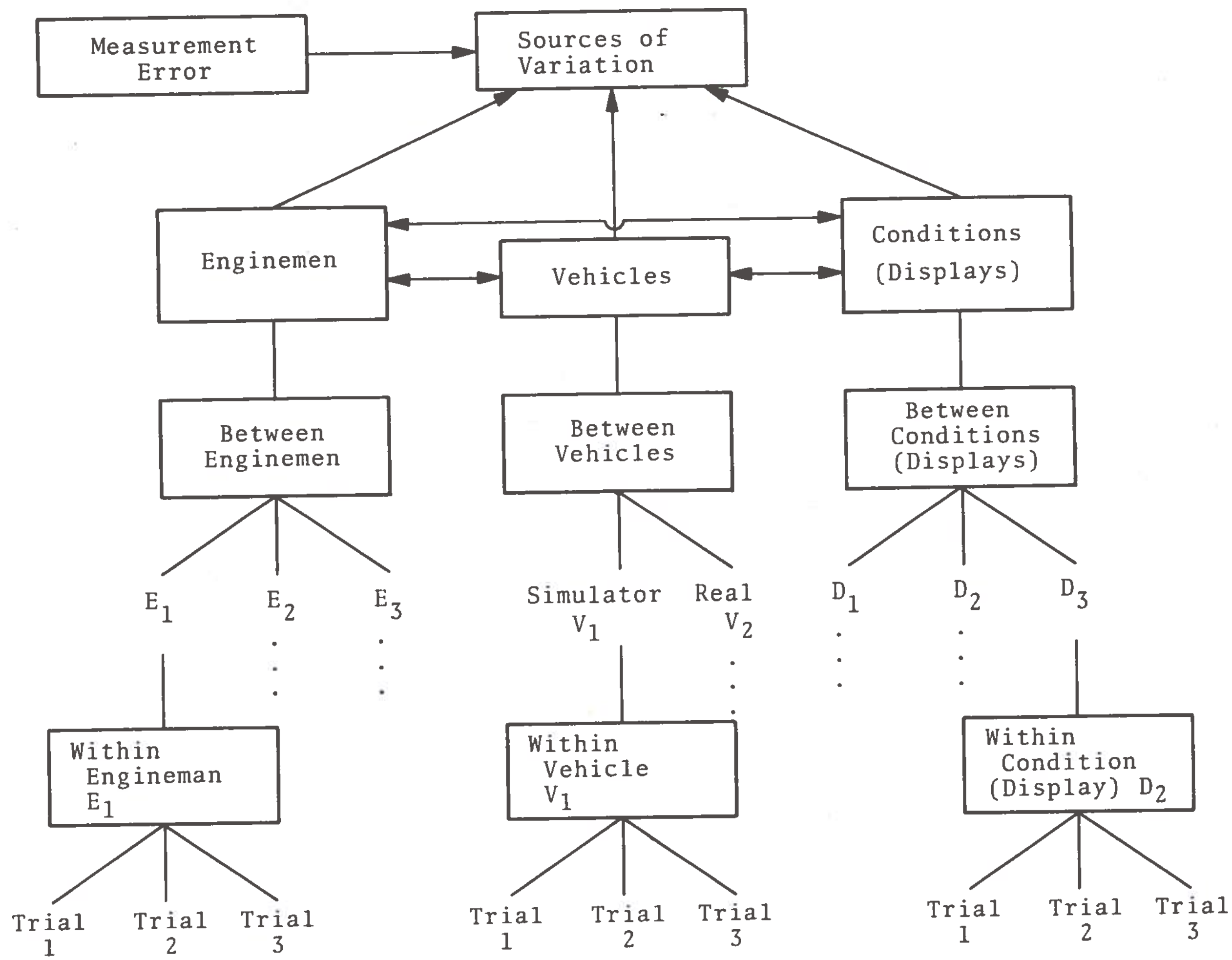

Figure 3-1. Sources of Variation in a Nominal Experiment Concerned with Relative Effectiveness of Three Different Displays

purpose of evaluating hardware and/or procedures. And, it should be clear that the extent to which the sources are under control will determine the degree of confidence one can place in the results. Until some estimates of the normal variation due to these sources can be made on the basis of accumulated data, there may be value in attempting to limit such variation as discussed below.

3.2.2 General Guidelines for Proposed Research

A major concern throughout the research program will be with determining and controlling sources of variation which are the result of intrinsic differences between real and simulated train operations. The prior validation series will aid in determiniation of at least some of these sources. However, whenever a new simulation study is performed in circumstances in which the real environment is not (directly) accessible for verification, doubt may remain as to which effects are simply artifacts of the simulation and which are real. There is, to our knowledge, no way to remove such doubt (except in a statistical sense). It is appropriate, though, to consider ways in which sources of possible variation might be controlled until a judgment can be made that they are not critical to the generality of the results obtained. Such sources and recommendations concerning their control appear below:

3.2.2.1 Integrity of Subject Engineer Samples - It is very likely that considerable variation will be found between different enginemen in their handling of a (real or simulated) train even when the parameters which define the vehicle., track and operational environment are held constant. (A major research task in the proposed series is to determine the character and limits of this variation.) In a study which compares engineman behavior under real and simulated conditions but in which differences in behavior between subjects are not of prime interest, it is recommended that integrity be maintained in the subject sample. That is to say, the same subject enginemen should be employed in the simulator portion of the study as were employed in the real-world portion.

3.2.2.2 Integrity of Locomotive and Train Consists - It is reasonable to anticipate significant differences in the behavioral and physiological performance of enginemen operating with different locomotive and train consists. (A specific research package identified later in this document is aimed at characterizing such differences.) We would recommend that, to the extent possible, the variation between real consists and simulated consists be minimized in any study in which results under real and simulated operations are to be compared.

3.2.2.3 Integrity of Visual Scenes - Operation of a train is obtained from the visual scene. (A specific research package aimed at assessing the extent and nature of information gained therefrom is presented later in this document.) We would recommend that variation between real and simulated visual scenes be minimized in any study in which results under real and simulated operations are to be compared. Until experience dictates otherwise, it seems wise to assume that each section of trackage is unique and that results obtained over one simulated section can only be compared against those over the corresponding real section.

3.2.3 Guidelines for Development of Scenarios

The total physical and psychological context within which study of a particular aspect of enginemen behavior occurs may be referred to as "scenario". Major dimensions of this scenario can be identified as follows:

1) The visual scene (including atmospheric conditions, time of day, etc.)
2) The locomotive and train consists
3) The characteristics of the track and roadbed (including condition, grade, curvature)
4) The configuration of the locomotive control compartment
5) The sound environment

6) The set of experimental conditions to be studied: their nature, schedule of administration, etc.

7) The enginemen population to which referenced conditions apply

The goals of each of the research sequences discussed in this paper are best served by a scenario (or scenarios) tailored individually to the requirements of that particular sequence. While initially more costly in time because of the extent of additional validation required, the provision of such scenarios will aid in assuring that behavioral phenomena observed during simulation are satisfactory approximations of what would be observed under real operating conditions.

To a large extent, the choice of experimental conditions (6 above) in a given study will determine the choices to be made among alternative visual scenes, locomotive and train consists etc. For example, if it is desired that the responses of the engineman be studied under conditions of high, sustained workload levels, it will probably be necessary to generate a visual scene in mountainous territory, to make provision for a rich variety of trackside signal indications and further to elaborate the task structure with a high density of train and locomotive malfunctions. On the other hand, if low load conditions are of interest in a context in which "boredom" might be though to be a determiner of slow or inappropriate engineman response, the total scenario will have to be such as to require few overt responses on the engineman's part. Between these two obvious extremes, where the bulk of operations to be simulated will (probably) lie, the choices among values on each dimension of the scenario may be more difficult to make on an intuitive basis. It is with respect to such choices that information gained during the prior validation series will be of extreme importance.

Until validation data become available, it is suggested that the following guidelines be observed during the generation of scenarios:

1) Visual Scenes

a) Terrain: Library should contain films taken over three basic types of terrain: Level (average grade not to exceed one percent); Undulating (instantaneous grade not to exceed two percent, average wavelength equal to 1.5 times the length of an average train operating over the area filmed); and mountainous (average grade two to three percent).

b) Time of Day/Atmospheric Conditions: Areas of track selected for filming should be photographed under daytime and nighttime conditions and under degraded atmospheric conditions in which the visibility of trackside signals is equal (on the average) to one-half the (computed) stopping distance of the average train operating over the area filmed.

2) Locomotive and Train Consists

The simulator specified in (FRA, March 15, 1972) will be capable of reproducing the dynamics of a range of locomotive and train consists from a single light engine to a freight train powered by up to ten units trailing up to 225 cars with helpers or remote power units. Most of the configuring and reconfiguring of trains will be accomplished through the depression of appropriate switches and function buttons on the experimenter's console. As such, no need is seen at this time for extensive planning of reproduction capability.

3) Characteristics of Track and Roadbed

To a large extent, the selection of a given area of track for filming of the visual scene will limit the amount of reasonable variation in track and roadbed scenario components. To allow for maximum flexibility during validation and research phases, it is recommended that the following extents of filmed track be available[2]:

a) Class 2 track (25 mph) ... 50 miles

b) Class 3 track (40 mph) ...100 miles

c) Class 5 track (80 mph) ...200 miles

Provision should be made for simulation of motion and sound over both jointed and welded rail.

4) Configuration of the Locomotive Control Compartment

The simulator specified provides for a control compartment typical of an EMD SD 45 locomotive with capability for reconfiguration. No need is seen at present for detailed planning relative to specific alternative compartment layouts.

5) Sound and Motion Environments

The sound and motion environments are determined almost entirely by choices made on other dimensions of the total scenario and require no individual attention at this time.

6) Experimental Conditions to be Studied

The current document provides a framework within which experimental designs and administrative routines can be detailed. We recommend that all designs and routines generated for the preliminary validation and early research efforts be as straightforward in concept as possible. Until judicious assumptions can be made concerning characteristics of distributions underlying different engineman populations, non-parametirc (i.e., distribution-free) statistical paradigms should be exploited and sequential analyses used to utmost advantage. In our judgment, the (power) inefficiency of the former and limitations on the ability to

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[2]See Notice of Proposed Rulemaking, part II, v. 36, No. 121, for track classifications.

characterize interactions with the latter are more than offset by factors such as computational ease, the ability one has to terminate an experiment as soon as a statistical decision can be reached, and the confidence one can place in conclusions drawn from the study effort.

7) Engineman Population

Some research discussed in this plan is addressed to the total spectrum of engineman experience and skill level while other research is directed at particular regions of that spectrum. The subject samples for a given study will, of necessity, have to be drawn in such a manner as to reflect the population of interest in that study. Table 3-3 (Section 3.6) summarizes sample requirements in terms of high, average and low experience levels. For purposes of preliminary planning, experience level in this context is considered to be equivalent to years of service.

Although no research activity is directed specifically at establishing the correlation between years of service and skill in train handling, it is expected that a major outcome of the total set of studies will be a qualitative appreciation for the extent of such a correlation. To the extent that "skill" in train handling can be defined and measured with respect to objective criteria, this "appreciation" will also be quantitative.

In our judgment, it is likely that years of service will emerge as but a rough guide to train handling expertise and that it will become important, for a thorough understanding of the results of the research sequences to follow, to evolve additional criteria for the constitution of skill level groups. Hence we recommend that considerable effort be made during Validation Sequence #1 (Behavioral Comparison) to draw on the complete range of years of service represented in the engineman population at large during constitution of the required "high", "average" and "low" experience level groups. Further, we recommend that subjects with comparable service time but with widely different apparent skill levels (as determine from the results of the study) be extensively debriefed in order to discover sources of the differences.

3.3 VALIDATION STUDIES

3.3.1 On Validation of the Simulator

A major goal in the specification of the locomotive and train simulator is a high degree of realism. Indeed, the argument can be made that the more closely the device approximates an actual locomotive and train in its static (appearance) and dynamic (performance) aspects, the more valid will be the results of human factors research proceeding therefrom. Particularly where such investigation may bear on questions of the effects of stress on job performance, it is most important that the "psychological environment" created in the simulator be a faithful copy of that existing in the real world.

It might be unreasonable, however, to expect that the simulation could ever provide a one-to-one (psychological) correspondence to the extent that a subject engineer could effectively be in doubt as to whether he was operating a real train or a facsimile from the beginning to the end of an experimental session. Too many distractions generated within the context of the total administration of an experiment would normally be present to permit the development of such a desirable state of confusion. These distractions, which are completely independent of the inherent validity of the simulator device itself, could be minimized but not entirely eliminated.

It is of extreme importance to the interpretation of results of human factors studies, then, that the relative degree of validity attained by the simulation be established. It is only with such information that spurious effects created by the simulation environment itself can be effectively separated from the total set of effects observed in an experimental investigation. The activities proposed in the next section are designed to elicit information on the independent validities of the simulator and of the total simulation. Their accomplishment is considered vital and necessarily prior to the commencement of the comprehensive research activities outlined later in the paper.

3.3.2 Validation Sequences

It is helpful to view the major concerns of the validation phase in terms of four fairly specific questions:

1) Does the simulator look like a real locomotive cab?

2) Does the simulator perform like a real locomotive and train?

3) Are the decision-making and action selection aspects of the engineman's performance at least qualitatively similar under actual and simulated conditions?

4) Does the operator exhibit the same psychophysiological profile during a simulated run as during an actual run?

The objective appearance of the simulator is more or less assured by adherence to the design specification. The subjective fidelity of its dynamic performance (question 2) is relatively less assured and merits at least cursory examination. The concern here is the degree to which the device, when programmed to represent a given combination of train and locomotive consists, brake and track conditions, visual and auditory inputs, etc. "feels" like the real composite to the operating engineer. From an experimental point of view, the question asked here is, "When I make an input to the controls, is the total response of the simulator, including required changes in the visual scene, noise level, dial indications, the pattern of vestibular and kinesthetic cues, etc. approximately equivalent to what I would experience as the result of a similar control movement in an actual train?"

Question three is concerned with the degree to which processes of decision making and action selection initiated in response to conditions encountered in the operation of a real train are reproduced when the subject engineman is exposed to "copies" of those conditions in the simulator. The essential question here is, "Does a given (programmed) event lead me to make the same decision(s) and the same response(s) I would be led to make under actual operating conditions?"

Questions two and three relate to what might be called "external" dimensions of the simulation; that is, to the capacity of the device to generate appropriate perceptual and behavioral patterns. By contrast, question four deals with an "internal" dimension. It is concerned with the capacity of the total simulation to generate EKG, EEG, Heart Rate and other psychophysiological profiles similar to those recorded under actual operating conditions. The attainment of a high degree of validity on this "internal" dimension will almost insure a correspondingly high degree of simulator utility during the research program.

In Table 3-1 below, the levels of validity in static and dynamic aspects of the simulation which are thought to be necessary in the various areas of study outlined in this document are presented qualitatively. It is important to note that the validities of some facets of the simulation may possibly be increased beyond initial levels through limited (procedural) redesign. The precise nature of the manipulations required to effect such increases, however, are likely to become clear only after some operational experience with the simulation has been gained.

In the sections which follow, the basic forms of proposed validation studies are developed. The first study is concerned with a comparison of the behaviors of the engineman under actual and simulated conditions with a view to establishing the validity of the simulation on external response dimensions. The second study is concerned with a comparison of engineman behavior under

TABLE 3-1 ESTIMATED LEVELS OF VALIDITY REQUIRED FOR SIMULATOR RESEARCH AREAS

Research Area	Estimated Validity	
	Static Aspects	Dynamic Aspects
1. Information Requirements of Engineman	high	high
2. Engineman Performance Enhancement	high	high
3. Training Requirements	medium	medium
4. Effects of Aging on Performance	medium	high
5. Effects of Drugs/Alcohol on Train Handling	medium	high
6. Effects of Fatigue on Train Handling	medium	high
7. Analysis of Accidents	high	high
8. Cab Design	low	medium

actual and simulated conditions with a view to establishing the validity of the simulation on internal response dimensions. It is assumed that whatever the sequence of studies finally adopted (see Figure 3-2 for suggested sequence), the validation studies will necessarily precede formal experimentation.

NOTE: Actual measures of engineman response and of simulator response to be taken in all studies are presented in (Appendix A) Table A-1 and Table A-2, respectively.

3.3.2.1 VALIDATION SEQUENCE #1: Behavioral Comparison

- Essential Research Questions
  - Are the decisions which the engineman makes and actions which he takes similar under real and simulated conditions?

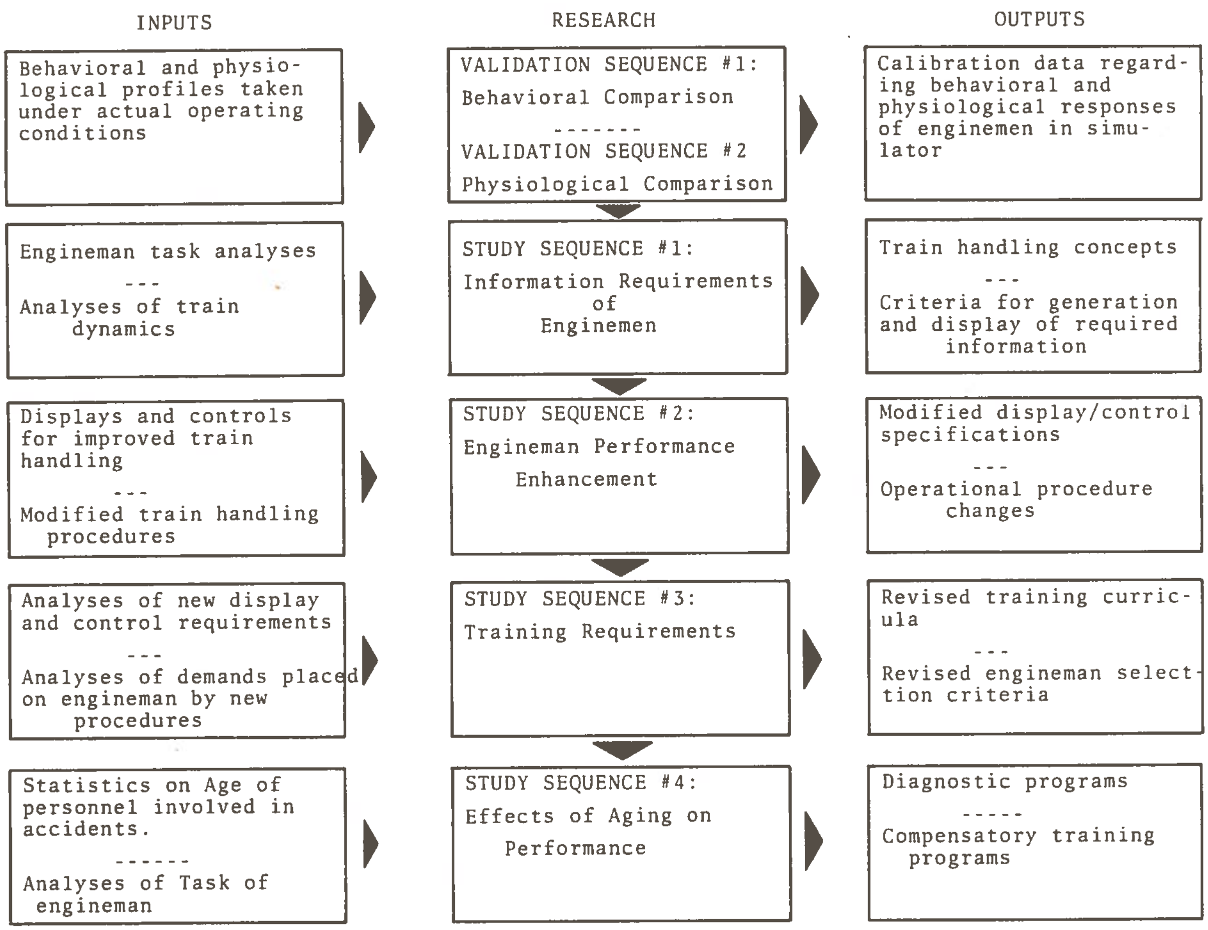

Figure 3-2 Validation and Research Studies Showing Major Inputs and Outputs

- Are differences between the behaviors noted in these two conditions attributable to the experience level of the engineman?
- Are the profiles of a given engineman repeatable?

- Basic Elements of Procedure
  - Generate groups of enginemen which differ in experience level
  - Collect behaviroal data (identity and frequency of control movements, reaction times, etc.) on each engineman while he operates real trains over selected areas of track.
  - Collect similar data on each engineman while he operates simulated trains over the same areas of (simulated) track.
  - Determine the correlation between each engineman's performance on the real and simulated runs.
  - On the basis of the behavioral profiles obtained in the simulated runs, attempt to regenerate original (experience level) groups.
  - Determine what corrections would have to be made to data obtained in the simulated runs to make future experimental runs in that device indicative of real runs.
  - Have the engineman attempt to operate a real train using the behavioral profiles developed on the simulator (if no corrections are required to make the two similar).

3.3.2.2 VALIDATION SEQUENCE #2: Physiological Comparison

- Essential Research Questions
  - Are the physiological responses of enginemen recorded under routine and emergency conditions the same under actual and simulated operations?

- Are there differences between the physiological responses attributable to the experience level of the enginemen tested?
- Are the profiles of a given engineman repeatable?

- Basic Elements of Procedure
  - Generate groups of enginemen which differ in experience level.
  - Collect physiological data (EKG, Heart Rate, Blood Pressure, EEG, etc.) on each engineman while he operates real trains over selected areas of track.
  - Collect similar data on each engineman while he operates simulated trains over the same areas of (simulated) track.
  - Determine the correlation between each engineman's physiological responses on the real and simulated runs.
  - On the basis of the behavioral profiles obtained in the simulated runs, attempt to regenerate the original (experience level) groupings.
  - Determine what corrections would have to be made to data obtained in the simulated runs to make future experimental runs in the device indicative of real runs.

3.4 RESEARCH STUDIES

3.4.1 Research Sequences

In the sections which follow, a series of four study sequences are described. These sequences explore, at a general level, the task of the engineman, changes in display instrumentation and procedures which could aid accomplishment of that task, implications of such changes for training of new re-training or experienced enginemen and, finally, the effects of aging on engineman performance.

The goal of this set of studies is a thorough understanding of the physical and psychological environments within which the engineman operates. As such, information gained in the course of the studies should -- and probably will -- aid in the definition of problem areas in addition to those already addressed in the plan.

3.4.1.1 STUDY SEQUENCE #1: Information Requirements of Engineman

- Essential Research Questions
  - What information currently available relative to the performance of the locomotive and train is used by the engineman?
  - Is the information used or the manner in which it is used a function of experience level?
  - What additional information is required?
- Basic Elements of Procedure
  - Obtain descriptions from subject enginemen of the data and cues used in judging the status of the train under defined load/equipment/road conditions of interest. Obtain descriptions of the judgment process.
  - On the basis of those descriptions, generate simulator runs under the conditions of interest and characterize the performance of each engineman.
  - Re-run each engineman with prime data and cues progressively deleted and determine the effect on performance.
  - Determine the correspondence between what the engineman considers to be critical in the way of data and cues and the results of the experiment.

- Simulate instabilities in the train which are known to results in derailments, track separation, break-in-two, climbing, etc. Determine the extent to which the engineman can sense the instability.
- Have the engineman consciously attempt to create the instabilities of interest and to report the earliest indication of the required condition.

3.4.1.2 STUDY SEQUENCE #2: Engineman Performance Enhancement

- Essential Research Questions:
  - How effective are the experimental display and control systems as a group in conveying the information identified in Study Sequence #1? What are the relative strengths and weaknesses of the systems reviewed in this sequence?
  - What changes in operational procedures would be required as a result of adoption of the most desirable of these systems?
  - What are the implications of the changes for other tasks associated with train handling?
- Basic Elements of Procedure
  - Perform tests and evaluations of each of the revised displays, controls and procedures over the same sections of track as those employed in Study Sequence #1.
  - Characterize differences, if any, between behavioral and between physiological profiles obtained with the different devices and procedures.
  - Determine the effectiveness of the revised systems in providing early warning of unstable conditions in the train.

- Secure estimates from the subject engineman as to the ease of working with the new controls, displays and procedures. Correlate these estimates with observed physiological and behavioral profiles.

3.4.1.3 STUDY SEQUENCE #3: Training Requirements

- Essential Research Questions
  - What are the implications of proposed changes in display/control systems and operational procedures for engineman selection and training?
  - In what areas of a responsive training curriculum can simulator experience and classroom experience be substituted for over-the-road experience?
- Basic Elements of Procedure
  - Expose a naive group of enginemen to the proposed hardware and procedural systems identified in Study Sequence #2. Train the group to use the systems to a given level of proficiency, noting, particularly, the range of times required to meet the criterion of satisfactory performance.
  - Expose the same group to real trains equipped with the proposed hardware. Determine the proficiencies of individual enginemen and correlate their respective proficiencies with those as judged from simulator performance.
  - Divide the group of enginemen in half. Continue training one half on the simulator until each member meets the performance criterion on the real train. Continue training the other half on the real train until all members meet the criterion. Compare the lengths of time required to meet the criterion under the two training conditions.

3.4.1.4 STUDY SEQUENCE #4: Effects of Aging on Performance

NOTE: Research identified with this sequence is cross-sectional in design. Inferences growing from it should be subjected to further intensive study of the longitudinal variety in order to enable assessment of effects possibly correlated with aging (e.g., experience level).

- Essential Research Questions
  - What are the effects of aging on the skilled performance of the engineman?
  - What tests can be devised for the diagnosis of performance deterioration due to aging which can be objectively administered and evaluated by railroad personnel?
  - What compensatory training can be given to enginemen which will enable their continued service at the required level of skill?
- Basic Elements of Procedure
  - Generate three equally-sized groups of enginemen as follows:

    Group I: Age Range 20-30, Mean Age 25

    Group II: Age Range 35-45, Mean Age 40

    Group III: Age Range 50-60, Mean Age 55
  - Run the three groups for extended periods of time on a scenario which demands a high density of judgments, decisions and control responses.
  - Characterize the differences obtained between the groups with respect to speed and correctness of responses and with respect to selected physiological measures.

- Run the three groups for an extended period of time on a scenario which places littled demand on judgment, decision making and control skills.
- Characterize differences between groups as above.
- Compare differences obtained with respect to criterion variables between groups on the high problem density and low problem density scenarios.
- Following outcomes (see Table 3-2) of latter comparison may be suggestive of a deleterious effect due to aging which would require further study.

3.5 PROBLEM STUDIES

3.5.1 Specific Problem Packages

In the sections which follow, a series of research studies aimed at specific, current problems is presented. A suggested sequence for this series, along with a short description of inputs to and outputs from each study, is presented in Figure 3-3. It is recommended that, to the extent possible, studies associated with Section 3.4 be accomplished in advance of those comprising this section.

3.5.1.1 PROBLEM PACKAGE #1: Effects of Drugs/Alcohol on Train Handling

- Essential Research Questions:
  - How is the skilled performance of the engineman affected by different concentrations of alcohol in his blood? What aspects of his task are most affected at given concentrations?
  - How is the skilled performance of the engineman affected by different types and dosages of common (non-prescription) drugs? What effects can be attributed to the interactions of specific combinations of such drugs?

TABLE 3-2 OUTCOMES OF STUDY SEQUENCE #4 SUGGESTIVE OF DELETERIOUS EFFECTS DUE TO AGING

Outcome	Low Problem Density Scenario	High Problem Density Scenario
1	No significant differences between groups	Significant Differences between groups; Group III exhibits least satisfactory performance
2	Significant differences between groups; Group III shows most satisfactory performance	Significant differences between groups, Group III shows least satisfactory performance
3	Significant differences between groups; Group III shows least satisfactory performance	No significant differences between groups

INPUTS	RESEARCH	OUTPUTS
Baseline behavioral profiles taken under real or simulated conditions in absence of drugs and/or alcohol	PROBLEM PACKAGE #1: Effects of Drugs and/or Alcohol on Train Handling	Estimates of influence of differing levels of blood alcohol and differing concentrations of drugs on skilled engineman performance
Baseline behavioral profiles taken at controlled levels of deprivation and workload	PROBLEM PACKAGE #2: Effects of Fatigue on Train Handling	Estimates of influence of differing levels of workload stress and work/rest ratios on skilled performance
Parameters of a given accident relating to signal aspects, workload, track, roadbed and train characteristics	PROBLEM PACKAGE #3: Analyses of Accidents Due to Signal Interpretation, Excessive Workload, Slow Reaction Time, Etc.	Support for or against arguments that given accident could have been due to specified performance deficiencies; support for design changes
Quantitative and Qualitative estimates of current workspaces and equipment configurations in terms of engineman operating efficiency	PROBLEM PACKAGE #4: Cab Design (including workspace layout, safety engineering, etc.)	Relative merits of specific workspace layouts; engineman performance and efficiency measurements under different types of design criteria

Figure 3-3 Specific Problem Packages Showing Major Inputs and Outputs

- How is the performance affected by different types and dosages of legal (prescription) and common illegal drugs? What effects can be attributed to interactions of specific combinations of such drugs?

- Basic Elements of Procedure

  - Administer measured amounts of alcohol to subject enginemen. Determine blood alcohol levels (BLA's) reached at specified periods after administration with Breathalyzer or other suitable instrument.

  - Collect behavioral data (identity and frequency of control movements, reaction times to in-cab and track-side signals, etc.) on each engineman at given BLA.

  - Determine extent of deterioration (if any) in train-handling performance (frequencies of adverse slack actions, changes in speed, etc.).

  - Determine extent of changes in vigilance (if any) with respect to signals and programmed emergency conditions in which information is conveyed by cab instrumentation (brake pipe leakage, loss of dynamic brake, wheel slip, etc.).

  - Establish correlations between BLA's and observed decrements in train handling and vigilance.

    NOTE: Replicate procedures for selected concentrations of drugs with dosage level as variable.

3.5.1.2 PROBLEM PACKAGE #2: Effects of Fatigue on Train Handling

- Essential Research Questions

  - How is the skilled performance of the engineman affected by different levels of fatigue?

  - Does fatigue induced by high workloads over relatively short periods of time produce qualitative and quantitative performance decrements similar to those induced by normal workloads continued beyond the standard shift?

- Basic Elements of Procedure
  - Establish basal performance levels of subject enginemen after one, two, four and eight hours of (simulator) duty at normal, moderate and high levels of workload.
  - Compare performance levels attained by each engineman across duty intervals and within workload levels.
  - Compare performance levels attained by each engineman within duty intervals and across workload levels.
  - Determine what aspects of the total train handling task are most affected by fatigue at defined levels.

3.5.1.3 PROBLEM PACKAGE #3: Analysis of Accidents

NOTE: Research identified with this package may be conducted in those instances in which faulty train-handling or other deficient performance on the part of the engineman is alleged to have been a prime cause or one of a set of contributing causes in a specific accident. Thus, precise parameters of the simulation can only be specified as the occasions for replication arise.

- Essential Research Questions
  - Could the accident replicated have been caused by the slow reaction time of the engineman, faulty train handling resulting in adverse slack action or other alleged cause?
  - Could future occurrences of accidents of the type experienced be prevented by the provision of more adequate information to the engineman concerning the dynamics of the train.
  - Could future occurrences of accidents of the type experienced be prevented through substantive changes in operating rules or training?

- Basic Elements of Procedure
  - Secure film footage of area of track in which accident occurred. (In event that visibility and/or track signal clarity are thought to be contributing factors, filmed scenes should replicate as closely as possible all environmental factors).
  - Reproduce as faithfully as possible all characteristics of the train involved in the accident, including such factors as total weight, car and train lengths, load distribution, brake complement, etc.
  - Reproduce as faithfully as possible all characteristics of track over area of interest, including type of rail, condition of rail and roadbed, curvature, grade, etc.
  - Replicate (alleged) profile of engineman performance and train response. Observe outcomes with respect to parameters of interest (e.g., stopping distance of train, absolute speed over given area, slack action, etc.).
  - Re-run simulation with recommended performance profile. Observe outcomes parallel to those above.
  - Compare results of two simulations. Establish probable validity of allegation concerning engineman's performance prior to accident.
  - Determine implications for revised training and/or improved cab instrumentation.
  - Verify efficacy of changes in training and/or instrumentation by rerunning simulation.

3.5.1.4 PROBLEM PACKAGE #4: Evaluation of Alternative Cab Designs

- Essential Research Questions
  - What are the relative strengths and weaknesses of current cab layouts with respect to accessibility to controls used under routine and emergency conditions,

proximity to communcations gear, seating confort, noise level, safety in the event of collision?

  - What are the relative strengths and weaknesses of proposed alternative cab layout designs with respect to these same criteria?
  - What are the implications of adopting an alternative design for training of new enginemen and retraining of experienced enginemen?

- Basic Elements of Procedure
  - Perform anthropometric measurements on population of enginemen (see Table A-3). Characterize accessibility of controls and information displays from ideal and normal seating positions for 5th and 95th percentiles within population.
  - Determine engineman response time to series of expected and unexpected events requiring the evaluation of in-cab and of trackside information and the performance of overt actions using current controls and instrumentation.
  - Derive intelligibility indices for communications between members of front-end crew and for communications via radio.
  - From accumulated accident data and knowledge of g-forces developed during (particularly) low-speed accidents, characterize level of safety for current control compartment configurations.
  - Evaluate alternative with respect to dimensions studied with current configuration.
  - Estimate transition training requirements for enginemen trained in context of current configuration by measuring lengths of time required for inexperienced and experienced personnel to meet criteria of satisfactory performance.

3.5.2 Comment

On the studies proposed in this document, those relating to the training of railroad engineman and to the study of railroad accidents are considered to have the highest potential payoff. (The latter type of study is also considered to the most difficult to accomplish satisfactorily, primarily because of the (probable) lack of information available concerning detailed behavior of the engineman just prior to a given accident.)

In view of this, we would recommend that steps be taken early in the program to establish a procedure by which samples of students in engineman training at major railroads be studied on a continuing basis. A major goal of this program would be to aid judgment of the relative effectiveness with which different railroad training regimes provide enginemen with a required minimum level of performance capability.

3.6 MANPOWER ESTIMATES

A continuing problem during the validation and early research efforts in simulation will be the specification of the appropriate sizes and compositions of groups of enginemen to be observed in the simulator. Estimates of such sample sizes are usually based on some prior knowledge of the normal variation to be expected in the performance of a given subject over time and on knowledge of the normal variation to be expected between subjects. In the study of engineman performance under simulated conditions, however, the data required for such knowledge become available only as the study proceeds.

Table 3-3 below presents estimates of the numbers of enginemen required during validation and research sequences. The estimates of manpower for the validation sequences were derived primarily on the basis of two considerations:

1) The (behavioral and physiological) performance characteristics of interest are likely to be normally distributed in the population of enginemen.

TABLE 3-3 RESEARCH MANNING REQUIREMENTS

Phase of Research

		Validation		Study Sequence				Problem Package			
		1	2	1	2	3	4	1	2	3	4
Total Number of Subjects		200	(200)	50	50	50	90	50	100	10	25
Experience Level Requirements	High	x	x	x	x		x			*	
	Avg.	x	x	x	x	x	x	x	x	*	x
	Low	x	x			x	x	x	x	*	x

* Matched to experience level of engineer(s) involved in accident

( ) Indicates same subjects as in prior study

2) A major interest will be the study of differences in performance between extremes in the engineman population. Thus, a group of enginemen large enough to include (on a statistical basis) a reasonable number of such extreme cases should be specified.

It is recommended that the numbers specified in Table 3-3 be considered to be upper bounds for manpower planning purposes, and that during actual prosecution of the research, sequential analyses be made of output data on a continuous basis. Such procedures will aid in maintaining maximal efficiency in the research program by enabling the termination of a given experiment as soon as statistical significance can be established.

4. TRAINING

4.1 BACKGROUND

This Section constitutes a progress report and impressions to date deriving from an ongoing survey of training procedures in selected railroads. This effort is part of a study also involving the analysis of job requirements, review of training literature, and the application of training principles in order to determine the minimum amount and kind of training needed to assure safe performance of safety-critical railroad jobs.

The task on training standards (Task 4A, PPA RR309) was initiated on the rationale that the Federal Railroad Administration (FRA) would be required for reasons of safety for both railroad employees and the public to regulate the training of both operating and maintenance personnel of the railroad industry. The precedent for such government regulation of the training, testing and inspection of operating and maintenance personnel of a common carrier has already been established; the air carriers have operated very successfully under such regulation for many years. The FRA, however, has only recently taken its first administrative step in this area with a proposal for the regulation of training for operating personnel.

A notice of proposed rulemaking in the field of railroad operating rules and practices was published 14 May 1973 in the Federal Register, Vol. 38, No. 92. Under the proposed regulation, each railroad will be required to submit for evaluation and approval two programs. One program is for the initial and recurrent instruction of its employees whose activities are governed by the railroads operating rules on the meaning and application of the railroads operating rules. The other program is for conducting tests and inspections to determine the extent of compliance of operating personnel with their own codes of operating rules, timetables and timetable special instructions. All railroad employees whose activities are goverened by railroad operating rules, timetables and timetable special instuctions will be covered by these programs. The job classifications of railroad engineer and the train dispatcher, however, are recognized as being the most critical to the safe operation of railroads and, to a somewhat lesser extent, the job classifications of train conductor and train order operator. These job classifications are, therefore, most likely to be affected to a greater degree by the institution of the proposed regulation. Furthermore, these job classifications could be, in the future, the subject of regulations for job-skill-training standards or standards for licensing certification.

In order to administer this proposed regulation on railroad operating rules and practices and the possible regulation of the training in job skills for the railroad engineer, train dispatcher, conductor and train order operation, the FRA will require guidelines (standards) against which each program submitted by the carriers can be evaluated for approval or disapproval. Such guidelines could also be of use to some of the railroads in the development of the necessary programs.

4.2 PURPOSE AND SCOPE

The purpose of this study is to provide the research necessary to support FRA efforts to develop the needed guidelines for (a) the evaluation of railroad programs of instruction in and testing and inspection of compliance with railroad operating rules and practices, and (b) the development of job skills training standards for the railroad engineer, train dispatcher, conductor and train order operator. Specifically, guidelines will be developed for evaluating programs of initial instructions and recurrent instruction in operating rules for all employees whose activities are governed by the railroad's operating rules. These guidelines will cover such aspects of these programs as the means and procedures used for instruction, the length of the course of instruction, the frequency of the recurrent instruction, and the means used to ensure that employees do in fact know the meaning and applications of the railroads operating rules as taught in these programs of instruction.

In addition to the guidelines for evaluating programs of instruction in operating rules, guidelines will be developed for evaluating programs of recurrent tests and inspections by which the railroad will be able to determine the extent to which its operation complies with its own code of operating rules, timetables and timetable special instructions. These guidelines will cover such aspects as types of tests and inspections and frequency, means and procedures with which the test and inspections are to be carried out. There is no doubt that these standards in training, testing and inspection are necessary in view of the accident records (FRA, 1971) and freight damage claims due to poor train handling (AAR, 1972). Certain safeguards must be taken, however, in the development of these standards, since such standards can be stultifying to progress in training procedures and methods as well as in training program content. Whatever else, any training standards must ensure that the programs developed by the carriers do what they are purported to do. The validity of the training programs must be established; the employees who complete these programs and who meet the standards must in fact be qualified. These precautions, while absolutely necessary, will make the task of establishing standards for these programs and the development of the programs themselves extremely difficult. The initial phase of this effort to develop training, testing and inspection standards is being limited to operating rules and practices for personnel whose activities are governed by operating rules, timetable and timetable special instructions and training standards for the more safety-critical job classifications of railroad conductors (road and yard), engineers (road, yard and outside hostler), train dispatchers and train order operator.

4.3 PROCEDURE

4.3.1 Applicable Job Classifications

Although all job classifications of railroad operating and maintenance personnel can be considered safety-critical, some job classification are obviously more so. The first step then was to identify the various operating and maintenance job classifications. An initial list of some 28 railroad operating and maintenance job classifications was drawn up with the assistance of Mr. Wilfred H. Holland, an FRA consultant. Appendix B contains the typical railroad organization charts, job requirement charts and brief job descriptions resulting from this effort. Since the titles of job classifications may well vary from railroad to railroad, the pertinent job classification will have to be identified by required activities as well as job classification title. With respect to the proposed regulation in the area of railroad operating rules and practices, it will apply to all these employees in job classifications with activities governed by the railroads operating rules, timetables and timetable special instructions.

Since the job skills training standards of only the most safety-critical job descriptions could be considered in this first phase of this effort, four job classifications were selected for study with the assistance of cognizant personnel at the FRA, who for most part are employed in the Office of Safety. These 18 FRA personnel were asked to rate, on a five-point scale, the 28 identified railroad operating and maintenance job classifications for safety-criticality in railroad operations. The list of job classifications and the average rating each received are shown in Table 4-1. The four classifications among the operating forces receiving the highest average safety-critically ratings were selected for study. These four job classifications are the railroad engineer, train conductor, train dispatcher, and train order operator. With the approval of the FRA task monitor, preparations were than made to collect the data necessary for the development of guidelines for evaluating the railroad programs for training, testing and inspection in the area of railroad operating rules and practices and the training in job skills of these above named job classifications.

4.3.2 Selection of Data Sources

The numerous articles on training in operating rules and job skills which appear in such publications as the Annual Procedings of the Railway Fuel and Operating Officers Association and the many

TABLE 4-1 JOB CLASSIFICATIONS RATED FOR SAFETY-CRITICALITY AND AVERAGE RATINGS (R) ON FIVE-POINT SCALE

OPERATING FORCES	R
1. Road Foreman of Engineers	3.5
2. Engineman-Road	4.8
3. Engineman-Yard	4.4
4. Fireman	2.7
5. Conductor-Yard	4.0
6. Conductor-Road	4.3
7. Brakeman	3.6
8. Yard Helper	3.0
9. Yardmaster	3.4
10. Switchtender	3.0
11. Train Dispatcher	4.4
12. Operator-Block	4.1
13. Operator-Tower	4.1
14. Hostler-Outside	3.6
15. Crossing Tender	2.6
16. Draw Bridge Tender	2.8

MAINTENANCE OF EQUIPMENT FORCES	R
1. Foreman-Car Repair	3.3
2. Foreman-Car Inspector	3.5
3. Car Inspector	3.5
4. Foreman-Enginehouse	3.5
5. Foreman-Locomotive Repair Shop	3.4

MAINTENANCE OF WAY AND STRUCTURES FORCES	
1. All Gang Foremen	3.9
2. Operators of Motor Cars and Self-propelled equipment on Track	4.1
3. Signal Maintainers	3.8
4. Signal Testmen	3.6
5. Radio Maintainer	2.9
6. Track Inspector	3.8
7. Rail Inspector	3.5

trade magazines of the railroad industry clearly indicated that the rail carriers themselves have given this problem extensive consideration. Their efforts warranted examination as a primary source of the data required to develop meaningful guidelines for the evaluation of programs for training, testing and inspection in operating rules and practices and training in job skills. Limitations in our resources required that we select a sample consisting of a few railroads to participate in this study. It was apparent from a very cursory review of the railroad training literature that many of the rail carriers have given considerable thought to our problem. Published articles describe the extensive programs carried out by these railroads in operating rules and practices for all operating personnel and the specialized training programs for specific job classifications. On the basis of on-going training programs, the number of qualified carriers far exceeded our requirements. The further criteria of geographical location and the economy and convenience of travel to visit the railroad were added to that of on-going training programs. The carriers finally selected are listed in Table 4-2.

4.3.3 Development and Pretesting of Interview Format

The data collecting procedure was developed on the assumption that much of the needed information would be immediately available from these selected railroads. Each of the railroads selected was known to be operating one or more training programs for which documents such as course outlines, textbooks and examinations should be available. Following at least a cursory review of this documented information, any further information desired would then be obtained by interview with the cognizant railroad officer. In order that the interviews would not vary too drastically from railroad to railroad, a draft of an interview guideline-questionnaire was drawn up ready for pretesting.

A railroad known to be concerned with training of their operating personnel and located not too far from Cambridge, Massachusetts, would be required for pretesting the data-collecting procedure. The Chessie System was contacted informally and kindly

TABLE 4-2 CARRIERS SELECTED FOR SURVEY

EAST-NORTHEAST
The Chesapeake & Ohio Railway Co.
Norfolk and Western Railway Co.
SOUTHEAST
Florida East Coast Railway Co.
Seaboard Coast Line Railway
CENTRAL
Illinois Central Gulf Railroad Co.
Chicago and Northwestern Transportation Co.
SOUTH CENTRAL
St. Louis - San Francisco Railway Co.
Missouri-Pacific Lines
CENTRAL-NORTHWEST
Chicago, Milwaukee, St. Paul and Pacific Railroad
Union Pacific Railroad
Burlington Northern
WEST-SOUTHWEST
Southern Pacific Lines
Western Pacific Railroad Company
Atchison, Topeka and Santa Fe Railway System

agreed to participate in the development and pretesting of the data collection procedure. Two lengthy question and answer sessions were held with a number of Chessie officers. During these sessions a great deal of general information was obtained, both on railroad operations and on the intricacies of training railroad operating personnel. On the basis of the information obtained from these sessions, the questionnaire-guideline for collecting data on training was appropriately edited and redrafted. A copy of the final form sent out to the selected carriers is attached as Appendix C. It was also learned from these sessions with the Chessie that railroads would require a minimum of two weeks time to gather together the various documents on training and operating rules and practices desired.

4.3.4 Data Collection

Data collection is now in progress. Letters signed by Mr. Mac E. Rogers, Associate Administrator, FRA were sent out to nine of the 14 railroads listed in Table 4-2, requesting their assistance in this task. In the event that the data collected from the first nine prove inadequate, the assistance of the other five will then be sought.

At this point in time (June 30, 1973), training documents have been collected and interviews held with five of the nine railroads. The remaining four interviews are scheduled to be held before the end of July 1973.

4.4 RESULTS TO DATE

The cooperation and assistance give by all the railroads interviewed has been exemplary. In every case they have given the interviewer as much time as he required. Furthermore, copies of all the documents requested have been made available even though some of them could be classified as containing proprietary information. The documents obtained from these five railroads include copies of their operating rules, timetable, timetable special instructions, safety rules, course outlines for the training of new hires for job classifications of trainman and yardman, course outlines for the training of engineers, and a number of examinations for the various job classifications under consideration. Of particular interest are the copies of efficiency testing procedures and examinations that were obtained. Testing efficiency appears at this time to be the best method of evaluating compliance with the operating rules of a railroad. The railroads interviewed are all actively engaged in revamping one or more of their training programs. Most importantly, the railroads are all concerned with the effectiveness of the training programs they are offering. Unfortunately, evaluation of such programs is quite difficult technically as well as often requiring longitudinal studies which may extend over years. All but one of the carriers interviewed are now conducting training programs for new hires that include three to five days of classroom and formal instruction on orientation to railroading and on operating rules and their application as well as job skills. These railroads all agree on the importance of the initial impression of railroading that the new hire obtains. Furthermore, these carriers are also very selective of the crews with whom these new hires work during their introductory work period, which is usually 45 days. The practice of assigning new hires to work crews at random for on-the-job-training is fast disappearing.

Every carrier interviewed expressed deep concern for recurrent training in operating rules and their applications and practices. This particular problem is tied up in the working agreements presently in force. These agreements are not uniform from railroad to railroad and the work rules on recurrent training on examinations vary accordingly.

Three of the five carriers have extensive programs in operation or about to be put in operation for the training of railroad engineers. With the training syllabuses from these programs and those of other programs known to be carried on by carriers still to be interviewed, the minimum training requirements for the railroad engineer should be readily apparent. None of the carriers interviewed has a formal training program for train dispatchers at this time. One carrier, however, does have one in the planning stages. The relatively small number of train dispatchers required by any one railroad system certainly inhibits the establishment of formal training programs with classroom study. The merging of the job classifications of operators and clerks is another factor influencing the recruiting and training of dispatchers. With the advances in train control systems, the needs for train order operators has been greatly reduced and with them the primary source of dispatchers. There just doesn't seem to be a formal training program for the train order operator and the conductor in operation at this time.

As can be seen from the results obtained to date, much is being done by the carriers; however, much more still has to be done. With the completion of the interviews, work on the formal analysis of the collected data will begin.

5. TRAIN HANDLING

5.1 INTRODUCTION

One of the locomotive engineer's major duties is that set of operations called "Train Handling". The term is used in this report to describe the engineer's efforts to control the dynamic behavior of the train. This includes, but is not limited to: starting and accelerating the train from rest in a manner which mimimizes the likelihood of "break-in-twos," maintaining the required speed when ascending grades so that the required drawbar pull is within allowable limits, minimizing "run-in" forces, maintaining and adjusting train speed to track conditions and thereby avoiding forces likely to cause damage to rolling stock, avoiding excessive forces and possible derailments while train is in "buff" during dynamic braking.

TSC is currently studying the train handling performance of railroad engineers in order to develop techniques for reducing safety hazards, loss and damage due to improper train handling.

The investigation has been undertaken in cooperation with the Association of American Railroads, Railroad Products Institute and Federal Railroad Administration's Track/Train Dynamics Program.

In this study, TSC's contribution is in the area of determining the locomotive engineer's sensitivity to indices of train stability. More specifically, TSC is designing and executing observational and experimental studies of the effects of various types of information or stimuli on the train handling skills of railroad engineers. This includes the measurement and analysis of the responses of locomotive engineers to preset environmental stimuli and informational sources such as accelerations, vibrations, instrument readings, and knowledge of track conditions, as well as evaluation of train handling enhancement through the addition of new stimuli or informational sources.

As a subsidiary effort to the study of "Train Handling" performance, TSC is also recording data on physiological responses of locomotive engineers. The goal here will be to increase the understanding of the stress levels encountered by engineers during difficult train handling.

5.2 EFFORTS DURING FY73

5.2.1 Accomplishments

The major accomplishments of the train handling study in FY73 include the development of the sensors, transducers and instruments required to measure train handling performance, the development of a "window" recording technique to allow storage of the data on a non-interference basis during revenue operation, the observation and measurement of train handling performance during switching operations on a Federal Railway and the observation and recording of train handling during "over-the-road" revenue operations on the Southern Railway and the Southern Pacific Transportation Company Railway (SPTC).

5.2.2 Instrumentation Development

During FY73, sensors, transducers and data acquisition techniques were developed, tested and used to record the following parameters:

a. acceleration along the x axis (Thrust)

b. acceleration along the y axis (Sway)

c. acceleration along the z axis (Bounce)

d. train speed

e. test car-lead locomotive coupler angle

f. traction motor current

g. train brake pipe pressure

h. train brake cylinder pressure

i. EKG

j. EMG right biceps

k. EMG left biceps

l. EEG occipital lobe left hemisphere

m. computer time signal

n. real time signal

o. mile post

p. forward-reverse

q. dynamic-brake

r. auto-sand

s. wheel slip

The techniques and instrumentation in detail will be the subject of a report to be completed in the fall of FY74.

5.2.3 <u>Digital Recording and Analysis of Train Handling Data</u>

In the observation of skilled performance such as train handling, a problem which usually arises is that a major portion of the observation period is uneventful. Most operator performance studies use one of three techniques to insure the inclusion of critical occurrences when recording performance such as train handling.

1) <u>Continuous Recording</u> - This technique involves the recording of all available data for a period of observation and by definition, it ensures the recording of all events of interest. However, data storage and data analysis costs are so high as to make sometimes long term observation impractical. Further data reduction may be so expensive and tedious that critical segments of the observation go unanalyzed for want of time, money or interest.

2) <u>Landmark Recording</u> - This technique involves recording data only during pre-arranged test periods or when passing over track segments considered critical. While more economical than the first technique, here the inclusion of events of interest is a function of how well the observer-experimenter can predict the

critical landmarks of features, as events not correlated with these landmarks will be lost as data. Furthermore, the performances measured may be artificially influenced due to the subject's anticipation of the test features (track segments).

3) Event-Correlated Recording - Here data recording is triggered by some event or change which exceeds preset thresholds and continues for a predetermined period. This technique is more economical than continuous recording and it will record unexpected events, unlike the Landmark Technique. However, it has one significant drawback: only data following some change are recorded, so no data on the antecendents of the actuating event are available.

The development of field portable digital computers has allowed the development of a fourth technique which is referred to in this report as "window recording". Here the computer process temporarily stores, processes, and tests data continuously. When the tests reveal that predetermined event thresholds have been exceeded, the computer transfers a time window of data surrounding the event to permanent storage. This technique allows the recording of data of unexpected events in an economical manner, and the recording includes data antecedent and possibly causal to the event of interest.

TSC has developed and used a "window recording" technique to meet the requirements of the Train Handling study. The system developed includes a Digital Equipment Corporation (DEC) PDP 11/20 "mini" computer for processing, sampling, testing, and temporary data storage and DEC magnetic digital tape units for permanent storage of the data. The first use of the system was made during the "Steel Coil Train" tests conducted in cooperation with the AAR in June of 1973. During these tests the computer was programmed to constantly process data inputs representing each of the parameters mentioned in Paragraph 5.2.2 above. When a train brake pipe pressure reduction of seven or more lbs./sq. in. or a transition between power and dynamic brake occured, a data window beginning 15 seconds before the change and ending one minute and 45 seconds after the event was permanently stored. The computer was also triggered manually during planned test segments, when entering terrain known to cause handling problems, and over specific sections of track which were included in the SPTC simulator film library. While the data is currently under analysis, field examination of the digital recordings indicates that the technique was successful.

5.2.4 <u>Crane Field Recording Tests</u>

Three field recording tests were made during FY73. In September, two four hour recordings were made from two locomotive engineers during switching operations. The observational tests were conducted at the Crane Naval Ammunition Depot (Crane NAD), Crane, Indiana.

The purpose of the observational tests was twofold: the refinement of instrumentation and the monitoring of physiological stress during normal switching operations.

The tests were conducted at Crane NAD for the following reasons:

1) TSC had access to working locomotive engineers who were willing to participate in the physiological recording aspects of the effort.

2) There was sufficient scheduling flexibility at the Crane Railroad to allow for the vagaries of instrumental development.

3) The Crane Railroad had sufficient locomotive power to allow TSC unrestricted access to a locomotive for the period necessary for equipment installation and calibration.

Conducting field recording tests at Crane had significant drawbacks in terms of the applicability of the recorded data. The Crane Railway consists of less than 200 miles of thru track and sidings in hilly terrain. The track profiles are characterized by very short radius curves and short, steep grades. Speed is limited to approximately 30 MPH. The locomotives are World War II vintage road switchers. In TSC's tests, a 1200 hp turbocharged

Baldwin road switcher locomotive was used. Train length during the tests rarely exceed three cars. Due to the strict safety precautions in force at Crane NAD, critical incidents likely to cause the engineer to exhibit stress were very rare.

One incident of interest did occur while moving the locomotive to an outlying siding to pick up a string of freight cars. The engineer inadvertently ran through an open switch at approximately 30 MPH. While there was no derailment or damage to the locomotive, the switch-actuating rod was bent and the switch was rendered inoperable. The damage to the switch required that it be "spiked" in the closed position. Subsequent examination of the recorded data provided an opportunity for a detailed examination of many of the critical events and changes occurring during the incident.

Figure 5-1 depicts recorded analogue signals representing the following eight variables:

a) velocity (the periodic wave form in the signal is an artifact caused by speedometer cable "wow")

b) acceleration along the z axis (bounce)

c) acceleration along the y axis (sway)

d) acceleration along the x axis (thrust)

e) traction motor current (load)

f) cardiac activity (EKG)

g) independent brake pipe pressure

In addition to the recorded data, a one-second time marker is provided between channels f and g.

The first indicant of the incident is an independent brake pipe pressure reduction of approximately 14 lbs/sq. in. The moment of application is noted as "second zero" on the figure. The record reveals full reduction was achieved after approximately 3.5 seconds. Examination of channel d reveals a relatively linear increase in deceleration after the brake application. The average deceleration was approximately 0.1 G and the peak deceleration

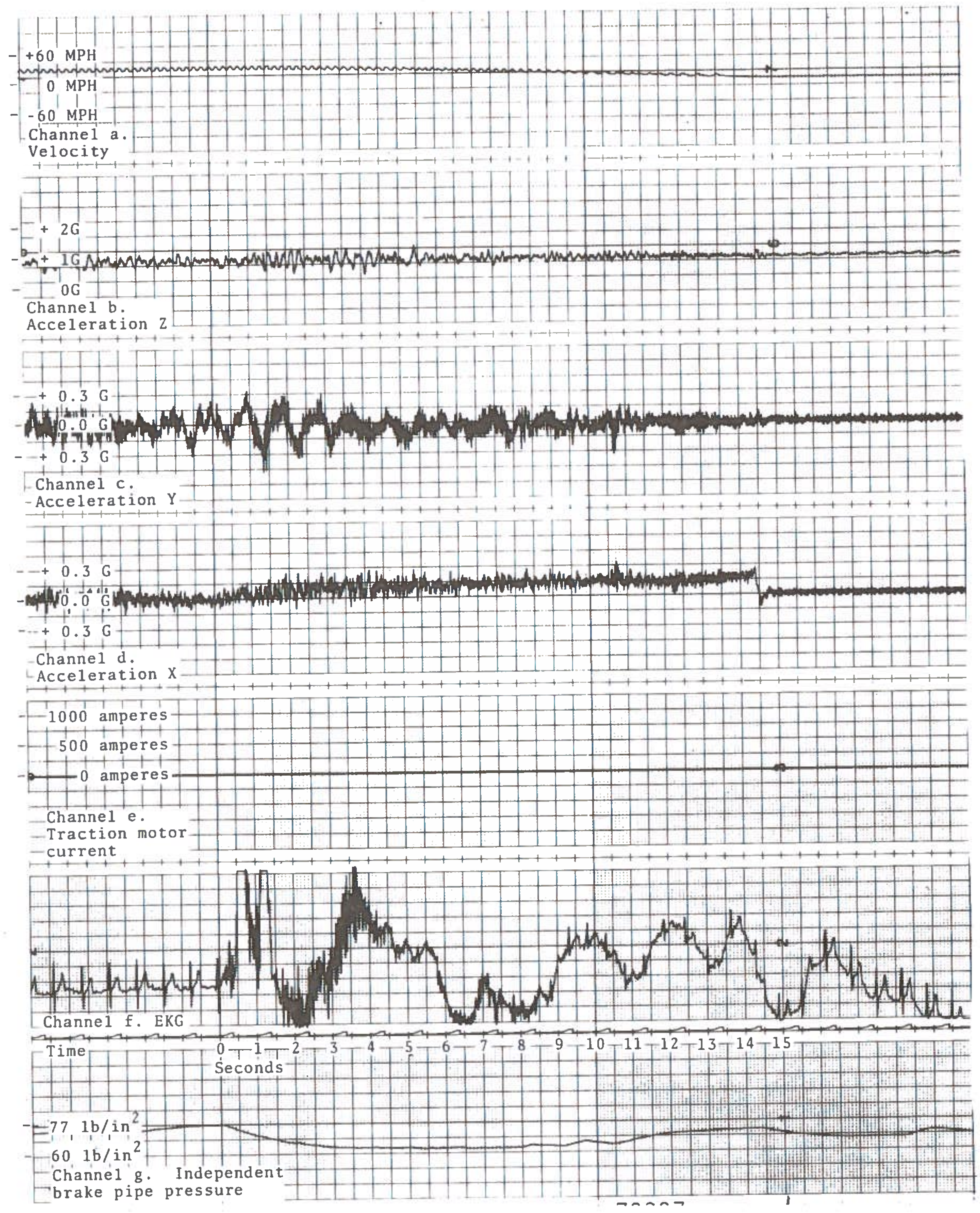

Figure 5-1 Data Recorded during "Open Switch Incident" on Crane NAD Railway

reached immediately before stopping was approximately 0.2 G.

Examination of channel c reveals that fairly large sway forces occurred during the first four or five seconds of deceleration. The forces had a peak amplitude of approximately ±0.3G and a period of about one second. Channel b depicts acceleration along the z axis (bounce) and as might be expected bounce decreased with velocity until, with the locomotive at rest, only the residual vibration from the diesel engine was present.

Perhaps the most interesting information appears in channel f which depicts the cardiac activity of the locomotive engineer. Most noticeable is the early masking or obscuring of the EKG signal by violent thoracic muscular activity. This obscuration occurs during the first 9 seconds after the brake application. Through examination of expanded graphic representations of channel f it was possible to compute the "beat-to-beat" heart rate immediately before the brake application and approximately 9 seconds after it. The rates were 83 beats/min. and 123 beats/min. respectively. This represents a substantial and rapid acceleration. Examination of the events accompanying normal service brake applications which result in planned stops revealed neither the thoracic activity present during the incident, nor did they reveal any systematic change (acceleration or deceleration) in heart rate.

Examination of the eight hours of recorded data yielded no other incidents which produced stress levels which may be directly correlated with train handling.

5.2.5 Observational Recordings on the Southern Railway System

In March of 1973, 16 hours of data was recorded during revenue operations between Atlanta, Georgia and Birmingham, Alabama on two Southern Railway System Freight Trains.

The purpose of the study was to gather the data needed to develop the digital recording system to be used in the "steel coil train" study on the Southern Pacific Transportation Company. Specifically, the data was necessary to determine the data sampling rate and to allow the development of threshold levels to trigger the "window" recording" technique. The recordings were made for a pair GM Electromotive Division (EMD) GP 38-2 2400 horsepower diesel electric locomotives. The choice of the locomotives was based on the similarity between these and the SD 45-2 EMD locomotives to be used in the "steel coil train" study.

The following paramters were recorded:

a) acceleration along the x axis (thrust)

b) acceleration along the y axis (sway)

c) acceleration along the z axis (bounce)

d) train speed

e) traction motor current

f) train brake pipe pressure

g) independent brake pipe pressure

h) throttle position

i) mile post

j) verbal comments

The recording was done on a 14 channel FM direct analogue magnetic tape recorder. The recordings were made with the cooperation of EMD of the General Motors Corporation who provided aid in the installation and calibration of the sensors, the Southern Railway System who provided access to the locomotives and crews, and the AAR who provided liason between TSC, EMD, and the Southern Railway System. It should be noted that while excellent cooperation was given by the operating personnel and maintenance personnel at the Southern Railway System, TSC was requested not to make physiological recordings of the engineers in order to eliminate any possibility of labor difficulties due to infringement on the prerogatives of the crews.

All but one of the parameters listed were recorded successfully. The exception was the measurement of Traction Motor Current (load). It was intended to measure load using an inductive current probe technique but examination of the data during and after the tests revealed intolerable signal instability. Based on this test, an optical isolation technique has subsequently been developed and is now employed to allow the measurement of traction motor current. Subsequent to the trip, the data was sampled and these samples used to develop the digital programs and thresholds on the "steel coil train" study.

5.2.6 Steel Coil Train Tests - Southern Pacific Transportation Company

In mid-June of 1973, TSC participated in the AAR-organized "steel coil train" study. The study was a cooperative effort of the following organizations: AAR, ENSCO, Inc., FRA, SPTC and TSC. The major purpose of the study was the gathering of data to be used in the development of a mathematical model of freight train dynamics. In order to accomplish this, a unit train made of identical cars specially built to carry coiled sheet steel was selected for the study.

A secondary goal of the study and the primary purpose of TSC involvement was to develop a data base of "good handling practice" recordings. Further, in view of the possible use of the SPTC locomotive simulator to evaluate train handling aids, it was considered highly desirable that measurements of "good handling practice" be made on sections of track included in the simulator's film library. Acquiring this data presented two difficulties: first, while the "steel coil train" travels over track included in the simulator library, it travels from west to east when loaded, while the simulator films run from east to west; and second, the steel coil train, because it is a unit train, represents an atypical and somewhat simple handling problem, whether loaded or empty. Because of these factors, it was decided that recordings would be made on the west to east trip on the steel coil train during planned AAR tests and over terrain identified by Southern Pacific operating personnel as presenting difficult handling problems. Recording would be made in the east-west direction on the SPTC's "Golden Streak", a heterogeneous fast freight train covering the same route as the returning empty "steel coil train" from El Paso, Texas to Los Angeles, California. Recordings on the "Golden Streak" were made on track segments in the simulator library, in particular the "Beaumont Hill", and on track sections selected because they represented difficult handling problems.

The sensors, transducers, signal conditioners, amplifiers and a DEC PDP 11/20 digital computer required to record the parameters mentioned in Section 5.2.2 above used the "window" recording technique, as described in Section 5.2.3. They were installed in an SPTC EMD SD45-2 3600 horsepower diesel electric locomotive and an accompanying dynamometer test car.

After installation, the system was statically and dynamically calibrated and provision was made for the recording of the time signal provided by the Ensco computer.

The data-gathering on the eastbound trip began at 1:00 AM PDT on 13 July, 1973 and ended at 8:00 PM MDT on 14 July 1973. During the eastbound trip, 22 AAR tests were made and recorded.

The westbound trip began at 9:00 AM MDT on 15 June, 1973 in El Paso, Texas and ended at 10:00 AM PDT on 16 June, 1973 in Los Angeles.

The data recorded on these tests is currently under analysis and will be the subject of a detailed report in the second quarter of FY 1974.

5.3 FY 74 EFFORTS

In the coming fiscal year, TSC plans to accomplish the following effort under the train handling subtask:

1) Analyze and report on data gathered during the "steel coil train" study.

2) Report in detail on the data acquisition system developed for the train handling study.

3) Determine the efficacy of the SPTC locomotive simulator for the investigation of train handling. This determination will be based on a number of divergent factors, including the availability

of recordable data outputs from the simulator, the extent to which skilled locomotive engineer performance on the simulator is correlated with their performance in the real world of the same track sections, and the availablility of the simulator for such research.

4) The evaluation of various handling aids, including some or all of the following:

a) Provision to the engineer of graphic representation of train weight distribution.

b) Provision to the engineer of a display which represents the total current drawn by all of the traction motors in his multiple unit consist.

c) Provision to the engineer of a set of minimum speeds required for the ascension of the ruling grades on his territory. These speeds are calculated from expected train resistance and predicted break-in-two forces.

d) Provision to the engineer of information regarding slack action at a small number of couplings spread through the train.

e) Provision to the engineer of information on coupler angle at the trailing coupling of his multiple unit consist during dynamic braking.

The utility of these aids shall be evaluated through field and/or simulator experiments depending on the factors mentioned in item 3 above.

5) The recording and analysis of data representing the time phase relationships between events significant to train handling, the engineer's response, and the response of the train. These recordings will be made on trains during revenue services and on the SPTC simulator depending on the factors mentioned in item 3 above.

6) The recording and evaluation of physiological responses to train handling problems during revenue service and/or during simulator tests depending on the factors listed in item 3 above.

6. FAULT-TREE ANALYSIS OF RAILROAD ACCIDENT DATA

6.1 SUMMARY

In connection with the effort of the Federal Railroad Administration to revise its accident investigation and reporting system, TSC initiated an activity designed to generate a list of data elements relative to human factors to be contained within a revised data base. During FY72, a number of such elements dealing with the selection, training, qualification and performance of railroad employees was specified for the FRA contractor charged with system's design. In addition, a technique was proposed which, it was felt, could facilitate the determination and specification of further such data elements. Since that proposal, additional effort has been expended in the analysis of railroad accident reports and limitations on the probable utility of the technique within the framework provided by those reports have become apparent.

The failure to find an effective short cut to the specification of critical human factors data through exploitation of what seems to us to represent the best of the railroad accident documentation makes all the more evident a need for a thoroughgoing research program in human factors. Those factors whose contribution to the accident picture are obvious have already been specified. Many currently receive attention in accident investigation activities. The remainder are likely to be very subtle and to exhibit complex interactions. But, it is these that must be understood if reliable control is to be gained in the operating system.

6.2 INTRODUCTION

The most cursory examination of the accident statistics presented in the annual Accident Bulletin leads to the conclusion that shortcomings in the collective performance of human elements accounts for a very large proportion of railroad accidents. The most recent Bulletin (No. 140) indicates that twenty-six percent of the 7,304 train accidents in 1971 were attributable to a broad range of employee negligence. Although this percentage is lower than those in preceding years, the requirement for understanding the sources of negligence and unsatisfactory performance remains. It is only through such understanding that the contribution of human error to total system error can be minimized over the long term.

A prerequisite to this understanding is, of course, an operational data base which enables inferences concerning the sources of negligence and unsatisfactory performance to be drawn. Such a data base and the analytic procedures for utilizing it are currently lacking in the FRA accident reporting system. The need has been identified within the Administration and forms at least part of the rationale for redesign of the system by the Tolis Cain Corporation.

Efforts to specify critical questions to be answered both at the scene of an accident and during the course of later investigation were begun at TSC in FY72, within the context of a larger program related to human factors in railroad operations. The outcome of these initial efforts was a list of data elements relating to railroad employee (particularly engineman) training, (medical and performance) qualification and, insofar as it could be reconstructed, behavior just prior to the accident. The list reflected the bias that an accounting for the apparent "negligence" of an employee might, in many cases, only be possible if a relatively complete profile of that employee from the date of his employment to the time of the accident could be assembled. The list containing these elements was forwarded to the FRA contractor for accommodation with the accident reporting system being designed.

It was acknowledged at the outset of this activity that it would be impossible immediately to specify a complete list of all employee selection, training, qualification and performance factors which might ultimately be of interest in accident study. Quite simply, there is too little known about the physical and psychological environments in which railroad employees work to accomplish such a feat. To work toward specification on an incremental basis, however, is reasonable. (And, indeed, it is expected that the human factors program at TSC will provide the groundwork for such an incremental approach.) As a supplement to formal research efforts, it was (and is) considered desirable to investigate any additional approaches which appear to offer promise of enabling specification of elements prior to the completion of the total program. At the beginning of FY73, it was felt that fault-tree analyses of specific accident types as reported in the Railroad Accident Investigation Report series represented such an approach. Efforts were then begun to estimate the probable utility of that approach as a "short-cut" to the completion of the data element list.

The assumption underlying pursuit of this approach was that, although a relatively small number of causal factors might be associated with any given single accident, a group of accidents of the same general type (e.g., rear end collisions, head end collisions) might yield a constellation of causal factors from which a fault-tree could be drawn. With such a structure, it might then be possible to infer potential relationships between cited factors and provide for the collection and analysis of data implied by those relationships. Although the analogy is far from perfect, the concept here is similar to one encountered in the construction of a jigsaw puzzle, where the shape of a (missing) piece might be inferred from the border formed by surrounding pieces, or the (pictorial) content of the piece might be inferred from the content of an adjacent piece.

6.3 DISCUSSION OF TECHNIQUE

As difficult as it may be to ferret out the causes of accidents which are due ultimately to the failure of equipment, the tasks of discovering and defining causes which ultimately lead to failure in human performance are far more difficult to investigate if prevention of future occurrence is the goal. A judgment that an engineman, for example, failed to operate his train in accord with signal indications because he failed to see the indications may be fairly easy to render and to represent in a causal explanation, but it generates precious little insight into what steps might be taken to improve either the perceptual or control environments in which enginemen operate. What we must somehow develop is a system generation breakdown for accidents which is formally exhaustive in the sense that it spells out all factors which could, in appropriate, explicitly formulated combinations result in the accident event of interest.

A block diagram which represents some of the conditions which could give rise to a collision is presented in Figure 6-1. The diagram is superficial in a number of ways, including the following: (1) At any given level, it presents only two conditions which alone or in combination (open or filled circles, respectively) could give rise to the effect at the next higher level. (2) It represents conditions relative only to brake function and those with respect to only one train. (3) The braking system is represented as a unit entity, not one composed of separate subsystems (independent brake, dynamic brake, train brake, retainers, etc.) which can be manipulated alone or in combination to control the speed of the train.

Despite these limitations, the diagram conveys the concept of a hierarchy of causes and interrelationships reasonably successfully. What is required to make such a diagram truly representative of collisions due to "insufficient braking action" is a complete catalog of causes and their (and/or) relationships at each level in the hierarchy. It is the contents of such a catalog which we would hope to generate on the basis of a study of railroad accidents.

Assuming that a hierarchy of causes and effects could be constructed, how might it be used in the investigation of accidents and in the redesign of hardware of procedural systems? It seems to us that, in addition to aiding the understanding of the dynamics of accident causation, it might have utility in at least two additional activities associated with accident study: (1) estimation of the relative likelihoods of given causal sequences

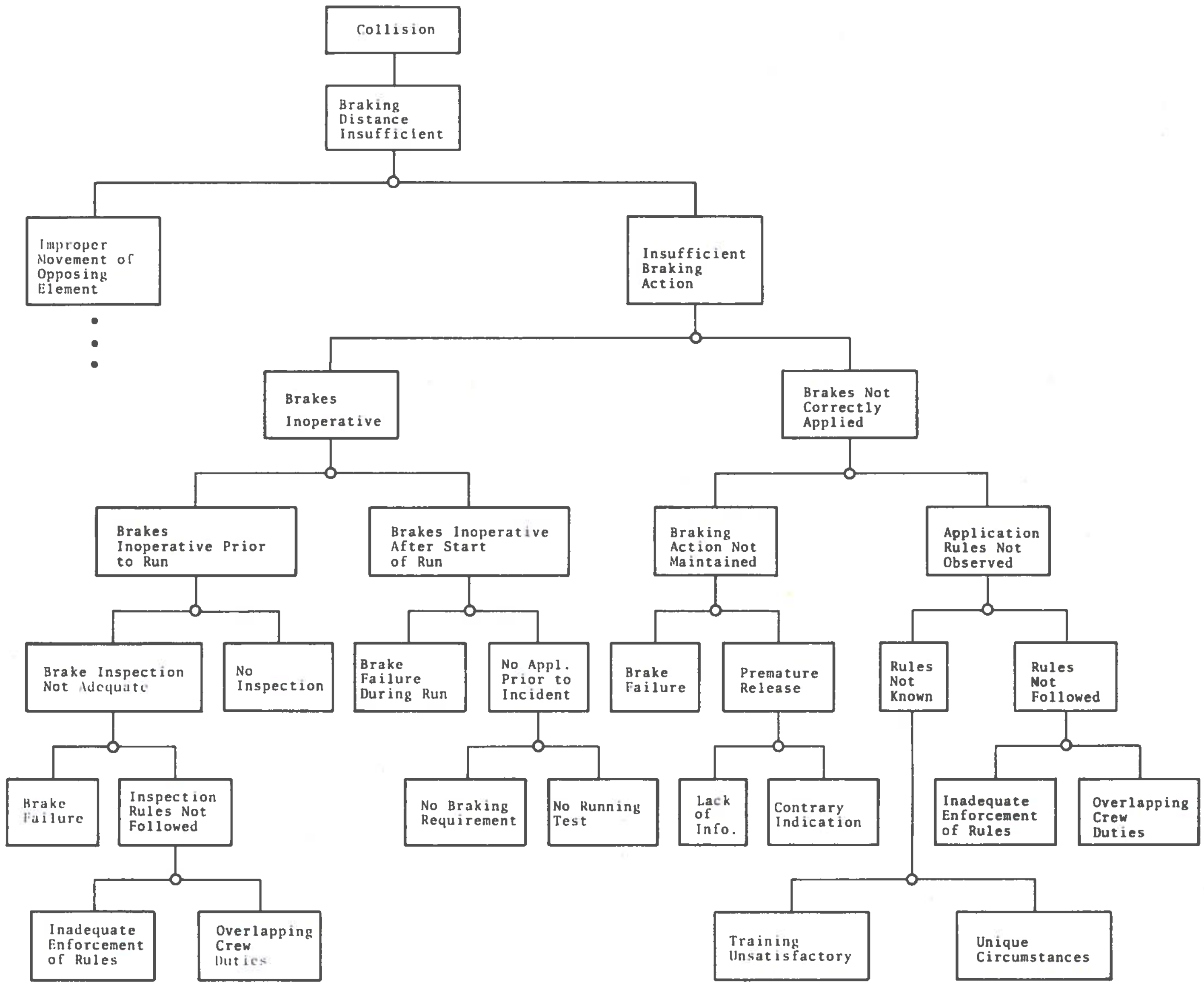

Figure 6-1 Gross Fault Tree Diagram for Collision Due to Insufficient Braking Action

in future accidents of a defined type; and (2) specification of critical areas within the hierarchy at which links in the causal chain might effectively be broken.

The estimation of relative likelihoods could be implemented by determining at each level in the hierarchy the percentage of accidents in which a given condition was found to have existed prior to the accident event. Since (theoretically) the relationships between conditions above and below a given level are completely specified, the percentages can serve as direct estimates of the probabilities that (1) the condition at that level was produced by a given condition at the next lower level and (2) the condition at that level will produce a given condition at the next higher level. This concept is illustrated in Figure 6-2, where a hierarchy of causes is shown with percentages (probabilities) associated at each level. Given an accident of a particular (event) type, we might now predict, on the basis of past experience, that it was most likely caused by condition "C", that "C" was most likely to have been caused by the combination of conditions "C_{21}" and "C_{22}" and that the former of these was caused by condition "$B_{22}C_{21}$".

As we have indicated, this approach may also aid the judgment of where to attempt to break causal sequences in order to avoid recurrence of a given accident (event) type. It seems clear from a study of the generation of cause "C" that if one found a way to eliminate "C_1" and "C_2", and "C_1" and "C_{21}", "C_1" and "C_{22}" or "C_1" and "$B_{22}C_{21}$" one would have eliminated the most frequent cause of the event type. A choice among these alternatives might be made on the basis of the cost of modifying the equipment or procedural system at the level associated with the cause(s) in question, on the probable degree of success of implementation at that level, or with respect to other explicit criteria.[3]

[3]Other things being equal, the best choice in our example might be "C_1" and "$B_{22}C_{21}$", since the latter is implicated in two high-level causes (C_2 and B_2).

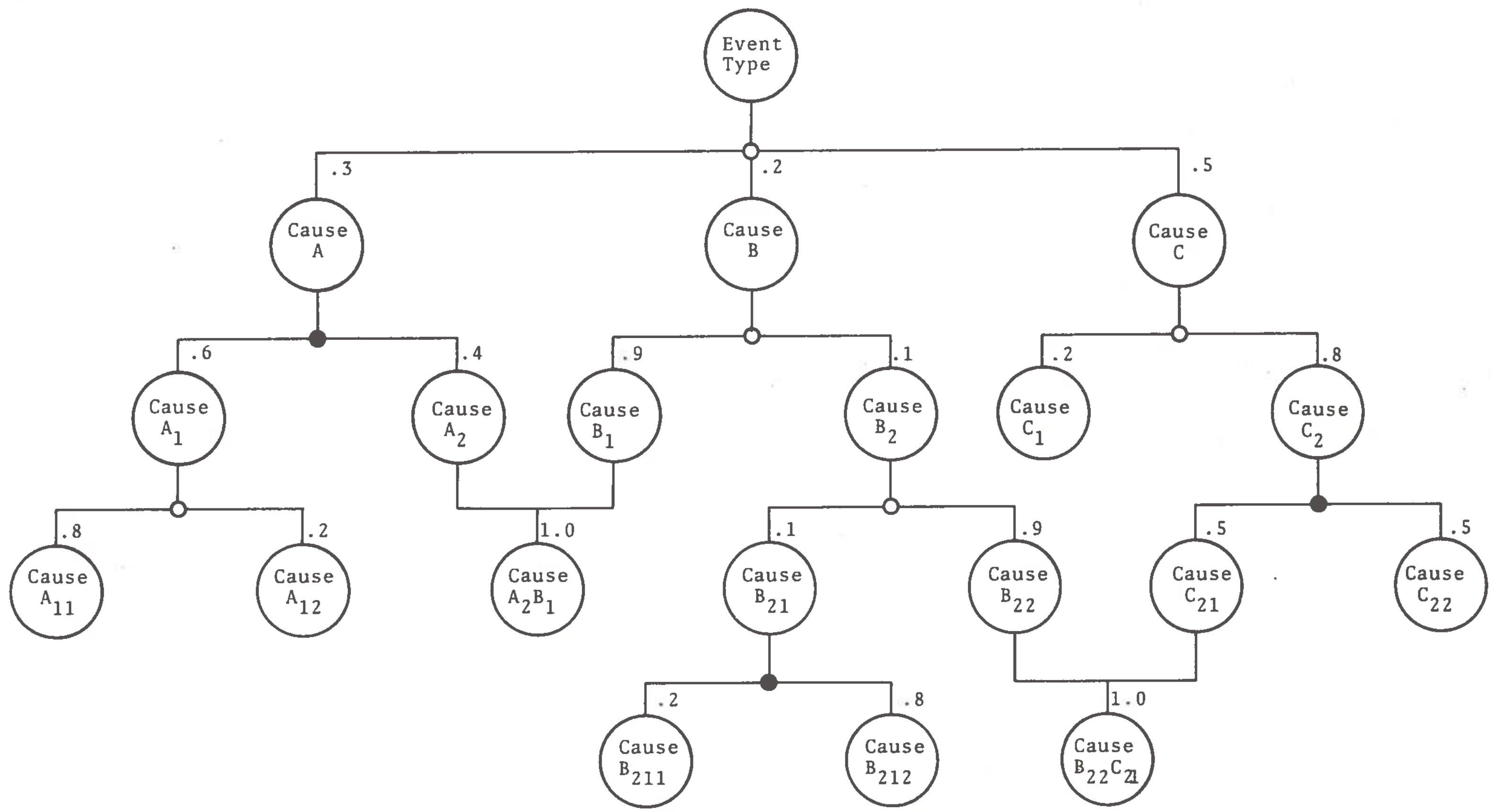

Figure 6-2 Diagram Showing Probabilities of Association Among Levels of Cause

6.4 REVIEW OF CURRENT EFFORT

To date, our attempts to exploit the fault-tree technique have not borne out the early optimism. Although it was never expected that the approach would unearth antecedents of particular types of "negligence" not already identified during the investigation of given accidents, it was anticipated that the formal delineation of conditions and sequences in which reported events had occurred would provide insight into possible sources of observed "negligence". That this has not been the case is due largely from the fact that the typical railroad accident (at least as judged from the *Summary Reports*) does not appear to occur as the result of extensive interaction of individual events. Though instances can be found in which errors in the dispatching function, faulty-train handling and such "negligence" as failure to protect the rear end of a train do interact and the prevention of any one of these errors could have lowered the probability of accident occurrence, those instances in which one or two events produce the accident are far more frequent.

It is most essential to recognize that the discussion here concerns *reported* causes and that any one of these reported causes might admit of a large number of underlying causes and effects which would be specifiable if we had the tools to uncover them. It must be remembered that the generation and exploitation of these "tools" is one of the goals of the total research program and that the activity reported here represented an attempt to make optimum use of what is *already* available. Thus the statement that most accidents are the result of a very small number of causal events is, in effect, a statement of the limitations of current data to provide insight at any finer level of detail.

To appreciate the problem more fully, it is necessary to examine the causes identified in the accident reports which formed out data base. In Table 6-1, a summary of thirty-two accidents (identified by accident report number) is presented.

TABLE 6-1 SUMMARY OF CAUSE DATA BY REPORT NUMBER

Single Cause		Multiple Cause			Cause(s) Unknown
Proximal	Distal	Proximal	Distal	Proximal and Distal	
4140	4145	4154	4143	4148	4153
4146	4155	4160	4162	4152	
4156	4159	4170	4173		
4157	4163	4176	4178	4164	
4168	4165			4166	
4169				4167	
4172				4171	
4174				4177	
4175				4179	
				4181	
9	5	4	4	9	1

The accidents are classified in terms of whether single or multiple causes were cited as an outcome of their investigation. They are further classified in terms of whether the cited causes occurred in close temporal or spatial proximity to the accident itself ("proximal" causes) or whether they occurred at some distance (temporarily or spatially - "distal" causes).[4] The important observations to be made here are that approximately 43 percent of the accidents appear to be due to either a single proximal or a single distal cause and that 53 percent are the result of multiple cause.

The fault-tree analysis proposed is of little value for the study of the single cause cases. The possibility does remain, however, that accidents admitting of multiple causes may be "rich" enough in contributing factors to enable speculation about interrelationships.

Table 6-2 presents a summary of the multiple cause accidents in Table 6-1. The number of prime and contributory causes identified in the cited reports are shown, along with an indication of whether those causes can be considered to be due to human failure, to hardware failure, or to both. It is clear from an examination of this table that in an overwhelming proportion (82 percent) of the accidents, only two causal factors are cited. If we delete from this set, those accidents which are attributable strictly to hardware failure and those in which human and hardware failures are unrelated (starred entries), we find that ten of the remaining thirteen entries have only two causes associated with them.

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[4] The distinction between proximal and distal causes is a highly judgmental one in this analysis. If the cause is associated with the actual operation of the train at a given point in time, is related primarily to the performance of a member (or members) of the train crew and does not appear to be the result of antecedent conditions which occurred much earlier in time or at a different location, it is classified as a proximal cause. If these conditions are not fulfilled, the cause is considered distal. Thus a failure to control speed in accordance with signal indications or failure to protect the rear of a standing train would be considered proximal causes while an error in dispatching or a failure to inspect a train prior to starting a run would be considered distal causes.

TABLE 6-2 NUMBER AND TYPE OF CAUSE ASSOCIATED WITH MULTIPLE CAUSE ACCIDENTS IN TABLE 6-1

Proximal Causes			Distal Causes			Proximal/Distal Causes		
Report No.	No. of Causes	Cause Type	Report No.	No. of Causes	Cause Type	Report No.	No. of Causes	Cause Type
4154	2	Human	4143	2	H'ware	4148	2	H'ware
4160	4	Human	4162	2	H'ware & Human	4152	2	Human
4170	2	Human	4173	2	H'ware & Human			
4176	2	Human	4178	2	Human	4164	2	H'ware & Human
						4166	2	H'ware
						4167	2	H'ware
						4171	5	Human
						4177	3	H'ware & Human
						4179	2	H'ware & Human
						4181	2	Human

If we can assume that the accidents reviewed in this set of reports are a random sample of all train accidents, we might reasonably conclude that a very large proportion of all railroad accidents are "caused" by no more than two related events. As indicated earlier, whether or not this would be the case given the wherewithall to measure cause and effect at a more molecular level is not clear.

By itself, the observation that a given accident has relatively few causal factors is not damaging to the prospect that accidents of a similar type might be grouped together to increase the pool of such factors. What _is_ required to make that effort successful is _variety_ in the causes identified. If we were to find among, say, five different rear end collisions a constellation of nine or ten different causal factors, we might have the basis for constructing a tree from which possible interrelationships could be identified.

Table 6-3 presents a tabulation of the number of different causes associated with head end and rear end collisions which can be clearly identified as due to human failure.[5] In addition, the actual causes cited are indicated. It is clear from brief examination of this table that the variety of causes within the species of accidents is low. And, although the fact cannot be established from the table, it is also the case that four of the seven causes associated with rear end collisions refer to the behavior of only one of the two possible operators involved in the accident. Thus the possibility of developing a notion of the potential interactions between events occurring in the two trains is low.

6.5 CONCLUSIONS

Our efforts to construct fault-trees from data growing out of the investigations of single accidents and out of cross-sections of accidents of a single species have not been successful. The

[5] Side and rear end/side collisions do not appear in this tabulation because of their low frequency in our data base -- four and two, respectively.

TABLE 6-3 NUMBER OF DIFFERENT CAUSES PER ACCIDENT CATEGORY

Accident Category	No. of Different Causes Cited	Causes (No. of Accidents in Which Cited)
Head End Collisions (8)	3	Excessive Speed (8) Misunderstanding of Instruction (1) Improper Meet Orders (2)
Rear End Collisions (12)	7	Excessive Speed (7) Failure to Protect Rear (2) Use of Alcohol (1) Failure to Restore Sliding Switch (1) Violation of Time/Work Limits (1) Communications (1) Block Operator Error (1)

apparent reasons for this are that the number of causes cited in connection with single accidents is too low to allow for inferences concerning their interrelationships and that the variety of causes (no. of different causes) cited within a species is low. The net effect of these "shortages", were a fault-tree to be drawn, would be a structure essentially without branches or at best, a structure with branches whose points of articulation are unknown.

The goal of this effort was to provide a framework within which inferences could be made concerning the possible antecedents of cited causes and their interrelationships. In the interest of maintaining a separation between causes arrived at by formal investigation (i.e., those actually cited in the Summaries) and those arrived at inductively, a constraint was imposed which required that causes identified in the Summaries be represented with a minimum amount of interpretation. All interpretive and inferential activity was to take place with respect to possible antecedents and their interconnections. The attempt to operate within this constraint has proved valuable, despite the fact that its imposition may well have mediated against our ability to generate a fault-tree. It has pointed up the shortcomings of the data base provided by the Railroad Accident Summaries for human factor analyses in any sort of depth and with any sort of rigor. This is not to say that the Summaries do not constitute a valuable commodity for the purposes of documenting the results of an investigation or that they do not fulfil completely the purposes for which they are really intended.[6] It is simply to say that they do not, in our judgment, provide a sufficient characterization of the human elements of the system and the conditions under which they operated to be of utility in an intelligence effort of the sort undertaken here.

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[6] In an earlier report (cf. Human Factors in Railroad Operations: Initial Studies, DOT-TSC-FRA-72-8, p. 79), the value of these reports was argued. Our opinion of this value vis a vis that of the Bulletin in an attempt to weigh the importance of human factors in accidents remains.

At this time, we know of no other analytic technique which might be applied to the data of the Summary Reports to aid in establishing the behavioral sequences of interest. On the basis of our results, we are inclined to believe that further specification of human factors' data elements must await the accomplishment of formal research programs in which the behavior of personnel critical to the safety of railroad operations is carefully observed under controlled conditions.

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APPENDIX A

TABLE A-1 MEASURES OF ENGINEMAN RESPONSE AND EXPERIMENTAL SEQUENCES TO WHICH APPLIED

	Validation		Study Sequence				Problem Package			
Behavioral Measures	1	2	1	2	3	4	1	2	3	4
Reaction Time (RT)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Frequency of Control Movements	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Frequency of Control Movement Reversal	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Frequency of Postural Adjustment				✓	✓	✓	✓	✓		✓
Display Reading Accuracy			✓	✓	✓	✓	✓	✓	✓	✓
Frequency of Communications	✓		✓	✓	✓	✓	✓	✓		✓
Visual Difference Threshold							✓	✓		
Auditory Difference Threshold							✓	✓		
Force Applied to Controls	✓					✓	✓	✓		✓
Physiological Measures										
Heart Rate (HR)		✓		✓		✓	✓	✓		
Blood Pressures (BP)		✓		✓		✓	✓	✓		
Electrocardiogram (EKG)		✓		✓		✓	✓			
Electroencephalogram (EEG)		✓		✓		✓	✓	✓		
Galvanic Skin Response (GSR)		✓		✓		✓	✓			
Electromyogram (EMG)		✓		✓		✓	✓			
Temperature		✓		✓		✓	✓	✓		
Respiration Rate		✓		✓		✓	✓	✓		
							✓			

TABLE A-2 MEASURES OF SIMULATOR RESPONSES TO CONTROL INPUTS

1. Velocities and accelerations of following components of simulator motion
   a. X-axis translation (fore/aft)
   b. Z-axis translation (up/down)
   c. Y-axis translation (side-to-side)
   d. X-axis rotation (roll)
   e. Z-axis rotation (yaw)
2. Brake pipe pressure
3. Brake pipe flow
4. Load current
5. Speed.

TABLE A-3 ANTHROPOMETRIC DIMENSIONS OF INTEREST IN ENGINE CAB DESIGN*

1. Sitting Height
2. Weight
3. Height
4. Maximum Body Depth
5. Maximum Body Breadth
6. Eye Height, Seated
7. Shoulder Height, Seated
8. Elbow Height, Seated
9. Forearm-Hand Length
10. Elbow-to-elbow Breadth
11 Hip Breadth, sitting
12. Buttock-Popliteal Length
13. Knee Height, Sitting
14. Popliteal Height, Sitting
15. Grasping Reach, Horizontal Boudnaries
16. Forward Reach, Seated.

*See Van Cott, H. P. and Kinkade, R. G., Human Engineering Guide to Equipment Design, McGraw-Hill Co., 1972.

APPENDIX B

ORGANIZATION CHARTS

In order to identify the classes of employees involved in the operating and maintenance functions of a sizeable railroad, three organization charts have been drawn delineating, in skeletonized form, commonly used job titles and the usual lines of authority and responsibility at the Division level.

The charts cover the personnel involved in the three major areas of railroad operation and maintenance:

Figure B-1 - Operating Forces
Figure B-2 - Maintenance of Equipment Forces
Figure B-3 - Maintenance of Way and Structures Forces

The charts do not show all the possible titles that will be understood to exist, such as:

1. Assistant officers in supervirsory positions
2. Assistant foremen
3. Helpers, apprentices and trainees
4. Laborers, cleaners, etc.
5. Various classes of yardmasters
6. Various classes of foremen and skilled workers.

Job titles on each chart that may not be self-explanatory are defined in the accompanying text.

FIGURE B-1

Travelling Car Agent. Checks supplies of empty cars and directs movement to points where they are needed or, if in surplus supply, to home railroads in accordance with Car Service Rules and Directives.

Safety Agent. Conducts campaigns to educate workmen in safety matters through meetings, lectures, demonstrations, etc.

Participates in the investigation of all accidents and compiles reports for the carrier and for submission to F.R.A.

Inspects property and reports conditions that constitute hazards from the standpoint of personal injury, fire, etc. Maintains a call list of specialists in handling hazardous material who will be available in the event of accident.

Chief Crew Dispatcher and Crew Dispatchers. Assign train and yard crew personnel to jobs in accordance with established qualifications and current agreements with the labor organizations.

Chief Train Dispatcher. The authority for the scheduling and movement of all trains on the division. He is responsible for the preparation of timetables and the inclusion of special instructions.

Train Dispatcher. Directs the movement of all trains and other track equipment over the tracks of specified lines of railroad by train orders, permissions, or control of signals and switches. Makes a permanent record of all movements within his assigned territory.

Operator. Under the control of Train Dispatcher, directs movements within specified blocks or within the limits of an interlocking plant. May also copy and deliver train orders. Maintains permanent records of movements.

Rules Examiner. Instructs and examines personnel on the rules and instructions governing train operations.

Company Police. Responsible for the general protection of company property and of people on the property, conduct investigation of theft, vandalism, etc., maintain liaison with public policies, including the F.B.I.

Trainmaster. Carries out the policies and instructions of the Superintendent with respect to train and yard operations within an assigned territory. Supervises operation generally with respect to performance of the assigned work and for compliance with company rules, regulations and instructions.

Yardmaster. May be a General Yardmaster with overall responsibility for the operation of a large yard and having Trick Yardmasters (with responsibility for operation during an eight-hour trick only), under him.

Hostler. May be an Inside Hostler, assigned to move engines only within a limited territory not involving signals, as within designated engine house territory, and shown on Chart #2. An Outside Hostler may be assigned to move engines only within designated and limited territory involving signals, and is shown on Chart #1.

Station Agent. The carrier's representative at one or more designated stations, maintaining direct contact with shippers and receivers of freight and directing local train and yard operations at their stations. A Station Agent may be freight only, passenger only, or may handle freight and passenger business, as the case may be.

Ground Crew of Yard Switcher. The person in immediate charge of a yard switching crew may be titled variously as a Yard Conductor, Yard Foreman, or Engine Foreman. Assistants may be titled variously as Yard Helper, Yard Brakeman, or Switchman.

Road Foreman of Engines. Generally responsible for training, qualifying and monitoring the performance of enginemen. He reports to the Division Superintendent, or Assistant, on Operating matters and to the Master Mechanic on Mechanical matters.

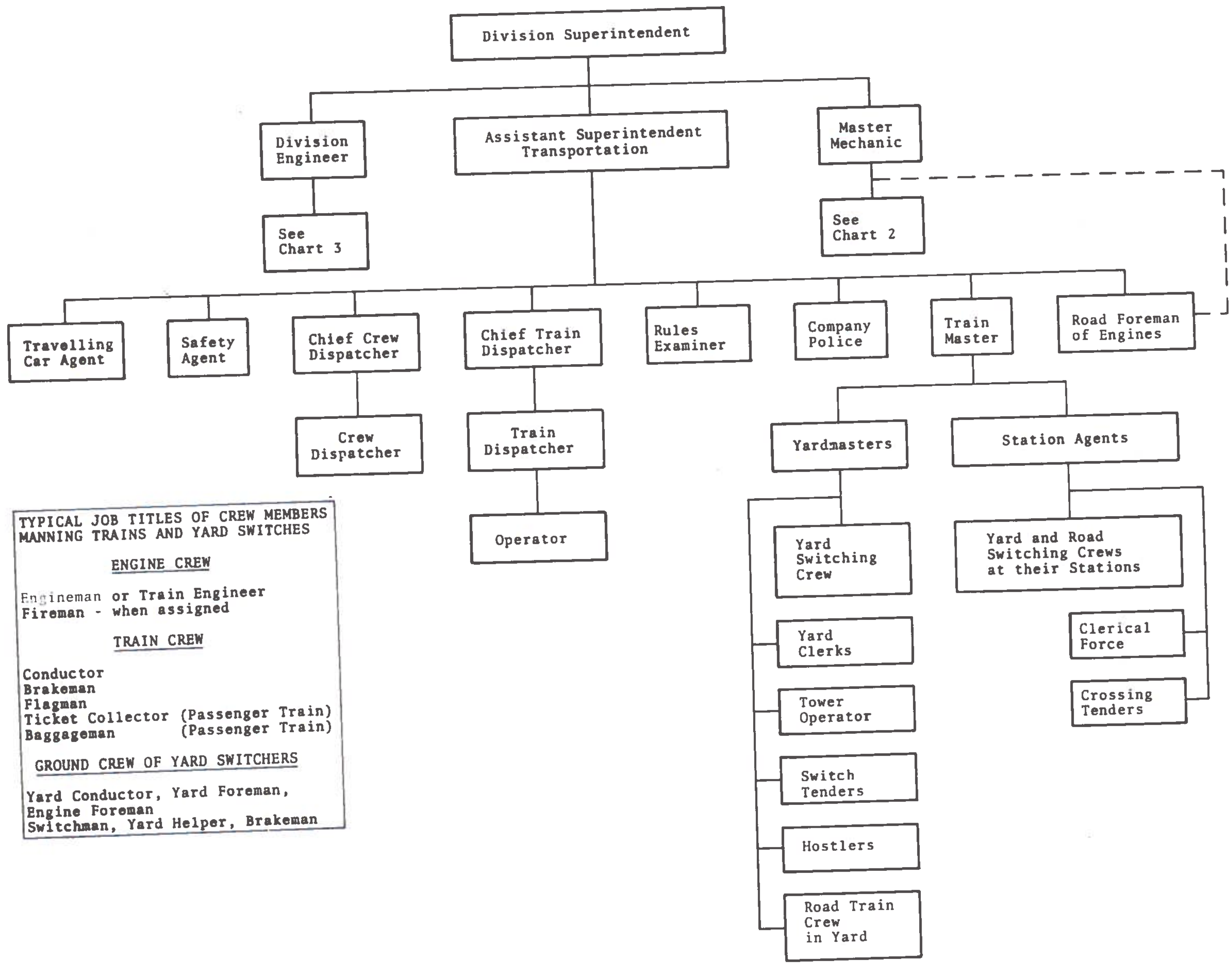

Figure B-1 Typical Organization of Railroad Operating Forces

FIGURE B-2

Carmen. May be used interchangeably at some points as Car Repairmen and as Car Inspectors. Car inspectors must know that all cars within their jurisdiction are in safe condition to be moved, meet the A.A.R. Standards for Interchange when received at Interchange Points, and that lading dimensions and weight are within specified limits. They must be familiar with rules governing train operation and A.A.R. Mechanical Division Rules.

Air Brake Supervisor. Responsible for training and qualifying personnel in the operation and maintenance of air brake equipment.

FIGURE B-3

Foreman. In addition to the "Gang" Foreman shown on the chart, there may be "General" Foremen, "Extra Crew" Foremen and "Worktrain" Foremen.

The Supervisor of Welding and his organization is responsible for building up worn rail ends, (at joints), joining rails together end-to-end, and rebuilding worn frogs, etc., by means of electric welding. This is distinguished from the category of Welder (structural steel, etc.) shown in the Bridge and Building Maintenance block.

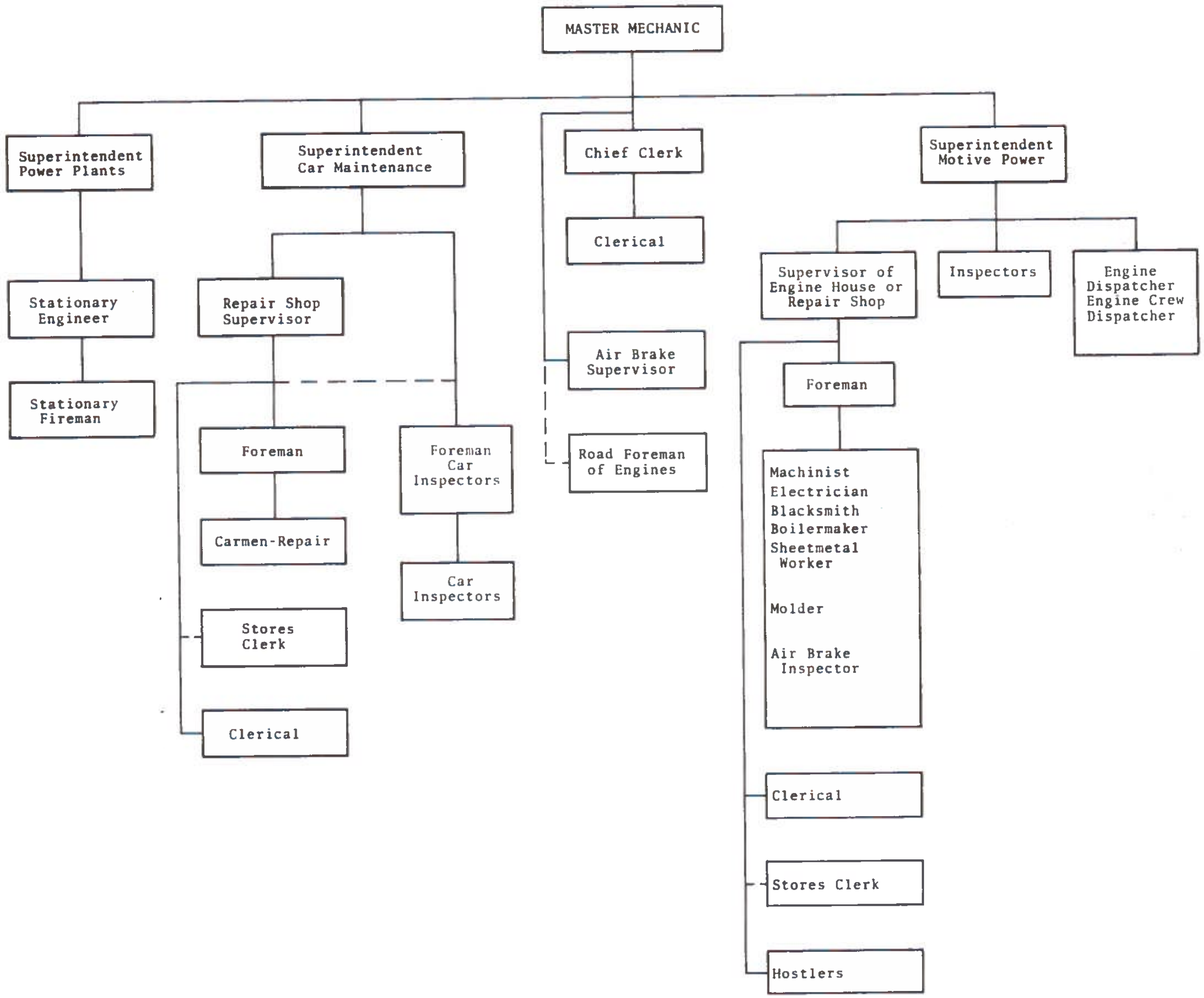

Figure B-2 Typical Organization of Railroad Maintenance of Equipment Forces

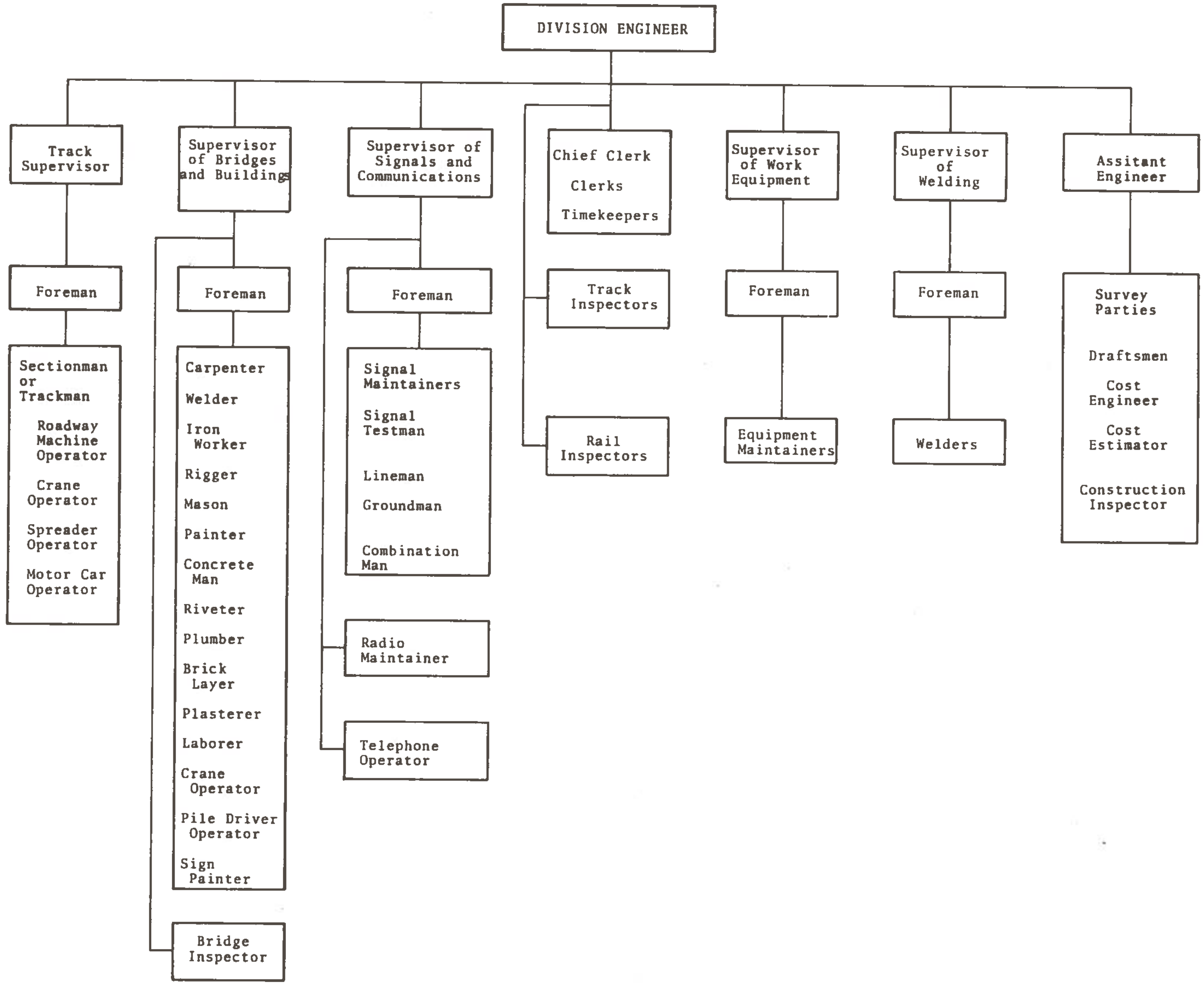

Figure B-3 Typical Organization of Railroad Maintenance of Way and Structures Forces

TABLE B-1 REQUIREMENTS (IN ADDITION TO CRAFT SKILLS), OF RAILROAD JOBS HAVING A DIRECT IMPACT ON THE SAFETY OF TRAIN OPERATIONS (COMPANY OFFICERS EXCLUDED)

	Adherence to:				
	Safety Rules	Operating Rules and Instructions	Air Brake Rules	Federal and other Regulations	Mechanical Rules and Instructions
Operating Forces					
Engineman-Road and Yard	Complete	Complete	Complete	Applicable	Applicable
Fireman	Complete	Complete	Applicable	---	Applicable
Conductor-Yard and Road	Complete	Complete	Applicable	Applicable	Applicable
Brakeman and Yard Helper	Complete	Complete	Applicable	---	---
Yardmaster	Complete	Complete	Applicable	Applicable	Applicable
Switchtender	Complete	Complete	---	---	---
Train Dispatcher	Complete	Complete	---	Applicable	Applicable
Operator - Block or Tower	Complete	Complete	---	---	---
Hostler - Outside	Complete	Complete	---	---	Applicable
Crossing Tender	Complete	Applicable	---	---	---
Draw Bridge Tender	Complete	Applicable	---	Applicable	---

TABLE B-2 REQUIREMENTS (IN ADDITION TO CRAFT SKILLS), OR RAILROAD JOBS HAVING A DIRECT IMPACT ON THE SAFETY OF TRAIN OPERATIONS (COMPANY OFFICERS EXCLUDED)

	Adherence to:				
	Safety Rules	Operating Rules and Instructions	Air Brake Rules	Federal and other Regulations	Mechanical Rules and Instructions
<u>Maintenence of Equipment Forces</u>					
Foreman - Car Repair	Complete	Applicable	Applicable	Applicable	Applicable
Foreman - Car Inspector	Complete	Complete	Applicable	Applicable	Applicable
Car Inspector	Complete	Complete	Applicable	Applicable	Applicable
Foreman - Enginehouse or Locomotive Repair Shop	Complete	Applicable	Applicable	Applicable	Applicable
<u>Maintenance of Way and Structures Forces</u>					
All Gang Foremen	Complete	Complete	---	Applicable	Applicable
Operators of Motor Cars and Self-Propelled Equipment on Track	Complete	Complete	---	Applicable	Applicable
Signal Maintainers, Testmen, etc.	Complete	Applicable	---	Applicable	---
Radio Maintainer	Complete	Applicable	---	Applicable	---
Track Inspector	Complete	Applicable	---	Applicable	---
Rail Inspector	Complete	Applicable	---	Applicable	---

APPENDIX C

QUESTIONNAIRE - GUIDELINE FOR TRAINING SURVEY

C.1 INTRODUCTION

The Transportation Systems Center of the U.S. Department of Transportation has been commissioned by the Federal Railroad Administration to review the training programs for operating personnel now being conducted by a number of railroads. This effort was initiated on the rationale that sooner or later training and/or proficiency standards shall have to be established for reasons of safety for both railroad personnel and the general public. Precedent for such standards has already been established by application to air carriers. To be acceptable, however, any training and/or proficiency standards shall have to be meaningful to both railroad management and railroad labor as well as the Federal Railroad Administration. For this reason plans are that most of the information required to develop training standards will be collected from the railroads on training programs now in operation and from the unions on the training programs they believe the railroads should have. Hopefully, areas of agreement will be found in these two sets of data which can serve as a nucleus from which a workable set of training standards can be developed. The training standards judged most likely to contribute to the safe operation of the railroads of the nation are those for instructions in (1) railroad operating rules and their applications to all operating personnel and (2) professional skills to railroad conductors (road and yard), engineers (road, yard and outside hostler), train-dispatchers and train-order operators.

C.2 INFORMATION REQUESTED

In general, the information requested from the railroads is that which can contribute in any way to the development of meaningful training standards for instructions in (1) operating rules and their applications for all operating personnel and (2) job skills for railroad conductors (road and yard), engineers (road, yard and outside hostler), train dispatchers and train-order operators.

Expectations are that the information that will be most useful is that contained in such documents as job descriptions, course outlines, course text books, course examinations, position qualifying examinations and experience requirements. Hopefully, copies of such documents can be made available for the purposes of this survey; however, under no condition will any of the information obtained be identified with a particular carrier in any of the resulting reports to the Federal Railroad Administration.

Each of the areas of interest is covered by a separte questionnaire-guideline, thus allowing them to be distributed among the appropriate individuals, if this is considered desirable. A number of copies of the Course Information Sheet and the Examination Information Sheet are enclosed for your convenience.

In completing these questionnaire-guidelines, please reference all answers by question number.

A. Training in Operating Rules

The safe operation of any railroad depends to a very great degree on how well the operating personnel know and understand the operating rules and their applications. The Federal Railroad Administration has commissioned us to determine what training and examinations in operation rules and their applications are given to operating personnel by the railroads. Answers to the following questions should give us much of the information we need. It would also be very helpful to us if we could obtain copies of all course outlines, textbooks, examinations with correct answers, and any other material you believe might be of help to us in this effort.

1. Describe the job qualifications of the individuals typically assigned the responsibility for training all operating personnel in operating rules and their applications. If possible, also furnish copies of the job descriptions of these individuals.

(Training of New Hires in Operating Rules and Their Applications)

2. Describe the job qualifications of the individuals typically assigned to instruct new hires in operating rules and their applications. If possible, furnish copies of the job descriptions of these individuals.

3. Does the training and/or examination in operating rules vary according to the job classification of the new hire? If so, how?

4. Does the training and/or examination in operating rules vary according to the location of employment within the railroad system? If so, how?

5. If the training in informal, what and how is training given to new hires to ensure that the operating rules and their applications are known and understood?

6. If the training is informal but an examination is given, the information outlined on Examination Information Sheet is requested.

7. If the training is formal and an examination is given, the information outlined on Course Information and Examination Information Sheets is requested for each training course and examination given to new hires in the area of operating rules and their application.

(Recurrent Training and/or Examinations in Operating Rules)

8. Describe the job qualifications of the individuals typically assigned to instruct and/or examine regular operating personnel in operating rules and their applications. If possible, furnish copies of the job descriptions of these individuals.

9. Are regular operating personnel required to take periodic training courses and/or examination in operating rules and their applications? If so, describe the procedures and requirements.

10. Does the training and/or examination in operating rules vary according to the job classification of the regular operating personnel? If so, describe the differences.

11. Does the training and/or examination in operating rules vary according to the location of employment within the railroad system? If so, describe the differences.

12. If the training is informal, what and how is training given to regular operating personnel to ensure that they maintain proficiency in operating rules and their applications?

13. If the training is informal but an examination is given, the information outlines on Examination Information Sheet is requested.

14. If the training is formal and an examination is given, the information outlined on Course Information and Examination Information Sheets is requested for each periodic training course and examination required for regular operating personnel in the area of operating rules and their application.

B. Training Program for Railroad Conductors

The purpose of this section of the questionnaire-guideline is to obtain as complete information as possible on your job training program and qualifications required in addition to operating rules for the road conductor and the yard conductor. It would also be most helpful if you would furnish us with copies of job descriptions, course outlines, course text books, course examination with the correct answers, job qualifying experience requirements and any other material you believe might be helpful to us.

1. Describe the job qualifications of the personnel typically assigned the responsibility for the job training and proficiency of the road conductor and the yard conductor. If available, please furnish copies of the job descriptions of these personnel.

2. Describe the job qualifications of personnel typically assigned to instruct the road conductor and the yard conductor in their job skills in addition to operating rules. If available, please furnish copies of the job descriptions of these instructors.

3. Type of training program (specify).
For example:

a. Informal on-the-job
b. Formal on-the-job
c. Home Study Courses
d. Apprentice
e. Classroom
f. Other (specify)

4. Is training program geared to specific equipment? If so, specify the equipment and the special training requirements.

5. Is training program geared to specific geographic locations? If so, please specify.

6. If the training is informal, what and how is training given to each of these job classifications to ensure appropriate proficiency? If appropriate, specify how training varies with specific geographic locations.

7. If the training is formal and an examination is given, the information outlines on Examination Information Sheet is requested.

8. If the training is formal and an examination is given, the information outlined on Course Information and Examination Information Sheets is requested for each training course and examination given in the training program.

9. Does successful completion of the training program job qualify the employee, or is there a separate job-qualifying examination? If so, Examination Information Sheet is requested.

10. Are recurrent periodic training courses and/or qualifying proficiency examination required of this job classification? If so, the information outlined on Course Information and Examination Information Sheets is requested.

C. Training Program for Railroad Engineers

The purpose of this section of the questionnaire-guideline is to obtain as complete information as possible on your job training program and qualifications required in addition to operating rules for the outside hostler, yard engineer, and road engineer.

It would also be most helpful if you would furnish us with copies of job descriptions, course outlines, course text books, course examination with the correct answers, job qualifying examinations with correct answers, job qualifying experinece requirements and any other material you believe might be helpful to us.

1. Describe the job qualifications of the personnel typically assigned the responsibility for the job training and proficiency of the outside hostler, yard engineer, and road engineer. If available, please furnish copies of the job descriptions of these personnel.

2. Describe the job qualifications of personnel typically assigned to instruct the outside hostler, yard engineer, and road engineer in their job skills in addition to operating rules. If available, please furnish copies of the job descriptions of these instructors.

3. Type of training program (specify).
For example:

a. Informal on-the-job
b. Formal on-the-job
c. Home Study Courses
d. Apprentice
e. Classroom
f. Other (specify)

4. Is training program geared to specific equipment? If so, specify the equipment and the special training requirements.

5. Is training program geared to specific geographic locations? If so, please specify.

6. If the training is informal, what and how is training given to each of these job classifications to ensure appropriate proficiency? If appropriate, specify how training varies with specific geographic locations.

7. If the training is formal and an examination is given, the information outlined on Examination Information Sheet is requested.

8. If the training is formal and an examination is given, the information outlined on Course Information and Examination

Information Sheets is requested for each training course and examination given in the training program.

9. Does successful completion of the training program job qualify the employee, or is there a separate job-qualifying examination? If so, Examination Information Sheet is requested.

10. Are recurrent periodic training courses and/or qualifying proficiency examination required of this job classification? If so, the information outlined on Course Information and Examination Information Sheets is requested.

D. Training Program for Railroad Train Dispatchers

The purpose of this section of the questionnaire-guideline is to obtain as complete information as possible on your job training program and qualifications required in addition to operating rules for the train dispatcher. It would also be most helpful if you would furnish us with copies of job descriptions, course outlines, course text books, course examination with the correct answers, job qualifying experience requirements and any other material you believe might be helpful to us.

1. Describe the job qualifications of the personnel typically assigned the responsibility for the job training and proficiency of the train dispatcher. If available, please furnish copies of the job descriptions of these personnel.

2. Describe the job qualifications of personnel typically assigned to instruct the train dispatcher in their job skills in addition to operating rules. If available, please furnish copies of the job descriptions of these instructors.

3. Type of training program (specify).
For example:

a. Informal on-the-job
b. Formal on-the-job
c. Home Study Courses
d. Apprentice
e. Classroom
f. Other (specify)

4. Is training program geared to specific equipment? If so, specify the equipment and the special training requirements.

5. Is training program geared to specific geographic locations? If so, please specify.

6. If the training is informal, what and how is training given to each of these job classifications to ensure appropriate proficiency? If appropriate, specify how training varies with specific geographic locations.

7. If the training is formal and an examination is given, the information outlined on Examination Information Sheet is requested.

8. If the training is formal and an examination is given, the information outlined on Course Information and Examination Information Sheets is requested for each training course and examination given in the training course and examination given in the training program.

9. Does successful completion of the training program job qualify the employee, or is there a separate job-qualifying examination? If so, Examination Information Sheet is requested.

10. Are recurrent periodic training courses and/or qualifying proficiency examination required of this job classification? If so, the information outlined on Course Information and Examination Information Sheets is requested.

E. Training Program for Railroad Train-Order Operators

The purpose of this section of the questionnaire-guideline is to obtain as complete information as possible on your job training program and qualifications required in addition to operating rules for the train-order operator. It would also be most helpful if you would furnish us with copies of job descriptions, course outlines, course text books, course examination with the correct answers, job qualifying examinations with correct answers, job qualifying experinece requirements and any other material you believe might be helpful to us.

1. Describe the job qualifications of the personnel typically assigned the responsibility for the job training and proficiency of the train-order operator. If available, please furnish copies of the job descriptions of these personnel.

2. Describe the job qualifications of personnel typically assigned to instruct the train-order operator in thier job skills in addition to operating rules. If available, please furnish copies of the job descriptions of these instructors.

3. Type of training program (specify).
For example:

a. Informal on-the-job
b. Formal on-the-job
c. Home Study Courses
d. Apprentice
e. Classroom
f. Other (specify)

4. Is training program geared to specific equipment? If so, specify the equipment and the special training requirements.

5. Is training program geared to specific geographic locations? If so, please specify.

6. If the training is informal, what and how is training given to each of these job classifications to ensure appropriate proficiency? If appropriate, specify how training varies with specific geographic locations.

7. If the training is formal and an examination is given, the information outlined on Examination Information Sheet is requested.

8. If the training is formal and an examination is given, the information outlined on Course Information and Examination Information Sheets is requested for each training course and examination given in the training program.

9. Does successful completion of the training program job qualify the employee, or is there a separate job-qualifying examination? If so, Examination Information Sheet is requested.

10. Are recurrent periodic training courses and/or qualifying proficiency examination required of this job classification? If so, the information outlined on Course Information and Examination Information Sheets is requested.

COURSE INFORMATION SHEET

The following information is requested for each training course. Please write any additional information under Comments.

1. Course Name ____________________

2. Job Classification ____________ New Hire/Recurrent/Promotion

3. Instructors' Qualifications ____________________

4. Length of Course (Hours) ________ Class Size ____________

5. Course Outline Furnished: Yes/No

6. Textbooks Furnished: Yes/No

   Textbook Title(s): ____________________

   ____

   ____

7. Special Teaching Aid(s):

   1. ____________________
   2. ____________________
   3. ____________________

Comments: ____________________

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EXAMINATION INFORMATION SHEET

The following information is requested for each examination. Please write any additional information under Comments.

1. Course Name ______________________________

2. Job Classification ______________________________

3. Course Examiners' Qualifications ______________________________

4. Type of Examination Given:

Examination	Yes/No	Copy	Yes/No	Key	Yes/No
Written	Yes/No	Oral	Yes/No	Job Sample	Yes/No

5. Passing Score __________ Errors Discussed Yes/No

   Failing Score Re-examination Allowed Yes/No No. of times __

   Conditions for re-examination: ______________________________

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6. Repeat Course Allowed Yes/No No. of times _____

   Condition for repeating: ______________________________

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Comments: ______________________________

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