DESIGN OF A CAR UTILIZATION AUDIT

By

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ABSTRACT

DESIGN OF A CAR UTILIZATION AUDIT

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This thesis presents an organizational and functional design of an audit of car utilization for monitoring and evaluating railroad operations. It is based upon the recommendation of the Task Force II of the Car Utilization Program sponsored by the Association of American Railroads (AAR).

The thesis develops a basic organizational structure for an Auditing Committee whose responsibilities would be to conduct regular, periodic studies of railroad operations, car utilization and service levels. The committee would be composed of a full time System Analysis and a part time Information Analysis Group. The two groups would be coordinated by a committee chairman reporting directly to the president of a railroad.

An audit should be based on a small, random sample of operating and marketing data. The thesis, therefore, summarizes various sampling algorithms and develops a procedure for determining sample size. At last, a case study of an audit is presented using data provided by the Boston & Maine Railroad. The complete set of tables summarizing car utilization performance is included as an appendix.

This thesis shows that meaningful, low cost information about system performance can be obtained from a small, 100% accurate sample of complete car movement records. This information represents a valuable input to decisions influencing car utilization and service. The thesis recommends audits as useful tools for understanding and controlling system operations.

CARL D. MARTLAND, Research Associate, MIT

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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

FIGURES

TABLES

CHAPTER I

MOTIVATION FOR AN AUDIT

1.1 Introduction

The most important aspect of a control system, as shown in Figure 1.1, is information. The efficient use of existing information sources can greatly increase a railroad's ability to control and improve freight car utilization and service reliability. This thesis will show how to conduct an audit of car utilization. When organized properly, an audit will yield an integrated data base containing valuable information about system performance. The work is based upon recommendations of previous tasks of the Car Utilization Program.

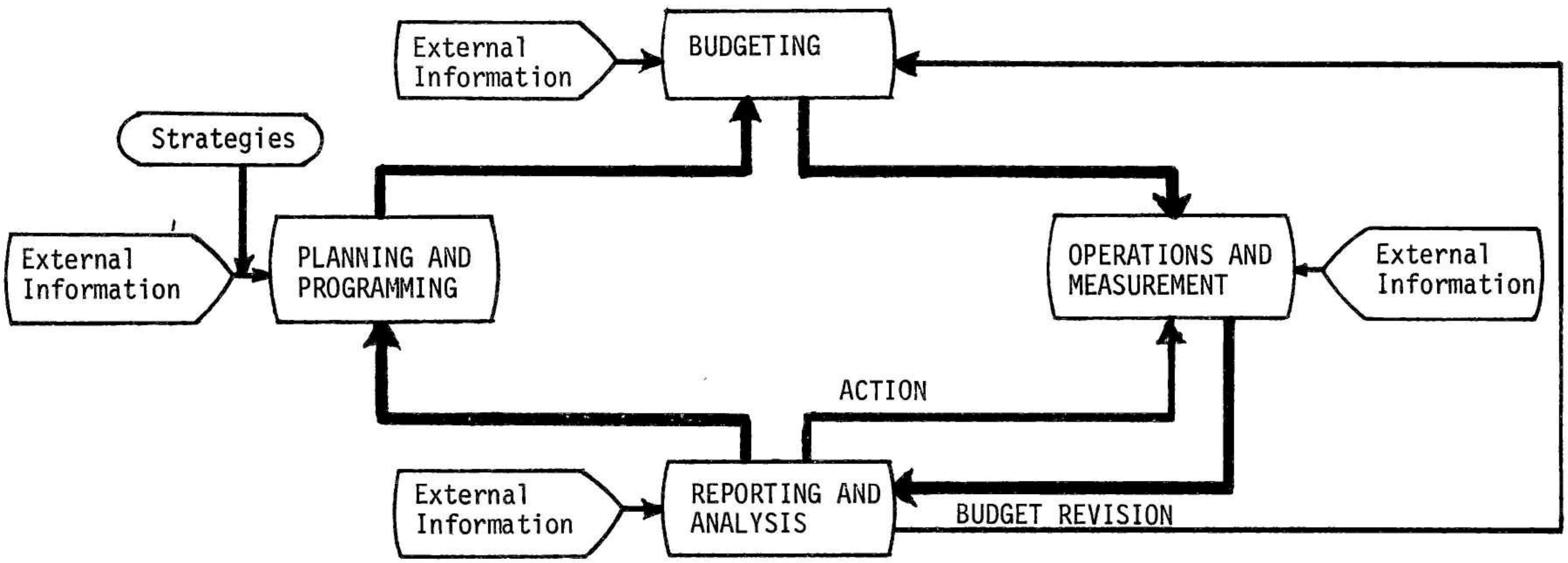
1.2 Freight Car Utilization--The Task Force II Report

Proper control mechanisms are needed for today's railroads to effectively cope with an increasingly complicated operating environment. There has been a mounting interest on the part of the U.S. government and the railroad industry itself to study railroad operations and make recommendations that will identify the crucial problems and improve service levels. One of these studies, conducted undersupervision of the Federal Railroad Administration (FRA) and the Association of American Railroads (AAR) by Task Force II of the Car Utilization Program, has analyzed freight car utilization problems and their impact on financial measures of performance for U.S. railroads. The major conclusions of the study were (1):

> "1) There have been no direct or predictable relationships between changes in physical utilization measures and railroad's financial performance.

FIGURE 1.1

MANAGEMENT CONTROL MODEL



2) No single measure of utilization is adequate for all purposes. Railroads need to use several measures in a well defined manner to relate physical utilization to financial performance.

3) Effective utilization involves much more than efficient empty car distribution or car movements. Car maintenance policy, pricing, equipment investment decisions, and the demand for freight transportation are critical determinants of utilization levels.

4) Although both the operating and marketing/traffic departments make decisions that affect utilization, the operating department is generally the principal department held responsible for utilization.

5) A utilization control system must enable operating and marketing/traffic officers to evaluate the tradeoffs among operating expenses, investment expenses, and car ownership costs. Lacking such a system, railroads will fail to provide incentives for officials at all levels of the organization to make proper decisions concerning freight car use."

Freight car utilization can be defined as the ability of a railroad or any other carrier to use its equipment to derive a maximum benefit from it. The benefit measure commonly associated with car utilization and recommended for use by Task Force II is the rate of return on investment (ROI). As suggested in conclusion (2) above, not one, but several different utilization measures must be considered to adequately reflect the complex relationship between freight car utilization and financial performance parameters. The Task Force, among its recommendations, suggested that the following five measures be used for this purpose (2):

1) Percent of demand filled;

2) Car days per load originated (car cycle);

3) Percent of car capacity used;

4) Revenue per load originated; and

5) Cost per load originated.

These five measures comprise the principal inputs to the decision process affecting utilization levels and to the determination of the rate of return on investment. The process suggested by Task Force II is shown as a decision tree in Figure 1.2. The diagram does not only conceptualize the relationship between freight car utilization and ROI, but it also identifies corrective actions necessary to improve utilization and ROI.

By not recognizing these five principal measures of freight car utilization, poor decisions may be made. This may have been the case in the 1950's and 1960's when railroads invested heavily in the expansion of their car fleets to meet rising demand levels. Little effort in terms of additional investment was directed at improving railroad's operations. The car utilization effects following this decision are shown in Table 1.1. The cycle times increased from 18 car-days in 1950, to 27 car-days in 1975, indicating a deteriorating car utilization performance. The ROI levels, however, as shown in Table 1.2, did not improve.

The Task Force's other recommendations included (3);

1) Present freight car utilization control systems should be reviewed. A control system should include an audit of current levels of car utilization.

2) National measures of car utilization should include:

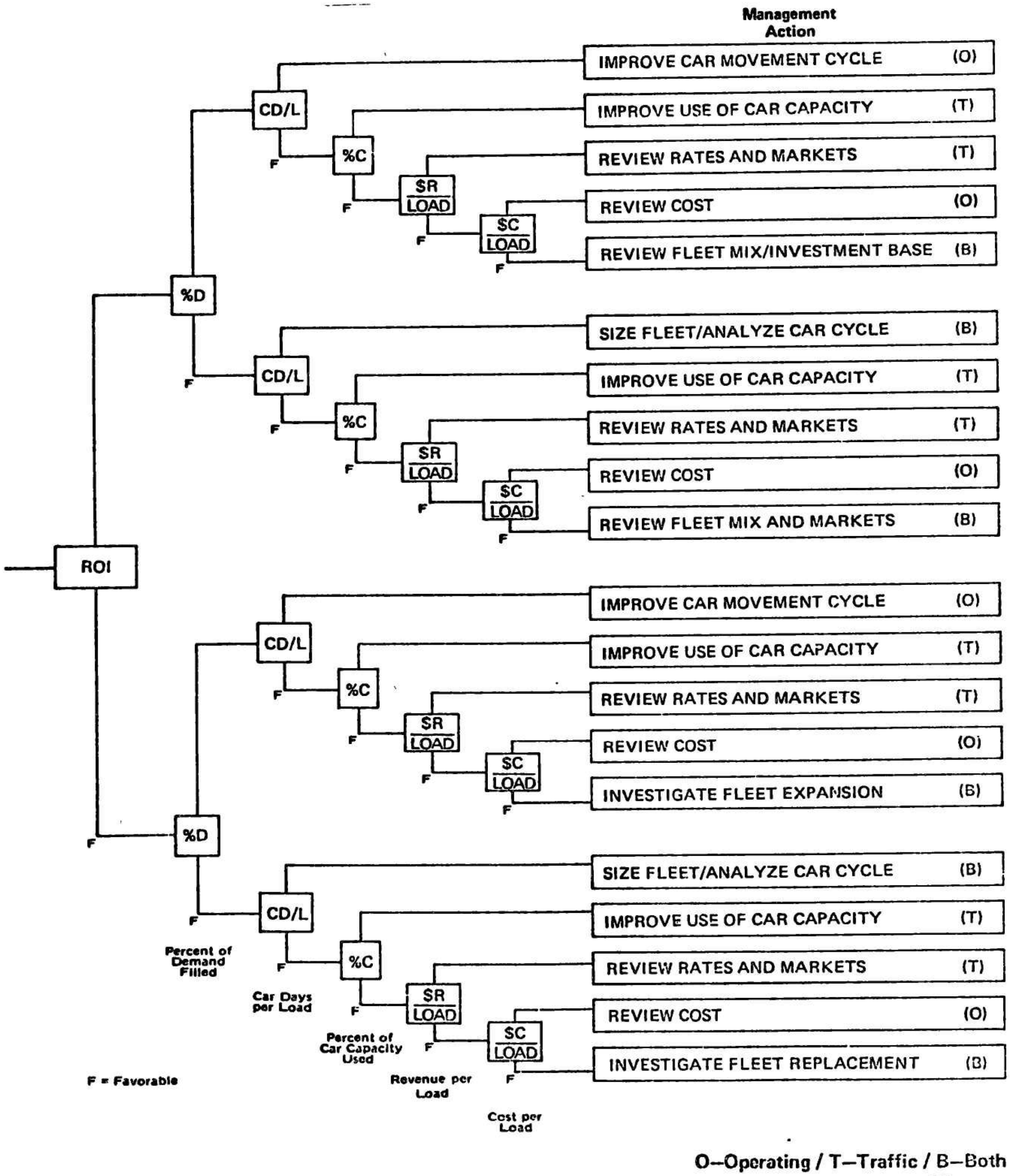
   - Identification of various components of car cycle time per load originated; and

   - Percent of demand filled per unit of time.

3) Although the Rate of Return on Investment should be the ultimate car utilization measure, considering the complexity of the relationship between utilization levels and financial performance, the five measures listed above should also be used.

FIGURE 1.2

RELATIONSHIP BETWEEN FRIEGHT CAR UTILIZATION AND ROI



Source: Task Force II, Freight Car Utilization: Definition, Evaluation, and Control, AAR-FRA Final Report, 1977.

TABLE 1.1

NATIONAL CAR UTILIZATION LEVELS AND ROI

YEAR	FREIGHT CARS[1]	REVENUE[1] CARLOADINGS	ROI (%)	CAR DAYS/LOAD
1951	2.046	40.499	3.76	18.4
1967	1.822	28.084	2.46	23.7
1968	1.800	28.253	2.44	23.3
1969	1.792	28.237	2.36	23.2
1970	1.784	27.160	1.73	23.9
1971	1.762	25.266	2.12	25.5
1972	1.717	26.105	2.34	24.0
1973	1.711	27.338	2.33	22.8
1974	1.721	26.184	2.70	24.0
1975	1.724	23.217	1.20	27.1
1976	1.699	23.638	1.49	26.2
1977	NA	23.298[2]	1.25[3]	NA

[1]Numbers in millions.

[2]Based on Railway Age, January 30, 1977, pp. 56-69.

[3]Transport Comments, Association of Commerce & Industry, May 5, 1978, No. 1631.

Source: AAR Yearbook of Railroad Facts, 1977.

4) Railroads should pursue initially only the utilization improvement areas which promise the greatest financial payoff.

5) A Car Service Contract concept should be studied for implementation in a railroad's organization to coordinate overlapping decisions affecting the car utilization among operating and marketing departments.

6) A role of service standards should be investigated as an effective way of improving freight car utilization.

1.3 Implications of the Task Force II Recommendations

1.3.1 An Audit of Car Utilization

Task Force II's recommendations provide a motivation for conducting an audit of car utilization. Their underlying message to the railroad industry is to:

1) Define the basic variables affecting the system operating and financial performance.

2) Device a control system which would monitor these variables.

3) Organize a Service Committee which would establish desired standards for the basic operating and financial variables.

4) Identify critical areas which affect the operating and financial performance by comparing the desired standards with corresponding values of current performance levels.

The primary task for the audit of car utilization should be consistent with the goals set above. The audit should provide a mechanism for frequent evaluation of system performance and an important input to the strategic decisions associated with improving troubled areas. In addition, an audit should be purely informational in context: it should increase information flow through the railroad organization and thus increase employee awareness of system operations. The success of this procedure depends on:

1) Its acceptability to the corporation;

2) Its flexibility in providing different information at different times;

3) The problem areas it addresses;

4) The cost of developing an auditng software;

5) The availability of proper machine and human resources;

6) The development of realistic performance standards; and

7) The willingness of various functional departments to cooperate in a common effort to improve system performance.

Although the list of the potential obstacles to obtain an effective control system is long, no railroad should hesitate about trying to overcome them. The benefits of implementing this procedure may outweigh the costs associated with the development of this procedure. The possible benefits may be realized by meeting the short term utilization and long term profitability goals. A railroad without a control system is running the risk of not being able to improve its system and financial performance. Figure 1.3 illustrates the major areas which may be positively affected by implementation of an audit control system. The costs and benefits are also summarized in Table 1.2.

1.3.2 Marketing Strategy

The Task Force II recommendations also provide a clue to the marketing strategy railroads should pursue. Recommendation (4) calls for identification of all railroad's activities which are "most profitable" or offer the greatest financial payoff and for concentration of efforts on improving these activities. This strategy assumes that the most profitable traffic represents the greatest potential for the future increases in the traffic volume with similar payoff characteristics and in general for improved financial performance.

FIGURE 1.3

IMPACT OF AN AUDIT ON VARIOUS COMPONENTS OF THE RAIL SYSTEM

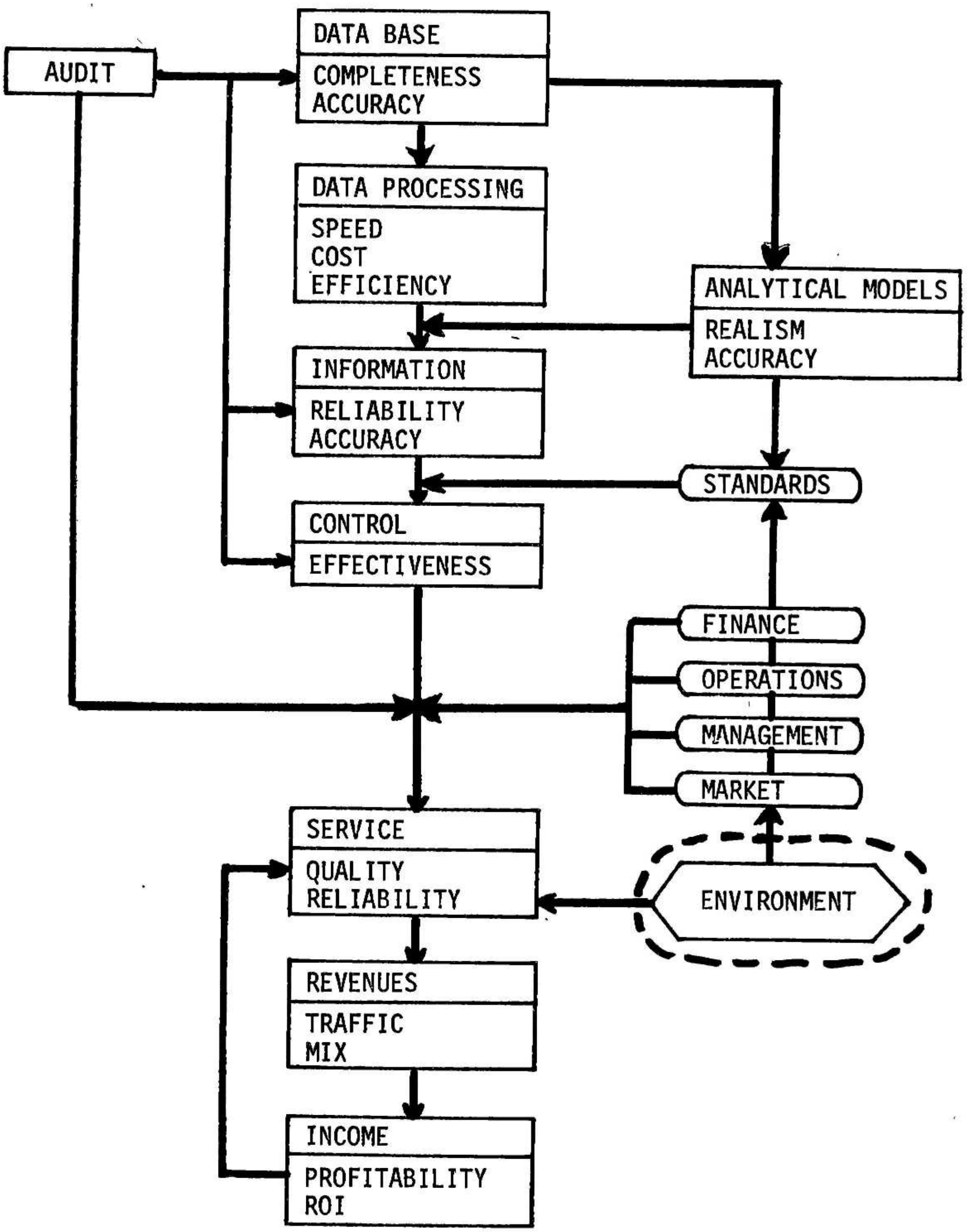


TABLE 1.2

BENEFITS AND COSTS ATTRIBUTABLE TO AUDIT OF CAR UTILIZATION

BENEFITS

1) Increased information flow within an organization.

2) Better cost and performance controls.

3) Improved data base for studying alternative marketing strategies.

4) Improved data base for studying alternative operating strategies.

5) Greater employee work motivation and productivity.

6) More widespread and frequent use of analytical models.

7) Indirect improvements in freight car utilization.

8) Indirect improvements in freight car service reliability.

COSTS

I. STARTUP COSTS

1) Conversion costs for new technologies necessary to upgrade the data collection systems.

2) Improved computer communication equipment.

3) Outside consulting fees for system development and design (optional).

4) Training/hiring costs associated with setting up the system analysis group for an Audit Committee.

II. CONTINUING COSTS

1) System analysis group's salaries.

2) Data processing costs plus royalties for use of Data Management programs.

3) Communication line leases plus fees on computer rentals.

Railroads in general have their marketing policies poorly defined. The industry Task Force on Reliability Studies (4) listed among its findings that "railroads generally do not have a clearly specified policy relating to shipment movement". This not only indicates lack of adequate operational planning, but it also indicates that there are no common bases on which the marketing department could build its marketing strategy. Defining a good strategy on weak foundations is simply not feasible.

A marketing strategy can be developed by formulating fundamental and supportive strategies. The fundamental strategy is composed of:

1) Definition of the target segment of the railroad's market;
2) Defining of shipper's needs and service expectations;
3) Definition of the competitive trends and prices; and
4) Identification of environmental trends that have a direct bearing on the railroad's function.

This strategy provides the marketing department with the informational data base defining the long range traffic characteristics that must be attained to ensure financial stability. This strategy must interact with the supportive strategy to properly evaluate the feasibility of the plan. The supportive strategy must be developed in close cooperation with the operating department. It provides the information on the feasibility of long range traffic goals and identifies pricing and operational policies that will guide the marketing and operating departments in their daily functions. The supportive strategy includes:

1) Determination of the system network and investment needs;
2) Determination of promotional, selling, and advertising policies;

3) Determination of the service characteristics and standards; and

4) Determination of rates.

Marketing strategy evaluation is necessary to assure that the fundamental concepts of profitability and corporate goals are met. The supportive strategy is nearly equivalent to the concept of operating/service plan proposed by the Task Force II. To ensure that such a plan is workable and feasible, an audit is needed to monitor the performance of the system and evaluate the goals stated in the marketing strategies.

1.3.3 Practical Applications of Auditing Procedures

Auditing procedures are logical and useful in practical applications on today's railroads. They provide a snapshot picture of the railroad's operations at a given time. When conducted on a routine and frequent basis, the reports generated can broaden the knowledge among managers of the system's performance and its trends over time. It may contribute to a deeper understanding of the complexity of the system which, in the long run, should lead to more rational and constructive decisions on the part of railroad managers.

The concepts presented in the subsequent chapters were developed mainly to acquaint a reader with auditing and allow him/her to relate the material to his/her own needs. Although the ideas presented here may not be applicable in their entirety in many situations, the concept itself should be "phased in" in most of the railroads in an experimental basis at first. If it is found useful, then the auditing procedure should be retained for regular use.

1.4 Organization of this Thesis

Chapter II gives a brief overview of the general requirements associated with auditing and discusses the organizational issues associated with establishing an internal Auditing Committee.

Chapter III focuses on statistical issues involved in the selection of a sample and determination of its size.

Chapter IV presents the results of a case study of an audit of car utilization on the Boston & Maine Railroad (B & M).

Chapter V presents a summary, conclusions and offers recommendations.

Appendix A contains the description and examples of verifying the statistical significance of the audit's results.

Appendix B presents results of the B & M audit.(Case Tables).

Appendix C outlines basic report design requirements.

Appendix D contains the listing of SAS programs used to generate the reports shown in Appendix B.

CHAPTER I--FOOTNOTES

1) Task Force II, Freight Car Utilization: Definition, Evaluation, and Control, AAR-FRA Final Report, 1977, pp. 1.

2) Task Force II, Freight Car Utilization: Definition, Evaluation, and Control, AAR-FRA Final Report, 1977, p. 8.

3) Task Force II, Freight Car Utilization: Definition, Evaluation, and Control, AAR-FRA Final Report, 1977, pp. 1-2.

4) The Industry Task Force on Reliability Studies, Freight Car Utilization and Railroad Reliability, Final Report, AAR Report No. R-283, October 1977.

CHAPTER II

CONDUCTING AN AUDIT OF CAR UTILIZATION

2.1 Introduction

The most important role of an audit is the communication and propagation of information. An audit should provide managers with feedback on their performance and the results of their decisions. This can be achieved by monitoring various measures of system performance with well designed reports. All reports must conform to the following minimum design criteria:

1) Address relevant issues;

2) Relate to appropriate staff functions and lines of responsibility; and

3) Be current, readable, and easy to understand.

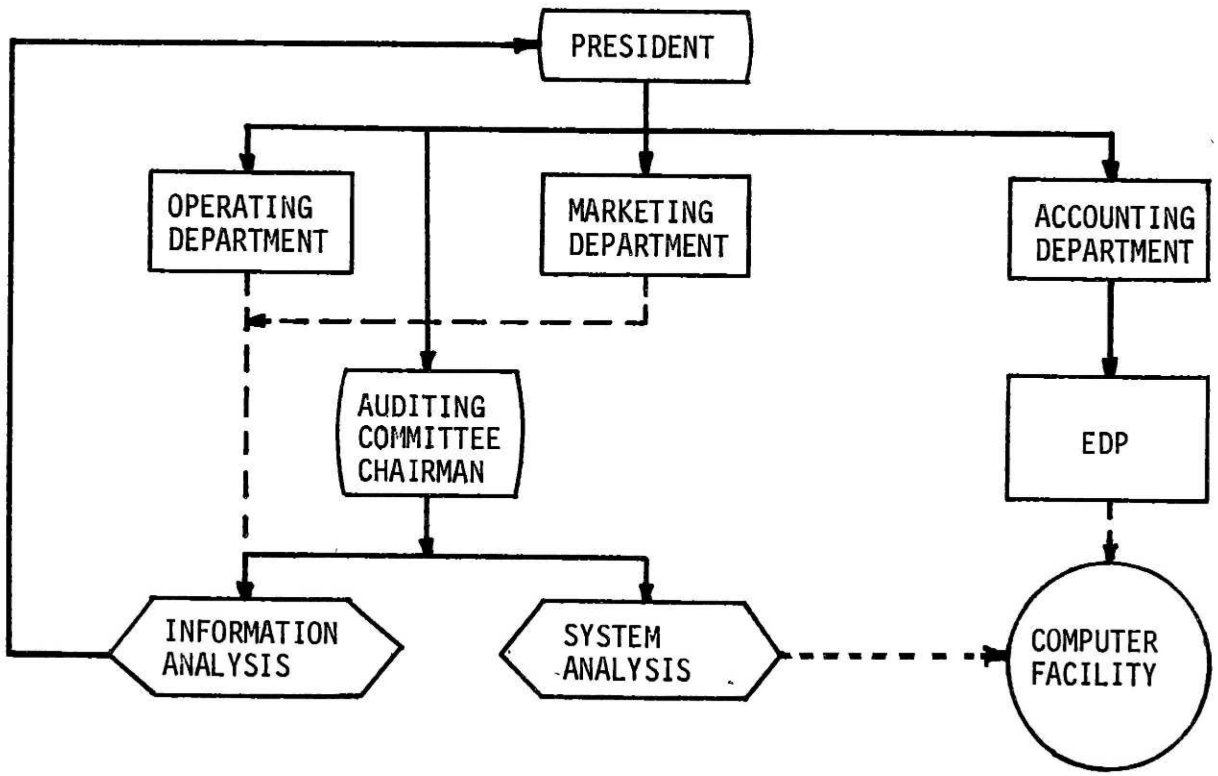
It is important to recognize that designing a report requires familiarity of the system operations, corporate organization, and report generation methods. The following sections will suggest one of many possible ways of organizing an Auditing Committee to achieve an informational system consistent with the criteria set above.

2.2 Organization of the Auditing Committee

An audit of car utilization should be conducted under the supervision of two separate but interactive bodies. The two groups, a system analysis group and information analysis group, would form a single committee whose functions would be the preparation and execution of the audit and the identification of major problem areas on a railroad system. The organizational chart of the Audit Committee is shown in Figure 2.1.

FIGURE 2.1

ORGANIZATIONAL CHART OF AUDITING COMMITTEE



2.2.1 The System Analysis Group

The System Analysis Group would be a full time body charged with the responsibility for data preparation, processing of reports, and analysis of system performance. The staff members involved in this group must have considerable data processing experience and a good understanding of the railroad operations. The position they would be occupying within this group would be equivalent to the system analyst positions offered in any other organization.

This group should be a separate entity, apart from the Electronic Data Processing (EDP) Department. The reason for this lies in the fundamental differences between the function of the EDP Department and the function of the System Analysis Group. The former department, usually attached to the Accounting Department, has a primary responsibility relating to the maintenance of system software without regard to the details associated with the applicability of the data and software to the problems of railroad operations. Ideally, the reason for forming a system analysis unit would be to fill that gap and provide an opportunity for railroads to improve their reporting system.

This group would, in effect, form an internal consulting body capable of data analysis support to any department in a railroad organization. Due to the nature of its function, the staff members must be thoroughly acquainted with the system and its operations. Since they must also have considerable data processing and programming backgrounds, the most effective way of obtaining this mixture of talent is to identify railroad employees already knowledgeable with system operations and establish a permanent training program under which these individuals would be exposed to the data processing environment. This program, in conjunction with external educational programs, would yield the individuals best suited for the system analysis function.

The primary responsibilities of the System Analysis Group would be to:

1) Identify the system data sources.

2) Combine the data into suitable data bases.

3) Edit the data to enhance its quality.

4) Form the random data sample for the audit.

5) Define audit reports based on information needs within the railroad organization.

6) Do the necessary programming to generate desired audit reports.

7) Analyze the reports and prepare summaries of system performance for the information analysis group.

8) Define the report formats to meet requests for additional or better information from other departments.

9) Study the problems associated with the data collection system and analyze the alternatives to improve it.

2.2.2 The Information Analysis Group

The Information Analysis Group would be a part-time body charged with:

1) Interpreting the data produced by the System Analysis Group; and

2) Studying the alternative courses of action to improve performance in areas identified by the System Analysis Group.

While the System Analysis Group's main function would be that of an internal consultant, the Information Analysis Group would have executive power to enact procedures aimed at improving the system performance.

The group's staffing should be parallel to the one described in the Task Force II report for the Operating-service Committee. It should be composed of upper management officials representing various departments. Although the committee membership should be open to any department in a railroad, a minimum of two departments should be present in the group: Operations and Marketing. These departments are most instrumental in defining policies affecting service levels and system performance. Each of these departments should be represented by people from its functional areas. They would be assigned to the Committee for a fixed period of time, on a rotating basis. The period of assignment should not be less than a year since understanding the Committee's function, generating reports, and understanding the system's problems may take a considerable amount of time for new members. In a way, the Committee serves an ideal educational function for the newly hired managers as it provides them with an opportunity to understand the operations and the problems of the organization they will manage.

As mentioned above, each department should be represented by people responsible for the functional areas affecting car utilization levels. This means that the Operating Department should be represented by managers of empty car distribution, transportation planning, terminal operations, dispatching, line operations, and car maintenance. The Marketing Department, on the other hand, should have its members representing sales, pricing, market research, and commodity management.

The Information Analysis Group's responsibilities can be defined as follows:

1) Identify all operational, marketing, and financial problems currently experienced on system.

2) Specify which of these issues should be addressed by an audit.

3) Interact with the System Analysis Group to see that information is being generated according to specifications.

4) Evaluate reports obtained from the System Analysis Group.

5) State findings of the system performance in a document which will also contain recommendations for actions that should be taken to improve the system performance.

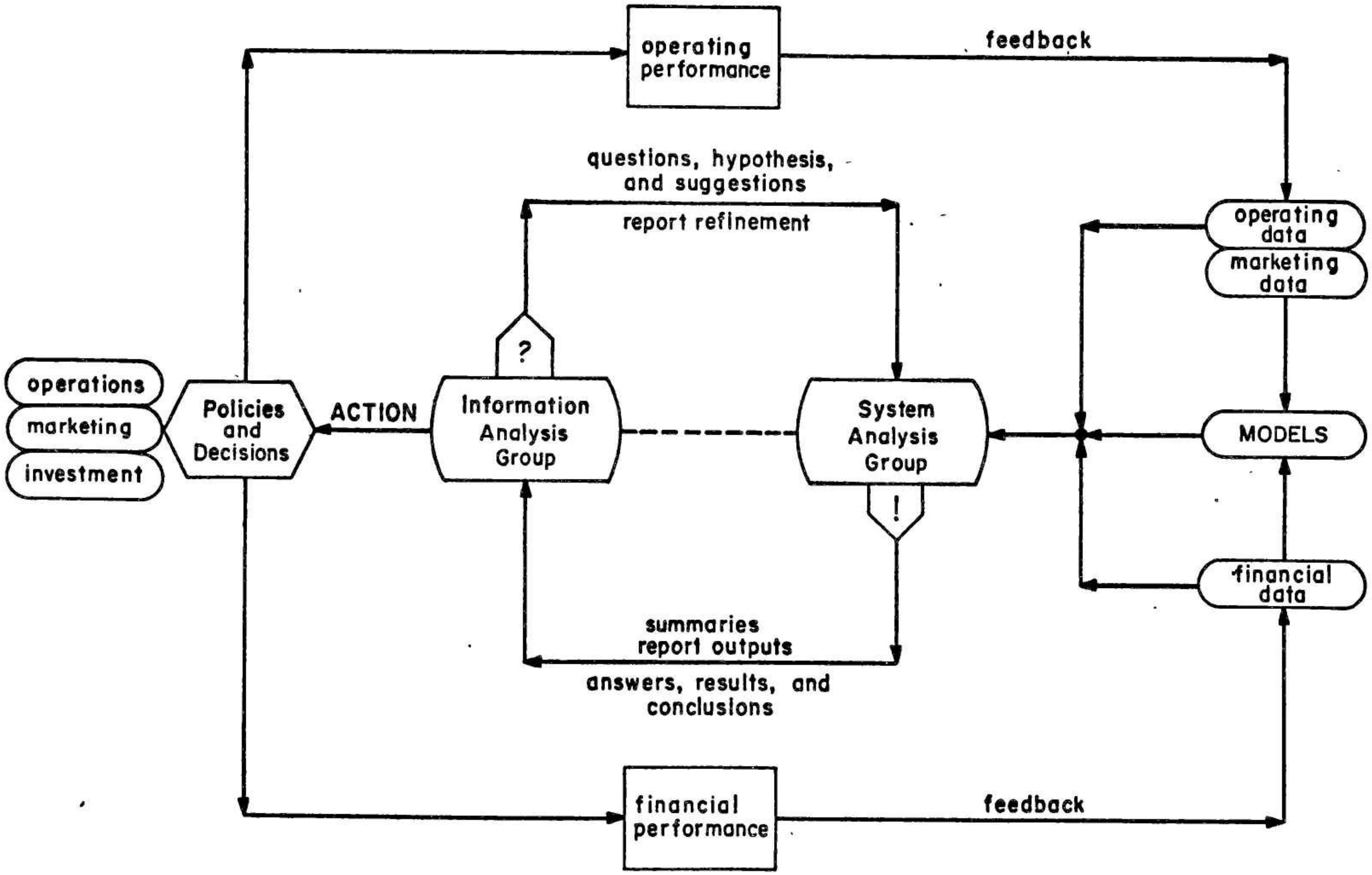
6) Refine the information needs and state new areas of interest that should be investigated by succeeding audit(s).

7) Monitor and evaluate the effectiveness of the group's previous actions.

Only continuous monitoring of system performance can provide the feedback necessary to evaluate and refine the auditing procedure. The railroad's operating environment is dynamic and the problems of yesterday are not likely to be the problems of today. Therefore, auditing reports must always address current situations if the procedure is to be useful and effective. The interaction of the two auditing groups, as shown in Figure 2.2, can have a profound effect on the system's operational and financial performance. If conducted with care, an audit can prove to be an efficient tool in upgrading the system.

FIGURE 2.2

THE IMPACT OF AUDITING COMMITTEE'S ACTION ON SYSTEM PERFORMANCE



2.2.3 The Auditing Committee's Chairman

A Chairman of the Auditing Committee is needed to supervise the Committee's functioning. He should be a person of high responsibility in the organization with sufficient authority to overcome departmental barriers and stimulate cooperation among the departments involved in the audit. The assignment to this position should be on a part-time basis. Since typical candidates for this position would include a Vice-President of Operations or Marketing which, if anything might hinder interdepartmental cooperation, the post should be linked to the office of the President of a railroad. This would ensure that if any communication difficulties arise, they would promptly be resolved by the President.

Duties of the Chairman would include the following:

1) Define the organizational schedule of the Auditing Committee including membership, frequency of meetings, dates of meetings, and the duties of the Committee.

2) Ensure proper communication between the two auditing groups.

3) Present the recommendations of the Informational Analysis Group concerning system improvements to the President and obtain his approval.

4) Communicate the approved recommendations to proper departments via the informational group for enactment of specific measures aimed at improving system performance.

5) Oversee that the actions described in (4) above are fully implemented.

2.3 General Considerations

2.3.1 Informational Requirements

Although the scope of the reports generated may vary from railroad to railroad, some basic core reports should always accompany audit results. These are:

1) Sample Characteristic Summaries--to evaluate sample make-up characteristics and sources of more significant information.

2) Performance Reports--yard, train, and origin-destination reports showing average times and distribution of the times for each major yard, train, and origin-destination pair.

3) Utilization Reports--to identify the magnitudes of various components of car cycle time on system.

4) Financial Reports--indicating operating and car hire costs, revenue per load, and contribution levels.

5) Marketing Reports--identifying major system flows by car type, shipper, commodity, origin, destination, etc.

6) Empty Car Distribution Reports--flow characteristics and components of empty car cycle time for empties in distribution, empty car inventories, cripples, constructive placements, etc.

7) Other reports associated with local railroad needs.

It is the last group of reports that truly justifies auditing as a necessary procedure to be implemented on railroads. Most of the reports that are included in this category are likely to be short lived and non-recurring, but are nevertheless essential in special railroad studies. Trying to commit resources for development of these reports is often thought too expensive and ineffective. With the audit's flexible programming and smaller data bases, the development costs would be considerably reduced, leading to improved information flow in the organization.

2.3.2 Programming Considerations

The key to the System Analysis Group's performance lies with the quality and availability of data. Any report based on inaccurate data would be perceived as unreliable and useless. This would contradict the purpose of the audit. Thus, it is often necessary to prepare programs to edit the data and delete erroneous records before auditing runs are made.

The generation of reports to support the audit's findings is a function of the information requirements. If auditing is periodic, in an environment where information needs rapidly change, it is unfeasible to develop programs in languages like COBOL or FORTRAN. These languages are too labor-, time-, and cost-intensive. Time delays caused by program development, debugging, and testing may make programs obsolete even before the work on them is completed. The System Analysis Group should look for prewritten software packages capable of data base management, statistical analysis, and report generation. Although the initial costs of installing these packages may be high, they may prove to be beneficial in the long run, due to lower program development and processing costs. Presently these packages can be purchased from most computer manufacturers and private companies under the name of Data Base Management programs (1).

2.3.3 Data Considerations

As mentioned in the previous section, the success of an audit is largely dependent on the quality of data. The quality of data is determined by:

1) Data availability;
2) Data accuracy;

3) Contents of the data base record; and

4) Data base structure.

To answer specific questions, appropriate data must be available. In many situations, railroads do not collect data with long term analysis goals in mind. Few of the railroads reflect status changes of a car moving through a yard in their data bases. They merely record the car's arrival and departure times with the symbols of the trains involved in the movement. The data pertaining to the car's time in receiving, classification, or departure yard is seldom collected. It is very rare to find information about the time empty cars spend awaiting distribution. However, these are the primary areas causing poor car utilization. Therefore, any question which requires a quick answer based on historical data simply cannot be answered because the information required is not available. Consequently, it is important that physical operational issues affecting railroad's performance are identified and corresponding data is collected.

The data accuracy is largely dependent on the data collection system in use. Typically the cardless data environment presently being phased in on several railroads along with interactive communication equipment represents the state of the art in an effort to reduce data errors and improve its accuracy. Many railroads, however, have not yet had the opportunity to change to this new technology. Their low profits do not leave enough funds for investment in the new equipment. These railroads are still operating in a card system under which the data pertaining to each car movement is key punched at each yard along car movement and once a day it is transmitted to a main computer to form a data base. This system often produces large data errors by failing to record all interyard car moves. Due to large traffic volumes, clerks have little time or motivation to record the information. Another source of errors is attributable to low quality transmission equipment. Data is carried over telephone lines to the main storage areas and frequent static on the lines distorts the data yielding unreadable fields. Again, seeking an alternative collection system in this area can significantly improve the quality and reliability of results.

The informational data base requirements depend on the scope of the audit. If only operational issues are considered, the data pertaining to car line-haul and yard movements would suffice. However, to increase the applicability of the audit to more than one area of the railroad organization, the data should contain the components of information about car movement relevant to several departments' interests. An ideal data record should consist of:

1) Operating data reflecting daily operations.

2) Cost data needed to evaluate basic variable costs associated with car movement.

3) Revenue data to evaluate contribution to fixed costs and profits.

4) Other data not related to a car utilization audit but necessary for expanded audit functions.

The data records in a data base must conform to some basic logical structure reflecting a car move. There are many ways or organizing a data base (2), of which the three most popular are:

1) Integrated single record within a single data base. This record structure lends itself to easy manipulation procedures but it is difficult to derive and tends to occupy much space on a data disc. This structure was used in the case study described in Section 4.0. The sample record is shown in Table 2.1.

TABLE 2.1

A SAMPLE AUDIT RECORD DESCRIPTION

1)	Car ownership initials
2)	Car number
3)	L/E status
4)	Prior move type (overhead, local, received, forwarded, off-line)
5)	Present move type (overhead, local, received, forwarded)
6)	Next move type (overhead, local, received, forwarded, off-line)
7)	Origin station code
8)	Origin station node--aggregated station code into a node
9)	Destination station code
10)	Destination station node--aggregated station code into a node
11)	O-D distance
12)	Trip time (from departure Orig Station to arrival Dest Station)
13)	Total loading time (0 for empties)
14)	Total unloading time (0 for loads)
15)	Car type
16	Number of intermediate yards included
YARD DATA--a block of up to 5 yards	
17)	Yard code
18)	Yard node--aggregated station code into a node
19)	Date and time arrived
20)	Date and time departed
21)	Total yard time
22)	Train the car arrived on
23)	Train the car departed on
24)	If more than 5 yards included, indicate carry-over to the next record.
25)	Per diem rate
26)	Mileage rate
27)	Incentive rate
28)	Revenue
29)	Cost
30)	Contribution
31)	Commodity
32)	Tons
33)	Flat for incomplete E move

2) Multiple records per car movement within a single data base with:

   a) Car identification header;

   b) A variable number of records, one for each interyard move;

   c) Other information like O-D pairs, aggregation identifiers, etc.

3) Relational multiple data files. In this organization each file contains records related to records in other files by some common identifier like car number and date. Possible files may contain information on yard movements, line-haul movements, train movements, cost information, revenue information, weather information, etc.

The last two ways of organizing data, although they usually require less disc space, are more difficult to use.

The easiest data base structure is the single integrated record within a single file. The records, like the one in Table 2.1, reflect the data associated with a single origin-destination car movement. A car movement is defined as the time between car's successive loading status changes. It is felt by the author that this type of data is readily available on most of the U.S. railroads and therefore should form the basic structure of the data file. This structure also reflects elementary measures of car utilization, like car cycle time and car miles.

The ease of manipulating data bases and obtaining reliable and useful information can all add to the success and acceptability of auditing procedure on the railroads. A careful analysis of each of these factors by the System Analysis Group of the Auditing Committee can indeed improve car utilization, service, reliability, and the financial performance of railroads.

2.4 Summary

Effective organization of the Auditing Committee can enhance the audit's quality and usefulness. Through wide participation in the program the audit's results can easily be propagated to interested departments.

The Committee's organization should be based on a Committee's Chairman superivising and coordinating the functions of an Information and a System Analysis Group. Under this set-up, a routine audit should have a profound impact on:

1) Interdepartmental communication and cooperation.
2) Operating performance.
3) Financial performance.
4) Marketing planning.
5) Methods for evaluating the system performance.

These results may be obtained by a common effort on the part of the participating departments to improve car utilization. The areas which require improvements would be identified by the System Analysis Group. The group would, on a full time basis, provide data management and analysis services to the Information Analysis Group. The latter, composed of individuals representing different functional areas of railroad operations, would formulate a set of recommendations and alternate performance improvement strategies. Upon approval of the President, these would be submitted to appropriate departments for execution. Proper compliance in carrying out the recommended actions would be overseen by Committee's Chairman. The post audit of past improvement actions would routinely be conducted by the Information Analysis Group from the information supplied by the System

Analysis Group. This completes the informational feedback loop associated with the function of the Auditing Committee.

The Committee would also be involved in systematic data evaluation studies. These would be aimed at improving the quality and performance of the data collection system in use. The scope of these studies would range from evaluating the physical equipment used for data recording and transmission to improving the data contents and organization of the data bases on system. To increase the utilization and the efficiency of the informational assets associated with the data bases on-line, the Committee would constantly upgrade the existing programs used in report generation and seek alternative packages which, in a long run, would be capable of providing more flexible and cheaper programming. The Committee's responsibility for these tasks would rest with the System Analysis Group .

CHAPTER II--FOOTNOTES

(1) B & M audit was conducted using Statistical Analysis System developed for IBM systems by: Barr, Goodnight, Sall and Helwig, SAS Institute, Inc., P. O. Box 10066, Raleigh, NC 27605.

(2) Refer to references 11-13.

CHAPTER III

STATISTICAL SAMPLING

3.1 Introduction

3.1.1 Motivation

The use of statistical sampling methods is one of the most promising features of auditing. Results can be obtained using two alternative strategies when processing a data base:

1) By processing every record in the data base, OR

2) Based on a random sample following statistical verification and validation.

The first procedure, although more precise in terms of findings, is more time consuming, tedious, and inefficient within the time and cost constraints of an audit. The second, under most circumstances, is more logical to follow. Statistical samplings have already been successfully applied in evaluating financial, operational, and technical problems (1). They are more cost effective because they require fewer human and machine resources.

3.1.2 The Advantages of Statistical Sampling

Statistical sampling may be defined as a selection process by which observations are drawn from a large population of events according to some prespecified, statistically justified rules. The selected observations form a smaller subset of observations which, under normal conditions, can be expected to contain information consistent with those of the original population. The advantages of statistical sampling techniques are as follows (2):

1) Measurement--Statistical sampling enables an auditor to measure the reliability and accuracy of findings derived from a sample. An application of the confidence interval concept to the estimated results provides for a method of measuring the significance of the results, the range of most likely results, and the probability that the derived estimate is beyond the obtained range limits. The results subjected to this kind of analysis are easily defensible. Unreliable results can be improved upon by increasing the sample size which will be demonstrated to have a great impact on the estimation results. (See Appendix A.)
2) Objectivity--A random selection procedure used to create a data sample eliminates any human subjectivity from the results. Furthermore, since the procedure is random, it may improve the mixture of observations. This, in the long run, may identify events that are not easily observable by simple intuition or manual analysis. The objectivity of this procedure is very effective in observing system frequencies like yard or O-D moves.
3) Effectiveness--The confidence interval analysis and the ease of defending the audit's results enhances the effectiveness of the procedure in the area of interdepartmental communication and presentation of results to other staff members.

4) Efficiency--Considerable economies can be attained through statistical sampling from large data populations. Savings can be attributed to the reduction in people, time, and computer resources required to conduct and supervise the audit. The claim that the results based on the total population are considerably more accurate is not always justified. According to statistical theory, a finite number of observations is needed to establish any predetermined level of reliability. Observations above this threshold number add little to the analysis. Consequently, the sampling population can be limited to the number of observations required to establish a desired level reliability of the results.

3.1.3 Error Types in Sampling

The sampling methodology gives rise to two types of errors that should be considered in auditing. The first one--the non-sampling error--usually results from physically poor data quality. The primary sources of this error lie at the roots of the data collection systems. Most commonly, it occurs due to physical mishandling of the data by people and machines at the time it is generated and transmitted to data collection centers. On railroads, the primary areas where errors are induced are:

- Clerks who update the operational data;
- Transmission "noise" in communication lines; and
- Hardware and software problems caused by computer failures.

The non-sampling error, which can be obtained by simply counting bad records in the data base, should be maintained as part of the audit to evaluate data collection. A large non-sampling error, 5% or more, should indicate to a manager that a system is ill-designed, or it simply lacks proper controls and motivations for proper functioning.

The second error that is associated with sampling is the sampling error (sometimes called the sampling precision). It simply refers to a range of values that the system performance parameters are expected to have under certain significance or confidence levels. The limits of that range define the confidence interval. If the width of the confidence interval is large, indicating large sampling error, the estimated results are uncertain and unreliable. Under this condition the obtained parameters are uninformative and should not be accepted as audit's results. To obtain meaningful results, the sampling error should be small and the confidence interval very narrow. This would indicate that large deviations of the actual system performance from the value of its estimated parameter are not likely.

Another statistical parameter often associated with sampling is the confidence level. Since the system operating performance is random in nature and the sampling error is a statistical statement describing that randomness, it is possible to have the actual performance parameters exceed the confidence interval limits set by the sampling error. The confidence level accounts for this fact in probabilistic terms. For example, the 95% confidence level implies that there is only a 5% probability of the actual system performance exceeding the confidence interval limits.

Although an auditor would ideally want to achieve the 100% confidence level to reduce the uncertainty of his statements, it is impossible to reach this goal in practice. This is due to the inherent inverse relationship between the confidence level and the confidence interval. If high confidence level requirements are imposed, the confidence interval will become wider to account for all possible variations of the system parameters. This will naturally lead to higher sampling errors and less acceptable results. Consequently, various trade-offs must be considered between the significance and uncertainty of the results.

3.2 Sampling Techniques

The sampling techniques described in the subsequent paragraphs were developed mainly to assist an auditor in dealing with large data environment and to enable him to perform a timely, accurate, and reliable analysis. The choice of a sampling technique must be based on the following considerations:

- The technique chosen must be applied consistently. Once a particular technique has been selected it must also be used in subsequent audits or the results will not be comparable.
- The basic structure of the original data set from which sampling is done must remain the same for all subsequent audits.
- The technique chosen must be systematic. If the data processing is manual, care must be exercised to avoid subjective biases such as a tendency to choose short records which are easier to process by hand. This may result in an excessive number of overhead moves in the sample since these moves have usually short records. If the procedure is computerized, this problem is not serious.
- The technique chosen must be feasible and cost effective.

There are many sampling techniques documented in the literature (3). The ones most useful for railroad applications are the random number sampling, systematic sampling, and stratified sampling. These techniques are independent of the data structure, data contents, or data quality. This may, in many situations, simplify sampling logic and data processing. Other known techniques include discovery, cluster, or last digits sampling used by DOT in their waybill sampling experiments. Since most of these techniques are simply derivatives of the techniques described below they will not be covered here.

3.2.1 Random Number Sampling

Random number sampling, flowcharted in Figure 3.1, involves sequential selection of records from a data set containing the original population of system events and assigning a random number to each selected record. A random number, X, must be drawn from a uniformly distributed population of events such that:

$$0.0 \leq X \leq 1.0 \quad (3\text{-}1)$$

For manual processing, random numbers can be obtained from tables available in statistical handbooks, or from hand calculators with built-in random number generators. For computerized procedures, random numbers can be referenced from on-line mathematical libraries.

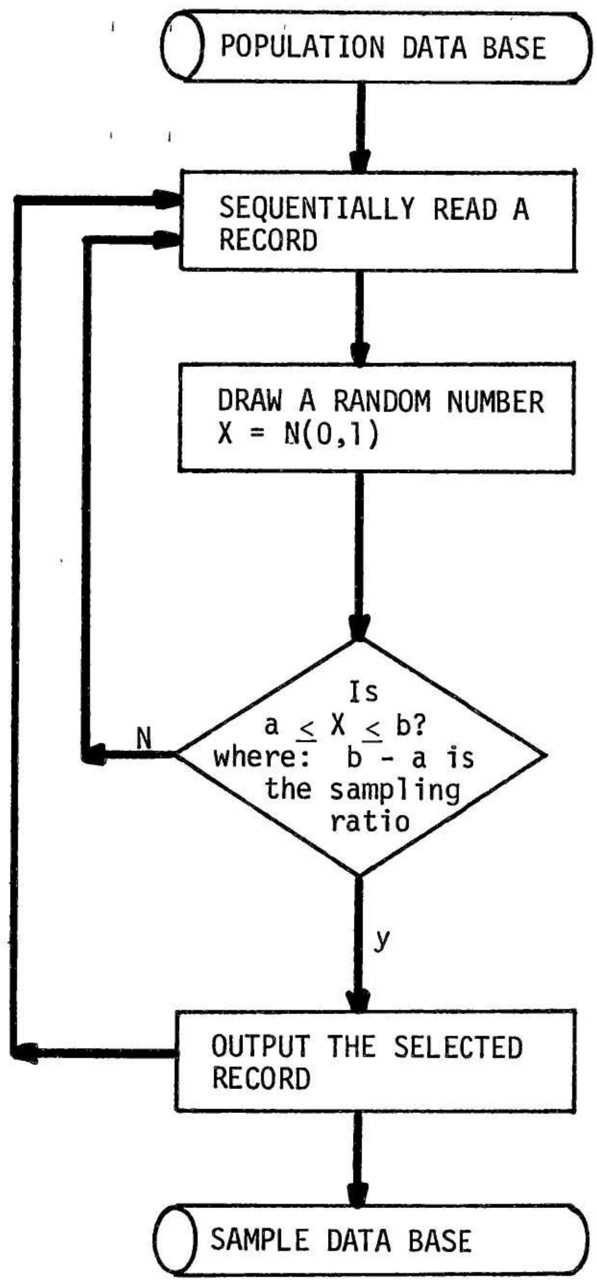
Once the selection of a record and its corresponding random number is completed, an acceptance test must be performed to determine if a record is to be included in a random sample. Prior to this, an approximate sample size must be computed to determine a_p, the percentage of the original population that needs to be chosen to form a sample of a desired size (see the section on the sample size determination).

The acceptance criterion can be stated as follows: accept a record if its corresponding random number X satisfies the following condition:

$$a \leq X \leq b \quad (3\text{-}2)$$

FIGURE 3.1

RANDOM NUMBER SAMPLING



where a and b are any two real numbers, such that:

$0.0 \leq a \leq b \leq 1.0$

and

$b - a = a_p$

where a_p - as defined above.

The technique can be illustrated with the following example:

Original population of events S = 200,000 records/month

Desired sample size n_t = 10,000 records

a_p = 10,000/200,000 = 5%

choose a = 0.20

b = 0.25

Select records:

Record 1 - X = 0.50 - reject, X is not between 0.20 and 0.25

Record 2 - X = 0.22 - accept $0.20 \leq 0.22 \leq 0.25$

.

.

.

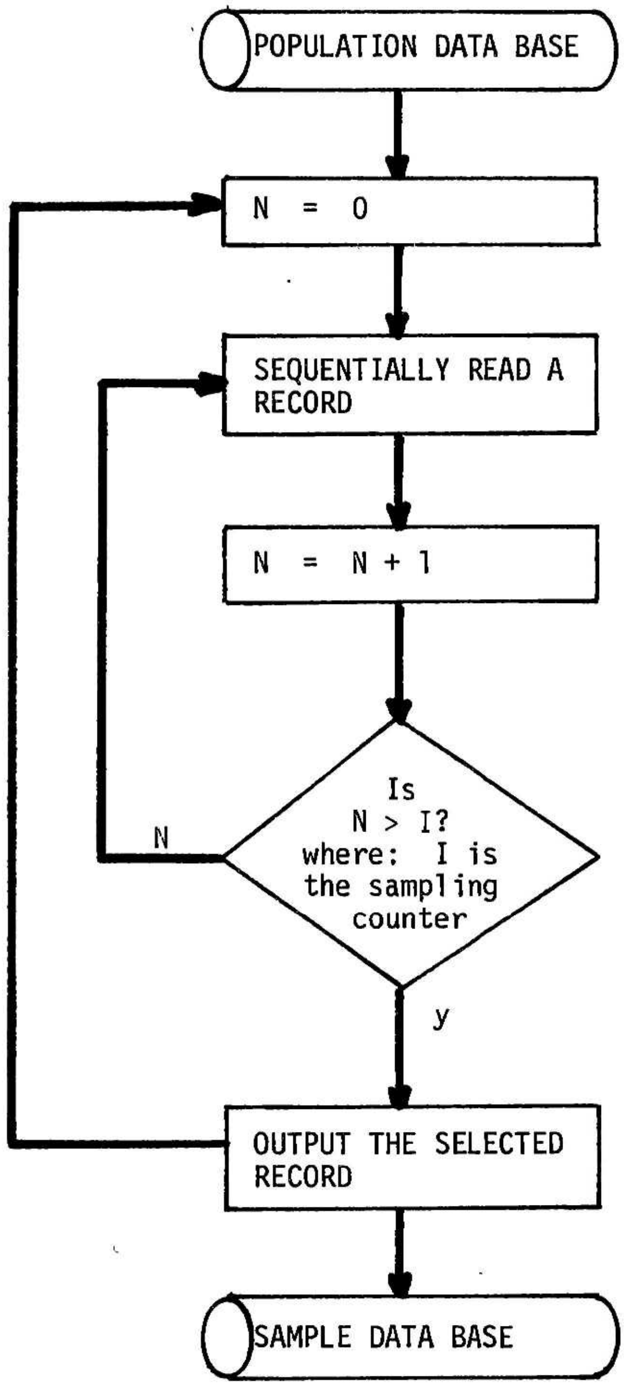
In the above example the record for which a random number between 0.20 and 0.25 is drawn will be added to the sample. If the data was not pre-edited and the expected rejection rate or the non-sampling error is 10%, a_p should be increased by 10%.

3.2.2 Systematic Sampling

The systematic sampling, flowcharted in Figure 3.2, is ideally suited for manual data processing, although it can also be implemented on a computer. This technique amounts to the selection of every Ith record from

FIGURE 3.2

SYSTEMATIC SAMPLING



the original population of events. The technique is straight forward and uncomplicated. Simple record counting establishes acceptance criteria with I found as follows:

$$I = 1/a_p \tag{3-3}$$

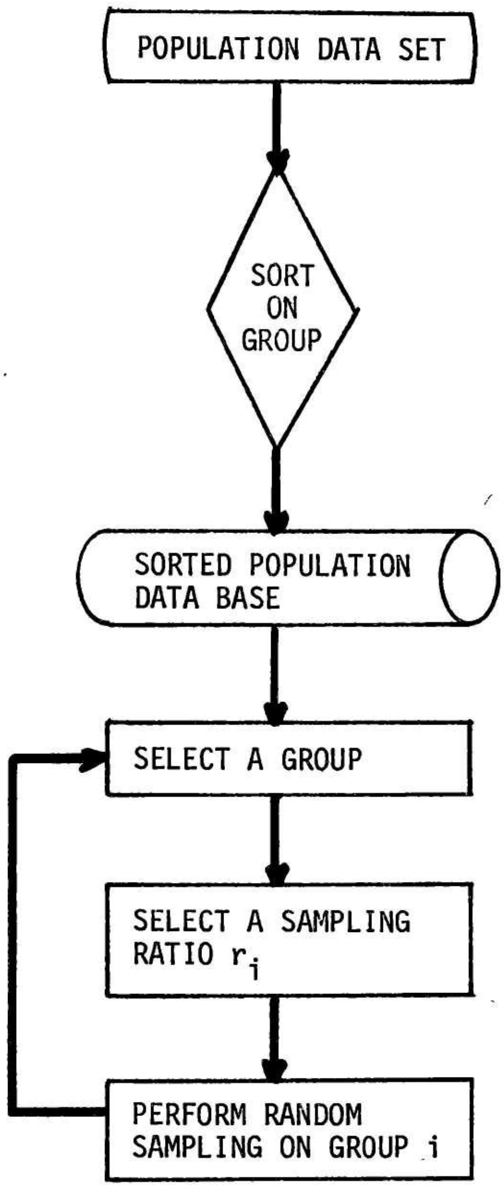
When using this algorithm, all principles listed before must be adhered to. Otherwise unreasonable answers may result. This technique has two main advantages. One, it is simple. Two, it is more realistic. A sample which is formed this way represents a uniform cross-section of actual events that occurred on the system.

3.2.3 Stratified Sampling

The flowchart in Figure 3.3 summarizes the stratified sampling technique. This technique is by far more complicated than the other two previously described. It recognizes that fact that the data in the population file occurs in unequal stratas. That is, the events which occur on the system are not distributed uniformly over all common characteristics. Take, for example, an origin-destination car movement file. It is reasonable to expect uneven distribution of traffic flows between various O-D pairs. Attempting to obtain reliable estimates for O-D pairs with low traffic frequencies after either random or systematic sampling is performed may yield unsatisfactory results. The remaining number of observations after sampling for such an O-D pair may be insufficient to obtain reliable estimates. One way of correcting this is to recognize the existence of small data groups or stratas and sample these groups with higher sampling ratios, a_p. Effectively, this method suggests that each strata in the

FIGURE 3.3

STRATIFIED SAMPLING



r_i - Sampling ratio for Group i

data set be identified and its size determined. Based on this measurement, different a_p's should be calculated for each strata so as to yield enough records, after sampling is performed, to ensure statistical validity of the parameters estimated on each strata.

Although the usefulness of this technique is appealing, its complexity makes implementation difficult in practice. With large numbers of data groups in a data base, considerable effort must be undertaken to identify each strata and determine its appropriate sampling ratio. Economically, this may not be the best alternative.

It is important to note at this point that irrespective of the sampling strategy followed, sample formation is not an exact science. The information contained in a sample will always depend on the structure of original records, ordering of the population file, and the spatial distribution characteristics of system events. For example, the quality of yard or train information in a sample is directly dependent on the original record structure, say O-D car movement records as shown in Table 2.1, and the frequency of car moves through certain yards on the system. If the car moves appear to be highly concentrated among a few of the O-D pairs, then the yards located along these corridors will be well represented in a sample. This will lead to very reliable parameter estimates for these yards while neglecting yards along less frequently used routes. This problem will always be present if a sample is used to obtain a wide range of information. An auditor must be ready to accept this fact and recognize that it is both impractical and uneconomical to obtain measures that are all equally significant and reliable.

3.3 Sample Size

The problem of the sample size determination is directly related to the problem of predetermining the significance and reliability levels of the audit's results. The procedure presented in this section is in no way unique. Others have been suggested in the statistical literature (4). However, these procedures differ from each other primarily in notation and recognition of certain variables. They all share common theoretical foundations. The procedure presented below was developed specifically to address the question of sampling from a population of origin-destination moves. This type of information is readily available on most railroads and therefore should serve as a basis for sampling procedure.

3.3.1 Basic Assumptions

The sample size procedure is based on the following assumptions:

1) If the sample size is adequate for estimating mean trip times for the most significant origin-destination system flows, then it will also provide meaningful mean value estimates of all the performance and utilization parameters considered in the audit.

2) Statistical estimates are based on populations of event that are normally or nearly normally distributed.

Assumption (1) holds for most railroad networks. If the number of observations per major O-D pair is large enough to establish satisfactory statistical significance of its performance estimates, then the number of the observations will also be large enough to yield good estimates for parameters like cycle time for major traffic classes and load status, yard performance, loading/unloading performance, major train connection performance, etc. Further implications of this assumption are discussed in the following section.

3.3.2 Identifying Major O-D Flows

Only a few origin-destination pairs carry sufficient traffic volumes over a period of time to provide meaningful performance estimates. Tables 3.1 and 3.2, as well as Figure 3.4 help illustrate this situation. Table 3.1 lists frequency counts for all O-D pairs on the B & M system. Although the data is based on the audit's random sample, it is indicative of the spacial distribution of the O-D flows over the B & M system.

For the B & M railroad the concentration of car moves over certain O-D pairs appears to be significant. For example, 48% of the total O-D pairs have on the average only one recorded car movement over a certain period of time (9). When the numbers are grouped and rewritten, one can arrive at Table 3.2, which is plotted in Figure 3.4. The concentration curve in Figure 3.4 shows the extent of major O-D flow concentration over all possible system O-D combinations. Nearly 60% of all cars moved between 16% of all possible O-D pairs. This indicates that sampling from such a population may result in estimates with uneven statistical significance. Measures for large O-D flows will be very significant while measures for the small O-D flows will be statistically unacceptable. Therefore, only large O-D flows will be considered in the analysis, in accordance with assumption (1). The minor, low volume flows will be ignored.

To identify major system flows and distinguish them from the minor ones, a point has to be determined at which O-D flows break into two categories. One such point can be computed from the data like the one

TABLE 3.1

ORIGIN-DESTINATION TRIP FREQUENCY COUNTS

A	B	C	D	E	F	
O-D TRIPS	O-D PAIRS	CUM. FREQ.	PERCENT	CUM. PERCENT	GROUP	CLASS
1	94	94	48.2	48.2	7	
2	47	141	24.1	72.3	6	
3	20	161	10.3	82.6	5	
4	4	165	2.1	84.7	5	m_s
5	6	171	3.1	87.8	4	↓
6	4	175	2.1	89.7	4	
7	4	179	2.1	91.8	3	major
8	4	183	2.1	93.8	3	flows
9	1	184	0.5	94.4	2	
11	3	187	1.5	95.9	2	
12	2	189	1.0	96.9	2	
18	1	190	0.5	97.4	1	
27	1	191	0.5	97.9	1	
35	1	192	0.5	98.4	1	
37	1	193	0.5	98.9	1	
42	1	194	0.5	99.4	1	
43	1	195	0.5	100.0	1	

Number of O-D pairs - 195
Number of major O-D pairs = 34
Number of car trips on this system = $A_i \times B_i$ = 646

Source: The B & M Audit Data Base, sample size a_p = 1.4%.

TABLE 3.2

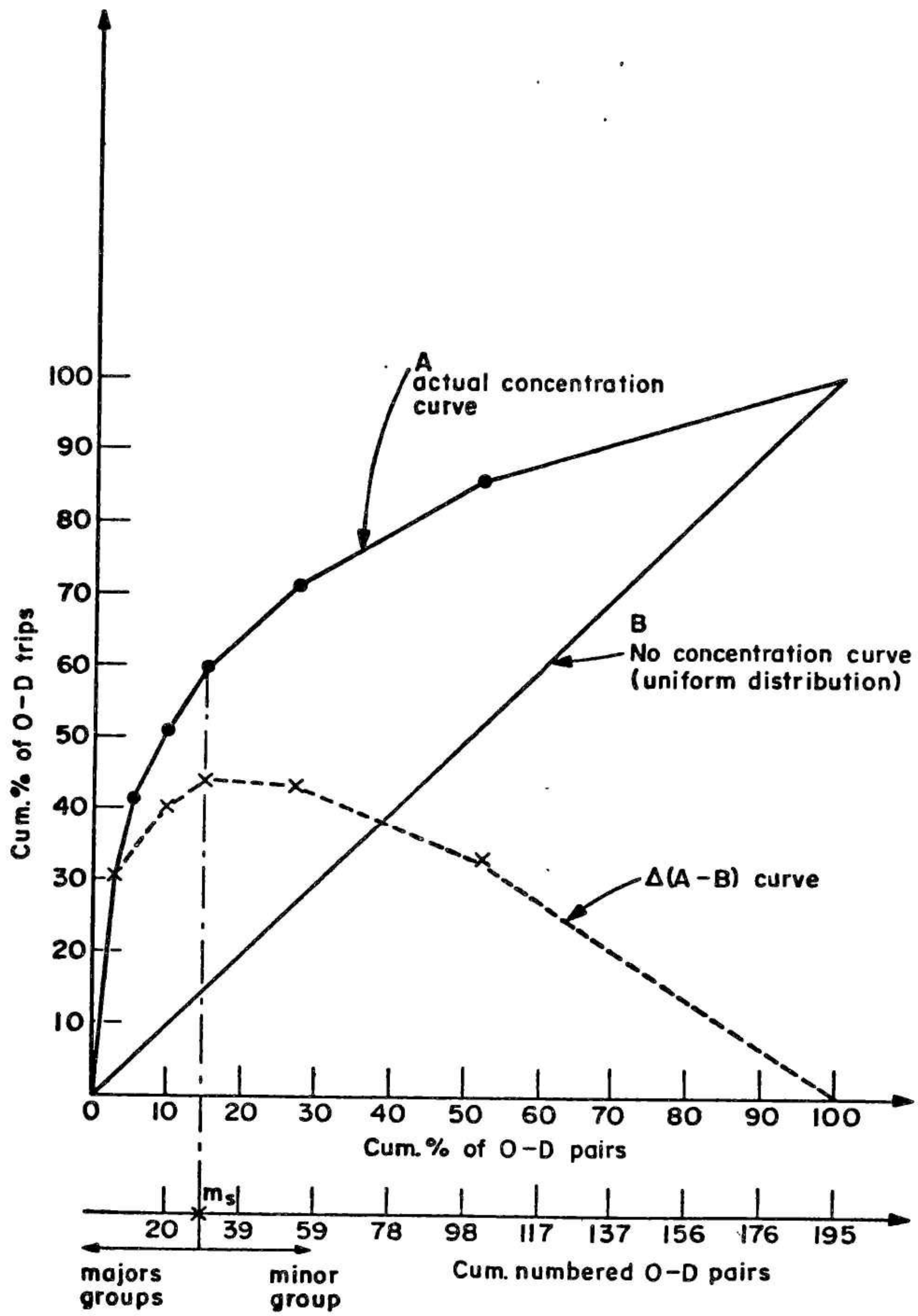
DISTRIBUTION OF O-D VOLUMES AMONG O-D CORRIDORS

A	B	C	D	E	F	G	H	I	J*
MOVES IN AUDIT	O-D PAIRS	CUMUL. B	PERCENT	CUMUL. D	TRIPS	CUMUL. F	PERCENT	CUMUL. H	Δ H - D
18 - 43	6	6	3.1	3.1	202	202	31.3	31.3	28.2
9 - 12	6	12	3.1	6.2	66	268	10.2	41.5	35.3
7 - 8	8	20	4.1	10.3	60	328	9.3	50.8	40.5
5 - 6	10	30	5.1	15.4	54	382	8.4	59.2	43.8 = m_s
3 - 4	24	54	12.3	27.7	76	458	11.8	71.0	43.3
2	47	101	24.1	51.8	94	552	14.6	85.6	33.8
1	94	195	48.2	100.0	94	646	14.6	100.0	0

*Column J results from subtraction of Column D from H. Calculated to find separation point between major and minor move.

FIGURE 3.4

CONCENTRATION CURVE FOR DISTRIBUTION OF O-D TRIPS



presented in Table 3.1. It simply corresponds to the value of the average car movement flow over a system O-D pair:

$$m_s = \frac{\Sigma \text{ (O-D trips)}_i * \text{(O-D pairs)}_i}{\Sigma \text{ (O-D pairs)}_i} \qquad (3\text{-}1)$$

All O-D pairs with flows larger than m_s can then be defined as major O-D pairs. Alternate ways of selecting major O-D flows can be summarized as follows:

1) Major flows are the ones that account for X% of the total system volume, where X might roughly be .5 to 1%.

2) Major flows are the largest system flows which all account for Y% of the total system volume, where Y might be 50 or 60%.

3) A major flow is a flow with minimum of N moves per time period, where N might be 100-250 moves per month.

3.3.3 Coefficient of Variation

The coefficient of variation is defined as:

$$R_i = s_i/t_i \qquad (3\text{-}2)$$

where t_i = average trip time for major O-D pair

s_i = standard deviation of the trip time.

This parameter may be interpreted as a measure of service reliability (5). It accounts for unreliability by measuring the dispersion of the trip time distribution relative to the expected service level, t_i. According to the definition of service, the higher the dispersion the lower is the service reliability.

The value of the coefficient of variation can be obtained in two ways. One, it can be computed directly out of the historical data for major O-D flows. Two, if the data is not available or difficult to compile, the coefficient can be selected subjectively. In most cases the value of R_i will range between zero and 1.0. Values of R_i exceeding 1.0 indicate that the obtained trip time distribution does not conform closely to the uni-variate normal distribution, or it fails to exhibit any coherent and consistent performance characteristics. These situations are graphically illustrated in Figure 3.5. When selecting the value of the coefficient subjectively, low R_i's (0.1 to 0.4) represent very reliable O-D pair service, whereas values above 0.4 but below 1.0 indicate increasingly inconsistent service performance.

3.3.4 A Simple Sample Size Formula

A desired sample size can be derived directly from the confidence interval concept. The basic form of the confidence interval is (6):

$$P\left(t - \frac{c_a * s}{\sqrt{n}} \leq T \leq t + \frac{c_a * s}{\sqrt{n}}\right) = 1 - a \qquad (3\text{-}3)$$

where t = the estimate of the mean trip time

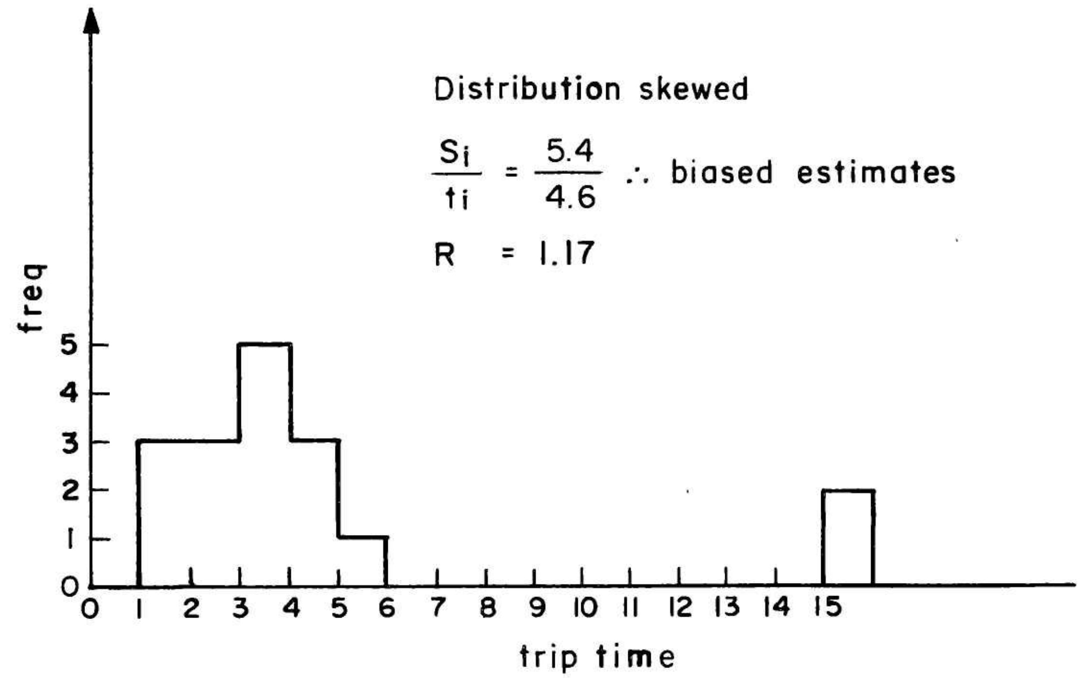
T = the true trip time

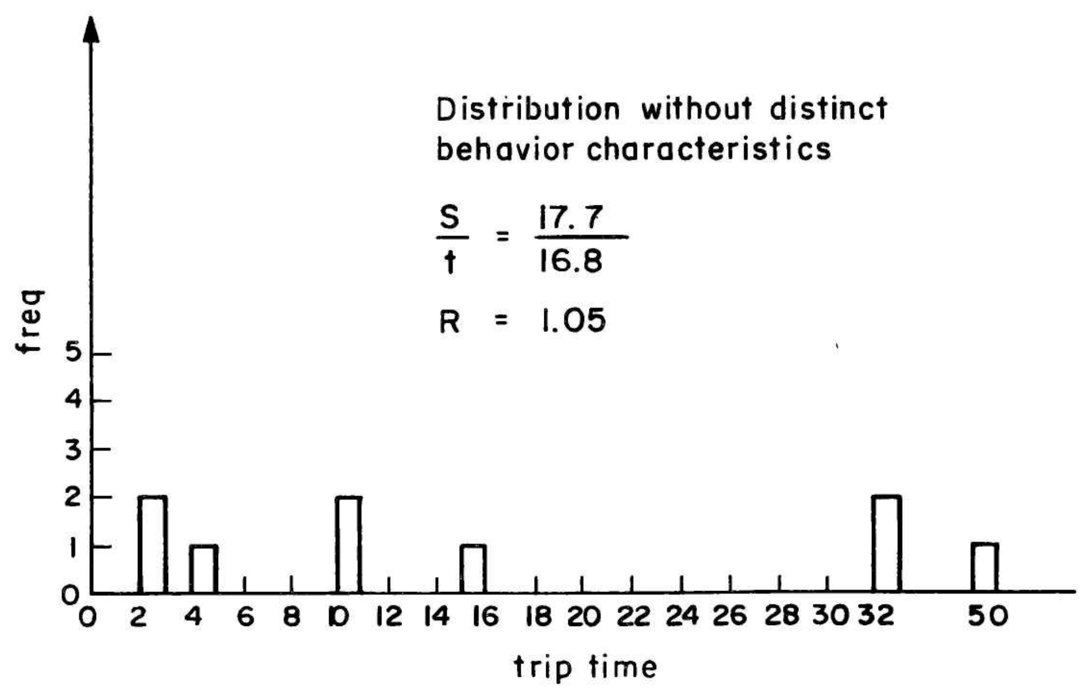
$1 - a$ = a confidence level of the confidence interval (10)

c_a = a t-statistic coefficient

n = a sample size.

FIGURE 3.5
EXAMPLES OF UNACCEPTABLE TRIP TIME DISTRIBUTIONS





The confidence interval stated above can be defined as a probabilistic statement about the expected range of system performance values that are likely to occur under certain criteria. For example, if the estimated mean trip time is 28.6 hours and the computed limits of the 95% confidence interval are ± 8.2 hours, then the true mean, T, will be 95% of the time within 8.2 hours of the estimated mean, i.e.,

$$T = 28.6 \pm 8.2 \text{ hours}$$

This can also be interpreted as a 5% probability that the true mean will be outside of the specified limits. Thus, this statement can be used to:

1) Specify the service reliability characteristics;
2) Determine desired sample size;
3) Determine the significance of estimation results obtained for system parameter values.

The basic assumptions behind this statement are:

1) The trip time variable, T, is normally distributed with mean t and standard deviation σ(sigma).
2) Since the parameter σ is in most cases difficult to obtain, the best estimate of this parameter is assumed to be:

$$s_i = \frac{\sum_{0=1}^{n_i} (t_o - t_i)^2}{\Sigma n_i - 1} \qquad (3\text{-}4)$$

where t_o = are actual observed trip times for a major O-D pair.

t_i = is the mean trip time for a major O-D pair i

n_i = the number of observations for a major O-D pair i.

The standard deviation estimate does not correspond to the value of the actual standard deviation. To account for this discrepancy the normal distribution is substituted with the Student t-statistic distribution which closely approximates the normal distribution and reflects possible uncertainty of the results with somewhat wider shape than the normal distribution (7).

The confidence interval limits can be found by (8):

$$|t_i - T| \leq s_i * c_a/\sqrt{n} \qquad \text{with probability } 1 - a \tag{3-5}$$

where all variables are defined as before. The length of the confidence interval must be constrained to ensure statistically acceptable results. For example, the length of the confidence interval could be constrained to be less than a certain percentage of the estimated mean. Taking this into account, the last inequality can be rewritten as:

$$|t_i - T| \leq s_i * c_a/\sqrt{n} \leq w * t_i \tag{3-6}$$

where w = sampling error as percent of the mean trip time.

This, in turn, can be solved for the sample size, n, by looking at the two rightmost terms of the above inequality. Thus:

$$n = (s_i/t_i)^2 * (c_a/w)^2 \tag{3-7}$$

$$= R_i^2 * (c_a/w)^2 \tag{3-8}$$

where R_i = coefficient of variation defined in the previous section.

Since c_a and w are constants associated with the sample size criteria, once they are set they can be merged into one coefficient, C(a,w) which is:

$$C(a,w) = c_a/w \tag{3-9}$$

The values of C(a,w) are tabulated in Table 3.3 for different combinations of desired sampling error and confidence level. This reduces equation (3-8) to the simple sample size formula:

$$n = (C(a,w) * R)^2 \tag{3-10}$$

The values of the sample size for various combinations of coefficients of variation and C(a,w)'s are computed in Table 3.4. This table, in conjunction with Table 3.3, can be used to find the sampling error of a data group with known sample size. For example, if the sample size and the coefficient of variation of that data group are known to be 144 and 0.3 respectively, then C(a,w) is 40 (Table 3.4). If the confidence level is 90%, then the sampling error is between 0.5 to 1.0%. For 95% confidence level the error becomes about 2%. However, if the same sample size is used and the coefficient of variation for that data batch is 0.7, then at a 90% confidence level the sampling error is 4%.

3.3.5 Determination of the Final Sample Size

Although the formula for the sample size just presented is statistically and mathematically valid, it cannot be applied directly to the problem of sample size determination for an O-D car movement file. The

TABLE 3.3

TABULATIONS OF SAMPLE SIZING CONSTANT AND t-STATISTIC

3.3A TABULATION OF SAMPLE SIZING CONSTANT

$C(a,w) = c_a/w$

w	CONFIDENCE LEVELS 90%	95%	97%	99%
0.15	4.47	11.00	13.07	17.07
0.10	6.70	16.50	19.60	25.60
0.09	7.44	18.33	21.78	28.44
0.07	9.57	23.57	28.00	36.57
0.06	11.17	27.50	32.67	42.67
0.05	13.40	33.00	39.20	51.20
0.04	16.75	41.25	49.00	64.00
0.03	22.33	55.00	65.33	85.33
0.02	33.50	82.50	98.00	128.00
0.01	67.00	165.00	196.00	256.00
0.005	134.00	330.00	392.00	512.00

3.3B TABULATION OF THE t-STATISTIC

c_a

CONFIDENCE LEVEL	c_a
90%	0.67
95%	1.65
97%	1.95
99%	2.56

TABLE 3.4

SIMPLE SAMPLE SIZES ($R = s_i/t_i$)

C(a,w)	0.3	0.4	0.5	0.6	0.7	0.8	0.9
5	2	4	6	9	12	16	12
10	9	16	25	36	49	64	81
15	20	36	56	81	110	144	182
20	36	64	100	144	196	256	400
25	56	100	156	225	306	400	506
30	81	144	225	324	441	576	729
40	144	256	400	576	784	1024	1296
50	225	400	625	900	1225		
70	441	784	1225				
100	900						

coefficient of variation, R, in the above formula represents a single population group. As mentioned before, an O-D movement file has many such groups. Therefore, it is necessary to modify the formula to account for this fact.

The modified final sample size formula is:

$$n_t = (C(a,w) * \overline{R})^2 * \frac{n_m}{w_m} \qquad (3\text{-}11)$$

where $\overline{R}$ = overall system coefficient of variation

n_m = number of major O-D pairs identified on a system

w_m = the ratio of total car moves for all major O-D pairs to total car moves over the entire system.

In most situations, however, n_m and w_m are difficult to obtain. Thus, it is more desirable to express the sample size in terms of "design" parameters. It can be shown that the last equation reduces to:

$$a_p = (C(a,w) * \overline{R})^2 /A_m = n/A_m \qquad (3\text{-}12)$$

where a_p = percent of the original population needed to form a sample of desired size

$\overline{R}$ = overall system coefficient of variation

A_m = average flow per major O-D pair

$C(a,w)$ = sample sizing coefficient.

The final sample size can be found by:

$$n_t = a_p * S \qquad (3\text{-}13)$$

where S = the size of the original population file.

Thus the sample size determination is reduced to a few easily available design parameters. The parameters can be broken down into three groups: statistical, performance, and system activity. The parameter C(a,w) reflects certain statistical criteria that must be met when computing the sample size as to yield statistically meaningful results. This parameter was discussed in the previous section.

The performance parameter, $\overline{R}$, can be obtained either by direct computation or by subjective evaluation of the overall system reliability. It can be computed only if the data pertaining to major O-D flows' trip times and their distribution is available. If it is, a weighted average coefficient of variation should be computed using:

$$\overline{R} = \frac{\Sigma n_i * R_i}{\Sigma n_i}$$

where R_i = coefficient of variation of major O-D pair i

n_i = number of moves per O-D pair i.

For B & M, $\overline{R}$ = 0.6, based on 1976 performance of 36 major O-D pairs.

If the overall system coefficient of variation is chosen subjectively, careful analysis is needed to determine the magnitude of this coefficient. As noted in Section 3.3.3, its value should be between 0.0 and 1.0. The lower the value the better the service performance. For most practical situations values of $\overline{R}$ below 0.3 and above 0.8 are not realistic.

The system activity parameter, A_m, can be obtained from data similar to the one presented in Table 3.1. It corresponds to the average number of trips per major O-D pair. A_m is a function of the number of major O-D pairs identified. The larger the number, the smaller the average flow per major pair will be. This will result in an increase of the sample size. However, if too few pairs are identified, the sample size will be too small to obtain meaningful results for all but a few major O-D pairs. Alternatively, this parameter may be chosen subjectively based on prior, external evidence from marketing or operational reports.

If the data from Table 3.1 was used, the sample size for B & M could be determined as follows:

1) Set confidence level to 90%

2) Set sampling error to 5%

3) Choose $\overline{R}$ = 0.5 (assumed reliability improvement over 1976)

4) Compute A_m. For Table 3.1 it is 12 moves per major O-D pair. Given that the sample represented 1.4% of the original population actual A_m = 857 moves per major O-D pair/month.

5) From Table 3.3 choose C(a,w) = 13.4

6) From Table 3.4 approximate or compute directly n = 45

7) Compute a_p = 45/857 = 0.053 or 5.3% sample size.

8) Given that the size of the original population was 46,000 O-D moves, the required sample size is 2,500 records.

3.3.6 Sample Size Determination--Summary

The sample size determination technique presented here requires the following steps:

1) Identify major O-D system flows and their corresponding O-D pairs. This requires definition of a major O-D pair.

2) Evaluate design parameters for the sample size formula. Three types of information must be compiled:

- Statistical--a choice of the confidence level and sampling error must be made to ensure proper statistical significance of the results.

- Performance--A coefficient of variation must be chosen which is representative of the overall service reliability.

- System activity--The average number of moves per major O-D pair must be determined.

3) Size of the original population of O-D moves must be determined.

4) Given the above parameters, the final sample size can be computed.

CHAPTER III--FOOTNOTES

1) See References 9 and 8.

2) This discussion is based on Reference 10.

3) Refer to References 7 through 10.

4) Use References 7 and 10..

5) For discussion of coefficient of variation, see Benjamin and Cornell, Probability, Statistics, and Decision for Civil Engineers, McGraw Hill, 1970, pp. 139-141.

6) See, P. L. Mayer, Introductory Probability and Statistical Applications, Addison-Wesley, 1970, pp. 303-311.

7) Benjamin and Cornell, pp. 394.

8) Wadsworth and Bryan, Introduction to Probability and Random Variables, McGraw Hill, 1960, pp. 260-261.

9) Since the data comes from the random sample, the O-D trips shown in the table are small. To obtain more realistic flow frequencies divide O-D trips by 0.014, the sample size.

10) Refer to Section 2.3 for discussion of this parameter.

CHAPTER IV

THE B & M CASE STUDY

4.1 The Audit of Car Utilization on B & M

4.1.1 Introduction

The B & M Railroad, as shown in Figure 4.1, is a major road serving the central New England shipper community. Its two main lines, east-west from Ayer to Mechanicville, and south-north from Springfield to White River Junction, carry nearly all of the B & M's traffic volume. At the intersection of these two lines is East Deerfield, B & M's major classification yard and its primary empty car distribution point.

B & M's traffic can be grouped into four distinct traffic classes:

1) Local traffic originating and terminating on system.

2) Received traffic originating on other railroads and terminating on B & M.

3) Forwarded traffic originating on B & M and terminating off-line.

4) Overhead traffic originating and terminating off-line, but passing through the B & M system.

B & M's operating and marketing problems revolve around the great imbalances of car movements in each of the above traffic classes. The statistics for each traffic class, broken down by loaded and empty car moves, are presented in Table 4.1, which shows that B & M receives more loaded traffic than it originates. The ratio of the received to forwarded loads is 3:1. This has a direct impact on the empty car flows and empty car distribution policies. These will be discussed further in subsequent sections.

The great bulk of B & M's traffic is overhead traffic. The overhead moves constitute about 30% of all the traffic handled on the B & M in 1977. Over 50% of the moves in this traffic class occur between Rigby and Mechanicville, and nearly 80% are in the other direction (1). Since most of

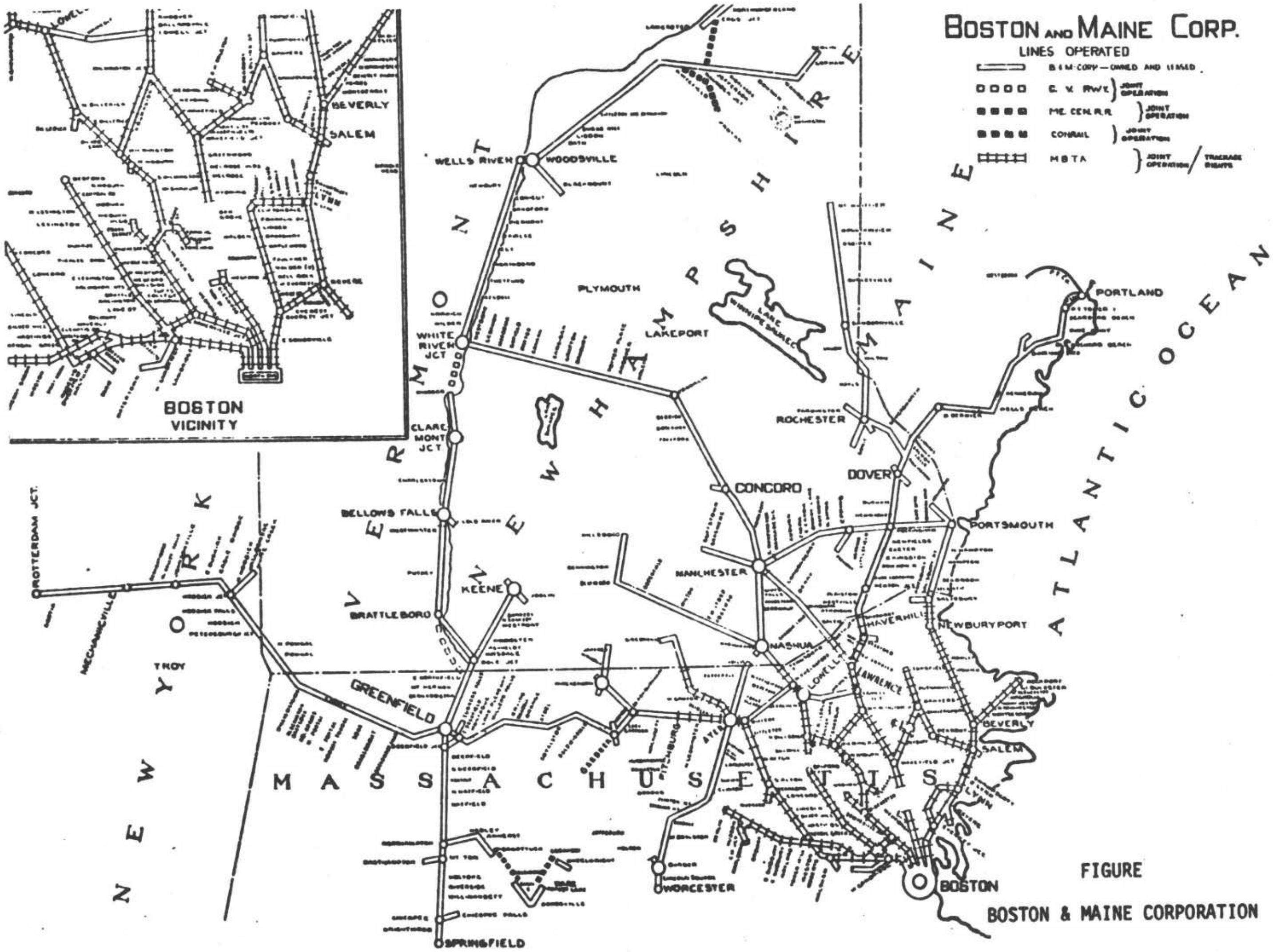


FIGURE
BOSTON & MAINE CORPORATION

FIGURE 4.1
B & M SYSTEM MAP

TABLE 4.1

TRAFFIC STATISTICS FOR B & M (1974 - 1977)

(CAR LOADS HANDLED)

YEAR	LOCALS	RECEIVED	FORWARDED	OVERHEAD	TOTAL
1974	13,815	162,981	62,752	103,702	343,250
1975	13,368	138,382	43,147	86,564	281,461
1976	10,452	130,208	42,159	93,482	276,301
1977	10,245	127,720	40,818	98,310	277,093

Source: B & M's Car Situation Reports, 1974-1977.

the overhead cars are foreign, B & M is often faced with formulating operating policies which would enable it to minimize the car hire costs associated with this traffic class.

The control of car hire costs is one of the primary areas of interest to B & M. As reflected in Table 4.2, B & M's car hire costs are steadily increasing. In 1977 they had reached an all time high of $9.8 million. Since these costs constitute nearly 10% of B & M's revenues in 1977, operational improvements which would reduce this expense are among the many possible alternatives for improving the railroad's profitability.

Although car hire cost control may be an effective way of improving B & M's viability, other controls must be imposed to upgrade service reliability, yard operations, train scheduling, and empty car distribution. This report will illustrate how an audit can help in setting up a monitoring system which would provide meaningful inputs in evaluating system performance and identifying areas which need greater control.

4.1.2 Preparation of Data for the B & M Audit

The car movement data needed to conduct the audit of car utilization for B & M was obtained from the file of monthly car moves for September 1977. At the time the project was initiated this was the most recent operational data. A sample file listing is shown in Figure 4.2. The listing is composed of blocked sets of records. Each, in chronological order, describes car movement history during a month. A car group contains information on car ownership, travel and yard time, trains to which it was assigned, miles traveled, the number of different and complete O-D trips it made over B & M's system, and car hire rates. The file does not provide information on car's revenue, commodity, tons, or operating costs. Each selected car movement history was compiled into an auditing record shown in Table 4.3.

TABLE 4.2

CAR HIRE AND REVENUE DATA

(000)

YEAR	CAR HIRE[1]	INCENTIVE[1]	MILEAGE[1]	TOTAL[1]	REVENUES[2]
1972	4,714	950	1,686	7,350	65,413
1973	5,285	935	1,954	8,174	69,796
1974	5,413	932	1,988	8,333	79,260
1975	4,789	753	1,825	7,367	72,826
1976	5,833	943	2,106	8,882	80,544
1977	6,336	1,133	2,376	9,845	82,255

[1] Source: B & M.

[2] *Moody's Transportation Manual*, 1977.

FIGURE 4.2 SAMPLE LISTING OF ORIGINAL CAR MOVEMENT FILE

```
BM      2066  L B106       530  09 17  2330  GARDNER           EAST DEERFIELD      17  0150   38
   0290  0291  0163    PER DIEM  7 DAYS 123 LOADED    123 EMPTY

BM      2070  E B106 NY10       09 17  1415  ROTTERDAM JCT     MECHANICVILLE       17  1500   23
BM      2070  E B106            09 17  1600  PC ROTTERDAM
BM      2070  E B106 NY10       09 19  1830  MECHANICVILLE     EAST DEERFIELD      19  2220   85
BM      2070  E B106       531  09 21  0335  EAST DEERFIELD    EAST FITCHBURG      21  0530   55
BM      2070  L B106 F5         09 28  1215  SO ASHBURNHAM     EAST FITCHBURG      28  1255   12
BM      2070  L B106       530  09 28  2300  AYER              EAST DEERFIELD      29  0200   67
BM      2070  L B106 SJ1        09 29  1645  EAST DEERFIELD    WHITE RIVER JCT     29  1950   87
BM      2070  L B106 915        09 29  2125  WHITE RIVER JCT   WELLS RIVER VT      29  2325   40
BM      2070  L B106            09 29  2325                    CP WELLS RIVER
   0290  0291  0163    PER DIEM 12 DAYS 206 LOADED    163 EMPTY

BM      2073  E B106            09 28  2120  PC ROTTERDAM
BM      2073  E B106 NY20       09 28  2315  ROTTERDAM JCT     EAST DEERFIELD      29  1835  108
   0290  0291  0163    TRANSFER  2 DAYS     LOADED    108 EMPTY

BM      2076  E B106 NY10       09 08  1430  ROTTERDAM JCT     MECHANICVILLE       08  1530   23
BM      2076  E B106            09 08  1725  PC ROTTERDAM
BM      2076  E B106 NY10       09 09  1735  MECHANICVILLE     EAST DEERFIELD      09  2140   35
BM      2076  E B106 JS2        09 13  1120  EAST DEERFIELD    SPRINGFIELD MAS     13  1250   36
BM      2076  L B106 SJ3        09 15  1525  CHICOPEE          EAST DEERFIELD      15  1645   33
BM      2076  L B106 SJ3        09 16  1900  EAST DEERFIELD    WHITE RIVER JCT     16  2200   87
BM      2076  L B106            09 16  2250                    CV WHITE RIVER
BM      2076  E B106            09 29  1930  PC ROTTERDAM
BM      2076  E B106 NY20       09 29  2359  ROTTERDAM JCT     EAST DEERFIELD      30  0715  108
   0290  0291  0163    TRANSFER  9 DAYS 120 LOADED    252 EMPTY

BM      2078  E B106            09 27  2125  PC ROTTERDAM
BM      2078  E B106 NY20       09 28  0045  ROTTERDAM JCT     EAST DEERFIELD      28  0600  108
BM      2078  E B106 JS4        09 28  2359  EAST DEERFIELD    SPRINGFIELD MAS     29  0130   36
   0290  0291  0163    TRANSFER  3 DAYS     LOADED    144 EMPTY

BM      2081    B106            08           BILLERICA SHOP
   0290  0291  0163  ***ERROR***            LOADED        EMPTY

BM      2082  L B106            09 19  2247  PC ROTTERDAM
BM      2082  L B106 NY20       09 20  0115  ROTTERDAM JCT     RIGBY YARD          20  1815  293
BM      2082  L B106            09 20  1815                    MEC PORTLAND
BM      2082  E B106            09 24  0535  MEC PORTLAND
BM      2082  E B106 NE87       09 24  1905  RIGBY YARD        EAST DEERFIELD      15  0400  185
BM      2082  E B106 JS4        09 28  2359  EAST DEERFIELD    SPRINGFIELD MAS     29  0130   36
```

TABLE 4.3

B & M AUDIT RECORD DESCRIPTION

1.	Car ownership initials
2.	Car number
3.	L/E status
4.	Prior move type (overhead, local, received, forwarded, off-line)
5.	Present move type (overhead, local, received, forwarded)
6.	Next move type (overhead, local, received, forwarded, off-line)
7.	Origin station code
8.	Origin station node--aggregated station code into a node
9.	Destination station code
10.	Destination station node--aggregated station code into a node
11.	O-D distance
12.	Trip time (from departure Originating station to arrival Destination station)
13.	Total loading time (0 for empties)
14.	Total unloading time (0 for loads)
15.	Car type
16.	Number of intermediate yards included
YARD DATA--A Block of up to 5 yards	
17.	Yard code
18.	Yard node--aggregated station code into a node
19.	Date and time arrived
20.	Date and time departed
21.	Total yard time
22.	Train the car arrived on
23.	Train the car departed on
24.	If more than 5 yards included, indicate carry-over to next record
25.	Per diem rate
26.	Mileage rate
27.	Incentive rate

The data used for sampling was compiled manually. About 40% of all movement histories were not acceptable for selection. The car movement records were often missing, had garbled data fields from transmission errors, and were sometimes inconsistent in reporting yard arrival and departure times. Although the same file was available on a magnetic tape, it was felt that it would be easier to process the data manually rather than develop a sophisticated data editing software.

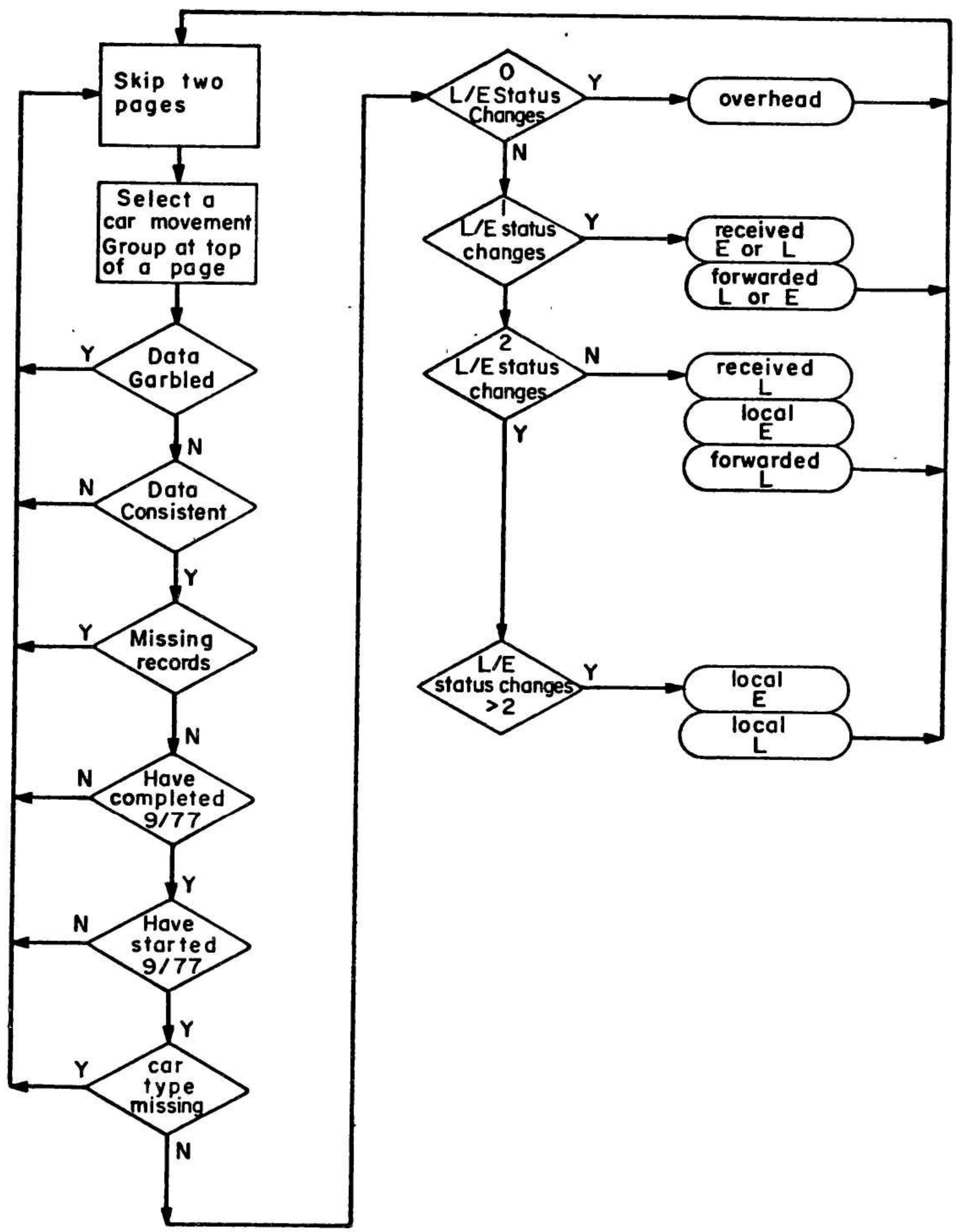
The random sample was created by employing a systematic sampling method. The desired sample size was determined to be 500-750 O-D records. The selection of this sample size was rather arbitrary and based more on considerations given to the availability of resources for conversion of the data to machine readable format than to the statistical validity of the sample.

Based on the approximate number of pages of the file listing, sampling was performed by selecting records at the top of every even page of the listing. Each selected car movement group was carefully checked for any logical car movement or physical data errors. If it was determined that there were missing car movement records, inconsistencies in reporting of times, or field errors, then that particular group of records was rejected and another group was selected after moving two pages into the listing. This process was repeated until a satisfactory group of records was found. The car moves which did not complete their O-D trip in September or started their trip in August were treated as incomplete and rejected from the analysis. The record selection process is flowcharted in Figure 4.3.

Classification of a car movement into four traffic classes was performed by analyzing the car movement history between two interchanges on system. If a car was not loaded or unloaded on line, then one overhead

FIGURE 4.3

SAMPLING LOGIC FLOWCHART



record was compiled for that movement history pertaining to the load status indicated. If a car showed a single loading or unloading on-line, then two records were compiled for its movement history. One was associated with the car's receipt at an interchange and its movement to a loading/unloading station. The other involved the return trip to an interchange and forwarding of the car to another carrier. Similarly, if a car was received by B & M, delivered for unloading, directed for reloading, and forwarded loaded, then three records were assembled, each pertaining to the car movement between its successive load status changes. The first one was associated with the received movement, the second with the local move, and the third with the forwarded move. In cases where there were more than two load status changes for each car, only two on-line local move records were collected. One was for an empty local move, and the other for the following loaded move. This allowed for a consistent analysis of freight car utilization as measured by car cycle times for different traffic classes.

4.1.3 Programming and Report Generation

Once the data had been edited and the random sample established, a set of reports was generated. Rather than write complex and lengthy programs to produce the reports, a prewritten software package--SAS--was used (2). The package considerably reduced the time and costs of data editing, analysis, and presentation. It virtually eliminated debugging. All reports presented in the subsequent sections and in Appendix B were prepared and written in SAS code. Sample SAS programs are shown in Appendix D.

As a result of the audit, several types of reports were generated. Major groups of reports presented are:

a) Car utilization reports--analysis of components of car cycle time for received/forwarded and overhead traffic.

b) System traffic flow reports--traffic volumes between major O-D pairs for all traffic classes.

c) Origin-destination performance reports--trip time and the trip time distributions for major O-D pairs.

d) Yard performance reports--yard times for major traffic classes and car ownerships.

e) Train performance reports--train-to-train connection times for major system yards.

f) Car hire reports--car hire costs per car owner and major car types for September moves.

g) Other reports--loading/unloading times at major system yards by major car type and ownership, and overhead car moves for Maine Central and BAR railroad cars over B & M system.

If revenue, tons, commodity, and cost information were available, additional reports would include:

a) Revenue reports--showing revenue per car, per car type, or commodity.

b) Contribution reports--indicating traffic profitability for major O-D corridors, per commodity, or per car type.

c) Commodity flow reports--indicating major commodity activity over a system.

d) Other marketing and cost control reports.

The reports included in Appendix B, referred to as "Case Tables" in the subsequent sections, will help illustrate various applications of audit information for control and monitoring purposes.

4.2 Applications of the B & M Car Utilization Audit

The following sections will illustrate how an audit can be applied in monitoring system performance by various departments of a railroad. The illustrations were originally developed for B & M to test the applicability of the concept in a real world environment. The results and observations associated with the presentation of this experiment are discussed in the following subsections.

4.2.1 Empty Car Distribution

Empty car distribution is a logistics problem involving a search for an optimum set of locations from which empty cars can be distributed over the system to minimize total car handling costs. The search typically occurs under a set of constraints defining the total car supply and demand conditions.

Empty car distribution remains today one of the more critical areas of railroad operation. Decisions are different from day to day, and the optimality of a given distribution system may change in time. The most important factors influencing a railroad distribution system are the operating environment and its relationship to the loading and unloading pattern. Since the distribution of empty cars is not independent from operating directives, any operating policy changes will affect the distribution policies, and vice versa.

There are three areas which may be affected by empty car distribution policies:

1) Shipper service quality (availability of equipment);
2) System operating performance and car utilization; and
3) System financial performance.

The effects of empty car distribution on service quality can be traced to the railroad's ability to satisfy shippers' demands for cars in a timely and responsive manner. Inadequate distribution strategies may result in an inefficient service. A customer who is faced with frequent car shortages, physically unacceptable cars, or car delivery delays, will be prone to seek the services of alternate transportation modes. This, in the long run, may result in a loss of traffic volume and revenues.

The empty car distribution policies may also have an impact on the overall system performance and car utilization levels. Bad distribution policies may yield excessive car detention times at yards and increased congestion. This affects not only the empty traffic in a yard but also the loaded traffic. This tends to increase transit times and transit time variability and therefore to decrease car utilization and service reliability. On the other hand, operational policies like train schedules, blocking, availability of motive power, and priorities have a great influence on effectiveness of empty car distribution.

The railroad's financial performance will eventually reflect the efficiency of the operating policies. The better the policies, the better the service. Since empty car distribution policies form a subset of operating policies, it is likely that they also affect the service. The service levels, in turn, will dictate the railroad's profitability. The better the service, the higher the profitability is likely to be. Therefore, it is to the railroad's advantage to carefully define its empty car distribution and other operational policies. From a marketing point of view, improved service makes railroads more attractive for shippers to transport their products. Clearly defined car handling policies can become convenient in defining selling strategies. Both can lead to increased traffic volumes and revenues. From an operational standpoint, better operating policies can lead to lower system and car hire costs, and a more systematic management of the railroad network. From a financial point of view, the resulting improved financial performance can lead to better cash flows, greater ease in locating sources of outside investment, and increased internal resources that can be funneled back into operations in the form of retained earnings.

It is important for a railroad to have proper monitoring mechanisms which would provide dynamic information for strategic marketing and operating decisions, and for evaluation of alternate operating policies. The output of an audit, which can be used as a monitoring device, would ideally be composed of a set of parameters specific to operations. In the audit of car utilization for B & M, the empty car distribution measures were:

a) Yard detention times for empties;

b) Shipper's loading and unloading detention times;

c) System and foreign empty flow imbalances;

d) Average empty yard volumes vs. total yard volumes;

e) Locations of loading and unloading points.

If proper data were available, additional statistics could be collected pertaining to:

a) Percentage of unfilled demand;

b) Average time delay in filling shipper's car orders;

c) Empty car inventories at major distribution points.

At B & M, the empty car distribution is one of the primary concerns of management. Its main empty car distribution center--East Deerfield--is located at the strategic intersection of B & M's two main lines. It is a logical point to do most of the classification and car cleaning work. However, due to the yard's physical design and limited expansion space, classification and the distribution of empties interfere with each other. Yard congestion which results from switching empties in the yard delays other traffic. This was the conclusion of the yard congestion study done at MIT which states that "volume and poor (yard) performance generally peak and bottom out together. It is apparent that the two are related and that congestion hinders the performance" (3). Since, as illustrated in Case Table 9A, East Deerfield is switching empties at an average rate of 57% of the total volume moving through the yard, the net impact of the empty overhead volume on the total yard performance may be significant.

B & M's empty car distribution policy has been to supply shippers with B & M empties coming on the system from other roads and send foreign empties to their home roads. This policy is illustrated in Case Table 13. The table lists loaded and empty traffic on B & M by traffic class. While overhead and local moves show a near balance between loaded and empty traffic, received and forwarded traffic display uneven loaded and empty flow characteristics. However, received empties nearly equal the originated loads, which is also true for received loads and originated empties.

The policy of preferential loading of the system cars is also demonstrated in Case Tables 14 to 16. These tables represent a detailed version of Table 13. Each traffic class and loading status are expanded and listed by major car ownership and car type. In this table, the empty car distribution policies are in the form of statistical frequency counts. Table 14A shows that 99% of the forwarded empty traffic were foreign empties of which 67% were box cars. As shown in Table 14B, only 27% of the forwarded loads were foreign cars. This means that only 10% of the foreign empties were reloaded and the remainder left the system empty. Note that 73% of the originated loads moved on B & M cars.

Case Tables 15A and 15B present similar results for received traffic. The situation in this table is nearly a mirror image to that presented in Table 14. The table shows that B & M empties accounted for 85% of the received empty traffic. These are the empties which are subsequently used by B & M for distribution to shippers.

Case tables 16A and 16B present car movement statistics for the overhead traffic. Here, the loaded and empty car movements are nearly balanced for each major car ownership. The table also shows that foreign cars are involved in nearly 85% of the overhead moves for both loads and empties.

The effect of empty car movements by traffic class and car ownership on the distribution policies can also be studied in case Tables 9A and 10A. Table 9A lists mean yard times for local, overhead, and delivered and forwarded traffic at major system yards. At East Deerfield, 34% of the average yard volume wereoverhead moves, 63% of total yard volume were received and forwarded moves. The yard handled empty traffic at a rate of 57% of its total volume. Since 19% of the total traffic was made up of overhead empties which in most cases do not quality for distribution, the volume attributable to all other empties may be put at about 38% of the total yard volume. Among these empties, B & M cars, as shown in Table 10A, spent an average 15 hours more in the yard than foreign empties. The difference in the yard time between these cars is attributable directly to the fact that the B & M empties are sitting in the yard and waiting for distribution assignments, while foreign empties are sent out of the system to avoid car hire costs.

The audit data base was also used to compile statistics on basic car distribution information presented in Table 4.4. This table lists utilization statistics for various combinations of car moves on the B & M system. Some observations that emerged concerning the distribution and handling of empty cars on B & M can be summarized as follows:

a) B & M, as well as foreign empties that were directed for loading, spent in excess of 163 and 105 hours, respectively, at the loading terminal and shipper's siding.

b) B & M empties spent more time moving from interchanges to their final loading points on system than loaded on their return trip to an interchange, although the trip mileage is nearly the same. This indicates that these cars are being held at the intermediate yards and at East Deerfield for excessively long times.

c) The traffic moving out of the system, loads and empties, is handled more expediently than the traffic terminating on-line. For example, B & M empties take 87 hours to move to their loading point and only half that much time is taken to make the return trip to an interchange. Foreign received loads take 51 hours to move to their unloading point and only 35 hours to return to an interchange empty.

d) The B & M Overhead empties, moving off-line to serve B & M customers, get there in nearly twice the time they take coming back loaded.

e) Foreign empties scheduled for reloading on B & M are not handled considerable faster than B & M empties, although they are the fastest moving traffic after loading is complete.

The statistics shown in Table 4.4 were used to evaluate alternative empty car distribution policies. One of the alternatives involved B & M joining the National Clearinghouse Experiment (4). Members of the Clearinghouse experiment (club roads) can use any club road's general purpose box cars as their own. This encourages reloading of foreign club cars and reduces empty car movements. Since B & M handles a considerable number of foreign empties, it might be to B & M's advantage to joint the Clearinghouse program. As case Table 14A shows, the empty foreign box cars in question

TABLE 4.4

BASIC CAR DISTRIBUTION INFORMATION

	HOURS	MILES	OBS
B & M CAR MOVES			
Received E to loading point	87	158	26
Loading time	163	-	47
From a loading point to interchange L	45	155	26
Overhead move E	117	262	17
Overhead move L	64	253	24
E time at E. Deerfield	35	-	43
FOREIGN CAR MOVES			
Received L to unloading point	51	185	50
Unloading time	116	-	109
From unloading point to interchange E	35	189	42
From unloading to reloading point E	73	205	5
Loading time	106	-	13
From reloading point to interchange L	27	200	4
Overhead move E	30	205	72
Overhead move L	32	199	76
E time at E. Deerfield if reloaded	30*	-	-
E time at E. Deerfield if not reloaded	20	-	125

*The time at E. Deerfield is expected to be similar to B & M's empties. However, due to car hire costs, an improvement of 5 hours was assumed for foreign empties over B & M empties.

constitute 41% of the total empty equipment moved out of the B & M system. Assuming that a considerable number of B & M box cars stay off-line earning car hire, and that the same number of foreign club empties are reloaded in their place, B & M would achieve car utilization benefits in terms of car-days and car-miles.

The analysis assumed that approximately 750 B & M cars will stay off-line and the same number of foreign club cars will be reloaded. If the B & M cars stay off-line, then car-days and car-miles will be reduced for the system car moves. Since the B & M system cycle time is on the average (87 + 163 + 45)/24 = 12.3 days, the net saving in car-days will be 750*12.3 days or 9200 car-days. Similarly, car-miles will be reduced by a total of 235,000.

The effect of reloading foreign club cars is to accumulate additional car-miles and car-days for these cars. Since there are two sources of foreign empty back-haul on B & M, from the overhead and forwarded moves, based on USRA date of B & M car flows, it was assumed that 50% of the reloads would come from overhead moves and the other half from forwarded moves. The net changes in car-days and car-miles are summarized in Table 4.5. The net B & M utilization benefits could be estimated at 78,000 car-miles and 3,800 car-days per month. This, at $5.25 per diem and 3.5¢ mileage rates per box car, translates to a net savings of roughly $23,000 per month.

4.2.2 Car Hire in Operating Budget

One of the most important tools of management control is a budget. Budgeting forms a key link between planning and operations. It allows management to transform conceptual plans into quantitative plans which, in the long run, helps control and direct the operations toward the desired goals.

TABLE 4.5

B & M CLEARINGHOUSE ANALYSIS

SEGMENT	CAR - DAYS			CAR - MILES	
	MOVES	AVERAGE TIME (HRS)	TOTAL DAYS	AVERAGE MILES	TOTAL MILES
ELIMINATED:					
B & M Cons					
B & M received empty moves to load point	750	87	2,719	158	118,500
B & M forwarded loads	750	45	1,406	155	116,250
B & M car-loading	750	163	5,094		
			9,219		234,750
Club Cons					
Club forwarded empties	375	35	547	189	70,875
Club overhead	375	30	469	205	76,875
			1,016		147,750
Total Eliminated			10,235		382,500
ADDED CLUB CONS:					
Forwarded					
Club empty to a reloading point	375	73	1,141	205	76,875
Club car-reloading	375	106	1,656		
Club forwarded loads	375	27	422	200	75,000
Overhead					
Club received empties	375	73	1,141	205	76,875
Club car-reloading	375	106	1,656		
Club forwarded loads	375	27	422	200	75,000
Total Added			6,438		303,750
Net Benefits			3,797		78,750

The car hire budget, developed for B & M operating budget by Mr. C. D. Martland of MIT, is basically a forecast of car hire expenses for one period into the future (5). The model assumes the next period's car hire payable to be a function of last period's car hire payable, and changes in the operating environment. The model can be written as:

$$C_{i+1} = K * C_i \tag{4-1}$$

where C_{i+1} = the next period's car hire payable

C_i = the last period's car hire payable

K = a constant reflecting changes in the operating environment.

This model is based on the following assumptions:

1) The mix of system and foreign cars on-line does not change significantly in time. If the mix changes and the number of system cars on-line increases, they may conceivably be replacing the foreign cars on-line thereby decreasing car hire payable for that period.

2) The car hire is directly proportional to the number of loaded cars handled on the system.

The coefficient, K, reflecting changes in the operating environment, is a composite variable. It represents the expected changes in the factors directly affecting the car hire. It measures the compounded effect of expected changes in car utilization, car hire rates, and traffic volumes on car hire relative to the last period levels. The coefficient can mathematically be written as:

$$K = k_u * k_r * k_v \tag{4-2}$$

where: k_u = utilization coefficient = desired utilization/base utilization

k_r = car hire rate coefficient = expected rate/base rate

k_v = volume coefficient = expected volume/base volume

Each of the above coefficients combines the effect of the operating environment on the car hire. Since the coefficients are also composite, they can be decomposed into the following:

1) The coefficient of utilization reflects all expected utilization level changes for the next period. They may include annual utilization improvement goals, the effect of better reporting and control systems like more reliable data and more comprehensive reports, and weather effects on the utilization levels. While the first two factors are rather subjective, the last one can be measured directly from historical data. Thus, k_u can be written as:

$$k_u = k_g * k_d * k_w * k_o \tag{4-3}$$

where k_g = coefficient representing annual utilization improvement goals (e.g., 5% annual improvement yields $k_g = 0.95$)

k_d = coefficient representing the impact of improved data systems on utilization control (e.g., 3% impact yields $k_d = 0.97$)

k_w = seasonal weather effect on utilization performance (e.g., if snow causes the utilization to drop 9% then $k_w = 1.09$)

k_o = coefficient representing utilization factors other than covered above.

2) The rate coefficient does not have to be decomposed. It simply reflects the expected changes in average car hire rates relative to the last period (e.g., if rates increase 5%, $k_r = 1.05$).

3) The volume coefficient reflects the seasonality of the traffic. It is assumed that seasonalities do not change from year to year significantly. The seasonality coefficients can be computed as percent deviations of monthly traffic volumes from the annual average. The coefficients also reflect the growth in the traffic volume projections and adjustment for commodities not included in the volume projections. Thus, the coefficient can be rewritten as:

$$k_v = k_s * k_g' * k_a \qquad (4\text{-}4)$$

where k_s = seasonal effect on traffic levels (e.g., if March traffic is 10% lower than the average, then k_s = 0.90).

k_g' = traffic growth projections (e.g., if traffic is assumed to grow at the rate of 4% per period then k_g' = 1.04).

k_a = percent of commodities not included in projections (e.g., if 7% of commodities loads were omitted from projection figures, then k_a = 1.07). Note that in most situations this coefficient will be 1.00 since new commodities will be included in the projections.

An audit of car utilization can be applied to the car hire budgeting in three ways. First, it can monitor periodic car hire expenses by direct computations based on the data sample. Second, it can be used to obtain the fleet mix and traffic mix information needed for forecasting the next period's car hire. Third, it can monitor car utilization in terms of cycle time for all traffic classes.

The use of the audit can be illustrated with Case Tables 18, 6 and 17A. Table 18 can be used to monitor the relative number of system versus foreign cars on-line. This is necessary to continuously evaluate the validity of the original assumptions underlying this model. If the ratio of system to foreign cars on system changes considerably, it is necessary to adjust the car hire budget forecast.

Tables 6 and 17A (of the Case Tables) are basically utilization reports which can help in monitoring actual utilization levels. When periodic auditing is performed, a set of reports can be compiled to identify trends and seasonality for utilization constant k_u. These reports can also be used by management to quickly pinpoint trouble areas. Since the reports break car trips into components, it is easy to see where problems occur. Case Table 6, compiled for the received and forwarded traffic, represents a complete car cycle analysis. The car cycle times and their components show great variability in handling policies for various car types. Cycle time, which has an overall average of 200 hours, is consistently composed of two large components. One, the terminal time in column E, represents the percentage of a car's cycle time spent at a terminal from which the car was directed for loading or unloading, plus the time at shipper's siding. The numbers in this column are typically around 100 hours, or 50% of the total cycle time. Since the railroad is responsible for car hire on these cars, it is in its interest to develop various alternatives which would help reduce this time to minimize car hire expenses. Among the most promising alternatives, ones that deal with increasing cooperation between railroads and shippers offer the greatest payoff. It is usually the shipper who can help reduce the loading/unloading time most by better scheduling and planning of his car delivery and pick-up requirements. Railroads could offer shippers a car management service which would assist shippers in this area. Both shippers and railroads would derive a common benefit from such a program.

The car utilization report for overhead moves is presented in Table 17A. The figures compiled for this report represent one way overhead traffic, with specified loaded status. However, since the figures for the total trip time represent only a half of a car's cycle time, they cannot be compared to the cycle times of Table 6. The overhead moves are normally handled differently and are not stopped on system for loading or unloading. Thus they must appear in a separate report like the one shown in Table 17A. The average trip time for the overhead moves in 36 hours. The great variability of the trip times among various car types indicates preferential car handling policies, differing car routing, and operating priorities on the B & M.

The direct measurement of car hire payable to other railroads for their cars handled over the B & M system is achievable by using Case Table 5A and 5B. Table 5A contains actual per diem and mileage costs paid out to roads listed under the column titled "owner". The computed costs pertain to all car moves included in the data sample. Therefore, the cost per car figures represent average costs associated with car moves in the sample and the total cost pertains to the product of the cost per car and number of cars in the sample for each owner. Although a lot of the cost figures are not statistically justifiable, they may be representative of the actual expense levels for the car moves with performance characteristics similar to those in the sample. The column of interest in this report should be the one referring to the relative distribution of car hire payable among various railroads which ship their cars via B & M. Similar reports could be generated to compute the car hire payable by O-D corridor, car type, traffic class, originating node, etc. The grand total payable may approximate the actual payable if divided by the sample size as a percentage of the original population size. Given that the audit data was a 1.4% sample, dividing $12,143 by 0.014 would yield $867,000 per month, or 7.6% above the actual $806,000 car hire paid out.

4.2.3 Measurement of System Performance Levels

The primary outputs of a railroad transportation system can be measured by its performance levels. The performance levels can be defined as measures of managerial efficiency in operating a system. The three areas for which performance data is commonly compiled are: operations, marketing, and finance.

Operating performance measures can be grouped into car service, car utilization, and car handling costs. Each of these three areas represent different aspects of managing car flows over a system. Marketing performance, on the other hand, can be measured by monitoring variables associated with soliciting new traffic, commodity flows, carload contribution levels, and its ability to maintain reasonable origin destination corridor profitability. The financial performance levels, directly dependent on the operating and marketing performance, are usually listed in periodic financial reports. Attention will be focused on operating and marketing performance levels since financial performance depends on both.

The operating department is responsible for car movement performance. Its tasks include decisions associated with moving a car between two points on a system at a lowest possible cost and within acceptable time constraints. Since costs and trip times of a car movement are inversely related to each other, the decisions pertaining to a car movement will often involve various trade-offs between these two parameters. The specific measures of operating performance can be as follows:

a) Car cycle time indicating the efficiency with which the railroad cars are being used.

b) O-D trip times indicating the levels of delivered service to a shipper.

c) O-D trip time variability indicating the reliability of service.

d) Yard detention times which are a component of the service levels and car utilization.

e) Various components of yard and line-haul costs per car handled.

f) Other measures pertaining to car costs, service levels, or car utilization.

The marketing department is responsible for seeking new and maintaining present markets for carloads. Its performance is related to the ability to derive more revenue from those markets. The decisions which commonly have to be made in this department involve evaluating various trade-offs between car revenue potential and operating costs associated with moving a car between two points on the system. The measures of marketing performance can be:

a) Percentage of car capacity used indicating fleet utilization levels;

b) Revenue per load handled;

c) Traffic growth;

d) Traffic profitability characteristics;

e) Other measures pertaining to responsibilities of marketing department.

Since both marketing and operating departments base their decisions on common inputs--the costs of moving a car over the system--it is necessary to establish close cooperation between these two departments in an effort to:

1) Have consistent cost data.

2) Discuss areas in which costs could be reduced to increase traffic profitability and car movement service; and

3) Establish a mutually agreeable set of operating policies which will reflect the long range goals of both the operating and marketing departments.

This interdepartmental cooperation was envisioned by the Task Force (6) as a concept of an operating-service plan--"This operating/service plan should provide a plan for handling <u>each</u> loaded or empty car tendered to the railroad for movement". Based on set standards for each movement, this plan would establish a control system which would ensure accomplishing desired service levels.

The role of standards is very important. They serve as:

1) An evaluation tool;

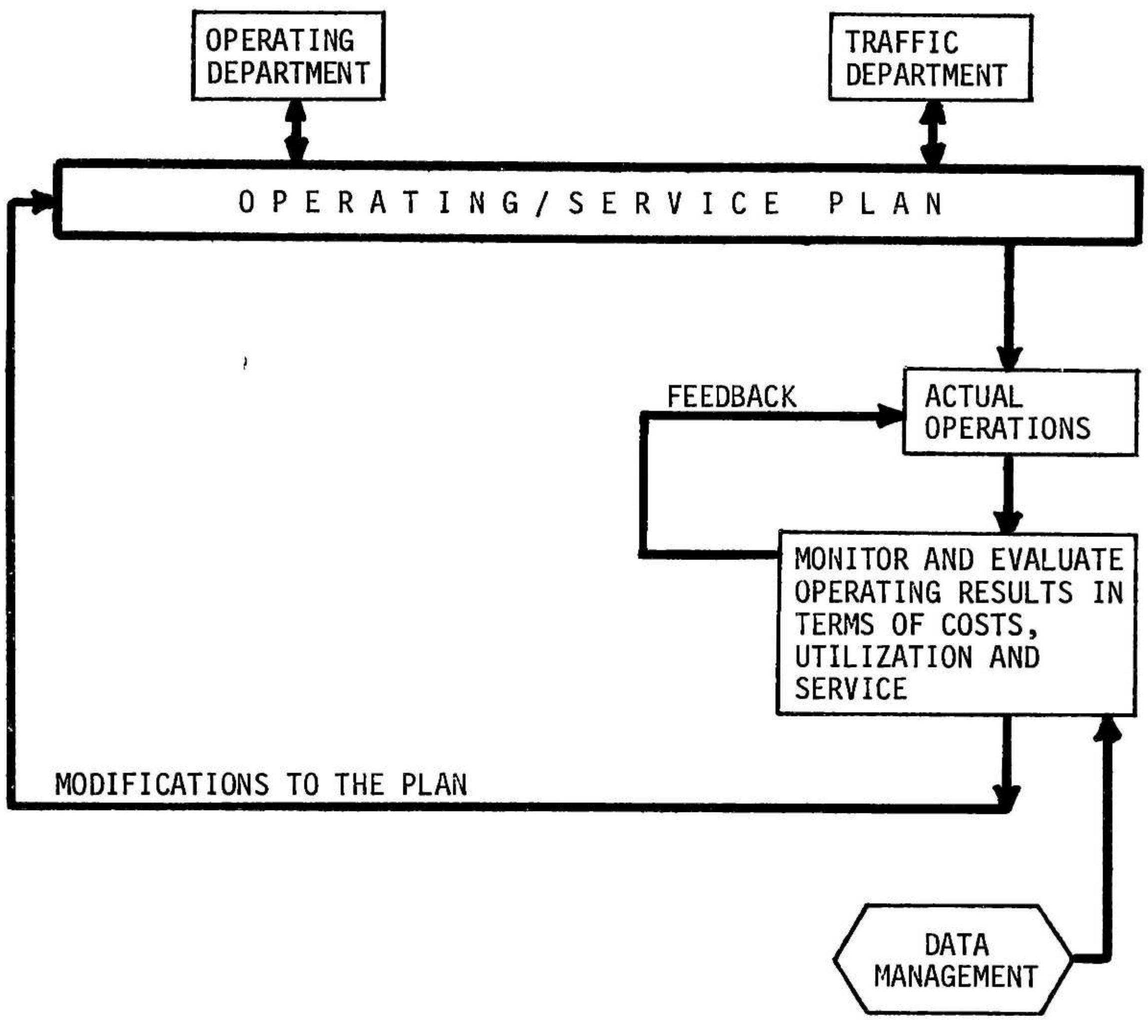
2) A planning tool; and

3) A control tool.

The standards are set to reflect management's short or long term goals for the levels of system performance. In their final report. Task Force II (7) state that the purpose of standards is to "serve as management's leading indicator to investigate or act in certain areas of the car utilization system".

FIGURE 4.4

DEVELOPMENT AND EVALUATION OF AN OPERATING/SERVICE PLAN



Source: The Industry Task Force on Reliability Studies, Freight Car Utilization and Railroad Reliability: Case Studies Final Report, AAR Report No. R283, October 1977.

A considerable data management task is necessary to monitor the system performance and evaluate possible variations between actual and standard performance levels. The relationship between the operating-service plan and data management is illustrated in Figure 4.4. If the variances are large, the operating-service plan needs to be re-evaluated. Thus, the data management provides an important input to the refinement of the plan and its standards.

The definition of standards lends itself to statistical sampling procedures used for audit sample formation. Standards are based on the expected values of parameters they represent. Therefore, as long as the number of data observations is large enough to provide statistically significant results, the standards can be compared to the means obtained from that data. This implies that statistically valid audit results can be directly applied in the evaluation and definition of performance standards.

The standards which can be measured using the audit are:

- Traffic flow standards or expected traffic volumes;
- Service standards for yard and origin to destination performance;
- Utilization standards; and
- Car cost and revenue standards, as well as traffic profitability standards.

Examples of each of these are described in the subsequent paragraphs.

The traffic flow statistics can be obtained from Case Tables 1-3, 12-16, and 18. Table 1B identifies major flows on the B & M for received or forwarded traffic. The major flow is defined as a flow with greatest relative volume and possibly greatest profitability potential. From a marketing point of view, identifying these flows and defining corresponding standards will lead to improved service. In the long run this may increase profitability since better service will attract more revenue traffic. This is consistent with the marketing strategy called for in Task Force II's report.

For forwarded traffic on the B & M, the major flows occur between the five terminating nodes of Mechanicville, Rigby, Rotterdam Junction, Springfield, and White River Junction, and nine originating nodes. In this case a major node is defined as an originating or terminating node contributing in excess of 5% of the total volume for each move type. The distribution of these flows between each major node is indicated in each cell (see Case Table 1B). For example, from the table it appears that 43% of all the traffic that originated in Boston went to Mechanicville, whereas from all the traffic that terminated in Mechanicville only 15% came from Boston. This indicates that for the forwarded traffic the Boston-Mechanicville flows are the largest relative to each node.

A further refinement to this report could be made by listing the same table for loaded traffic and empty traffic separately. This would indicate the nature of standards to be set. If the majority of the forwarded traffic are empties, then standards should be set either to reflect the most expedient handling of these cars to interchanges, or to minimize per diem. If major flows are loads, then the standards should be oriented toward satisfying marketing service goals for this traffic so as to minimize car handling costs and maximize the profit.

Tables 2B and 3B contain similar information for received and overhead traffic, respectively. Again, for both traffic classes there are five strategic interchange nodes. For received traffic, 20% of the total traffic terminates in Boston and 61% of the total traffic terminates in the

Boston area. Of the seven major terminating nodes, five are in the Boston area. The most important major flow is between Mechanicville and Boston. Mechanicville originates 10% of its volume to Boston, while 67% of Boston traffic comes from Mechanicville. This, for all practical purposes, is consistent with the flow statistics for forwarded traffic. It indicates that the loaded traffic coming on B & M and moving east to the Boston area is moved out of the system along the same O-D corridors.

Tables 12-16 and 18 present system flow statistics. Table 12 lists car movement statistics by load status and major car type. It may be useful for monitoring car supply position on the system and obtaining some measure of empty car availability. Similar information can be obtained from Tables 13-16. Table 18 can be used for monitoring and setting standards for the total system car volumes. By dividing the total number of cars in the sample, one can arrive at a close approximation of the actual volume handled. This may help in identifying the reasons for variances between actual and standard performance levels.

The yard performance levels can be evaluated using Case Tables 9-11. Tables 9A and 9B list the performance data for major yards on the system. The listing is ordered by traffic class and car loaded status. This table can be used to set and monitor performance standards for all traffic classes. This, as well as other performance reports, should not be used for defining standards, but only for their evaluation and monitoring. Yard standards can be determined by more realistic models of yard performance (8) which account for external variables affecting mean yard times and service reliability like yard volumes, train schedules, priorities, and weather effects.

Table 10 lists information similar to those presented in Table 9. The major difference is that the traffic is ordered by major car ownership and loaded status. Therefore, the report is capable of showing the distinct differences in performance of empty system and foreign cars in all major B & M yards. This report may be useful in monitoring the service reliability and empty car handling performance.

Table 11 shows another aspect of yard performance--the train to train connection times for major yards on the B & M. This report should also be used only for monitoring and evaluation of standards. If the connection times remain high over long periods of time--an indication of bad scheduling of trains--policies as well as connection standards should be revised.

The origin to destination performance can only be monitored using audit's results because it is a functionof the time a car spends in intermediate yards. The performance is highly variable and depends on operating policies and external weather inputs. Origin to destination performance can be obtained from Case Tables 1-3 and origin-destination service reliability levels from Case Table 7. Table 1A lists the origin destination trip times and the standard deviations of the trip times for forwarded traffic. Tables 2A and 3A present similar data for received and overhead traffic. Note the differences in handling different traffic classes between the same nodes. For example, the primarily loaded traffic from Mechanicville to Lowell takes an average 20.6 hours to arrive at its destination. The predominantly empty traffic going back to Mechanicville from Lowell takes an average 38.7 hours. This indicates excessive delays to this traffic at the intermediate yards. Although the statistical significance of these results is questionable, they may be indicative of car handling policies on B & M.

Car utilization monitoring on a system-wide basis can be done by reports such as Case Tables 4, 6, and 17A. These tables identify components of car cycle time on system. Tables 4A, 4B and 4C list car detention times at shipper's sidings for various car types, car owners, and major yards on the system, respectively. These tables can be used in conjunction with planning goals to set standards to cut the detention time of loading or unloading cars. An expanded version of this report is presented in Table 6. Here, non-overhead moves were grouped to provide information on foreign car-hours on system for each load handled. The components of each car's system cycle time were identified and computed as percentages of the cycle time for the total yard time loaded and empty, the total line-haul time loaded and empty, the total time spent in a move following car's receipt at an interchange to the destination point, and the time spent loading or unloading. The data is compiled for different car types and the loading status printed pertains to the status of the forwarded car. This report not only indicates areas of car detention on system, but it also provides direct information about car cycle time. Although the statistical significance of the results may be questionable, it is representative of the overall system utilization levels. In routine audits, larger sample sizes would help improve the statistical significance of the results.

Similar information is contained in Table 17 for overhead moves. These moves do not originate nor terminate on B & M. They merely pass through the system to other railroads. Thus, cycle time is defined to be a time on system for move in one direction. Car cycle for an empty moving from Rigby to Mechanicville is defined to be the time between the two interchanges. The empties are grouped in the report separately from the loads to maintain the distinction between two different types of cycle times. The loading/unloading time component is omitted. The report indicates considerable variations in handling various equipment types on the system.

The above reports are only a sample of a nearly unlimited set of possibilities. They were presented merely to serve as an illustration of possible applications of an audit. It is important to observe, however, that the reports present more information than would have been possible had normal data processing procedures of utilizing whole monthly data sets been applied. The results of such an audit do not have to be 100% accurate. They merely should indicate most likely trends that can be observed in system performance. For this, statistical sampling and the formation of a reliable data base seem to be the best alternative.

4.2.4 Alternate Practical Uses of the Audit

The previous three sections do not fully exhaust the number of possible applications of the audit. Other areas could include:

1) Monitoring revenues per load by type of traffic.[1]

2) Profitability of traffic based on revenue and variable cost information by corridor, type of traffic, shipper, etc.

3) Planning car equipment requirements based on car availability statistics.

4) Planning of car distribution based on utilization of equipment.

5) As a front end to provide inputs for system and yard performance models.

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[1] For an example, see Table 4.6.

TABLE 4.6

B & M REVENUE STATISTICS--OVERHEAD MOVES

OVERHEAD SEGMENT[2]	CARS	REVENUE AVG. $	TONS AVG.	REVENUE DISTRIBUTION (%)[1]						
				0-100	100-200	200-300	300-400	400-500	500-600	600+
1	88	379	62	7	16	24	15	22	3	16
2	92	328	68	0	9	31	31	27	3	0
3	90	303	41	0	13	41	23	16	6	1
4	96	316	49	1	20	23	31	21	3	1
5	13	253	66	7	15	38	31	7	0	0
6	24	206	46	21	33	29	12	4	0	0
7	44	191	59	13	38	38	7	2	0	0
	447	308	55							

[1]Totals may not add to 100% due to rounding.

[2]Segments 1-4 are high revenue corridors.

CHAPTER IV--FOOTNOTES

(1) Refer to Case Table 3B in Appendix B.

(2) See footnote in Section 2.3.2.

(3) The Industry Task Force on Reliability Studies, Freight Car Utilization and Railroad Reliability: Case Studies, AAR Report No. R-283, October 1977, p. 85.

(4) Clearinghouse experiment includes the following railroads: ATSF, CNW, ICG, L&N, MILW, MOPAC, RI, SCL, SOU, and SSW.

(5) Refer to the Memorandum by C. D. Martland on Car Hire in the Operating Budget of January 27, 1978, for discussion of assumptions and applications (MIT).

(6) The Industry Task Force on Reliability Studies, Freight Car Utilization and Railroad Reliability, Conclusions and Recommendations, Extract from AAR Report No. R-283, October 1977, p. 5.

(7) Task Force II, Freight Car Utilization: Definition, Evaluation and Control, Final Report, AAR-FRA.

(8) S. C. Rotheberg, The Design of a Management Control System for Railroad Freight Terminals, S.M. Thesis, MIT, 1978.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Summary

One of the problems facing railroads today is the failure to use available data to formulate better operations control and monitoring systems. Primary areas affected by the lack of these systems are car utilization and service. Since car utilization and service levels directly affect railroads financial performance, it is necessary either to improve the existing control system, or device new ones more responsive to the present problems facing railroads.

The explicit relationship between the railroad's financial measures and car utilization and service levels is not well known or understood. The conclusion of the Task Force II of the Phase I of the Car Utilization Program, concerned with the measurement of the car utilization levels, was that(1):

> "there have been no direct or predictable relationships between changes in physical utilization measures and a railroads financial performance"

and that

> "no single measure is adequate... to relate physical utilization to financial performance."

The Task Force suggested using and monitoring several physical measures of car utilization as a means of allowing management to improve the performance in this area. To perform this function, an audit of car utilization was recommended.

Consequently, as part of the Phase II of the Car Utilization Program, an audit of car utilization on the Boston & Maine was conducted by MIT. The audit was divided into three parts:

1) Data preparation and random sample formulation;

2) Programming and report generation; and

3) Procedure evaluation and documentation.

The data was obtained from the B & M car movement records. It was processed manually from the listing of the September 1977 car movement file. By application of systematic sampling technique, a random file of car movements was compiled as a data base for the audit reports. The file contained 646 complete, 100% accurate origin to destination car movements which constituted a 1.4% sample of the original O-D movement file. Although the sample size for the B & M audit was determined rather arbitrarily within the limited time available for manual data processing, a more rational procedure for the sample size determination is developed in this thesis.

The programs necessary to generate desired reports were coded with a prewritten data management package, SAS, rather than a high level language like FORTRAN or COBOL. This allowed significant reductions in programming, debugging, and processing time. All computer runs were below $10 per report. A number of reports were generated. Among the most important were:

1) Performance reports of the O-D and yard car movements for different traffic classes and car ownership.

2) Utilization reports listing car cycle time and its physical components for different traffic classes and car types.

3) System flow distributions for different car types and car ownerships.

4) Car hire reports showing the total car hire costs for various car ownerships, car types, O-D corridors, traffic classes, etc.

5) Sample statistics for future sample characteristics evaluations.

6) Other reports for specific B & M operating characteristics.

Most of the above reports are the Case Tables included in Appendix B of this report. The SAS programs used in generating these reports are listed in Appendix D.

The audit reports were submitted to B & M and managers of other railroads (1) for comments and evaluations. Although a formal evaluation and feedback is still outstanding, there was a favorable response from B & M. The management unofficially acknowledged a need for the audit in their organization as a prerequisite for improvements of the system operations. Their interest was, in most part, reflected in requests for further reports pertaining to specific questions about the daily distribution of arrivals and departures for the major interchange yards, foreign car flow information by traffic classes, and estimation of the probability of missed connection for cars at East Deerfield. Given the flexibility of programming and manipulating the data sample, all of these requests were readily answered.

This report documents a formalized auditing procedure and provides sample applications. The report recommends the organization, functions, and techniques needed to make auditing worthwhile and reliable. They are in no way unique, but they do define the minimum organizational and functional requirements for conducting an audit.

5.2 Conclusions

1) The audit is a useful mechanism for increasing management's awareness of the system's operations and its performance. Through informal discussions with railroad managers, a general appreciation of the technique has been voiced.

2) In many situations it may be difficult to obtain well organized and coherent data for car movements. For B & M, it was almost impossible to match a car movement to its revenue and cost information.

3) Random sampling may be useful for many railroads in analyzing its operations. Given large enough sample size, meaningful information can be obtained for major system flows and facilities at a fraction of the cost, time, and effort.

4) A 1.4% sample size for the B & M audit is not large enough. More meaningful estimates can be obtained with a 5.4% sample size (or 2,500 records in the data base). However, the existing 1.4% sample was useful for evaluating the most important system flows, yards, and cycle times for major traffic classes.

5) The use of SAS system for data management, statistical analysis, and report writing package proved to be an excellent way of reducing the programming requirements associated with report generation for the audit. The programs written for this package required little time for coding, no time for debugging, and reduced data processing costs.

6) To perform the evaluation of the car's utilization levels and the system's performance, the audit must be conducted on a routine basis.

7) An audit may, in effect, lead to more rational management decisions affecting car utilization and service levels. This may, in the long run, improve the railroad's profitability.

8) A small, integrated data base with nearly 100% complete and accurate records can provide information nearly as accurate as a large, incomplete data base of monthly car moves.

5.3 Recommendations

1) Railroads should make extensive use of auditing procedures to monitor their system performance. This would involve:

   a. Using less expensive statistical sampling techniques in report generation procedures in place of full scale data processing programs.

   b. Developing a set of performance standards to state operational criteria for traffic moving over a system.

   c. Obtaining performance measures for traffic moving over a system and comparing them to the standards set above. Large deviations between standards and actual estimates of performance measures would indicate the need for more managerial attention to improving service.

2) Railroads should investigate the informational value of their data bases. Two conditions may result when such a study is initiated:

   a. A data base may be found to contain more information than anticipated. This, by itself, should help people realize a potential that the data base may have in generating desired reports.

   b. A data base may be found outdated as well as containing information of no useful value. It may be missing variables reflecting recent system changes, or it may have an ackward organization which may reduce the data manipulation flexibility needed to generate desired reports.

3) Railroads should introduce formal procedures for evaluating and refining their reporting systems. All too often reports are lengthy, too detailed, and try to bring too many issues into focus at once. This contributes to a general lack of understanding of the report. In the long run this leads to a great under-utilization of important informational resources.

4) Railroads should improve their data gathering and reporting procedures to increase the quality of operating data. This might involve:

   a. Investigating the practices used in a field where the data is actually collected. This might reveal that the people assigned to this task have had little training in operation of the modern computer equipment and that they do not have a clear conception of what is required of them and how to perform their tasks efficiently. They may not understand the reporting system they are contributing to, and may therefore put little effort to improve their work. Little attention is paid to their motivation and management for most part ignores the problem as "unsolvable".

   b. Investigating inter-railroad data exchanges. These might significantly improve the quality of data and reduce the costs of its generation. These would also allow inter-line advance consists.

   c. Integrating, as part of providing a better service to the customer, shipper's needs in their car reporting system. Currently, an opposite trend is taking place. Disillusioned with the railroad's ability to monitor their shipments, shippers are forced to keep track of them with their own reporting system which often exceeded the railroad's in quality, accuracy, and flexibility.

   d. Investigation of the minicomputer market for possible application of this technology in monitoring yard and line-haul car performance.

   e. Studying alternative Automatic Car Identification technologies for minimizating data errors. This is the most promising area where significant progress can be achieved in improving the data quality control.

5) Railroads, in conjunction with the auditing concept, should establish and experiment with the service contract concept. An audit provides an excellent tool in assessment of the concept's impact on car utilization, service, and reliability.

6) An extensive use of various O-D and terminal performance models should be used in conjunction with audit reports to monitor and refine car utilization and service standards. This could also improve the quality of forecasting and management strategic modeling since the better data resulting from some of the programs described above would positively affect the effectiveness and credibility of such models.

7) Railroads should ensure that appropriate reports are propagated to lower organizational ranks. With proper introductions, these reports could enhance the employee's understanding of system operation and contribute to a greater motivation among railroad's work force.

8) Railroads should establish an Auditing Committee such as the one suggested in Chapter II, to monitor, evaluate, and recommend improvements in the system operations to increase the levels of car utilization performance.

9) Railroads should perform an audit of car utilization on at least a monthly basis. This would allow continuity in monitoring system performance as well as a timely reponse to any operational and marketing problems.

10) Each audit of car utilization conducted by a railroad should be composed of at least the following report types:

    a. Routine reports referring to the usual operating and marketing areas of interest.

    b. Reports specific to each railroads' needs.

    c. Special inquiries answering the questions posed by special studies of alternative actions initiated by a railroad in an effort to improve its performance.

11) Each railroad should evaluate their existing data bases and provide general guidelines for better integration of car movement, car revenue, and cost data among the files.

CHAPTER V--FOOTNOTES

1) Task Force II, Freight Car Utilization: Definition, Evaluation, and Control, AAR-FRA Final Report, 1977, p. 1.

2) The reports were distributed to the member of the Task Force II-2 of the Car Utilization Program.

BIBLIOGRAPHY

1) Day, George S., "Diagnosing the Product Portfolio", Journal of Marketing, No. 41, April 77, pp. 29-38.

2) Levitt, Theodore, "Marketing Myopia", HBR, July-August, 1960.

3) Gaddis, Paul, "The Computer and the Management of Corporate Resources", Sloan School Review, Fall of 1967.

4) Pessemier, E. A., "Market Structure Analysis of New Product and Marketing Opportunities", Journal of Contemporary Business, Spring 1975.

5) Coughlin, E. W., Freight Car Distribution and Car Handling in the United States, AAR, Car Service Division, 1956.

6) Sullivan, W. G., et al., Fundamentals of Forecasting, Reston Publ., 1977.

7) Mace, Arthur, Sample Size Determination, Reinhold Publishing Co., 1964.

8) McRae, T. W., Statistical Sampling for Audit and Control, J. Wiley & Sons, 1974.

9) Norbeck, E., et al., Operational Auditing for Management Control, A.M.A., 1969.

10) Hill, H., et al., Sampling in Auditing, A Simplified Guide and Statistical Tables, The Ronald Press Co., 1962.

11) Carlson, E. E., "Evaluating the Impact of Information Systems", Management Informatics, Vol. 2, No. 2, 1974.

12) Dodd, G. E., "Elements of Data Management Systems", Computing Surveys, Vol. 1, No. 2, June 1969, pp. 117-132.

13) Date, C. J., "Relational Data Base Concepts", Datamation, April 1976, pp. 50-53.

14) Gorry, G. A. and Scott Morton, M. S., "A Framework for Management Information Systems", Sloan Management Review, Fall 1971.

15) Yearbook of Railroad Facts, AAR, 1977.

16) Martland, C. D., et al., The Role of Screening Models in Evaluating Railroad Rationalization Proposals, MIT Report No. R77-13, October 1977.

17) The Industry Task Force on Reliability Studies, Railroad Reliability and Freight Car Utilization: An Introduction, MIT Report No. CTS75-8, July 1975.

18) Lang, A. S., Railroad Profit Measurement and Organizational Structure, AAR Staff Studies Group, Memo 77-12, November 9, 1977.

19) Troup III, K. F., "The Application of Management Information and Process Control Systems to Intercity Freight Transportation", U.S. D.O.T., Freight Transportation Digest, October 1976.

20) Sines, G. S., "Research Opportunities for Railroad Information Systems, 1975-1990", Conference Papers on Advanced Freight System Technology, U.S. D.O.T., TSC, December 1976, Boston.

21) Benton, J. F., "World's Shortest Course on Computers", Computers and Communications Issue, January 17, 1977, pp. 20-28.

22) Philip, G. E., A Discrete Event Simulation Model of Car Distribution Decisions in a Railroad Terminal Area, S.M. Thesis, MIT, 1977.

23) The Missouri Pacific's Computerized Freight Car Scheduling System--System Functional Requirements, DOT Report No. FR-65139, June 30, 1977.

APPENDIX A

ESTABLISHING STATISTICAL VALIDITY OF AUDIT'S RESULTS AND AGGREGATION PROCEDURES

Throughout this thesis references were made to the statistical validity of the audit's results. In the next few paragraphs an example will be presented which will illustrate how to test the statistical significance of the results.

The statistical significance of the audit's results can be verified by using the concept of confidence interval. The theory and assumptions of the interval analysis were presented in the section on the determination of the random sample size in Chapter III. The reader is urged to review that section for background information before proceeding to the below example.

The confidence interval can be written as:[1]

$$T = t \pm q \qquad \text{(A-1)}$$

where T = the true mean of a variable

t = the estimated mean of a variable

q = the width of a confidence interval given by:

$$q = c_a * s / \sqrt{n} \qquad \text{(A-2)}$$

[1]Note that Eq. A-1 is in a conventional form of expressing the confidence interval and is equivalent to the formula used to derive a sample size.

where c_a = a t-statistic coefficient at significance level, a

s = the estimate of the standard deviation of variable

n = the number of observations involved in estimating both t and s.

Sometimes it is more convenient to display the confidence interval in terms of sampling error. The sampling error, as described in Chapter III, is simply the width of the confidence interval expressed as a percentage of the estimated mean. The reason for presenting the confidence interval in terms of this parameter is that q, the absolute width of the interval, is meaningless unless compared to the estimated mean. For example, if the width of the interval is 6 hours relative to the mean of 12 hours, this may indicate highly uncertain estimates of the mean. However, if the mean is 260 hours and the width of the interval is 6 hours, the estimated mean is more reliable. Thus, the confidence interval can be written as:

$$T = t \pm w \tag{A-3}$$

where T = the true mean of a variable

t = the estimated mean of a variable

w = the width of the confidence interval as a percent of the estimated mean = 100 * q/t

In the audit, all parameters needed to compute a confidence interval are listed on each report and are known. Only one parameter, c_a, needs to be chosen. The choice is subjective but it should be made with some a priori knowledge of the variable being estimated. For example, the overhead traffic, known to perform fairly consistently, should be evaluated using a t-statistic reflecting a high level of confidence. On the other hand, local traffic with highly uncertain performance history, should be evaluated using somewhat lower confidence level criteria. The effect of choosing various confidence levels and the examples of computation of confidence interval are shown in Table A.1. This table is based on the loading/unloading performance report, Case Table 4B (Appendix B).

Sometimes an analyst or auditor will find that if the data is computed on a disaggregate level, some groups of data lack sufficient numbers of observations to validate the results statistically. This may also occur in the audit of car utilization when the sampling of origin-destination records is performed. It will be impossible to find enough records in the original population for all O-D pairs to yield a desired sampling error. This will be true if a railroad has many low traffic density lines for which moves are recorded in the sample. At some point an auditor will have to perform aggregation of these records to form a new group with enough observations to yield statistically meaningful information.

Although there is no set method for aggregation procedures, there are few guidelines an auditor should follow:

1) If consolidation of stations is performed, an auditor should make sure that the aggregation includes only the stations which physically form a logical node. That is, the nodes which geographically are not along the same branch lines should not be grouped together.

2) If consolidation of different traffic classes is performed, an auditor should make sure that the characteristics of the strategic flows are not altered.

3) If the O-D flows are aggregated into segment flows, each car movement should bear a reference to the original status of its move.

4) If the moves through a yard are highly concentrated, the moves with low frequencies can be aggregated into several larger classes with some common logical characteristic.

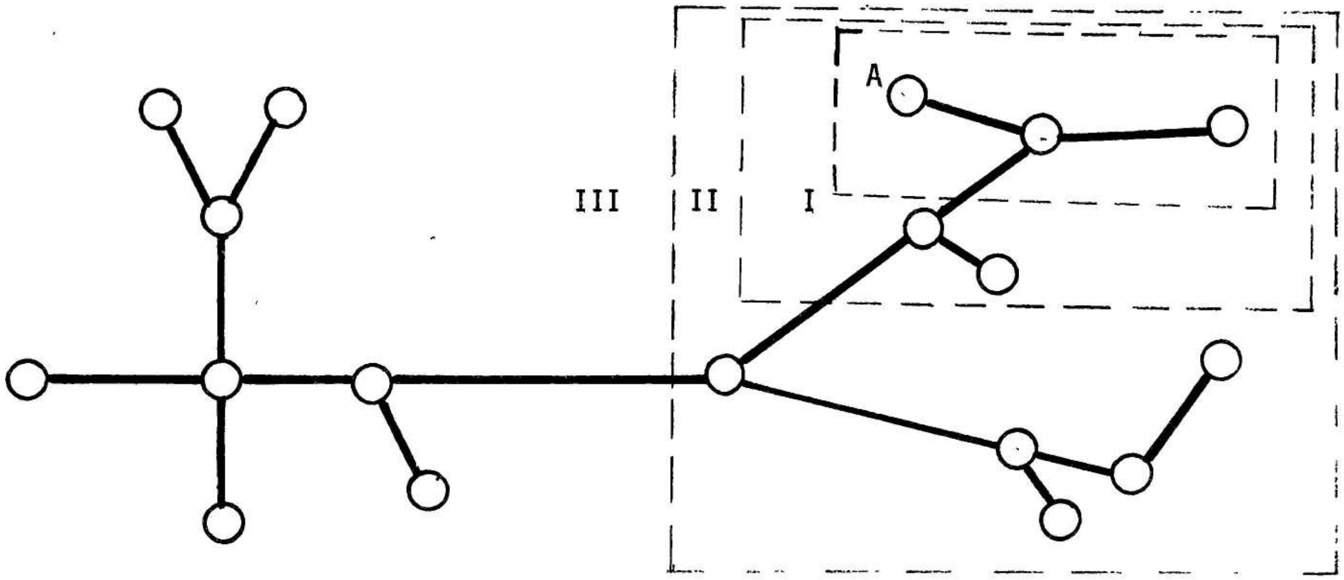
TABLE 4.1

EFFECT OF CHOOSING VARIOUS CONFIDENCE LEVELS AND EXAMPLES OF CONFIDENCE INTERVAL

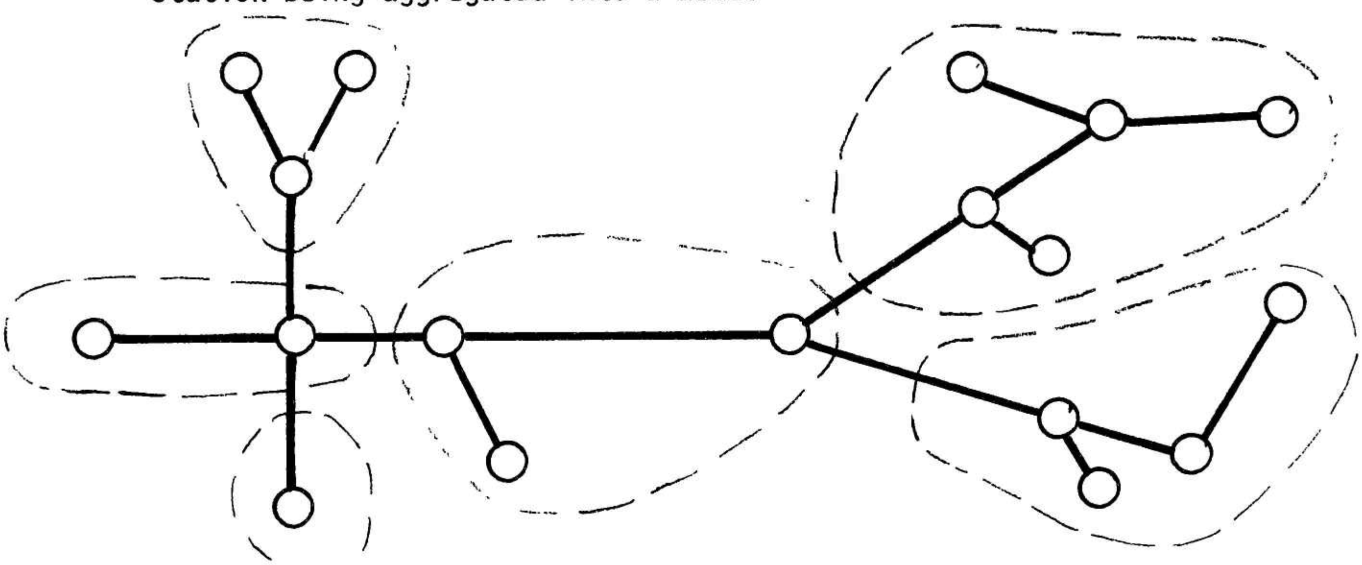
CAR OWNER	LE/STATUS	NCARS	MEAN	STD	w (%)			
					c_a = 90%	c_a = 95%	c_a = 97%	c_a = 99%
B & M	L	47	163	129	8	19	23	30
B & M	U	14	59	37	11	28	33	43
Foreign	L	13	106	64	11	28	33	43
Foreign	U	109	116	71	4	10	11	15

Source: B & M Car Utilization Audit, Case Table 4B.

TABLE A.1



An example of O-D pair aggregation. I indicates first level of aggregation, II the second, and so forth. Point A is the origin station being aggregated into a node.



O-D flow aggregation into segments.

APPENDIX B

CASE TABLES

B.16 System Movement Statistics--Overhead Traffic Broken Down by Car Ownership and L/E Status

B.17A Car Utilization Report--Overhead Traffic Trip Time Components by Car Type and L/E Status

B.18 System Movement Statistics--By Car Ownership and Load Status

<u>TABLE B.1A</u>

<u>O-D FORWARDED TRAFFIC PERFORMANCE*</u>

FROM/TO	MECHANICVILLE	RIGBY	ROTTERDAM	SPRINGFIELD	W. RIVER	MOVES
Boston	29.1 (12.8)	26.5 (19.1)	37.5 (17.9)	44 (-)	28 (7)	26
Concord	27.5 (10.6)	41 (-)	31.5 (10.6)		28 (-)	8
E. Deerfield	42.8 (35.7)		22.3 (17.7)	5 (4.2)	23 (18.2)	16
Fitchburg	25.2 (6.9)	77 (-)	21.5 (4.0)		27 (-)	9
Lawrence	15.8 (19.2)		31 (16.0)			8
Lowell	38.7 (45.5)		94 (-)		48 (36.8)	10
Manchester	33.7 (28.4)	47 (-)	42.7 (5.7)	56.5 (23.3)		13
Nashua	38.5 (19.1)	32 (-)	39.7 (12.9)		26 (-)	7
Rigby	22.5 (2.3)		20 (6.1)		74 (-)	8
Other Moves						52
Total Moves	71	7	40	11	18	157

*Exclusive of Interchanges.

TRIP TIME (HRS)
(STD. DEVIATION)

TABLE B.1B

O-D MAJOR FORWARDED TRAFFIC FLOW STATISTICS

FROM/TO	MECHANICVILLE	RIGBY	ROTTERDAM	SPRINGFIELD	W. RIVER	MOVES
Boston*	43 (15)	8 (29)	32 (20)	4 (9)	12 (17)	17
Concord*	28 (3)	15 (14)	28 (5)		28 (11)	8
E. Deerfield	31 (7)		38 (15)	13 (18)	19 (17)	16
Fitchburg*	56 (7)	11 (14)	22 (5)		11 (6)	9
Lawrence*	75 (8)		25 (5)			8
Lowell*	70 (10)		10 (3)		20 (11)	10
Manchester*	54 (10)	8 (14)	23 (8)	15 (18)		13
Nashua*	29 (3)	14 (14)	43 (8)		14 (6)	7
Rigby	67 (11)		25 8		9 6	8
Other Moves Total Moves	26% (71)	15% (7)	23% (40)	55% (11)	26% (18)	(52) 157

*Boston area = 52% of total traffic.

% OF TRAFFIC ORIGINATING
% OF TRAFFIC TERMINATING

TABLE B.2A

O-D RECEIVED TRAFFIC PERFORMANCE*

TO/FROM	MECHANICVILLE	RIGBY	ROTTERDAM	SPRINGFIELD	W. RIVER	MOVES
Boston	13 (10.8)	20 (10.4)	48.7 (31)	32 (5.7)	33.5 (13.5)	32
Concord	190 (-)	53 (-)	71 (45.3)	20 (-)	32.5 (0.7)	8
E. Deerfield	41.3 (27.2)	9 (-)	68 (62.9)	2 (-)	17.7 (16)	17
Lawrence	19 (15.9)		70 (34)	29 (-)		8
Lowell	20.6 (7.9)		48.7 (19.4)		143 (75)	12
Manchester	65 (64.5)	31 (-)	79 (69.4)	22 (5.7)	83 (-)	12
Rigby	14.1 (2.2)		27.6 (10.4)	73.4 (47.4)		13
Other Moves						58
Total Moves	62	10	46	15		160

*Exclusive of Interchanges.

TRIP TIME (HRS)
(STD. DEVIATION)

TABLE B.2B

O-D MAJOR RECEIVED TRAFFIC FLOW STATISTICS

TO/FROM	MECHANICVILLE	RIGBY	ROTTERDAM	SPRINGFIELD	W. RIVER	MOVES
Boston	19 (39)	30 (9)	26 (39)	13 (6)	11 (6)	(32)
Concord	2 (14)	10 (14)	4 (29)	7 (14)	11 (29)	(8)
E. Deerfield	11 (43)	9	9 (25)	13 (13)	11 (19)	(17)
Lawrence	6 (50)		7 (37)	7 (12)		(8)
Lowell	8 (45)		7 (28)		16 (27)	(12)
Manchester	8 (45)	10 (7)	4 (18)	13 (18)	5 (7)	(12)
Rigby	10 (46)		11 (38)	13 (15)		(13)
Other Moves Total Moves	36% (62)	41% (18)	32% (46)	34% (15)	46% (19)	(58) (160)

% OF TRAFFIC ORIGINATING
% OF TRAFFIC TERMINATING

TABLE B.3A

O-D OVERHEAD TRAFFIC PERFORMANCE*

FROM/TO	MECHANICVILLE	RIGBY	ROTTERDAM	SPRINGFIELD	W. RIVER	MOVES
Mechanicville		18 (16.1)		17.9 (2.2)	31 (6.6)	54
Rigby	22.8 (13.3)		17.2 (2.8)	23.4 (5.2)		67
Rotterdam		29.8 (18.6)			87.0 (-)	19
Springfield	39.5 (17.7)	31.9 (10.0)			11.4 (10.3)	51
W. River	40 (5.7)		26.0 (-)	7.9 (5.3)		40
Moves	39	65	28	51	47	230

*Exclusive of interchanges.

TRIP TIME (HRS)
(STD. DEVIATION)

TABLE B.3B

O-D MAJOR OVERHEAD TRAFFIC FLOW STATISTICS

FROM/TO	MECHANICVILLE	RIGBY	ROTTERDAM	SPRINGFIELD	W. RIVER	MOVES
Mechanicville		78 (63)		17 (18)	6 7	54
Rigby	52 (90)		40 96	8 10		67
Rotterdam		94 27			6 2	19
Springfield	4 (5)	13 (11)			83 (91)	51
W. River	5 (5)		2 (4)	92 (72)		40
Moves	39	65	28	51	47	230

% OF TRAFFIC ORIGINATING
% OF TRAFFIC TERMINATING

TABLE B.4A

B&M CAR UTILIZATION AUDIT
LOADING AND UNLOADING TIMES BY CAR TYPE CODE

OBS	CAR_TYPE	LE_STAT	NCARS	MEAN_TM	STD_TM	MAX_TM
1	A - Box	L	6	137.8	120.4	343.0
2	A	U	26	97.3	49.4	217.0
3	B - Box	L	32	197.2	128.1	682.0
4	B	U	49	127.2	74.5	377.0
5	F - Flat	U	7	86.6	60.8	185.0
6	G - Gons	L	3	190.7	110.4	306.0
7	G	U	3	100.7	45.9	153.0
8	H - Hopper	L	11	49.3	43.2	172.0
9	H	U	11	44.4	19.6	76.0
10	L - Cov. Hopp	L	4	86.8	69.3	148.0
11	L	U	7	121.7	99.0	293.0
12	R - Reefer	L	4	107.5	32.2	153.0
13	R	U	18	133.6	68.4	284.0
14	V - Auto	U	2	15.0	2.8	17.0

TABLE B.4B

B&M CAR UTILIZATION AUDIT
LOADING AND UNLOADING TIMES BY CAR OWNERSHIP

OBS	CAR_OWN	LE_STAT	NCARS	MEAN_TM	STD_TM	MAX_TM
1	BM	L	47	162.9	129.4	682.0
2	BM	U	14	59.0	37.3	157.0
3	FORE	L	13	105.5	64.3	255.0
4	FORE	U	109	115.8	70.5	377.0

TABLE B.4C

BSM CAR UTILIZATION AUDIT
LOADING AND UNLOADING TIMES BY TERMINAL NODES

OBS	ORG_NODE	LE_STAT	CARS	MEAN_TM	STD_TM	MAX_TM
1	21 - Ayer	U	5	97.6	85.5	217.0
2	70 - Boston	L	5	106.0	73.9	183.0
3	70	U	37	107.1	79.2	310.0
4	76 - Brattle	L	6	200.7	96.4	344.0
5	123 - Concord	U	9	114.0	51.3	185.0
6	169 - E.Deerfl	L	7	294.3	192.2	682.0
7	169	U	8	101.4	54.4	170.0
8	210 - Farmgt	U	1	26.0	.	26.0
9	212 - Fitchbg	L	5	198.3	103.6	343.0
10	212	U	4	68.3	24.7	98.0
11	229 - Gardner	L	2	326.0	116.0	408.0
12	229	U	2	150.5	102.5	223.0
13	255 - Grovent	L	6	92.3	31.2	117.0
14	255	U	1	116.0	.	116.0
15	366 - Lawrence	L	3	160.7	74.5	243.0
16	366	U	6	160.8	72.8	230.0
17	380 - Lowell	L	2	86.0	94.8	153.0
18	380	U	8	156.9	80.3	264.0
19	403 - Manchest	L	3	52.7	23.7	78.0
20	403	U	9	106.2	31.5	137.0
21	418 - Mech'le	U	1	66.0	.	66.0
22	447 - Nashua	L	3	132.0	43.6	180.0
23	447	U	6	101.7	36.2	170.0
24	464 - N-ampton	L	0	.	.	.
25	464	U	1	28.0	.	28.0
26	506 - Ossipee	L	11	49.3	43.2	172.0
27	536 - Rigby	L	3	229.7	101.3	343.0
28	536	U	9	108.4	27.5	164.0
29	538 - Potter	U	1	136.0	.	136.0
30	576 - Rock-ham	U	1	155.0	.	155.0
31	597 - Salem	L	3	143.0	50.3	181.0
32	597	U	2	52.0	36.8	78.0
33	633 - Springfl	U	4	87.0	28.3	119.0
34	734 - W.Camb	L	1	167.0	.	167.0
35	734	U	3	180.0	187.0	377.0
36	764 - W.River	U	3	11.3	18.8	33.0
37	785 - Worcest	U	2	134.5	34.6	159.0

TABLE B.5A

TOTAL CAR HIRE COSTS PER CAR OWNER

OWNER	CARS	COST/CAR	TOTAL COST	STD.DEV.	PCT.GRAND TOT.	GRAND TOTAL
AA	1	11.6	11.6	.	0.1	12143
ACL	5	16.6	83.2	8.7	0.7	12143
AMR	2	39.3	78.5	7.1	0.6	12143
ARMH	1	87.0	87.0	.	0.7	12143
ARMN	2	18.3	36.5	2.3	0.3	12143
ATSF	19	49.1	933.5	62.5	7.7	12143
ATW	2	28.0	56.0	25.9	0.5	12143
AWP	2	16.5	32.9	10.8	0.3	12143
BAR	59	20.0	1179.5	16.3	9.7	12143
BCIT	2	22.4	44.8	22.4	0.4	12143
BCK	3	7.6	22.7	3.3	0.2	143
BKTY	2	47.5	94.9	6.1	0.8	12143
BLE	2	7.7	15.4	4.4	0.1	12143
BN	14	30.9	433.1	22.5	3.6	12143
BO	11	23.1	254.5	25.4	2.1	12143
CIRR	1	12.9	12.9	.	0.1	12143
CN	29	21.4	621.7	28.0	5.1	12143
CNA	1	9.9	9.9	.	0.1	12143
CNIS	2	7.4	14.8	0.5	0.1	12143
CNW	5	12.1	60.5	6.2	0.5	12143
CN35	1	5.1	5.1	.	0.0	12143
CO	8	18.1	144.8	19.4	1.2	12143
CP	21	17.3	362.6	26.4	3.0	12143
CPAA	1	15.4	15.4	.	0.1	12133
CR	3	13.1	39.4	9.6	0.3	12143
CV	2	9.9	19.8	0.0	0.2	12143
CVC	16	15.8	253.3	27.4	2.1	12143
DH	16	10.9	173.7	5.0	1.4	12143
DRGW	2	39.7	79.4	33.0	0.7	12143
DWC	3	6.6	19.9	1.6	0.2	12143
EL	8	12.7	101.3	6.5	0.8	12143
FJG	1	9.2	9.2	.	0.1	12143
GBW	1	13.2	13.2	.	0.1	12143
GN	1	5.1	5.1	.	0.0	121 3
GNWR	1	9.2	9.2	.	0.1	12143
GTW	4	6.7	26.9	4.1	0.2	12143
ITC	2	15.9	31.7	1.6	0.3	12143
KCS	4	48.7	194.9	37.7	1.6	12143
LN	11	19.3	212.3	11.6	1.7	12143
LNAC	1	20.3	20.3	.	0.2	12143
LOAM	2	48.9	97.9	45.2	0.8	12143
LV	4	23.9	95.6	18.6	0.8	12143
MEC	23	26.4	606.8	24.3	5.0	12143
PCB	2	40.0	80.0	31.3	0.7	12143
PLE	1	19.4	19.4	.	0.2	12143
PRR	5	6.7	33.4	2.3	0.3	12143
PW	1	98.6	98.6	.	0.8	12143
RBOX	14	38.1	533.0	35.9	4.4	12143
RDG	3	13.1	39.4	8.9	0.3	12143
RI	2	26.0	52.0	26.4	0.4	12143
SCL	4	50.3	201.1	52.1	1.7	12143
SFRB	1	25.3	25.3	.	0.2	12143
SFRC	4	36.1	144.3	24.5	1.2	12143
SJL	2	104.2	208.3	113.1	1.7	12143

TABLE B.5A (cont'd)

TOTAL CAR HIRE COSTS PER CAR OWNER

OWNER	CARS	COST/CAR	TOTAL COST	STD.DEV.	PCT.GRAND TOT.	GRAND TOTAL
SLSF	3	18.5	55.4	12.4	0.5	12143
SOO	2	40.2	80.5	9.1	0.7	12143
SOU	39	24.6	958.6	24.7	7.9	12143
SP	23	41.8	961.1	40.0	7.9	12143
SPFE	3	39.0	116.9	31.8	1.0	12143
SSW	5	22.3	111.4	10.1	0.9	12143
TOC	2	18.6	37.2	7.6	0.3	12143
TP	3	37.9	113.8	38.6	0.9	12143
UP	19	28.7	546.2	21.6	4.5	12143
UPFE	4	29.9	119.6	20.1	1.0	12143
VC	1	88.7	88.7	.	0.7	12143
VTR	9	68.0	611.9	106.6	5.0	12143
WAB	4	28.0	112.0	17.7	0.9	12143
WCTR	1	38.9	38.9	.	0.3	12143
WM	5	14.6	73.1	4.4	0.6	12143
WP	3	20.5	61.4	10.2	0.5	12143

TABLE B.5B

TOTAL CAR HIRE COSTS PER CAR TYPE

TYPE	CARS	COST/CAR	TOTAL COST	STD.DEV.	PCT.GRAND TOT.	GRAND TOTAL
A - Box	66	27.3	1799.5	23.1	14.8	12143
B	250	26.5	6620.9	37.8	54.5	12143
F - Flat	27	20.4	549.9	23.5	4.5	12143
G - Gons	15	24.5	367.9	28.8	3.0	12143
H - Hopp	3	17.1	51.4	6.2	0.4	12143
J	1	4.6	4.6	.	0.0	12143
L -C.Hop	49	20.3	992.8	21.9	8.2	12143
R - Reef	51	33.9	1726.8	23.9	14.2	12143
V - Auto	4	7.4	29.6	1.0	0.2	12143

TABLE B.6

RECEIVED/FORWARDED TRAFFIC

CAR UTILIZATION REPORT - CYCLE TIME.

CAR TYPE	L/E (A)	MOVES	% YRD TM (B)	% LINE TM (C)	% TRIP1 (D)	% TERMTM (E)*	TOTAL TIME (F)
A - Box	E	26	17.51127	18.15828	18.20766	52.26651	176.9231
A	L	1	41.34615	18.75	44.23077	33.65385	208
B - Box	E	42	27.43389	5.566863	17.02201	56.54671	220.0952
F - Flat	E	7	27.16296	13.63263	21.96763	41.17949	256
G - Gons	E	2	22.58151	11.63664	15.19019	45.42757	168.5
L - Covd hopp.	E	7	34.00872	12.90828	24.60258	46.84152	224.5714
L	L	2	36.36195	8.850838	16.13411	53.16986	210.5
R - Reef	E	13	21.55583	9.803842	14.0226	62.80245	203
R	L	4	37.05943	11.56001	29.96564	42.86378	255.5
V - Auto	E	2	0	41.77019	29.08903	29.65839	55.5

<u>Note:</u> (A) - This column indicates the loading status for forwarded cars (cars leaving B&M).

(B) - Percent of cycle at interchange and intermediate yards (L and E).

(c) - Percent of cycle in train (L and E).

(D) - Percent of cycle from interchange receipt to arrive final yard (loaded time if status leaving B&M empty).

(E) - Percent of cycle in terminal (final yard (L) plus final yard (E) if status leaving B&M empty)

(F) - Cycle time analysis for completed moves only (interchange to industry to interchange)

(*) - Note unusually high percentage of the cycle time spent in terminal areas at final destinations.

TABLE B.7

B&M CAR UTILIZATION AUDIT
O-D PERFORMANCE REPORT - I

TABLE OF DST_NODE BY TRIP_TM
CONTROLLING FOR PRES_MVE= 0 ORG_NODE= 56

From Berlin to:

	DST_NODE FREQUENCY / ROW PCT	TRIP_TM 0	12	24	36	48	60	72	TOTAL moves
Mechanicville	418	0	0	2	3	3	0	0	8
		.	0.00	25.00	37.50	37.50	.	.	
	447	0	0	0	0	0	0	0	0
		.	.	.	.	.	.	.	
	404	0	0	0	0	0	0	0	0
		.	.	.	.	.	.	.	
	506	0	0	0	0	0	0	0	0
		.	.	.	.	.	.	.	
Rigby	536	0	0	0	0	0	0	0	0
		.	.	.	.	.	.	.	
	576	0	0	0	0	0	0	0	0
		.	.	.	.	.	.	.	
Rotterdam Jct.	580	0	0	2	0	0	0	0	2
		.	0.00	100.00	0.00	0.00	.	.	
	597	0	0	0	0	0	0	0	0
		.	.	.	.	.	.	.	
Springfield	633	0	1	0	0	0	0	0	1
		.	100.00	0.00	0.00	0.00	.	.	
	734	0	0	0	0	0	0	0	0
		.	.	.	.	.	.	.	
W. River Jct.	764	0	0	1	0	0	0	0	1
		.	0.00	100.00	0.00	0.00	.	.	
Worcester	785	0	0	0	1	0	0	0	1
		.	0.00	0.00	100.00	0.00	.	.	
	TOTAL	.	1	5	4	3	.	.	13

TABLE B.8A

Empty OVERHEAD MOVES FOR .MEC. AND .BAR.

TABLE OF ORG_NODE BY DST_NODE
CONTROLLING FOR LE_STAT=E

ORG_NODE / FREQUENCY / PERCENT / ROW PCT / COL PCT	DST_NODE Brattle. 76	Mech'le 418	Rigby 536	Rotter. 580	Spring 633	W.River 764	TOTAL
Mechanicville 418	0	0	23	0	0	0	23
	.	0.00	65.71	.	.	0.00	65.71
	.	0.00	100.00	.	.	0.00	
	.	0.00	69.70	.	.	0.00	
Rigby 536	0	1	0	0	0	0	1
	.	2.86	0.00	.	.	0.00	2.86
	.	100.00	0.00	.	.	0.00	
	.	100.00	0.00	.	.	0.00	
Rotterdam_Jct 580	0	0	2	0	0	0	2
	.	0.00	5.71	.	.	0.00	5.71
	.	0.00	100.00	.	.	0.00	
	.	0.00	6.06	.	.	0.00	
Springfield 633	0	0	7	0	0	0	7
	.	0.00	20.00	.	.	0.00	20.00
	.	0.00	100.00	.	.	0.00	
	.	0.00	21.21	.	.	0.00	
Worcester 785	0	0	1	0	0	1	2
	.	0.00	2.86	.	.	2.86	5.71
	.	0.00	50.00	.	.	50.00	
	.	0.00	3.03	.	.	100.00	
TOTAL	.	1	33	.	.	1	35
	.	2.86	94.29	.	.	2.86	100.00

TABLE B.8B

Loaded OVERHEAD MOVES FOR .MEC. AND .BAR.

TABLE OF ORG_NODE BY DST_NODE
CONTROLLING FOR LE_STAT=L

ORG_NODE	FREQUENCY / PERCENT / ROW PCT / COL PCT	DST_NODE Brattle. 76	Mech'le 418	Rigby 536	Rotter. 580	Spring. 633	W.River 764	TOTAL moves
418 Mechanicville	FREQUENCY	0	0	1	0	0	0	1
	PERCENT	0.00	0.00	3.57	0.00	0.00	.	3.57
	ROW PCT	0.00	0.00	100.00	0.00	0.00	.	
	COL PCT	0.00	0.00	100.00	0.00	0.00	.	
536 Rigby	FREQUENCY	2	13	0	8	4	0	27
	PERCENT	7.14	46.43	0.00	28.57	14.29	.	96.43
	ROW PCT	7.41	48.15	0.00	29.63	14.81	.	
	COL PCT	100.00	100.00	0.00	100.00	100.00	.	
580 Rotterdam Jct.	FREQUENCY	0	0	0	0	0	0	0
	PERCENT	.	.	.	.	.	.	0.00
	ROW PCT	.	.	.	.	.	.	
	COL PCT	.	.	.	.	.	.	
633 Springfield	FREQUENCY	0	0	0	0	0	0	0
	PERCENT	.	.	.	.	.	.	0.00
	ROW PCT	.	.	.	.	.	.	
	COL PCT	.	.	.	.	.	.	
785 Worcester	FREQUENCY	0	0	0	0	0	0	0
	PERCENT	.	.	.	.	.	.	0.00
	ROW PCT	.	.	.	.	.	.	
	COL PCT	.	.	.	.	.	.	
TOTAL		2	13	1	8	4	.	28
		7.14	46.43	3.57	28.57	14.29	.	100.00

TABLE B.9A

Pres_mve=0 overhead moves
1 local moves
2 received and forwarded moves

B&M CAR UTILIZATION AUDIT
YARD PERFORMANCE REPORT - I

Ayer							
	YARD_CD=21	PRES_MVE=0	LE_STAT=E	MOVES=5	AVG_TIME=13.4	STD_TIME=4.9	AVG_DIEM=5.4
	YARD_CD=21	PRES_MVE=2	LE_STAT=E	MOVES=6	AVG_TIME=9.7	STD_TIME=6.4	AVG_DIEM=4.9
	YARD_CD=21	PRES_MVE=2	LE_STAT=L	MOVES=13	AVG_TIME=12.5	STD_TIME=8.8	AVG_DIEM=7.1
Berlin							
	YARD_CD=56	PRES_MVE=0	LE_STAT=E	MOVES=17	AVG_TIME=33.9	STD_TIME=22.4	AVG_DIEM=5.2
	YARD_CD=56	PRES_MVE=0	LE_STAT=L	MOVES=17	AVG_TIME=14.2	STD_TIME=21.0	AVG_DIEM=4.6
Brattleboro							
	YARD_CD=76	PRES_MVE=0	LE_STAT=E	MOVES=5	AVG_TIME=1.6	STD_TIME=1.5	AVG_DIEM=2.9
	YARD_CD=76	PRES_MVE=0	LE_STAT=L	MOVES=7	AVG_TIME=1.0	STD_TIME=1.5	AVG_DIEM=4.2
	YARD_CD=76	PRES_MVE=2	LE_STAT=E	MOVES=7	AVG_TIME=8.3	STD_TIME=11.6	AVG_DIEM=4.7
	YARD_CD=76	PRES_MVE=2	LE_STAT=L	MOVES=8	AVG_TIME=5.5	STD_TIME=3.3	AVG_DIEM=4.0
Dover							
	YARD_CD=150	PRES_MVE=1	LE_STAT=E	MOVES=11	AVG_TIME=2.7	STD_TIME=0.6	AVG_DIEM=2.7
	YARD_CD=150	PRES_MVE=1	LE_STAT=L	MOVES=11	AVG_TIME=8.6	STD_TIME=10.1	AVG_DIEM=2.7
E.Fitchburg							
	YARD_CD=168	PRES_MVE=2	LE_STAT=E	MOVES=4	AVG_TIME=32.0	STD_TIME=27.4	AVG_DIEM=4.5
	YARD_CD=168	PRES_MVE=2	LE_STAT=L	MOVES=5	AVG_TIME=23.6	STD_TIME=23.9	AVG_DIEM=4.6
E.Deerfield							
	YARD_CD=169	PRES_MVE=0	LE_STAT=E	MOVES=55	AVG_TIME=24.3	STD_TIME=14.0	AVG_DIEM=4.8
	YARD_CD=169	PRES_MVE=0	LE_STAT=L	MOVES=40	AVG_TIME=20.2	STD_TIME=15.2	AVG_DIEM=5.4
	YARD_CD=169	PRES_MVE=1	LE_STAT=E	MOVES=7	AVG_TIME=38.4	STD_TIME=9.1	AVG_DIEM=9.7
	YARD_CD=169	PRES_MVE=2	LE_STAT=E	MOVES=106	AVG_TIME=22.8	STD_TIME=15.3	AVG_DIEM=5.8
	YARD_CD=169	PRES_MVE=2	LE_STAT=L	MOVES=80	AVG_TIME=25.5	STD_TIME=16.2	AVG_DIEM=5.6
Lawrence							
	YARD_CD=366	PRES_MVE=2	LE_STAT=E	MOVES=5	AVG_TIME=13.8	STD_TIME=5.5	AVG_DIEM=4.0
	YARD_CD=366	PRES_MVE=2	LE_STAT=L	MOVES=8	AVG_TIME=34.8	STD_TIME=27.1	AVG_DIEM=6.7
Lowell							
	YARD_CD=380	PRES_MVE=2	LE_STAT=E	MOVES=7	AVG_TIME=33.9	STD_TIME=23.7	AVG_DIEM=5.3
	YARD_CD=380	PRES_MVE=2	LE_STAT=L	MOVES=6	AVG_TIME=16.8	STD_TIME=8.3	AVG_DIEM=5.4
Manchester							
	YARD_CD=403	PRES_MVE=2	LE_STAT=E	MOVES=4	AVG_TIME=20.8	STD_TIME=10.5	AVG_DIEM=6.5
Mechanicville							
	YARD_CD=418	PRES_MVE=0	LE_STAT=E	MOVES=61	AVG_TIME=7.2	STD_TIME=13.4	AVG_DIEM=4.8
	YARD_CD=418	PRES_MVE=0	LE_STAT=L	MOVES=66	AVG_TIME=13.1	STD_TIME=17.1	AVG_DIEM=5.4
	YARD_CD=418	PRES_MVE=1	LE_STAT=L	MOVES=5	AVG_TIME=22.4	STD_TIME=24.2	AVG_DIEM=4.3

TABLE B.9B

B&M CAR UTILIZATION AUDIT
YARD PERFORMANCE REPORT - I

Mechanicville							
YARD_CD=418	PRES_MVE=2	LE_STAT=E	MOVES=80	AVG_TIME=8.9	STD_TIME=14.2	AVG_DIEM=5.2	STD_DIEM=2.6
YARD_CD=418	PRES_MVE=2	LE_STAT=L	MOVES=98	AVG_TIME=20.1	STD_TIME=16.9	AVG_DIEM=5.6	STD_DIEM=2.9
Nashua							
YARD_CD=447	PRES_MVE=2	LE_STAT=L	MOVES=6	AVG_TIME=28.0	STD_TIME=24.6	AVG_DIEM=6.6	STD_DIEM=2.7
Rigby							
YARD_CD=536	PRES_MVE=0	LE_STAT=E	MOVES=71	AVG_TIME=9.8	STD_TIME=13.1	AVG_DIEM=4.7	STD_DIEM=2.1
YARD_CD=536	PRES_MVE=0	LE_STAT=L	MOVES=69	AVG_TIME=9.6	STD_TIME=15.2	AVG_DIEM=5.5	STD_DIEM=2.3
YARD_CD=536	PRES_MVE=2	LE_STAT=E	MOVES=10	AVG_TIME=9.2	STD_TIME=18.5	AVG_DIEM=5.4	STD_DIEM=4.1
YARD_CD=536	PRES_MVE=2	LE_STAT=L	MOVES=8	AVG_TIME=24.6	STD_TIME=28.7	AVG_DIEM=5.8	STD_DIEM=3.7
Rotterdam Jct.							
YARD_CD=580	PRES_MVE=0	LE_STAT=E	MOVES=23	AVG_TIME=4.0	STD_TIME=6.3	AVG_DIEM=5.0	STD_DIEM=2.6
YARD_CD=580	PRES_MVE=0	LE_STAT=L	MOVES=33	AVG_TIME=6.2	STD_TIME=11.7	AVG_DIEM=6.3	STD_DIEM=2.9
YARD_CD=580	PRES_MVE=2	LE_STAT=E	MOVES=39	AVG_TIME=1.9	STD_TIME=2.7	AVG_DIEM=5.2	STD_DIEM=2.6
YARD_CD=580	PRES_MVE=2	LE_STAT=L	MOVES=47	AVG_TIME=5.5	STD_TIME=11.0	AVG_DIEM=6.2	STD_DIEM=3.1
Springfield							
YARD_CD=633	PRES_MVE=0	LE_STAT=E	MOVES=53	AVG_TIME=17.7	STD_TIME=13.1	AVG_DIEM=4.6	STD_DIEM=1.8
YARD_CD=633	PRES_MVE=0	LE_STAT=L	MOVES=57	AVG_TIME=9.8	STD_TIME=10.8	AVG_DIEM=4.7	STD_DIEM=1.9
YARD_CD=633	PRES_MVE=2	LE_STAT=E	MOVES=9	AVG_TIME=14.1	STD_TIME=11.6	AVG_DIEM=4.4	STD_DIEM=2.1
YARD_CD=633	PRES_MVE=2	LE_STAT=L	MOVES=18	AVG_TIME=9.7	STD_TIME=6.9	AVG_DIEM=5.2	STD_DIEM=2.8
Waumbek							
YARD_CD=716	PRES_MVE=2	LE_STAT=L	MOVES=7	AVG_TIME=4.1	STD_TIME=0.7	AVG_DIEM=9.1	STD_DIEM=3.0
Wells River							
YARD_CD=725	PRES_MVE=0	LE_STAT=E	MOVES=10	AVG_TIME=6.1	STD_TIME=18.9	AVG_DIEM=4.2	STD_DIEM=1.4
YARD_CD=725	PRES_MVE=0	LE_STAT=L	MOVES=9	AVG_TIME=9.4	STD_TIME=20.5	AVG_DIEM=4.5	STD_DIEM=1.3
YARD_CD=725	PRES_MVE=2	LE_STAT=E	MOVES=6	AVG_TIME=0.2	STD_TIME=0.4	AVG_DIEM=5.5	STD_DIEM=3.7
YARD_CD=725	PRES_MVE=2	LE_STAT=L	MOVES=7	AVG_TIME=0.0	STD_TIME=0.0	AVG_DIEM=4.8	STD_DIEM=2.9
White River							
YARD_CD=764	PRES_MVE=0	LE_STAT=E	MOVES=63	AVG_TIME=4.1	STD_TIME=5.9	AVG_DIEM=4.9	STD_DIEM=2.0
YARD_CD=764	PRES_MVE=0	LE_STAT=L	MOVES=63	AVG_TIME=3.6	STD_TIME=6.2	AVG_DIEM=4.6	STD_DIEM=2.1
YARD_CD=764	PRES_MVE=2	LE_STAT=E	MOVES=23	AVG_TIME=8.1	STD_TIME=14.5	AVG_DIEM=6.7	STD_DIEM=3.5
YARD_CD=764	PRES_MVE=2	LE_STAT=L	MOVES=23	AVG_TIME=3.3	STD_TIME=3.9	AVG_DIEM=7.0	STD_DIEM=3.6
Whinchester							
YARD_CD=775	PRES_MVE=0	LE_STAT=L	MOVES=4	AVG_TIME=0.3	STD_TIME=0.5	AVG_DIEM=3.9	STD_DIEM=2.0
Worcester							
YARD_CD=785	PRES_MVE=0	LE_STAT=E	MOVES=4	AVG_TIME=7.5	STD_TIME=5.1	AVG_DIEM=5.0	STD_DIEM=3.0

TABLE B.10A

Car_own=BM B&M cars
FORE Foreign cars

B&M CAR UTILIZATION AUDIT
YARD PERFORMANCE REPORT - II

Ayer

YARD_CD=21	CAR_OWN=BM	LE_STAT=E	MOVES=4	AVG_TIME=10.5	STD_TIME=8.1	AVG_DIEM=5.0	STD_DIEM=3.1
YARD_CD=21	CAR_OWN=FORE	LE_STAT=E	MOVES=7	AVG_TIME=11.9	STD_TIME=4.7	AVG_DIEM=5.2	STD_DIEM=1.9
YARD_CD=21	CAR_OWN=FORE	LE_STAT=L	MOVES=14	AVG_TIME=12.3	STD_TIME=8.5	AVG_DIEM=7.4	STD_DIEM=3.4

Berlin

YARD_CD=56	CAR_OWN=BM	LE_STAT=E	MOVES=16	AVG_TIME=30.9	STD_TIME=23.3	AVG_DIEM=5.0	STD_DIEM=2.0
YARD_CD=56	CAR_OWN=BM	LE_STAT=L	MOVES=15	AVG_TIME=12.1	STD_TIME=18.3	AVG_DIEM=4.2	STD_DIEM=2.0

Boston

YARD_CD=70	CAR_OWN=FORE	LE_STAT=L	MOVES=5	AVG_TIME=12.6	STD_TIME=5.8	AVG_DIEM=3.0	STD_DIEM=1.1

Brattleboro

YARD_CD=76	CAR_OWN=BM	LE_STAT=E	MOVES=8	AVG_TIME=7.6	STD_TIME=10.9	AVG_DIEM=2.8	STD_DIEM=0.2
YARD_CD=76	CAR_OWN=FORE	LE_STAT=E	MOVES=5	AVG_TIME=1.0	STD_TIME=1.8	AVG_DIEM=6.3	STD_DIEM=3.8
YARD_CD=76	CAR_OWN=BM	LE_STAT=L	MOVES=7	AVG_TIME=5.4	STD_TIME=3.1	AVG_DIEM=2.8	STD_DIEM=0.2
YARD_CD=76	CAR_OWN=FORE	LE_STAT=L	MOVES=8	AVG_TIME=1.6	STD_TIME=2.7	AVG_DIEM=5.2	STD_DIEM=2.1

Dover

YARD_CD=150	CAR_OWN=BM	LE_STAT=E	MOVES=11	AVG_TIME=2.7	STD_TIME=0.6	AVG_DIEM=2.7	STD_DIEM=0.0
YARD_CD=150	CAR_OWN=BM	LE_STAT=L	MOVES=11	AVG_TIME=8.6	STD_TIME=10.1	AVG_DIEM=2.7	STD_DIEM=0.0
YARD_CD=150	CAR_OWN=FORE	LE_STAT=L	MOVES=4	AVG_TIME=18.5	STD_TIME=27.0	AVG_DIEM=4.3	STD_DIEM=1.5

E.Fitchburg

YARD_CD=168	CAR_OWN=FORE	LE_STAT=E	MOVES=5	AVG_TIME=21.4	STD_TIME=20.3	AVG_DIEM=6.2	STD_DIEM=2.9

E.Deerfield

YARD_CD=169	CAR_OWN=BM	LE_STAT=E	MOVES=43	AVG_TIME=35.1	STD_TIME=16.6	AVG_DIEM=4.3	STD_DIEM=2.0
YARD_CD=169	CAR_OWN=FORE	LE_STAT=E	MOVES=125	AVG_TIME=20.1	STD_TIME=12.3	AVG_DIEM=6.1	STD_DIEM=3.0
YARD_CD=169	CAR_OWN=BM	LE_STAT=L	MOVES=40	AVG_TIME=26.8	STD_TIME=17.3	AVG_DIEM=3.7	STD_DIEM=1.7
YARD_CD=169	CAR_OWN=FORE	LE_STAT=L	MOVES=88	AVG_TIME=22.0	STD_TIME=15.1	AVG_DIEM=6.3	STD_DIEM=3.0

Lawrence

YARD_CD=366	CAR_OWN=FORE	LE_STAT=E	MOVES=5	AVG_TIME=24.0	STD_TIME=20.7	AVG_DIEM=4.3	STD_DIEM=2.0
YARD_CD=366	CAR_OWN=FORE	LE_STAT=L	MOVES=8	AVG_TIME=28.1	STD_TIME=26.5	AVG_DIEM=6.7	STD_DIEM=3.1

Lowell

YARD_CD=380	CAR_OWN=FORE	LE_STAT=E	MOVES=7	AVG_TIME=30.1	STD_TIME=23.8	AVG_DIEM=5.9	STD_DIEM=1.9
YARD_CD=380	CAR_OWN=FORE	LE_STAT=L	MOVES=5	AVG_TIME=16.6	STD_TIME=9.2	AVG_DIEM=6.0	STD_DIEM=2.3

Manchester

YARD_CD=403	CAR_OWN=FORE	LE_STAT=E	MOVES=4	AVG_TIME=20.8	STD_TIME=10.5	AVG_DIEM=6.5	STD_DIEM=3.2

TABLE B.10B

B&M CAR UTILIZATION AUDIT
YARD PERFORMANCE REPORT - II

Mechanicville								
	YARD_CD=418	CAR_OWN=BM	LE_STAT=E	MOVES=25	AVG_TIME=26.0	STD_TIME=15.9	AVG_DIEM=4.0	STD_DIEM=2.0
	YARD_CD=418	CAR_OWN=FORE	LE_STAT=E	MOVES=116	AVG_TIME=4.4	STD_TIME=9.9	AVG_DIEM=5.3	STD_DIEM=2.5
	YARD_CD=418	CAR_OWN=BM	LE_STAT=L	MOVES=34	AVG_TIME=11.5	STD_TIME=19.3	AVG_DIEM=4.1	STD_DIEM=1.8
	YARD_CD=418	CAR_OWN=FORE	LE_STAT=L	MOVES=135	AVG_TIME=19.0	STD_TIME=16.7	AVG_DIEM=5.9	STD_DIEM=2.7
Nashua								
	YARD_CD=447	CAR_OWN=FORE	LE_STAT=L	MOVES=6	AVG_TIME=28.0	STD_TIME=24.6	AVG_DIEM=6.6	STD_DIEM=2.7
Rigby								
	YARD_CD=536	CAR_OWN=BM	LE_STAT=E	MOVES=7	AVG_TIME=24.7	STD_TIME=21.1	AVG_DIEM=2.9	STD_DIEM=1.1
	YARD_CD=536	CAR_OWN=FORE	LE_STAT=E	MOVES=74	AVG_TIME=8.3	STD_TIME=12.1	AVG_DIEM=5.0	STD_DIEM=2.4
	YARD_CD=536	CAR_OWN=BM	LE_STAT=L	MOVES=8	AVG_TIME=24.6	STD_TIME=29.6	AVG_DIEM=5.1	STD_DIEM=2.4
	YARD_CD=536	CAR_OWN=FORE	LE_STAT=L	MOVES=69	AVG_TIME=9.6	STD_TIME=15.0	AVG_DIEM=5.6	STD_DIEM=2.4
Rotterdam Jct.								
	YARD_CD=580	CAR_OWN=BM	LE_STAT=E	MOVES=18	AVG_TIME=4.9	STD_TIME=4.8	AVG_DIEM=4.3	STD_DIEM=2.0
	YARD_CD=580	CAR_OWN=FORE	LE_STAT=E	MOVES=44	AVG_TIME=1.8	STD_TIME=4.0	AVG_DIEM=5.5	STD_DIEM=2.7
	YARD_CD=580	CAR_OWN=BM	LE_STAT=L	MOVES=16	AVG_TIME=6.9	STD_TIME=15.2	AVG_DIEM=4.8	STD_DIEM=2.2
	YARD_CD=580	CAR_OWN=FORE	LE_STAT=L	MOVES=64	AVG_TIME=5.5	STD_TIME=10.1	AVG_DIEM=6.6	STD_DIEM=3.1
Springfield								
	YARD_CD=633	CAR_OWN=BM	LE_STAT=E	MOVES=13	AVG_TIME=12.8	STD_TIME=11.8	AVG_DIEM=3.8	STD_DIEM=1.7
	YARD_CD=633	CAR_OWN=FORE	LE_STAT=E	MOVES=49	AVG_TIME=18.3	STD_TIME=13.0	AVG_DIEM=4.8	STD_DIEM=1.8
	YARD_CD=633	CAR_OWN=BM	LE_STAT=L	MOVES=14	AVG_TIME=13.9	STD_TIME=11.7	AVG_DIEM=4.3	STD_DIEM=2.0
	YARD_CD=633	CAR_OWN=FORE	LE_STAT=L	MOVES=62	AVG_TIME=8.7	STD_TIME=9.3	AVG_DIEM=5.0	STD_DIEM=2.2
Waumbek								
	YARD_CD=716	CAR_OWN=FORE	LE_STAT=E	MOVES=6	AVG_TIME=8.2	STD_TIME=9.8	AVG_DIEM=9.8	STD_DIEM=3.1
	YARD_CD=716	CAR_OWN=BM	LE_STAT=L	MOVES=5	AVG_TIME=2.2	STD_TIME=1.8	AVG_DIEM=5.2	STD_DIEM=2.3
	YARD_CD=716	CAR_OWN=FORE	LE_STAT=L	MOVES=6	AVG_TIME=4.0	STD_TIME=0.9	AVG_DIEM=9.9	STD_DIEM=2.8
Wells River								
	YARD_CD=725	CAR_OWN=FORE	LE_STAT=E	MOVES=16	AVG_TIME=3.9	STD_TIME=15.0	AVG_DIEM=4.7	STD_DIEM=2.5
	YARD_CD=725	CAR_OWN=FORE	LE_STAT=L	MOVES=15	AVG_TIME=5.7	STD_TIME=16.2	AVG_DIEM=4.7	STD_DIEM=2.1
White River								
	YARD_CD=764	CAR_OWN=BM	LE_STAT=E	MOVES=24	AVG_TIME=12.4	STD_TIME=12.9	AVG_DIEM=5.3	STD_DIEM=2.1
	YARD_CD=764	CAR_OWN=FORE	LE_STAT=E	MOVES=65	AVG_TIME=2.6	STD_TIME=4.8	AVG_DIEM=5.6	STD_DIEM=2.8
	YARD_CD=764	CAR_OWN=BM	LE_STAT=L	MOVES=23	AVG_TIME=6.5	STD_TIME=6.6	AVG_DIEM=4.4	STD_DIEM=2.0
	YARD_CD=764	CAR_OWN=FORE	LE_STAT=L	MOVES=64	AVG_TIME=2.5	STD_TIME=4.9	AVG_DIEM=5.6	STD_DIEM=3.0
Worcester								
	YARD_CD=775	CAR_OWN=FORE	LE_STAT=L	MOVES=4	AVG_TIME=0.8	STD_TIME=0.5	AVG_DIEM=6.5	STD_DIEM=5.1

TABLE B.11

TRAIN TO TRAIN PERFORMANCE - MAJOR CONNECTIONS ONLY

YARD	TRN_IN	TRN_OUT		MOVES	AVG TIME	C_VAR
21	W2	530		5	10.6	0.1
21	510	EC2		7	11.3	0.7
76	E8	JS4		6	4.2	0.3
76	SJ5	E7		8	8.6	1.2
150	302	359		10	2.8	0.2
150	358	303		12	8.1	1.2
169	AP3	NE87		7	14.7	0.1
169	CE1	AP3	(A)	6	14.8	0.8
169	CE1	BM7		7	13.7	0.5
169	CE1	NE87		6	21.3	0.4
169	CE1	SJ1		3	19.3	0.5
169	CE1	511		3	13.3	0.0
169	JS2	AP3	(A)	4	26.3	0.4
169	JS2	BM7		4	7.0	0.2
169	JS2	NE87		5	21.2	0.1
169	NE87	AP3	(A)	4	23.8	1.0
169	NE87	BM7		9	15.9	1.6
169	NE87	SJ1	(B)	7	35.4	0.6
169	NE87	SJ5	.	5	27.4	0.4
169	NE87	511	.	8	13.5	0.8
169	NY10	EC2	.	3	29.7	0.5
169	NY10	E2	.	4	60.3	1.0
169	NY10	JS2	.	9	10.9	0.2
169	NY10	SJ1	.	10	19.6	0.4
169	NY10	SJ5	.	8	43.9	0.5
169	NY20	JS2	(B)	3	11.0	0.4
169	SJ1	NE84		4	13.0	0.0
169	SJ1	SJ1	(B)	4	25.5	0.1
169	SJ3	SJ1	(B)	5	22.0	0.0
169	SJ5	NY20		4	26.8	0.2
169	025	AP3	(A)	5	14.4	0.5
169	025	BM7		5	24.2	0.9
169	025	NE87		4	26.3	0.1
169	025	NY20		3	41.7	0.4
169	025	511		5	14.2	0.3
169	510	EC2		5	44.6	1.7
169	511	AP3	(A)	4	24.5	0.1
364	G2	215		3	1.0	0.0
380	LM1	511		4	15.8	0.2
403	Y3	CE1		4	15.8	0.8
418	BM7	M4		3	28.7	0.8
418	NE87	093		14	7.2	0.6
418	NY10	AP4		6	21.2	0.1
418	NY10	510		10	22.0	1.0
418	NY20	AP4		3	44.7	1.2
418	NY20	NY10		9	21.8	0.8
418	092	510		3	61.0	0.0
447	EC2	Y3		3	14.0	0.2
716	G2	UJ2		3	4.3	0.1
716	JU1	G1		5	9.6	1.1
716	215	UJ2		3	2.7	0.2
764	SJ1	JU1		27	14.3	0.9
764	SJ1	915		23	1.7	0.5
764	UJ2	JS2		19	4.5	0.3

(A) Poor connections to AP3, piggyback train

(B) Lengthy connections to northbound trains

TABLE B.12

DISTRIBUTION OF CAR TYPES BY L/E STATUS

TABLE OF LE_STAT BY CAR_TYPE

LE_STAT / FREQUENCY / PERCENT / ROW PCT / COL PCT	CAR_TYPE	Box A	Box B	Flat F	Gons G	Hopper H	J	Covered Hopper L	Reefer R	Auto V	TOTAL
E	0	45	164	15	9	12	0	31	26	2	304
	.	7.13	25.99	2.38	1.43	1.90	0.00	4.91	4.12	0.32	48.18
	.	14.80	53.95	4.93	2.96	3.95	0.00	10.20	8.55	0.66	
	.	51.14	47.13	50.00	45.00	48.00	0.00	49.21	50.00	50.00	
L	3	43	184	15	11	13	1	32	26	2	327
	.	6.81	29.16	2.38	1.74	2.06	0.16	5.07	4.12	0.32	51.82
	.	13.15	56.27	4.59	3.36	3.98	0.31	9.79	7.95	0.61	
	.	48.86	52.87	50.00	55.00	52.00	100.00	50.79	50.00	50.00	
TOTAL	.	88	348	30	20	25	1	63	52	4	631
	.	13.95	55.15	4.75	3.17	3.96	0.16	9.98	8.24	0.63	100.00

TABLE B.13

DISTRIBUTION OF LOADS AND EMTIES AMONG DIFFERENT TRAFFIC CLASSES.

TABLE OF PRES_MVE BY LE_STAT

PRES_MVE LE_STAT

	PRES_MVE	FREQUENCY / PERCENT / ROW PCT / COL PCT	E	L	TOTAL
Overhead	0	FREQUENCY	140	149	289
		PERCENT	22.08	23.50	45.58
		ROW PCT	48.44	51.56	
		COL PCT	46.05	45.15	
Locals	1	FREQUENCY	20	16	36
		PERCENT	3.15	2.52	5.68
		ROW PCT	55.56	44.44	
		COL PCT	6.58	4.85	
Received	2	FREQUENCY	41	117	158
		PERCENT	6.47	18.45	24.92
		ROW PCT	25.95	74.05	
		COL PCT	13.49	35.45	
Forwarded	3	FREQUENCY	103	48	151
		PERCENT	16.25	7.57	23.82
		ROW PCT	68.21	31.79	
		COL PCT	33.88	14.55	
	TOTAL		304	330	634
			47.95	52.05	100.00

TABLE B.14A

FORWARDED EMPTIES BY CAR TYPE AND OWNERSHIP

TABLE OF CAR_OWN BY CAR_TYPE
CONTROLLING FOR LE_STAT=E PRES_MVE= 3

CAR_OWN CAR_TYPE

FREQUENCY / PERCENT / ROW PCT / COL PCT		Box A	Box B	Flat F	Gons G	Hopper H	J	Covered Hopper L	Reefer R	Auto V	TOTAL
RM	0	0	1	0	0	0	0	0	0	0	1
	.	0.00	0.97	0.00	0.00	.	.	0.00	0.00	0.00	0.97
	.	0.00	100.00	0.00	0.00	.	.	0.00	0.00	0.00	
	.	0.00	2.33	0.00	0.00	.	.	0.00	0.00	0.00	
FORE	0	26	42	7	2	0	0	7	16	2	102
	.	25.24	40.78	6.80	1.94	.	.	6.80	15.53	1.94	99.03
	.	25.49	41.18	6.86	1.96	.	.	6.86	15.69	1.96	
	.	100.00	97.67	100.00	100.00	.	.	100.00	100.00	100.00	
TOTAL	.	26	43	7	2	.	.	7	16	2	103
	.	25.24	41.75	6.80	1.94	.	.	6.80	15.53	1.94	100.00

TABLE B.14B

FORWARDED LOADS BY CAR TYPE AND OWNERSHIP

TABLE OF CAR_OWN BY CAR_TYPE
CONTROLLING FOR LE_STAT=L PRES_MVE= 3

CAR_OWN CAR_TYPE

FREQUENCY / PERCENT / ROW PCT / COL PCT		A	B	F	G	H	J	L	R	V	TOTAL
RM	0	4	27	0	2	0	0	2	0	0	35
	.	8.33	56.25	.	4.17	.	.	4.17	0.00	.	72.92
	.	11.43	77.14	.	5.71	.	.	5.71	0.00	.	
	.	80.00	87.10	.	66.67	.	.	50.00	0.00	.	
FORE	0	1	4	0	1	0	0	2	5	0	13
	.	2.08	8.33	.	2.08	.	.	4.17	10.42	.	27.08
	.	7.69	30.77	.	7.69	.	.	15.38	38.46	.	
	.	20.00	12.90	.	33.33	.	.	50.00	100.00	.	
TOTAL	.	5	31	.	3	.	.	4	5	.	48
	.	10.42	64.58	.	6.25	.	.	8.33	10.42	.	100.00

TABLE B.15A

RECEIVED EMPTIES BY CAR TYPE AND OWNERSHIP

TABLE OF CAR_OWN BY CAR_TYPE
CONTROLLING FOR LE_STAT=E PRES_MVE= 2

CAR_OWN / CAR_TYPE FREQUENCY PERCENT ROW PCT COL PCT		Box A	Box B	Flat F	Gons G	Hopper H	J	Covered Hopper L	Reefer R	Auto V	TOTAL
PM	0 . . .	5 12.20 14.29 83.33	26 63.41 74.29 100.00	0 . . .	2 4.88 5.71 100.00	0 . . .	0 . . .	2 4.88 5.71 66.67	0 0.00 0.00 0.00	0 . . .	35 85.37
FORE	0 . . .	1 2.44 16.67 16.67	0 0.00 0.00 0.00	0 . . .	0 0.00 0.00 0.00	0 . . .	0 . . .	1 2.44 16.67 33.33	4 9.76 66.67 100.00	0 . . .	6 14.63
TOTAL	. .	6 14.63	26 63.41	. .	2 4.88	. .	. .	3 7.32	4 9.76	. .	41 100.00

TABLE B.15B

RECEIVED LOADS BY CAR TYPE AND OWNERSHIP.

TABLE OF CAR_OWN BY CAR_TYPE
CONTROLLING FOR LE_STAT=L PRES_MVE= 2

CAR_OWN / CAR_TYPE FREQUENCY PERCENT ROW PCT COL PCT		A	B	F	G	H	J	L	R	V	TOTAL
PM	0 . . .	0 0.00 0.00 0.00	2 1.72 100.00 3.92	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 . . .	0 . . .	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	2 1.72
FORE	1 . . .	26 22.41 22.81 100.00	49 42.24 42.98 96.08	8 6.90 7.02 100.00	3 2.59 2.63 100.00	0 . . .	0 . . .	8 6.90 7.02 100.00	18 15.52 15.79 100.00	2 1.72 1.75 100.00	114 98.28
TOTAL	. .	26 22.41	51 43.97	8 6.90	3 2.59	. .	. .	8 6.90	18 15.52	2 1.72	116 100.00

TABLE B.16A

OVERHEAD EMPTIES BY CAR TYPE AND OWNERSHIP

TABLE OF CAR_OWN BY CAR_TYPE
CONTROLLING FOR LE_STAT=E PRES_MVE= 0

CAR_OWN FREQUENCY PERCENT ROW PCT COL PCT	CAR_TYPE	Box A	Box B	Flat F	Gons G	Hopper H	J	Covered Hopper L	Reefer R	Auto V	TOTAL
BM	0 . . .	2 1.43 9.52 16.67	17 12.14 80.95 19.10	0 0.00 0.00 0.00	1 0.71 4.76 25.00	0 0.00 0.00 0.00	0 . . .	1 0.71 4.76 4.76	0 0.00 0.00 0.00	0 . . .	21 15.00
FORE	0 . . .	10 7.14 8.40 83.33	72 51.43 60.50 80.90	8 5.71 6.72 100.00	3 2.14 2.52 75.00	1 0.71 0.84 100.00	0 . . .	20 14.29 16.81 95.24	5 3.57 4.20 100.00	0 . . .	119 85.00
TOTAL	. .	12 8.57	89 63.57	8 5.71	4 2.86	1 0.71	. .	21 15.00	5 3.57	. .	140 100.00

TABLE B.16B

OVERHEAD LOADS BY CAR TYPE AND OWNERSHIP

TABLE OF CAR_OWN BY CAR_TYPE
CONTROLLING FOR LE_STAT=L PRES_MVE= 0

CAR_OWN FREQUENCY PERCENT ROW PCT COL PCT	CAR_TYPE	A	B	F	G	H	J	L	R	V	TOTAL
BM	0 . . .	0 0.00 0.00 0.00	24 16.22 96.00 24.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	1 0.68 4.00 5.00	0 0.00 0.00 0.00	0 . . .	25 16.89
FORE	1 . . .	10 6.76 8.13 100.00	76 51.35 61.79 76.00	7 4.73 5.69 100.00	5 3.38 4.07 100.00	2 1.35 1.63 100.00	1 0.68 0.81 100.00	19 12.84 15.45 95.00	3 2.03 2.44 100.00	0 . . .	123 83.11
TOTAL	. .	10 6.76	100 67.57	7 4.73	5 3.38	2 1.35	1 0.68	20 13.51	3 2.03	. .	148 100.00

TABLE B.17

B&M CAR UTILIZATION AUDIT
OVERHEAD TRAFFIC - TRIP TIMES BY LINE HAUL COMPONENTS

CAR_TYPE	LE_STAT	MOVES	INTCHGE	YARD	LINE	TOT_TRIP	PER_DIEM	MILES
A - Box	E	10	30.8	18.1	13.0	61.9	4.3	218.7
A	L	10	17.8	6.9	9.3	34.0	6.5	175.3
B - Box	E	72	13.7	5.7	10.7	30.1	5.1	204.5
B	L	76	14.3	5.9	11.5	31.6	5.4	199.1
F - Flat	F	8	18.6	1.6	15.9	36.1	3.0	246.4
F	L	7	13.6	4.9	14.9	33.3	5.2	237.9
G - Gons	E	3	106.7	7.7	17.0	131.3	5.6	257.7
G	L	5	31.6	15.8	10.4	57.8	3.5	144.6
H - Hopper	E	1	53.0	0.0	18.0	71.0	3.1	270.0
H	L	2	3.0	61.5	6.0	70.5	5.6	120.5
J	L	1	16.0	7.0	5.0	28.0	2.4	111.0
L - Cov.Hopp.	E	20	20.3	8.9	14.6	43.8	4.1	229.9
L	L	19	12.1	6.6	12.9	31.6	4.7	240.9
R - Reefer	E	5	3.4	8.0	12.8	24.2	7.3	254.4
R	L	3	9.0	7.7	17.7	34.3	7.5	249.7

TABLE 18

B & M AND FOREIGN CARS IN THE SAMPLE

TABLE OF CAR_OWN BY LE_STAT

CAR_OWN LE_STAT

FREQUENCY / PERCENT / ROW PCT / COL PCT	E	L	TOTAL
BM	70 11.04 47.95 23.03	76 11.99 52.05 23.03	146 23.03
FORE	234 36.91 47.95 76.97	254 40.06 52.05 76.97	488 76.97
TOTAL	304 47.95	330 52.05	634 100.00

APPENDIX C

HINTS ON DESIGNING REPORT FORMATS

The effectiveness of communication of various results can be increased by presenting them in concise and comprehensive reports. Designing a report requires a planning effort similar to that used in a new product development process.

First, major classes of information users must be identified. Their tasks, responsibilities, and daily decisions must be documented. This should provide an input to the decision of whether a report should address several user groups with a single, multi-purpose form, or if it should be directed to a single user. Although the use of the multi-purpose report may seem attractive, as it may require smaller development costs, it has several disadvantages. Since it usually involves a greater concentration of information per page, it may:

- Decrease the clarity of a report;
- Increase the time needed to understand proper figures in a report;
- Increase the user's confusion about the significance of various numbers and their relevance to his/her responsibilities.

After reports are developed and released they should be routinely evaluated by all their users. All their comments should periodically be compiled and used as a basis for refining the content and formats of the report(s) in question. New informational needs should also be identified and new reports introduced in these areas. This feedback on the product quality is necessary to ensure that the provided information is used properly and effectively.

Incorporation of feedback and new information needs should also have an overall effect on:

- Greater employee motivation to use the provided information effectively;
- Increased employee awareness of system operations;
- Increased employee perception of his/her responsibilities;
- Increased information flow in an organization;
- Improved system performance due to the above items;
- Introduction of new measures to control the system more effectively.

In general, a report design should conform to the following criteria:

- Contain data relevant to a specific user;
- Address only one problem at a time;
- Have a visually appealing layout;
- Contain information in a form which takes the least time to read, interpret and understand.

These design criteria should encourage greater experimentation with alternative data display methods, such as graphical representation, condensation of data with smoothing techniques, or base indexing. These are illustrated below in Tables C.2, C.3 and C.4, based on the following Table. (Table C.1).

TABLE C.1

CAR HOURS ON SYSTEM[1]

CAR TYPE	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER...
BOX	288	270	263	240	267	285	273	250	266
GOND	300	310	398	349	330	320	297	295	270
HOPP	240	234	221	227	285	258	246	250	247
AUTO	194	187	189	200	183	195	193	194	189

[1] This form is similar to the one used on MoPac's car scheduling system, Report on Car Utilization.

TABLE C.2

CASE I. GRAPHICAL PRESENTATION OF DATA

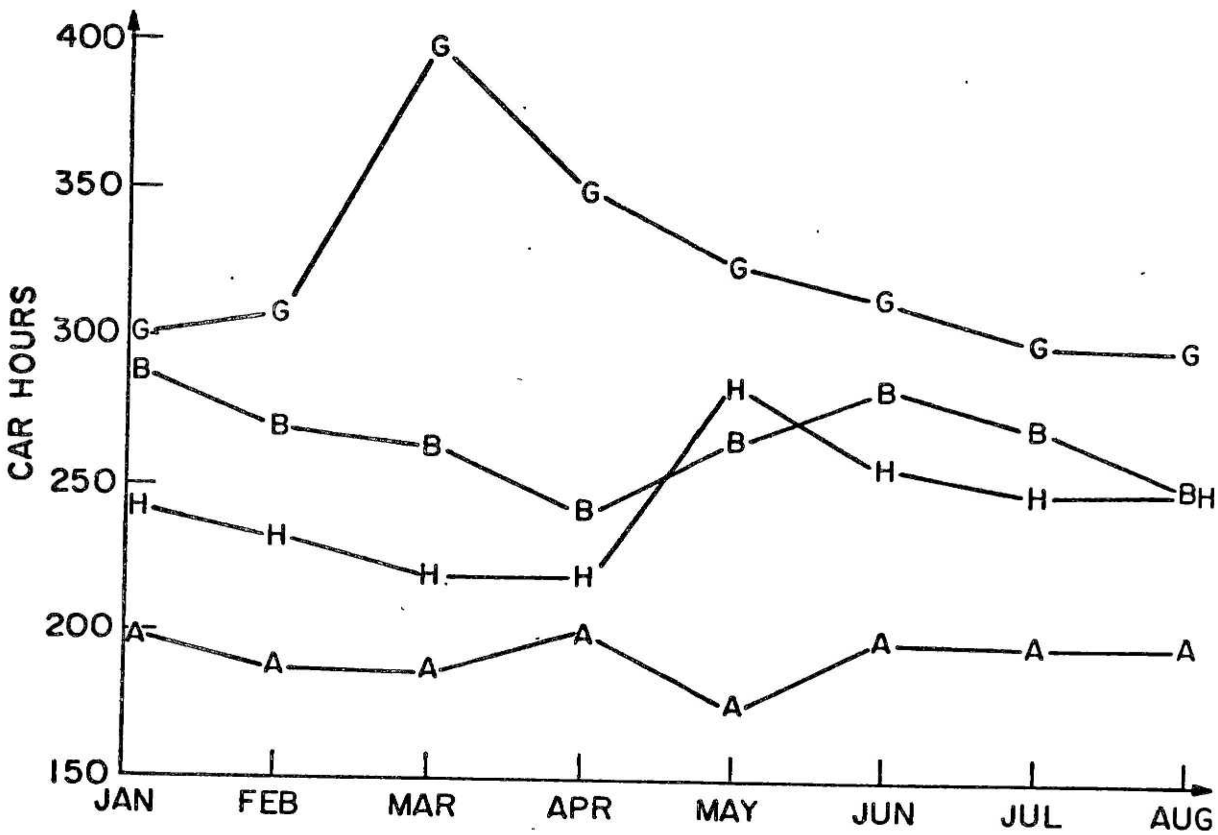


TABLE C.3

CASE 2. CONDENSATION OF DATA WITH SMOOTHING TECHNIQUES

(TECHNIQUE USED: MOVING 4-MONTH AVERAGE)

CAR TYPE	CAR HOURS ON SYSTEM		DELTA (%)
	PRESENT PERIOD (JULY)	LAST PERIOD (MARCH-JUNE)	
BOX	273	264	3
GOND	297	349	-14
HOPP	246	248	-1
AUTO	193	191	1

Comments:

1) Other techniques like exponential smoothing could be used.

2) Additional information pertaining to last year's period could be included. This would have to take into account traffic mix and volume variations.

3) The length of the moving average could be different.

4) Last period comparison to the present period performance might be done differently. For example, if the present period is known to be a peak period, then comparison to the performance during the last peak period could be included with traffic mix variations highlighted to explain possible performance deviations.

TABLE C.4

CASE 3. INDEXING OF DATA[1]

CAR TYPE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	....	SEPT
BOX	288	-6	-7	-17	-7	-1	-5	-13	-8		266
GOND	300	+3	+33	+16	+10	+7	-1	-2	-10		270
HOPP	240	-3	-8	-5	+19	+8	+3	+4	+3		247
AUTO	194	-4	-3	+3	-6	+1	-1	0	-3		189

---

[1] Base index is January performance. Present period is September.

Comments:

1) Indexing can be done on differently defined bases. For example, peak period situation described in Case 2 (Table C.3), comment (4) can similarly be used here as an index base. However, the trend and variations from trend can easily be spotted when using this method no matter what an index base is.

2) This method can be combined with any other method previously described in this appendix.

APPENDIX D

SAMPLE CASE STUDY PROGRAMS

Table	Contents
D.1	Car Cycle Analysis for the B & M Clearinghouse Study
D.2	Yard Performance Analysis
D.3	Car Utilization Report for Forwarded and Received Traffic
D.4	O-D Performance--Trip Times and Trip Time Reliability
D.5	Car Hire Report
D.6	Car Utilization Report for Overhead Traffic
D.7	PMAKE Analysis for the B & M's Major Yards
D.8	Creation of the Audit's Data Base
D.9	Tabulation of Sample Statistics
D.10	Loading/Unloading Reports
D.11	Car Utilization Analysis for All Traffic Classes
D.12	Train to Train Connection Performance Report

TABLE D.1

CAR CYCLE ANALYSIS FOR B & M CLEARINGHOUSE STUDY

```
// 'CLEAR',REGION=200K
/*MITID  USER=(M12121,P14509
/*MAIN LINES=3,TIME=2
// EXEC SAS
//AUDIT DD DSNAME=U.M12121.P14509.SAS.BM.AUDIT.DATA.SET,DISP=SHR
//SYSIN DD *
DATA X1 ;
SET AUDIT.DATABASE ;
IF CAR_TYPE¬='B' THEN DELETE ;
IF CAR_OWN¬='BM' THEN CAR_OWN='FORN' ;
IF PRES_MVE=0 THEN LINK OVH ;
IF PRES_MVE=2 THEN LINK REC ;
IF PRES_MVE=3 THEN LINK FOR ;
IF PRES_MVE=1 THEN LINK LOC ;
TOTAL=TRIP_TM+INT1+INT2 ;
DROP INT1 INT2 ;
RETURN ;
OVH: INT1=YD1_TIME ;
     LINK LOOK ;
     RETURN ;
LOC: INT1=0 ;
     INT2=0 ;
     RETURN ;
FOR: INT1=0 ;
     LINK LOOK ;
     RETURN ;
REC: INT1=YD1_TIME ;
     INT2=0 ;
     RETURN ;
LOOK: IF NUM_YRDS=0 THEN INT2=0 ;
      IF NUM_YRDS=1 AND PRES_MVE=0 THEN INT2=0 ;
      IF NUM_YRDS=1 AND PRES_MVE=3 THEN INT2=YD1_TIME ;
      IF NUM_YRDS=2 THEN INT2=YD2_TIME ;
      IF NUM_YRDS=3 THEN INT2=YD3_TIME ;
      IF NUM_YRDS=4 THEN INT2=YD4_TIME ;
      IF NUM_YRDS=5 THEN INT2=YD5_TIME ;
      RETURN ;
PROC SORT ; BY CAR_OWN PRES_MVE NEXT_MVE LE_STAT ;
PROC MEANS N MEAN SUM ; BY CAR_OWN PRES_MVE NEXT_MVE LE_STAT ;
VAR TOTAL OD_DIST ;
TITLE CLEARING HOUSE CAR HOURS AND CAR MILES DATA ;
/*
/*EOJ ********
```

TABLE D.2

YARD PERFORMANCE ANALYSIS

(Page 1 of 2)

```
// 'YARDS',REGION=200K
/*MITID USER=(M12121,P14509,
/*MAIN TIME=5 LINES=4
// EXEC SAS
//AUDIT DD DSNAME=U.M12121.P14509.SAS.BM.AUDIT.DATA.SET,DISP=SHR
//SYSIN DD *
DATA YARDS ;
SET AUDIT.DATABASE ;
KEEP CAR_OWN LE_STAT PRES_MVE YARD_CD YRD_TIME TRN_IN TRN_OUT CAR_TYPE
      PER_DIEM ;
IF PRES_MVE=3 THEN PRES_MVE=2 ;
IF CAR_OWN¬='BM' THEN CAR_OWN='FOREIGN' ;
IF NUM_YRDS=0 THEN RETURN ;
YARD_CD=YRD1_CD;
YRD_TIME=MIN(YD1_TIME,60) ;
TRN_IN=TRN1_IN ;
TRN_OUT=TRN1_OUT ; OUTPUT ;
IF NUM_YRDS=1 THEN RETURN ;
YARD_CD=YRD2_CD ;
YRD_TIME=MIN(YD2_TIME,60) ;
TRN_IN=TRN2_IN ;
TRN_OUT=TRN2_OUT ;   OUTPUT ;
IF NUM_YRDS=2 THEN RETURN ;
YARD_CD=YRD3_CD ;
YRD_TIME=MIN(YD3_TIME,60) ;
TRN_IN=TRN3_IN ;
TRN_OUT=TRN3_OUT ;   OUTPUT ;
IF NUM_YRDS=3 THEN RETURN ;
YARD_CD=YRD4_CD ;
YRD_TIME=MIN(YD4_TIME,60) ;
TRN_IN=TRN4_IN ;
TRN_OUT=TRN4_OUT ;   OUTPUT ;
IF NUM_YRDS=4 THEN RETURN ;
YARD_CD=YRD5_CD ;
YRD_TIME=MIN(YD5_TIME,60) ;
TRN_IN=TRN5_IN ;
TRN_OUT=TRN5_OUT ; OUTPUT ;
PROC SORT ; BY YARD_CD PRES_MVE LE_STAT ;
PROC MEANS N MEAN STD NOPRINT ;
BY YARD_CD PRES_MVE LE_STAT ;
VAR YRD_TIME PER_DIEM ;
OUTPUT OUT=MEANX N=MOVES MEAN=AVG_TIME AVG_DIEM STD=STD_TIME STD_DIEM ;
DATA _NULL_ ;
SET MEANX ;
BY YARD_CD PRES_MVE LE_STAT ;
FORMAT AVG_TIME AVG_DIEM STD_TIME STD_DIEM 4.1 ;
IF MOVES<2 THEN DELETE ;
IF YARD_CD=. THEN DELETE ;
RETAIN Y ;
FILE PRINT ;
IF YARD_CD¬=Y THEN PUT // ;
Y=YARD_CD ;
PUT @5 YARD_CD= @20 PRES_MVE= @35 LE_STAT= @50 MOVES=
     @65 AVG_TIME= @80 STD_TIME= @95 AVG_DIEM= @110 STD_DIEM= ;
TITLE1 B&M CAR UTILIZATION AUDIT ;
TITLE2 YARD PERFORMANCE REPORT - I ;
PROC DELETE DATA=MEANX ;
PROC SORT DATA=YARDS ; BY YARD_CD LE_STAT CAR_OWN ;
PROC MEANS N MEAN STD NOPRINT ;
BY YARD_CD LE_STAT CAR_OWN;
VAR YRD_TIME PER_DIEM ;
```

TABLE D.2


```
OUTPUT OUT=MEANX N=MOVES MEAN=AVG_TIME AVG_DIEM STD=STD_TIME STD_DIEM ;
DATA _NULL_ ;
SET MEANX ;
BY YARD_CD LE_STAT CAR_OWN ;
FORMAT AVG_TIME AVG_DIEM STD_TIME STD_DIEM 4.1 ;
IF MOVES<2 THEN DELETE ;
IF YARD_CD=. THEN DELETE ;
FILE PRINT ;
RETAIN Y ;
IF YARD_CD¬=Y THEN PUT // ;
Y=YARD_CD ;
PUT @5 YARD_CD= @20 CAR_OWN=  @35 LE_STAT= @50 MOVES=
     @65 AVG_TIME= @80 STD_TIME= @95 AVG_DIEM= @110 STD_DIEM= ;
TITLE1 B&M CAR UTILIZATION AUDIT ;
TITLE2 YARD PERFORMANCE REPORT - II ;
/*
/*EOJ ********
```

TABLE D.3

CAR UTILIZATION REPORT FOR FORWARDED AND RECEIVED TRAFFIC

```
// 'FORWRD',REGION=200K
/*MITID  USER=(M12121,P14509
/*MAIN LINES=3,TIME=2
/*SRI LOW
// EXEC SAS
//ANL1 DD DSNAME=U.M12121.P14509.SAS.BM.AUDIT.UTILIZ,DISP=SHR
//SYSIN DD *
DATA ;
SET ANL1.FWRD END=EOF ;
IF CAR_OWN='BM' THEN DELETE ;
COST=(PER_DIEM*TOTAL)/24 ;
YRDP=(YDTM1+YDTM2)/TOTAL*100  ;
LINEP=(LINE1+LINE2)/TOTAL*100 ;
TRIP1P=TRIP_TM1/TOTAL*100 ;
TERMP=TERML_TM/TOTAL*100 ;
TOT_COST+COST ;
IF EOF THEN PUT / 'TOTAL CAR HIRE COST FOR DEL/FWRD MOVES='  TOT_COST ;
PROC SORT ; BY CAR_TYPE LE_STAT ;
PROC MEANS N MEAN NOPRINT ;
BY CAR_TYPE LE_STAT ;
VAR YRDP LINEP TRIP1P TERMP TOTAL ;
OUTPUT OUT=XX N=MOVES MEAN=YRDP LINEP TRIP1P TERMP TOTAL ;
DATA _NULL_ ;
SET XX ; BY CAR_TYPE LE_STAT ;
TITLE B&M CAR UTILIZATION AUDIT ;
FORMAT YRDP LINEP TRIP1P TERMP 7.1 ;
FILE PRINT HEADER=HDR ;
PUT / @5 CAR_TYPE @15 LE_STAT @20 MOVES @30 YRDP @40 LINEP @50 TRIP1P
      @60 TERMP @70 TOTAL ;
RETURN ;
HDR : PUT @2 'CAR TYPE' @15 'L/E' @20 'MOVES' @30 '% YRD TM' @40 '% LINE TM'
      @50 '% TRIP1' @60 '% TERMTM' @70 'TOTAL TIME' /;
RETURN ;
/*
/*EOJ ********
```

TABLE D.4

O-D PERFORMANCE--TRIP TIMES AND TRIP TIME RELIABILITY

```
// 'ODPERF',REGION=180K
/*MITID  USER=(M12121,P14509
/*MAIN TIME=5 LINES=4
// EXEC SAS
//AUDIT DD DSNAME=U.M12121.P14509.SAS.BM.AUDIT.DATA.SET,DISP=SHR
//SYSIN DD *
DATA MEANY ;
SET AUDIT.DATABASE ;
IF NUM_YRDS=1 AND PRES_MVE=0 THEN DELETE ;
IF TRIP_TM>96 THEN TRIP_TM=96 ;
IF PRES_MVE=0 THEN NUM_YRDS=NUM_YRDS-2 ;
IF PRES_MVE¬=0 THEN NUM_YRDS=NUM_YRDS-1 ;
PROC FREQ ; TABLES NUM_YRDS * PRES_MVE ;
PROC SORT ; BY ORG_NODE DST_NODE LE_STAT ;
PROC MEANS NOPRINT N MEAN STD ;
BY ORG_NODE DST_NODE ;
VAR TRIP_TM OD_DIST NUM_YRDS ;
OUTPUT OUT=MEANX N=NTRIPS  MEAN=TRIP_HRS DIST YARDS STD=STD_TRIP ;
DATA TAB ;
SET MEANX ;
IF NTRIPS<=1 THEN DELETE ;
RELIAB=(STD_TRIP/TRIP_HRS)**2 ;
SPEED=DIST/TRIP_HRS ;
YRD=1/YARDS ;
NTR=NTRIPS**0.5 ;
PROC GLM;
MODEL  SPEED=NTR YRD RELIAB/SOLUTION ;
TITLE O-D RELIABILITY TEST ;
PROC SCATTER ;
PLOT RELIAB*SPEED YRD*SPEED NTR*SPEED ;
/*
/*EOJ ********
```

TABLE D.5

CAR HIRE REPORT (Page 1 of 2)

```
// 'HIRSUM',REGION=250K
/*MITID  USER=(M12121,P14509
/*MAIN TIME=10 LINES=10
/*SRI LOW
// EXEC SAS
//AUDIT DD DSNAMF=U.M12121.P14509.SAS.BM.AUDIT.DATA.SET,DISP=SHR
//SYSIN DD *
DATA HIRE;
SET AUDIT.DATABASE;
IF PRES_MVE=0 THEN LINK OVHD;
IF PRES_MVE=1 THEN LINK LOCAL;
IF PRES_MVE=2 THEN LINK RCVD;
IF PRES_MVE=3 THEN LINK FRWD;
IF PRES_MVE=4 THEN DELETE;
IF CAR_OWN='BM' THEN DELETE;
YD_TM=YD1_TIME+YD2_TIME+YD3_TIME+YD4_TIME+YD5_TIME-INT_TIME;
LINE_TM=TRIP_TM-YD_TM;
TERML_TM=LD_TM+UNLD_TM;
TOT_TM=YD_TM+LINE_TM+TERML_TM;
CARHIRE=(PER_DIEM*TOT_TM)/24;
MIL_COST=MILEAGE*OD_DIST;
INC_COST=(INCENT*TOT_TM)/24;
TOT_COST=CARHIRE+MIL_COST+INC_COST;
KEEP CAR_OWN CAR_TYPE LE_STAT ORG_NODE DST_NODE TOT_COST;
RETURN;
OVHD: NYDS=NUM_YRDS-2;
IF NYDS<0 THEN NYDS=0;
IF NUM_YRDS=1 THEN INT_TIME=YD1_TIME;
IF NUM_YRDS=2 THEN INT_TIME=YD1_TIME+YD2_TIME;
IF NUM_YRDS=3 THEN INT_TIME=YD1_TIME+YD3_TIME;
IF NUM_YRDS=4 THEN INT_TIME=YD1_TIME+YD4_TIME;
IF NUM_YRDS=5 THEN INT_TIME=YD1_TIME+YD5_TIME;
RETURN;
LOCAL: NYDS=NUM_YRDS;
INT_TIME=0;
RETURN;
RCVD: NYDS=NUM_YRDS-1;
INT_TIME=YD1_TIME;
RETURN;
FRWD: NYDS=NUM_YRDS-1;
IF NUM_YRDS=1 THEN INT_TIME=YD1_TIME ;
IF NUM_YRDS=2 THEN INT_TIME=YD2_TIME;
IF NUM_YRDS=3 THEN INT_TIME=YD3_TIME;
IF NUM_YRDS=4 THEN INT_TIME=YD4_TIME;
IF NUM_YRDS=5 THEN INT_TIME=YD5_TIME;
RETURN;
DATA;
SET HIRE;
PROC MEANS SUM NOPRINT;
VAR TOT_COST;
OUTPUT OUT=GRAND SUM=WHOLE;
DATA;
SET HIRE;
PROC SORT DATA=HIRE;
BY CAR_OWN;
PROC MEANS N MEAN SUM STD NOPRINT DATA=HIRE;
BY CAR_OWN;
VAR TOT_COST;
OUTPUT OUT=OWN N=CARS MEAN=PER_CAR  SUM=TOTAL STD=STD_DEV;
DATA _NULL_;
```

TABLE D.5

(Page 2 of 2)

```
SET GRAND OWN;
RETAIN ALL ;
IF _N_=1 THEN ALL=WHOLE;
IF _N_=1 THEN RETURN;
WHOLE = ALL;
IF CARS=0 THEN DELETE;
PERCENT=(TOTAL/WHOLE)*100;
TITLE1 TOTAL CAR HIRE COSTS PER CAR OWNER ;
TITLE2 ;
FILE PRINT HEADER=NEWPAGE;
FORMAT  PER_CAR TOTAL STD_DEV PERCENT 6.1 WHOLE 6.0 ;
PUT @5 CAR_OWN @15 CARS @25 PER_CAR @40 TOTAL @55 STD_DEV @70 PERCENT @90 WHOLE;
RETURN;
NEWPAGE:  PUT @5 'OWNER' @15 'CARS'  @25 'COST/CAR'  @40  'TOTAL COST'
     @55 'STD.DEV.'  @70 'PCT.GRAND TOT.'  @90 'GRAND TOTAL'/ ;
RETURN;
PROC SORT DATA=HIRE;
BY CAR_TYPE;
PROC MEANS N MEAN SUM STD NOPRINT DATA=HIRE;
BY CAR_TYPE;
VAR TOT_COST;
OUTPUT OUT=TYPE N=CARS MEAN=PER_CAR SUM=TOTAL STD=STD_DEV;
DATA _NULL_;
SET GRAND TYPE;
RETAIN ALL ;
IF _N_=1 THEN ALL=WHOLE;
IF _N_=1 THEN RETURN;
WHOLE = ALL;
IF CARS=0 THEN DELETE;
PERCENT=(TOTAL/WHOLE)*100;
TITLE1 TOTAL CAR HIRE COSTS PER CAR TYPE ;
TITLE2 ;
FILE PRINT HEADER=OLDPAGE;
FORMAT  PER_CAR TOTAL STD_DEV PERCENT 6.1 WHOLE 6.0 ;
PUT @5 CAR_TYPE @15 CARS @25 PER_CAR @40 TOTAL @55 STD_DEV @70 PERCENT
     @90 WHOLE;
RETURN;
OLDPAGE: PUT @5 'TYPE'  @15 'CARS'  @25 'COST/CAR'  @40 'TOTAL COST'
     @55 'STD.DEV.'  @70 'PCT.GRAND TOT.'  @90 'GRAND TOTAL'/ ;
RETURN;
/*
/*EOJ ********
```

TABLE D.6

CAR UTILIZATION REPORT FOR OVERHEAD TRAFFIC

```
// 'OVHDRD',REGION=200K
/*MITID  USER=(M12121,P14509.
/*MAIN LINES=3,TIME=2
// EXEC SAS
//ANL1 DD DSNAME=U.M12121.P14509.SAS.BM.AUDIT.UTILIZ,DISP=SHR
//SYSIN DD *
DATA X1 ;
SET ANL1.OVHD ;
IF CAR_OWN='BM' THEN DELETE ;
TOTAL=TRIP_TM+INT ;
INTP=INT/TOTAL*100 ;
YDTMP=YDTM/TOTAL*100 ;
LINEP=LINE_TM/TOTAL*100 ;
PROC SORT ;
BY CAR_TYPE LE_STAT ;
PROC MEANS N MEAN NOPRINT ;
BY CAR_TYPE LE_STAT ;
VAR INT YDTM LINE_TM TOTAL        PER_DIEM MILEAGE OD_DIST ;
OUTPUT OUT=MS N=MOVES MEAN=INTCHGE YARD LINE TOT_TRIP        PER_DIEM
       MILEAGE MILES ;
PROC PRINT ;
FORMAT INTCHGE YARD LINE TOT_TRIP        PER_DIEM MILEAGE MILES 5.1 ;
TITLE1 B&M CAR UTILIZATION AUDIT ;
TITLE2 OVERHEAD TRAFFIC - TRIP TIMES BY LINE HAUL COMPONENTS ;
PROC MEANS  DATA=X1 N MEAN NOPRINT ; BY CAR_TYPE LE_STAT ;
VAR INTP YDTMP LINEP TOTAL ;
OUTPUT OUT=C1 N=MOVES MEAN= INTCHGE YARD LINE TOT_TRIP ;
PROC PRINT ;
FORMAT INTCHGE YARD LINE TOT_TRIP 5.1 ;
TITLE1 B&M CAR UTILIZATION AUDIT ;
TITLE2 OVERHEAD TRAFFIC - COMPONENT TRIP TIME PERCENTAGES ;
/*
/*EOJ ********
```

TABLE D.7

"PMAKE" ANALYSIS FOR B & M'S MAJOR YARDS

(Page 1 of 2)

```
// 'PMAKE',REGION=200K
/*MITID USER=(M12121,P14509
/*MAIN TIME=5 LINES=4
// EXEC SAS
//AUDIT DD DSNAME=U.M12121.P14509.SAS.BM.AUDIT.DATA.SET,DISP=SHR
//SYSIN DD *
DATA YARDS ;
SET AUDIT.DATABASE ;
KEEP CAR_OWN LE_STAT PRES_MVE YARD_CD YRD_TIME TRN_IN TRN_OUT CAR_TYPE
       PER_DIEM DT_IN TM_IN DT_OUT TM_OUT ;
IF PRES_MVE=3 THEN PRES_MVE=2 ;
IF CAR_OWN¬='BM' THEN CAR_OWN='FOREIGN' ;
IF NUM_YRDS=0 THEN RETURN ;
YARD_CD=YRD1_CD;
YRD_TIME=MIN(YD1_TIME,60) ;
TRN_IN=TRN1_IN ;
DT_IN=DT1_ARR ;
TM_IN=INT(TM1_ARR/100)+MOD(TM1_ARR,100)/60  ;
DT_OUT=DT1_DEP ;
TM_OUT=INT(TM1_DEP/100)+MOD(TM1_DEP,100)/60 ;
TRN_OUT=TRN1_OUT ; OUTPUT ;
IF NUM_YRDS=1 THEN RETURN ;
YARD_CD=YRD2_CD ;
YRD_TIME=MIN(YD2_TIME,60) ;
TRN_IN=TRN2_IN ;
DT_IN=DT2_ARR ;
TM_IN=INT(TM2_ARR/100)+MOD(TM2_ARR,100)/60  ;
DT_OUT=DT2_DEP ;
TM_OUT=INT(TM2_DEP/100)+MOD(TM2_DEP,100)/60 ;
TRN_OUT=TRN2_OUT ;   OUTPUT ;
IF NUM_YRDS=2 THEN RETURN ;
YARD_CD=YRD3_CD ;
YRD_TIME=MIN(YD3_TIME,60) ;
TRN_IN=TRN3_IN ;
DT_IN=DT3_ARR ;
TM_IN=INT(TM3_ARR/100)+MOD(TM3_ARR,100)/60   ;
DT_OUT=DT3_DEP ;
TM_OUT=INT(TM3_DEP/100)+MOD(TM3_DEP,100)/60 ;
TRN_OUT=TRN3_OUT ;   OUTPUT ;
IF NUM_YRDS=3 THEN RETURN ;
YARD_CD=YRD4_CD ;
YRD_TIME=MIN(YD4_TIME,60) ;
TRN_IN=TRN4_IN ;
DT_IN=DT4_ARR ;
TM_IN=INT(TM4_ARR/100)+MOD(TM4_ARR,100)/60   ;
DT_OUT=DT4_DEP ;
TM_OUT=INT(TM4_DEP/100)+MOD(TM4_DEP,100)/60 ;
TRN_OUT=TRN4_OUT ;   OUTPUT ;
IF NUM_YRDS=4 THEN RETURN ;
YARD_CD=YRD5_CD ;
YRD_TIME=MIN(YD5_TIME,60) ;
TRN_IN=TRN5_IN ;
DT_IN=DT5_ARR ;
TM_IN=INT(TM5_ARR/100)+MOD(TM5_ARR,100)/60   ;
DT_OUT=DT5_DEP ;
TM_OUT=INT(TM5_DEP/100)+MOD(TM5_DEP,100)/60 ;
TRN_OUT=TRN5_OUT ; OUTPUT ;
PROC SORT; BY YARD_CD ;
PROC MEANS N NOPRINT ; BY YARD_CD ;
VAR YARD_CD ;
OUTPUT OUT=NUMB N=CARS ;
```

TABLE D.7


```
DATA COUNT ;
SET NUMB ;
KEEP YARD_CD GOOD ;
GOOD=1 ;
IF CARS<40 THEN GOOD=0 ;
OUTPUT ;
PROC SORT ; BY YARD_CD ;
DATA PMAKE ;
MERGE COUNT YARDS ; BY YARD_CD ;
PROC DELETE DATA=COUNT NUMB ;
DATA TABS ;
SET PMAKE ;
IF GOOD=0 THEN DELETE ;
TB=INT(YRD_TIME);
ACTUAL=TB-MOD(TB,4) ;
IF ACTUAL>48 THEN ACTUAL=48 ;
IF TM_OUT<=TM_IN THEN TM_OUT=TM_OUT+24 ;
TB=INT(TM_OUT-TM_IN) ;
SCHEDULE=TB-MOD(TB,2) ;
IF SCHEDULE>24 THEN SCHEDULE=24 ;
PROC FREQ ; TABLES
      YARD_CD * LE_STAT * ACTUAL * SCHEDULE / NOPERCENT ;
/*
/*EOJ ********
```

TABLE D.8

CREATION OF THE AUDIT'S DATA BASE


```
// 'SECOND',REGION=250K
/*MITID  USER=(M12121,P14509,
/*MAIN TIME=2
/*SRI HIGH
//DELETE EXEC PGM=IEFBR14
//DD1 DD DSNAME=U.M12121.P14509.SAS.BM.AUDIT.DATA.SET,
//     UNIT=STORAGE,DISP=(MOD,DELETE),SPACE=(TRK,0)
// EXEC SAS
//AUDIT DD DSNAME=U.M12121.P14509.SAS.BM.AUDIT.DATA.SET,
//       UNIT=STORAGE,DISP=(NEW,CATLG),SPACE=(TRK,(25,2),RLSE)
//INPUTB DD DSNAME=U.M12121.P14509.DATA.BASE.BM.AUDIT,DISP=OLD
//SYSIN DD *,DCB=BLKSIZE=2000
DATA AUDIT.DATABASE(LABEL=BM CAR UTILIZATION AUDIT DATA);
* THIS PROGRAM WILL ESTABILISH A SAS DATA BASE FOR FUTURE WORK
   ON B & M  CAR UTILIZATION AUDIT.      ;
INFILE INPUTB LRECL=240;
INPUT CAR_OWN $ 1-4
      CAR_NUMB 5-10
      LE_STAT $ 11
      LAST_MVE 12
      PRES_MVE 13
      NEXT_MVE 14
      ORG_CODE 15-17
      ORG_NODE 18-20
      DST_CODE 21-23
      DST_NODE 24-26
      OD_DIST 27-29
      TRIP_TM 30-32
      LD_TM  33-35
      UNLD_TM  37-39
      NUM_YRDS 41-42
      YRD1_CD  43-45
      DT1_ARR 46-47
      TM1_ARR 48-51
      DT1_DEP 52-53
      TM1_DEP 54-57
      YD1_TIME 58-60
      TRN1_IN $ 61-64
      TRN1_OUT $ 65-68
      YRD2_CD 69-71
      DT2_ARR 72-73
      TM2_ARR 74-77
      DT2_DEP 78-79
      TM2_DEP 80-83
      YD2_TIME 84-86
      TRN2_IN $ 87-90
      TRN2_OUT $ 91-94
      YRD3_CD 95-97
      DT3_ARR 98-99
      TM3_ARR 100-103
      DT3_DEP 104-105
      TM3_DEP 106-109
      YD3_TIME 110-112
      TRN3_IN $ 113-116
      TRN3_OUT $ 117-120
      YRD4_CD 121-123
      DT4_ARR 124-125
      TM4_ARR 126-129
      DT4_DEP 130-131
      TM4_DEP 132-135
```

TABLE D.8


```
       YD4_TIME 136-138
       TRN4_IN $ 139-142
       TRN4_OUT $ 143-146
       YRD5_CD 147-149
       DT5_ARR 150-151
       TM5_ARR 152-155
       DT5_DEP 156-157
       TM5_DEP 158-161
       YD5_TIME 162-164
       TRN5_IN $ 165-168
       TRN5_OUT $ 169-172
       PER_DIEM  174-177  2
       MILEAGE  178-181  4
       INCENT  182-185  2
       CAR_TYPE $ 186
       CAR_DSG 187-189   ;
IF TRN1_IN='AP40' THEN TRN1_IN='AP4'  ;
IF TRN2_IN='AP40' THEN TRN2_IN='AP4'  ;
IF TRN3_IN='AP40' THEN TRN3_IN='AP4'  ;
IF TRN4_IN='AP40' THEN TRN4_IN='AP4'  ;
IF TRN5_IN='AP40' THEN TRN5_IN='AP4'  ;
IF TRN1_OUT='AP40' THEN TRN1_OUT='AP4'   ;
IF TRN2_OUT='AP40' THEN TRN2_OUT='AP4'   ;
IF TRN3_OUT='AP40' THEN TRN3_OUT='AP4'   ;
IF TRN4_OUT='AP40' THEN TRN4_OUT='AP4'   ;
IF TRN5_OUT='AP40' THEN TRN5_OUT='AP4'   ;
IF ORG_CODE=633 THEN ORG_NODE=633;
IF DST_CODE=633 THEN DST_NODE=633;
IF NUM_YRDS>5 THEN DELETE;
IF CAR_OWN='S/U' THEN CAR_OWN='SOU';
IF YD1_TIME=. THEN YD1_TIME=0 ;
IF YD2_TIME=. THEN YD2_TIME=0 ;
IF YD3_TIME=. THEN YD3_TIME=0 ;
IF YD4_TIME=. THEN YD4_TIME=0 ;
IF YD5_TIME=. THEN YD5_TIME=0 ;
IF LD_TM=. THEN LD_TM=0 ;
IF UNLD_TM=. THEN UNLD_TM=0 ;
PROC SORT ; BY CAR_OWN CAR_NUM PRES_MVE ;
PROC PRINT PAGE=1 N ; BY CAR_OWN CAR_NUM PRES_MVE ;
ID CAR_OWN ;
TITLE B&M CAR UTILIZATION AUDIT - DATA BASE LISTING ;
/*
/*EOJ ********
```

TABLE D.9

TABULATION OF SAMPLE STATISTICS

```
// 'SUMMARY',REGION=250K
/*MITID  USER=(M12121,P14509
/*MAIN LINES=3,TIME=2
// EXEC SAS
//AUDIT DD DSNAME=U.M12121.P14509.SAS.BM.AUDIT.DATA.SET,DISP=SHR
//SYSIN DD *
DATA ;
SET AUDIT.DATABASE ;
IF CAR_OWN='ATSF' OR CAR_OWN='CNW' OR CAR_OWN='CR' OR CAR_OWN='ICG' OR
  CAR_OWN='LN' OR CAR_OWN='MILW' OR CAR_OWN='MP' OR CAR_OWN='RI' OR
  CAR_OWN='SCL' OR CAR_OWN='SOU' THEN CAR_OWN='FCLB' ;
IF CAR_OWN¬='BM' AND CAR_OWN¬='FCLB' THEN CAR_OWN='FORN' ;
IF CAR_TYPE¬='B' THEN CAR_TYPE='O' ;
PROC FREQ ; TABLES
 LE_STAT * CAR_OWN * CAR_TYPE
PRES_MVE * LE_STAT * CAR_OWN * CAR_TYPE
PRES_MVE * CAR_OWN * CAR_TYPE
CAR_OWN * CAR_TYPE ;
TITLE CLEARINGHOUSE DATA ON GENERAL BOX CARS ;
/*
/*EOJ ********
```

TABLE D.10

LOADING/UNLOADING REPORTS

```
// 'LDUNLD',REGION=200K
/*MITID  USER=(M12121,P14509
/*MAIN TIME=3,LINES=3
// EXEC SAS
//AUDIT DD DSNAME=U.M12121.P14509.SAS.BM.AUDIT.DATA.SET,DISP=SHR
//SYSIN DD *
DATA LOADUN ;
SET AUDIT.DATABASE ;
LENGTH LE_STAT 4 ;
IF LD_TM=0 AND UNLD_TM=0 THEN DELETE ;
IF CAR_OWN¬='BM' THEN CAR_OWN='FOREIGN' ;
IF LE_STAT='L' THEN TERML_TM=LD_TM ;
IF LE_STAT='E' THEN TERML_TM=UNLD_TM ;
IF LE_STAT='E' THEN LE_STAT='UNLD' ;
IF LE_STAT='L' THEN LE_STAT='LOAD' ;
KEEP CAR_OWN CAR_TYPE TERML_TM LE_STAT ORG_NODE ;
OUTPUT ;
PROC SORT ; BY CAR_TYPE LE_STAT ;
PROC MEANS NOPRINT N MEAN STD MAX ; BY CAR_TYPE LE_STAT ;
VAR TERML_TM ;
OUTPUT OUT=NEW N=NCARS MEAN=MEAN_TM STD=STD_TM MAX=MAX_TM ;
PROC PRINT ;
LENGTH LE_STAT 4 ;
FORMAT  MEAN_TM STD_TM MAX_TM 5.1 LE_STAT $4. ;
TITLE1 B&M CAR UTILIZATION AUDIT ;
TITLE2 LOADING AND UNLOADING TIMES BY CAR TYPE CODE ;
PROC SORT DATA =LOADUN ; BY CAR_OWN LE_STAT ;
PROC DELETE DATA=NEW ;
PROC MEANS NOPRINT N MEAN STD MAX ;
BY CAR_OWN LE_STAT ;
VAR TERML_TM ;
OUTPUT OUT=NEW N=NCARS MEAN=MEAN_TM STD=STD_TM MAX=MAX_TM ;
PROC PRINT ;
LENGTH LE_STAT 4 ;
FORMAT  MEAN_TM STD_TM MAX_TM 5.1 LE_STAT $4. ;
TITLE1 B&M CAR UTILIZATION AUDIT ;
TITLE2 LOADING AND UNLOADING TIMES BY CAR OWNERSHIP ;
PROC SORT  DATA=LOADUN ; BY ORG_NODE LE_STAT ;
PROC MEANS N MEAN STD MAX NOPRINT ;
BY ORG_NODE LE_STAT ;
VAR TERML_TM ;
OUTPUT OUT=NODES N=CARS MEAN=MEAN_TM STD=STD_TM MAX=MAX_TM ;
PROC PRINT ;
LENGTH LE_STAT 4 ;
FORMAT  MEAN_TM STD_TM MAX_TM 5.1 LE_STAT $4. ;
TITLE1 B&M CAR UTILIZATION AUDIT ;
TITLE2 LOADING AND UNLOADING TIMES BY TERMINAL NODES ;
/*
/*EOJ ********
```

TABLE D.11

CAR UTILIZATION ANALYSIS FOR ALL TRAFFIC CLASSES


```
// 'UTILIZ',REGION=200K
/*MITID  USER=(M12121,P14509
/*MAIN TIME=10 LINES=10
/*SRI LOW
//DELETE EXEC PGM=IEFBR14
//DD1 DD DSN=U.M12121.P14509.SAS.BM.AUDIT.UTILIZ,DISP=(MOD,DELETE)
// EXEC SAS
//AUDIT DD DSNAME=U.M12121.P14509.SAS.BM.AUDIT.DATA.SET,DISP=SHR
//ANL1 DD DSN=U.M12121.P14509.SAS.BM.AUDIT.UTILIZ,DISP=(NEW,CATLG),
//      UNIT=STORAGE,SPACE=(TRK,20,RLSE)
//SYSIN DD *
PROC SORT DATA=AUDIT.DATABASE OUT=SORTED ;
BY CAR_OWN CAR_NUM PRES_MVE ;
DATA ANL1.OVHD ANL1.FWRD;
SET SORTED ;  BY CAR_OWN CAR_NUM PRES_MVE ;
DROP YRD1_CD YRD2_CD YRD3_CD YRD4_CD YRD5_CD
     DT1_ARR TM1_ARR DT2_ARR TM2_ARR DT3_ARR TM3_ARR DT4_ARR TM4_ARR
     DT5_ARR TM5_ARR DT1_DEP TM1_DEP DT2_DEP TM2_DEP DT3_DEP TM3_DEP
     DT4_DEP TM4_DEP DT5_DEP TM5_DEP TRN1_IN TRN2_IN TRN3_IN TRN4_IN TRN5_IN
TRN1_OUT TRN2_OUT TRN3_OUT TRN4_OUT TRN5_OUT ;
IF PRES_MVE=0 THEN GO TO OVHDR ;
IF PRES_MVE=2 AND NEXT_MVE=3 THEN GO TO FX1 ;
IF PRES_MVE=3 AND LAST_MVE=2 THEN GO TO FX2 ;
RETURN ;
OVHDR : LINK FIND ;
YDTM=YD1_TIME+YD2_TIME+YD3_TIME+YD4_TIME+YD5_TIME-INT ;
LINE_TM=TRIP_TM-YDTM ;
SPEED=OD_DIST/(TRIP_TM+INT) ;
OUTPUT ANL1.OVHD ;
RETURN ;
FIND : INT=YD1_TIME ;
IF NUM_YRDS<=1 THEN RETURN ;
IF NUM_YRDS=2 THEN INT=INT+YD2_TIME ;
IF NUM_YRDS=3 THEN INT=INT+YD3_TIME ;
IF NUM_YRDS=4 THEN INT=INT+YD4_TIME ;
IF NUM_YRDS=5 THEN INT=INT+YD5_TIME ;
RETURN ;
FX1 : INT1=YD1_TIME ;
YDTM1=YD2_TIME+YD3_TIME+YD4_TIME+YD5_TIME ;
LINE1=TRIP_TM-YDTM1 ;
OD_DIST1=OD_DIST ;
LD_UN=LD_TM+UNLD_TM ;
NYRDS=NUM_YRDS ;
TRIP_TM1=TRIP_TM ;
TOT1=TRIP_TM+INT1;
X=0 ;
RETAIN INT1 YDTM1 LINE1 OD_DIST1 LD_UN NYRDS TRIP_TM1 TOT1 X ;
RETURN;
FX2 : LINK LOOK ;
RETAIN X;
IF X=1 THEN RETURN ;
X=1 ;
YDTM2=YD1_TIME+YD2_TIME+YD3_TIME+YD4_TIME+YD5_TIME-INT2 ;
LINE2=TRIP_TM-YDTM2 ;
TERML_TM=LD_UN+LD_TM+UNLD_TM ;
TOT2=TRIP_TM+INT2 ;
TOTAL=TRIP_TM1+TRIP_TM+TERML_TM+INT1+INT2 ;
SPEED=(OD_DIST1+OD_DIST)/TOTAL ;
OUTPUT ANL1.FWRD ;
RETURN ;
LOOK : IF NUM_YRDS=0 THEN RETURN ;
```

TABLE D.11


```
IF NUM_YRDS=1 THEN INT2=YD1_TIME ;
IF NUM_YRDS=2 THEN INT2=YD2_TIME ;
IF NUM_YRDS=3 THEN INT2=YD3_TIME ;
IF NUM_YRDS=4 THEN INT2=YD4_TIME ;
IF NUM_YRDS=5 THEN INT2=YD5_TIME ;
RETURN ;
/*
/*EOJ ********
```

TABLE D.12

TRAIN TO TRAIN CONNECTION PERFORMANCE REPORT


```
// 'DECPAR',REGION=200K
/*MITID USER=(M12121,P14509,
/*MAIN TIME=5 LINES=8
/*SRI LOW
// EXEC SAS
//AUDIT DD DSNAME=U.M12121.P14509.SAS.BM.AUDIT.DATA.SET,DISP=SHR
//SYSIN DD *
DATA YARDS;
SET AUDIT.DATABASE;
RETAIN YARD TRN_IN TRN_OUT TIME;
IF NUM_YRDS=0 THEN RETURN;
YARD=YRD1_CD;
TRN_IN=TRN1_IN;
TRN_OUT=TRN1_OUT;
TIME=YD1_TIME;
IF TIME=0 THEN DELETE;
OUTPUT;
IF NUM_YRDS=1 THEN RETURN;
YARD=YRD2_CD;
TRN_IN=TRN2_IN;
TRN_OUT=TRN2_OUT;
TIME=YD2_TIME;
IF TIME=0 THEN DELETE;
OUTPUT;
IF NUM_YRDS=2 THEN RETURN;
YARD=YRD3_CD;
TRN_IN=TRN3_IN;
TRN_OUT=TRN3_OUT;
TIME=YD3_TIME;
IF TIME=0 THEN DELETE;
OUTPUT;
IF NUM_YRDS=3 THEN RETURN;
YARD=YRD4_CD;
TRN_IN=TRN4_IN;
TRN_OUT=TRN4_OUT;
TIME=YD4_TIME;
IF TIME=0 THEN DELETE;
OUTPUT;
IF NUM_YRDS=4 THEN RETURN;
YARD=YRD5_CD;
TRN_IN=TRN5_IN;
TRN_OUT=TRN5_OUT;
TIME=YD5_TIME;
IF TIME=0 THEN DELETE;
OUTPUT;
DATA;
SET YARDS;
PROC SORT;
BY YARD TRN_IN TRN_OUT;
PROC MEANS N MEAN STD NOPRINT;
BY YARD TRN_IN TRN_OUT;
VAR TIME;
OUTPUT OUT=CONN N=MOVES MEAN=AVG_TIME STD=STD_TIME;
DATA _NULL_;
SET CONN;
BY YARD TRN_IN TRN_OUT;
IF TRN_IN='     ' OR TRN_OUT='     ' THEN RETURN;
IF MOVES<=2 THEN DELETE;
FORMAT AVG_TIME C_VAR 5.1 ;
C_VAR=STD_TIME/AVG_TIME ;
FILE PRINT HEADER=XX ;
```

```
PUT @2 YARD @20 TRN_IN @35 TRN_OUT @50 MOVES @65 AVG_TIME @80 C_VAR ;
RETURN ;
TITLE1 B&M CAR UTILIZATION AUDIT ;
TITLE2 TRAIN TO TRAIN PERFORMANCE - MAJOR  CONNECTIONS ONLY ;
XX : PUT
   @2 'YARD' @20 'TRN_IN' @35 'TRN_OUT' @50 'MOVES' @65 'AVG TIME' @80 'C_VAR' ;
RETURN ;
/*
/*EOJ ********
```