U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
PB-280 545

The Railroad Performance Model

Transportation Systems Center, Cambridge, Mass

Prepared for

Federal Railroad Administration, Washington, D C Office of Policy and Program Development

Oct 77

PB 280 545

REPORT NO. FRA-OPPD-77-11

THE RAILROAD PERFORMANCE MODEL

James F. Oiesen

U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge MA 02142

OCTOBER 1977

FINAL REPORT

Prepared for
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION
Office of Policy and Program Development
Office of Rail Systems Analysis and
Program Division
Washington DC 20590

Technical Report Documentation Page

1. Report No. FRA-OPPD-77-11	2. Government Accession No.	3. Recipient's Catalog No. PB280545
4. Title and Subtitle THE RAILROAD PERFORMANCE MODEL		5. Report Date October 1977
		6. Performing Organization Code
		8. Performing Organization Report No. DOT-TSC-FRA-77-1
7. Author(s) James F. Olesen		
9. Performing Organization Name and Address U.S. Department of Transportation, Transportation Systems Center, Kendall Square, Cambridge MA 02142		10. Work Unit No. (TRAIS) RR727/R8302
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation, Federal Railroad Administration, Office of Policy and Program Development, Office of Rail Systems Analysis and Program Division, Washington DC 20590		13. Type of Report and Period Covered Final Report September 1975 - September 1976
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This report describes an operational, though preliminary, version of the Railroad Performance Model, which is a computer simulation model of the nation's railroad system. The ultimate purpose of this model is to predict the effect of changes in government or industry policies on the performance of the railroads.

This model simulates the history of individual cars and individual loads of freight; and it explicitly incorporates a number of decisions made by government, railroads, and shippers.

This model includes phenomena such as freight car shortages and surpluses, interlining, per diem rates, car service rules, the demurrage system, routing of cars, and the allocation of home and foreign empty cars.

17. Key Words Freight Car Management, Per Diem Rates, Network Model		18. Distribution Statement DOCUMENT IS AVAILABLE TO THE U.S. PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 312	22. Price A14-A01

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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PREFACE

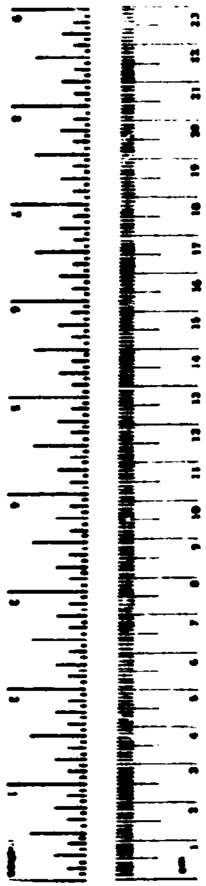
This report joins two strands of thought that have recently occupied the author. The first strand is policy-oriented and has been concerned with the substantive question of determining the effect of proposed policies on the railroads [Oiesen, 1975]. The second is methodological and has been concerned with what models can be expected to do and how those models should be constructed and exposited [Oiesen, 1975a, 1976b]. This report is an attempt to apply the methodological principles of the second strand to the substantive problems of the first strand.

This report has benefited greatly from the meticulous, judicious editing of Martha Celestino. The typing was skillfully done by Elissa Collins, Karen Daly, and Jeannie Sciandra.

METRIC CONVERSION FACTORS

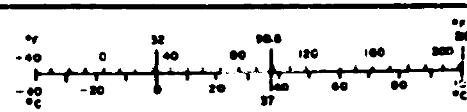
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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SUMMARY

This report describes the current, preliminary version of the Railroad Performance Model (RPM), which is a simulation model that predicts the effect of changes in government policies, railroad operating policies, shipper policies, and other factors on the performance of the nation's railroad system. This report consists of the motivation, specification, application, documentation, and evaluation of this model.

Motivation (Section 1, Appendix E). Many different changes in policy have been proposed with the aim of improving railroad performance. Determining whether these suggested policy changes would have the desired beneficial effects is difficult because of the complicated manner in which the railroads operate and because of the interdependence of railroads. Because of the potentially large gains that would result from well-conceived policies, it would be valuable to have a systematic model that explictly incorporated the main features of railroad operation and could predict the effects of proposed policy changes on railroad performance. The need for such a model is the motivation for constructing the RPM.

Specification (Sections 2-4, Appendixes A,B,G,H). The RPM is a computer simulation model that concentrates on the operation of the nation's rail system and on the effect that decisions have on that operation. The RPM models the stock of cars owned by each road, the origin-destination demand that arises each day, the loading of freight into cars, the linehaul of cars, the unloading of cars, and the allocation of empty cars among roads. Each of these processes is guided by the decisions made by the various decision-makers. Decisions made by the government (or which can be heavily influenced by the government) that are explicitly modeled are the level of per diem rates, the system of car service rules, and the revenue that railroads earn per loaded car-mile. Decisions made by individual railroads that are modeled are the number of cars owned, the order in which demand is serviced, the particular car into which demand is loaded, the route assigned to a car, the maximum number of empty cars held on line, and the empty foreign cars that are sent away. Shipper decisions that are modeled are the daily level of demand, the amount of time cars are held while being loaded or unloaded, and the decisions on when unserviced demand is withdrawn. These decisions, together with technical data such as distances and average speeds, are integrated into a coherent model of the nation's rail system.

Application (Section 5, Appendixes D and K). While the version of the RPM described in this report is not yet developed enough to give definitive answers to policy questions, a number

of example applications are carried out to show the capabilities of the RPM. The model is used to predict the effect of changes in per diem rates, in car service rules, in the demurrage system, and in the level of demand. These applications show how the RPM can give quantitative answers to policy questions, how it can be used to trace the channels through which policy changes exert an effect, and how it can be used to build up one's intuition about how railroads work and about what effects proposed policies would have.

Documentation (Appendixes I and J). The mathematical calculations required by the model specification are carried out by a computer program written in the GPSS V language. The appendixes list this program, which includes over 300 comments, and describe the organization and logic of the program.

Evaluation (Section 5.8, Section 6, Appendixes C and F). The version of the RPM described in this report is not a finished product but rather a demonstration model that indicates how a more sophisticated model could be constructed. How accurate and useful could an improved version of the RPM be? In a relative sense, the RPM seems to be superior to other models since it can handle a range of policy questions that other models cannot. In an absolute sense, the RPM has many desirable features that commend it, though there are obstacles that might hinder further development. In short, a model embodying the method and philosophy outlined in this report could apparently lead to an increased understanding of railroads and also yield answers to a range of policy questions that could be addressed by no other model. Thus, the RPM seems to hold great promise, though that promise is not fully realized in this report.

1. THE NEED FOR A MODEL OF RAILROAD PERFORMANCE

1.1 INTRODUCTION

Because some of the railroads both earn low profits and provide an uneven quality of service, they are often considered to be one of the problem areas of the economy. On the one hand, it might be that this is the best that these railroads can do; burdened with unfavorable cost and demand conditions, they may already be making the best of a bad situation. On the other hand, it might be that if the railroads or the government did things differently, then the railroads would perform much better. This latter view is taken by many people and there is consequently a wealth of suggestions for actions that should be taken by government or by the industry.

With many different people championing many different courses of action, the difficulty lies in deciding which, if any, of these suggested actions are worthwhile. In order to judge the desirability of a change, one would like to know what the effect of that change would probably be. For example, what would be the nation-wide effect if:

- there were a general raising or lowering of per diem rates, which are fees that a railroad pays for the use of cars belonging to other railroads?

- empty cars were charged a lower per diem rate than loaded cars?
- there were a change in the car service rules, which govern how a railroad treats cars belonging to other railroads?
- per diem rates or car service rules were varied monthly in response to the level of demand?
- per diem rates or car service rules were varied in different parts of the country in response to regional imbalances in the supply and demand for cars?
- there were a large fleet of free-running cars that were exempt from car service rules?
- there were a decrease in transit time through major terminal areas such as Chicago, Kansas City, and St. Louis?
- the reliability of transit time on individual links were increased?
- there were a decrease in transit time on major rail links?
- there were a speed-up in the loading and unloading of cars?

These questions are representative of many factual questions to which one would like to have answers before forming an opinion on which, if any, actions the industry or government should take.

1.2 THE NEED FOR A MODELING APPROACH

How might one arrive at answers to the questions just listed and to others like them? One approach would be to ask people with railroading experience to express an opinion on these questions. There are many problems with this approach. One is that these knowledgeable people perhaps have no direct experience with the altered environment that would be brought about by the fundamental changes that some of these changes call for. Another problem is that the knowledgeable people might not agree among themselves. Therefore, it would be desirable to have an alternative approach to obtaining answers to questions like these.

The alternative approach taken in this report is a modeling approach. A model, in brief, is a mathematical statement of the relationships between specified variables. These mathematical relationships contain within them answers to questions like those listed above. So a model is a device that organizes our knowledge and extracts from that knowledge the answers to questions of interest. Moreover, by developing a model we increase our knowledge and, therefore, increase our ability to answer questions about the railroads. However, modeling is not a panacea. If the relationships between the variables are too unstable or too complicated for the modeler to capture in mathematics, then the model will not give reliable answers to the questions it is called on to answer.

This paper is based on two facts and one working hypothesis. The facts are:

- there are many questions of interest about railroads that cannot be reliably answered by non-modeling approaches
- models have not yet been developed that try to answer these questions.

The working hypothesis is:

- the relationships that are to be modeled are not so complicated as to defy modeling.

These two facts, this working hypothesis, and the urgency of the questions under discussion provide the rationale for the development of the Railroad Performance Model, which is the name given to the model developed in this paper.

1.3 THE NATURE OF A MODEL

In order to make the Railroad Performance Model (RPM) easier to understand and to provide a unifying framework for the bulk of this report, a few words will be said about the three components that are common to all models. This discussion is drawn from Oiesen [1976b, pp. 5-29].

Any model has three components -- model inputs, model outputs, and model logic. The model inputs are the independent variables that drive the system; in the RPM these independent variables consist of government policies, industry policies, shipper policies, and other things that will be spelled out in Section 2. The model outputs are the dependent variables whose values are determined by the independent variables (i.e. the inputs) and by the way the system operates. The outputs of the RPM are a number of measures of railroad performance such as profit for the railroads, the frequency of car shortages, the average car cycle, and other things listed in Section 3. The model logic consists of assumptions about the way the system being considered operates. Therefore, when the inputs take on particular values, the model logic is used to determine what values the outputs take on in response. Therefore, as Figure One indicates, the model logic is a function that associates a unique value of the output variables with each value of the input variables.

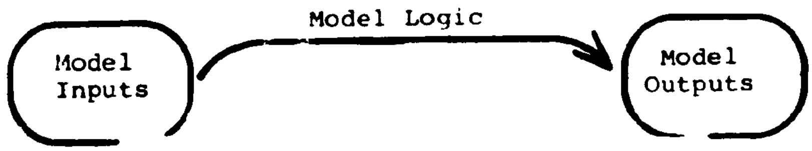

FIGURE 1. THE COMPONENTS OF A MODEL

If some of the inputs, e.g. government policies, are changed, then the model logic is used to calculate the induced change in the measures of railroad performance. In this way one can estimate the effects of changes in government policies, and one can arrive at answers to the types of questions listed in Section 1.1.

Therefore, the strategy for using a model has three steps:

Step 1: Run the model for one set of input values and note the output values that result.

Step 2: Run the model for a different set of input values and note the output values that result.

Step 3: Interpret any changes in the output values as the effect that is caused by changing the inputs.

After Sections 2, 3, and 4 explain the RPM inputs, outputs, and model logic, respectively, Section 5 will implement this strategy.

1.4 TERMINOLOGY

A few of the terms used in this report will now be defined. A car is on line from the viewpoint of a particular railroad if that car is on the tracks controlled by that railroad. A car is off line if it is not on that railroad's tracks. A car is a home car for a particular railroad if that railroad owns that car; the car is a foreign car if that railroad does not own it. Empty cars are called empties. Interlining occurs if a shipment travels over the tracks of more than one railroad. The phrases unit of demand, load of demand, and demand are used interchangably to refer to the desire of a shipper to send one carload of freight from an origin to a destination. These phrases are used not only to refer to the intangible desire but also to the freight itself.

1.5 BRIEF DESCRIPTION OF THE MODEL LOGIC

In order to make the next two chapters easier to understand and to give the reader an immediate feel for the RPM, a brief description of the model logic will now be given. A fuller description will be given in Section 4.

To be picturesque, think of a large wall map of the United States that has blinking lights as in a nuclear war movie. Suppose that the country's railroad tracks are sketched in. Suppose there is a little blinking red light on the map wherever there is an empty railroad car. Suppose there is a little blinking green light wherever there is a load of demand waiting for a car. Whenever a red and green light blink together, that means that the demand is loaded into that car. When the red and green lights are blinking together and moving, that represents a loaded car that is moving. When a red light is blinking and moving with no green light in tandem, that represents an empty car that is moving. If we sit in front of this map and watch all the lights, we are watching the nation's railroad system being simulated. That is what the Railroad Performance Model does, except that it uses a computer instead of a big map.

It is a plain fact that we will not be satisfied with this simulation if all the red and green lights move around at random; we want them to move so that, in some sense, their movement reproduces the activity of the real railroad system. The RPM attempts to achieve this goal by concentrating on the decisions that railroads, shippers, and government make and by focusing on how these decisions influence railroad performance. The RPM models the behavior of railroads and shippers with decision rules that state what the railroad or shipper will do in any given situation. These decision rules govern the amount of demand that will arise every day and how that demand will be loaded into cars and routed. These decision rules also govern the actions that will be taken by railroads or shippers when cars are in shortage or excess. Further assumptions about things like distances and average train speeds determine what happens to moving cars.

The sequence of decisions and other events that occur in a typical day as simulated by the RPM is as follows:

- cars arrive at each road; if loaded, they are sent to be unloaded; if unloaded, they are added to the stock of empties
- railroads decide which, if any, of the demand held over from the previous day will be loaded into cars
- shippers decide how much new demand will be created for this day for each origin-destination pair

- railroads decide which, if any, of the new demand will be loaded into cars
- railroads choose a route for loaded cars and these cars begin their journey
- if demand has not been loaded, then shippers decide whether this demand should be held over until the next day or whether it should be removed from the model
- each road decides whether to send away any foreign empties on line; if any are sent away, their route is chosen and their journey begins.

The RPM gathers statistics on all this activity; at the end of a simulated year these data are processed and displayed to the user of the model.

In short, the RPM simulates the railroad system by stepping through a year one day at a time. On any day, the state of the railroad system consists of things like the number and owner-composition of empty cars on the lines of each railroad, the amount and origin-destination composition of demand at each railroad, and the number of cars in transit and the time at which they are to arrive at their destinations. The decisions made by railroads and shippers on a particular day depend on the state of the railroad system for that day, and these decisions in turn determine what the state of the railroad system will be in the future.

In this way, the RPM works through the year one day at a time, modeling the history of each unit of demand and each car separately. This, then, summarizes the RPM's view of the way the railroad system operates and of how government policies along with railroad and shipper decision rules determine railroad performance.

1.6 LIMITATIONS AND PURPOSE OF THE CURRENT MODEL

The version of the Railroad Performance Model that is explained in this paper has a number of limitations. These limitations flow largely from simplifying assumptions in the model logic and from flaws in the data base; these specific shortcomings will be spelled out in later chapters. However, at this time it should be stated that while the RPM has been constructed with a number of policy questions in mind, the version of the RPM explained in this report cannot provide accurate answers to these questions. The answers generated by the current version of the RPM are wrong, probably very wrong, and it would be irresponsible to base any policy decisions on the results of this version of the model.

Despite this seemingly harsh judgment, the current version of the model has achieved three objectives. First, while it cannot reliably answer policy questions, it goes a long way toward showing how a model that could reliably answer those questions could be constructed. The degree to which this objective is reached is discussed in Section 6.5. Second, it shows how an improved version of the model could serve as a unifying framework that could simplify and organize much of railroad research; this point is developed in Section 6.3. Third, even the crude current version of the model reflects enough of the complexity of the railroad system that it can be used as a tool to build up one's intuition about how railroads work and about the possible effects that a policy change could have on the railroad system. This advantage is developed in Section 5.8. These benefits of the current model are listed here to emphasize that a model can be valuable even if it cannot make accurate quantitative predictions. These advantages will become more apparent as the exposition proceeds.

The next step is to consider the question of whether an improved version of the model should be developed; this will be taken up in Section 6. Until Section 6, the focus will be on explaining the current version of the RPM so that the reader can understand it. Because only limited resources were devoted to this demonstration model, it suffers from many shortcuts and simplifications. These will be pointed out below; and no justification is given for most of them. These simplifications should be seen as the temporary stepping-stones to a more complete model, not as a finished product ready for searching criticism. Every effort will be made, starting in the next two sections, to point out the essential features of the model that would endure into a more sophisticated versions since these features do deserve criticism, and a judgment on the acceptability of those features will be a factor in the decision of whether further development of this model is desirable.

1.7 SCOPE OF THE RAILROAD PERFORMANCE MODEL

To make clear the types of policy questions which the Railroad Performance Model can and cannot answer, a brief discussion will be given of the stages through which a government decision-making process ideally passes. Constructing a parallel discussion of decision-making in the railroads is left to the reader. The ideas in this section are drawn from Oiesen [1976a, esp. pp. 13-19].

A government decision-making process ideally has four stages.

- List the alternative decisions under consideration
- Determine the variables of interest that those decisions could affect
- Predict the effect that each of those alternative decisions would have on the variables of interest
- Choose the best decision in light of the predicted effects of each decision.

These four states can be interpreted in terms of the RPM. First, listing the alternative decisions under consideration is analogous to listing the proposed policies that are to be investigated and determining how to choose values for the RPM's inputs to reflect these proposed policies.

These proposed policies include things like changing the per diem rate, changing the car service rules, and changing the demurrage system. Second, determining the variables of interest is analogous to specifying the outputs of the RPM, i.e. the measures of railroad performance such as railroad profit. Third, predicting the effect of the possible decisions on the variables of interest is analogous to running the RPM and, thus, to determing what values of the outputs result when values are specified for the inputs. Fourth, choosing the best decision has no analog in the RPM. The RPM only predicts the effects, for example, of raising the per diem rate by fifty cents; the RPM makes no judgment as to whether raising the rate is a better idea than leaving it alone. Suppose that some railroads are helped by the increase and others are hurt. Is the increase a good idea? This is not a question that can be scientifically answered, at least not unless criteria are specified for determing how one judges whether one set of values for the measures of railroad performance is better than another set. If such criteria (e.g. the best decision is the one that maximizes aggregate railroad profit) are provided, then an extension of the RPM could determine the best decision; but such criteria are rarely provided.

In summary, the RPM, at best, determines how different policies affect the measures of railroad performance; it cannot determine the best decision for the government (unless social preferences or something like that are provided). In other words, the RPM generates technical information that is necessary to informed decision-making, but it does not make the ethical judgments that are necessary to go from that technical information to a final decision. Therefore, the RPM does not even in principle completely solve the government decision-making problem, but it does address three of the four stages of the problem. Appendix G contains a more detailed treatment of this topic.

1.8 SYSTEM EFFECTS

Since a large number of rail shipments travel over the lines of more than one railroad, the decisions made by one railroad can affect other railroads. These effects that one railroad has on others are called system effects. When constructing a model of the railroads, one must make a choice as to the relative emphasis given to modeling effects on a single railroad and system effects.

The RPM puts greater emphasis on modeling the system effects; two reasons underlie this decision. First, as Appendix F points out, there are a number of models that treat single railroads in great detail; but there is apparently no model that can answer questions concerning the effect of changes in policies that inherently involve more than one railroad such as per diem rates and car service rules. Second, there is reason to believe that because system effects exist, policies such as per diem rates and car service rules can have a significant effect on the performance of the railroad system. Therefore, the RPM given heavy emphasis to system effects. This is not to say that the RPM ignores the effects on individual railroads; as Chapter 3 points out, the effects on individual railroads are measured in many different ways. It is to say that the RPM has less detail on individual railroads than models that deal solely with one railroad. In short, a disadvantage of the RPM is that it models individual railroads in less detail than other models; counterbalancing this, an advantage is that the RPM explicitly includes system effects. Appendix E discusses in detail the points raised in this section.

1.9 ORGANIZATION OF THIS REPORT

Section 2 describes the inputs to the Railroad Performance Model. These are the variables that can be changed between runs, so the RPM estimates how the measures of railroad performance change in response to these input variables. If a government or industry policy change can be reflected in a change in these input variables, then the model can estimate the effect of that policy change on the measures of railroad performance. Thus, the richness of the set of policy questions on which the RPM can throw light is determined by the input variables that the model can accommodate.

Section 3 describes the outputs of the RPM. Since the RPM communicates to the user through these outputs, the usefulness of the model depends on the appropriateness of these outputs.

Section 4 describes the model logic. This chapter describes the assumptions about how the railroad system works. These assumptions cover both the decision rules followed by railroads and shippers and also more technical matters.

Section 5 contains a series of sample applications of the RPM that displays the output from computer runs showing how the measures of railroad performance change in response to changes in per diem rates, car service rules, the demurrage system, and demand.

Section 6 concludes by stressing the strengths and weaknesses of the current version of the model and also the promise of future versions.

These chapters are all designed to be non-technical and comprehensible to any determined reader. At points where a complete description of the model would either be too technical or detailed for the general reader, the material is placed in an appendix. Appendixes A through H are written so that they can be understood by one unfamiliar with GPSS V, the computer language in which the model is programmed.

The rest of this report can be divided into the portion that explains the RPM and the portion that evaluates it. Sections 2, 3, 4, and Sections 5.1 through 5.7 explain the current version of the RPM, and Section 5.8 and Section 6 evaluate it. That is, the first portion explains the assumptions of the model and detail its workings; the second portion discusses the good and bad aspects of the model. This sharp segregation of the two portions of the report is maintained for three reasons. First, the model is fairly complicated; understanding it is hard enough and would be even harder if debates over the assumptions were inserted every few pages. Second, the reader who is only interested in a broad evaluation of the model can skip directly to Section 5.8 and Section 6. Third, since the current version of the RPM is only a demonstration model that is a forerunner of more sophisticated models and since the cruder assumptions of the model would not appear in future versions and since no claims of accuracy are made for the current model, it would be out of place to criticize the details of the current model. The model as a whole embodies a comprehensive vision of how railroads work and how they can be modeled; it is this comprehensive approach, rather than the details of the current model, that merit criticism. Therefore, evaluation of the model is postponed until Section 6.

2. MODEL INPUTS

2.1 INTRODUCTION

This chapter describes the inputs to the Railroad Performance Model (RPM). There are some structural inputs that are not allowed to vary in different runs of the model; these are discussed in Section 2. The rest of the inputs can be varied. Section 3 deals with the inputs chosen by the government, Section 4 with inputs chosen by the railroads, Section 5 with the inputs chosen by shippers, and Section 6 with the remaining inputs. To make it easy to recognize the inputs, each is stated and marked with a black dot before it is explained.

Two distinctions must be kept in mind while reading this chapter. The first distinction is between the model inputs and the values taken on by those inputs. The model inputs are a set of variables; the values taken on by those inputs are the values given to those variables for a particular run of the model. For example, the expected number of days it takes a car to travel from road 1 to road 2 is an input; in any one run of the model, that input will take on a value such as 2,3, or 4. Thus, the set of input variables does not change between runs; what changes is the values given to those variables. This section will explain what the input variables are, and it will state the Base Case values for many of the input variables. The Base Case is interpreted as business-as-usual or as the status quo. It is anticipated that in a typical run of the model, most of the values used for the inputs will be the Base Case values; typically, a small number of Base Case values are altered to reflect a change (such as a policy change) that is being simulated. (Note: Sometimes "inputs" is used in place of "values taken on by the inputs;" this shorthand should cause no confusion. Also, some of the inputs are functions rather than numbers. Thus, the value of the input will be a function rather than a number.)

The second distinction is between a decision rule and a decision. A decision rule states what a decision-maker (such as a railroad or shipper) will do when faced with particular conditions. A decision is whatever it is that the decision-maker does. Consider a simple example. One decision you must make every morning is whether to carry your umbrella to work. You might use the following decision rule: Call the weather and find out what the probability of rain is; then carry your umbrella if the probability of rain is greater than or equal to 50 percent and leave it at home if the probability is less than 50 percent. In this example, the decision is either "carry the umbrella" or "leave it at home," and the decision rule determines which decision is taken based on the probability of rain. In the RPM a decision rule must be input for each decision that a railroad or shipper is assumed to make. This section explains what these decision rules are and the factors on which decisions are assumed to depend.

The exposition in this section is designed to be comprehensible and enlightening rather than exhaustive and tedious; Appendix A contains an exhaustive treatment of the material in this section. Moreover, this section only describes the model inputs; it does not describe how those inputs combine to determine railroad performance. That latter task is postponed to Section 4.

The section describes the assumptions that are embodied in the current version of the model. While not always as realistic as one might desire, the assumptions are as realistic as they could be made for the preliminary model. Future work will be devoted to improving these assumptions.

2.2 STRUCTURAL INPUTS

Certain features of the RPM cannot easily be changed between different runs of the current model. These features might be called the structure of the model. In the current version of the RPM, it is assumed that:

- there are ten railroads in the country
- there is a link of track connecting each pair of adjacent roads
- each railroad has only one yard
- there is only one type of car
- there are 1000 cars in the national fleet
- there is only one type of commodity.

It is assumed in the model that the country is divided into ten regions as shown in Figure 2. Each contains one railroad with one yard. The geographic area for each railroad has been picked so that the roads cover the country and so that the roads in the model display variety in size, number of interline connections, and other characteristics. There is no overlapping of roads, so the current model does not capture any competition between railroads. The links of track between adjacent roads that are used for interline shipments are shown. Each railroad includes that portion of a link up to the boundary with the next railroad. The actual exchange of cars occurs at one or the other of the yards rather than at the railroad boundary. In this sense, a railroad in the model is not a truly realistic representation of an existing railroad.

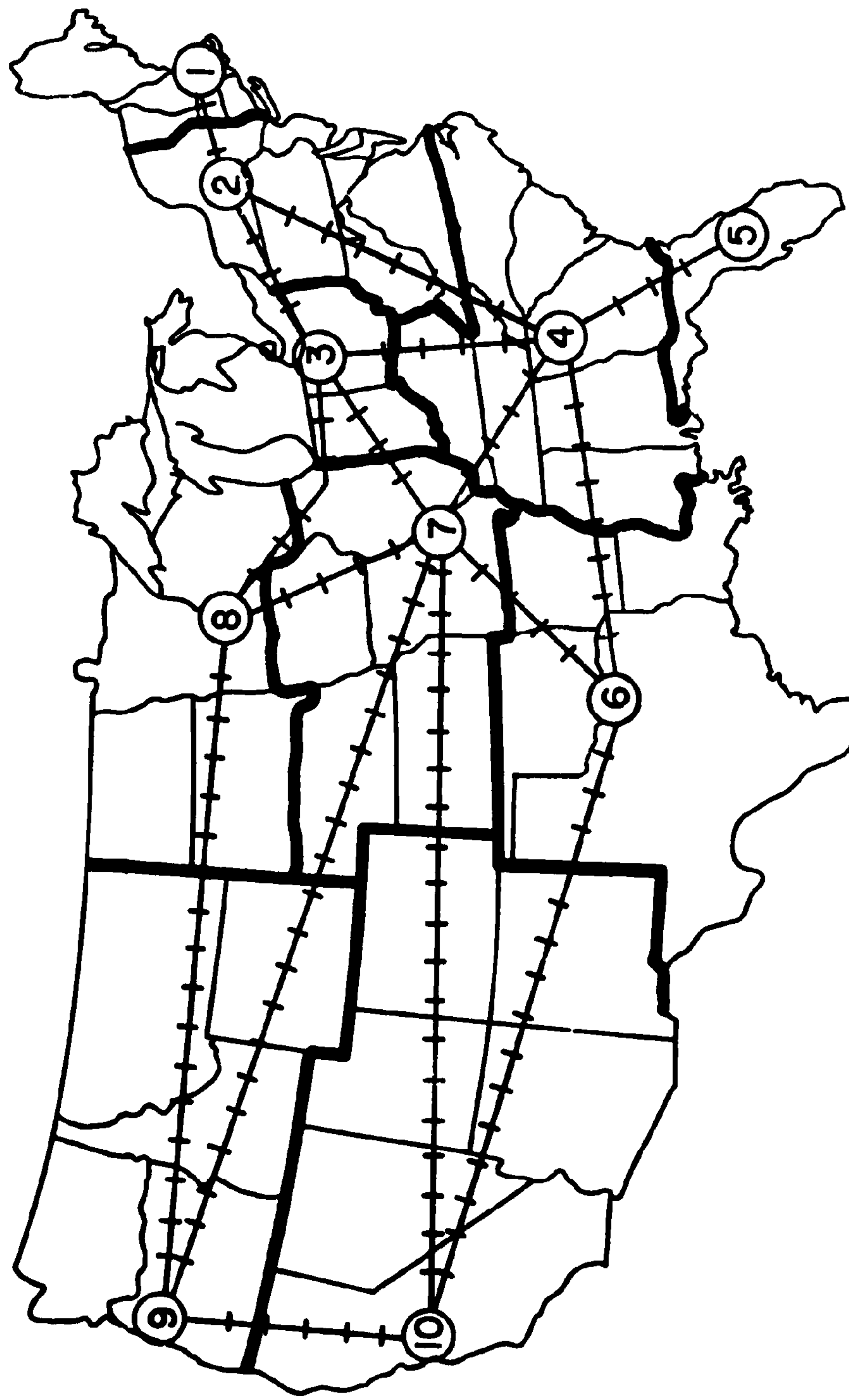

FIGURE 2. THE RAILROAD PERFORMANCE MODEL NETWORK

The links of track used for intraline shipments are not shown. Since there is only one yard per road, we will not mention the yards any further and will speak only of roads; when we say, "the distance between road 3 and road 4 is 490 miles," what is meant is "the distance between road 3's yard and road 4's yard in 490 miles."

Since there is one homogenous type of car in the model, differences in car types and ages are ignored. Since there in one homogeneous commodity, differences in revenue and other factors associated with different commodities are ignored. The reader's attention is directed to the assumption that there are only 1000 cars in the national fleet. It is also assumed that a car is either empty or fully loaded; shipments that are less than a car load are not permitted.

All of these assumptions are features of the current model that, in principle, could be relaxed in future versions of the model.

2.3 INPUTS CHOSEN BY THE GOVERNMENT

There are four inputs to the model that the government has the power to set, though it does not always exercise that power today. These are:

- the car hire charge per day
- the car hire charge per mile
- the foreign cars into which a load may legally be placed
- the revenue per car-mile.

These inputs to the RPM will now be discussed in turn.

When a car belonging to one railroad is on the lines of another railroad, the road that temporarily has the car is required to pay a fee, called a car hire charge, to the car's owner. The car hire charge has two components. First, there is a flat charge that is paid for each day that a foreign car is on line. Second, there is a mileage charge that is paid for each mile that the foreign car travels on line. The assumed Base Case values for these two charges are $5.00 and $0.05, respectively. The phrase "per diem rate" is usually used loosely to refer to car hire charges, and it will be used in this report to refer to the daily car hire charge. Discussions of historical and other aspects of per diem rates can be found in Reebie Associates [1972, pp. 195-203] and in Mosbaek [1971, pp. 1-4]. The significance of per diem rates as a policy tool is discussed in Appendix E.

The car service rules specify how a railroad must treat foreign cars on its lines. A complete list of the permanent car service rules can be found in Association of American Railroads [1974, pp. 2-5]. The only car service rule included in the Base Case is that a road cannot load a foreign car and send it away from its home lines. For example, a glance back at the map in Figure 2 shows that road 7 would not be allowed to load a car belonging to road 10 and send it to road 1. Thus, the car service rules are a constraint subject to which the railroads operate; these rules specify the foreign cars into which a unit of demand may legally be placed. It is assumed that the car service rules are always observed. A complete list of the legal loadings can be found in Section A.2. A detailed discussion of historical and other aspects of car service tules can be found in U.S. Senate Hearings [1971, pp. 350 ff]. The significance of car service rules as a policy tool is discussed in Section 5.4 and in Appendix E.

The RPM assumes that a road earns a constant amount of revenue by hauling a loaded car a mile, though this revenue per loaded car-mile can be changed between runs of the model. The value assumed in the Base Case is $1.00 per mile. This is a variable that the government can influence since the Interstate Commerce Commission has the power to set rail rates.

The four inputs just discussed are the only ones which the government can set directly, but it can indirectly affect many of the others. For example, the government cannot set the cost of hauling a car a mile, but the government can influence this cost through loan guarantees or in other ways. The point is that the government role is not necessarily limited to the four inputs just discussed.

2.4 INPUTS CHOSEN BY THE RAILROADS

The RPM allows each railroad to choose its own decision rules that it follows in its daily operations. The decision rules which are inputs to the model govern:

- the order in which demand is serviced
- the particular car into which a unit of demand is loaded
- the route assigned to a car
- the maximum number of empty cars held on line
- the specific empty foreign cars that are sent away
- the number of cars owned by each road.

These decision rules will now be discussed for a typical railroad.

A railroad must first decide on the order in which demand is to be serviced. That is, on a typical day, a road will be faced with different types of demand (i.e. demand with different destinations). The road must decide which demand will be given the first shot at the available empty cars, which gets the second shot, etc. The general decision rule assumed in this analysis for the Base Case is that the closer destinations will be serviced first and the further ones afterwards. For example, if on a particular day road 4 has demand destined for roads 4, 7, and 9, it will first load demand for road 4, then road 7, and then road 9, if possible. The details of this decision rule can be found in Section A.3.

A rule is needed to govern the decision of which car a particular load of demand should be placed into. For example, road 4 might hold empty cars belonging to many different roads; into which car is road 4 to place a load destined for road 7? The decision rule used in the Base Case is:

1) put the load into a car owned by the road to which the load is destined;

2) if no such car is available, put the load into a home car;

3) if no home car is available, then place the load into a car permitted by the car service rules that is owned by a road close to the destination road.

The precise interpretation of these rules is spelled out in Section A.3.

After a car has been loaded, or after it has been decided that an empty foreign car is to be sent off line, it is necessary to route the car, i.e. to decide what link of track it will be sent on. The decision rule used in the Base Case of the RPM is that the car is sent on the most direct route. The details of this are spelled out in Section A.3.

Each railroad is allowed to choose the maximum number of empty cars that it would like to hold on line. For example, under the Base Case assumptions, road 3 desires to hold a maximum of 79 empty cars at any one time. The maximum number of cars a road wishes to hold depends on the per diem rate. For example, when the per diem rate is raised from its Base Case value of $5.00 to $6.00, the maximum number of cars that road 3 wishes to hold falls to 63; when the per diem rate is raised to $7.00, the maximum number falls further to 47. The full Base Case decision rules for each railroad are stated in Section A.3.

If the maximum number of empties that a road would like to hold on line is exceeded by the number it actually holds, then it must decide which empties to send away. The Base Case decision rule is, loosely, to send away first the empties belonging to roads that are farthest away. This decision rule is precisely specified in Section A.3. It is assumed that empty home cars are never sent off line.

Another input controlled by each railroad is the number of cars that it owns, which is constant throughout the simulation year. This brings up an important point. The effects of many government, railroad, or shipper actions will be manifested not only through a change in how the railroads utilize their current stock of plant and equipment but also through a change in that stock. For example, if per diem rates are raised, this will probably affect not only how railroads currently operate but also, after a lag of a year or two, the number of freight cars that railroads own. Therefore, in order to estimate the long-run effect of increased per diem rates on railroad performance, it is necessary to estimate how each road's stock of cars will change in response to the new per diem rates. A model that performs this estimation can be found in Oiesen [1975]. This model requires as input the profit that a railroad would earn from a fleet of a specified size as a function of per diem rates, car service rules, etc. This input can be provided by the RPM. Thus, these two models can be integrated in order to estimate the total effect of a change in, say, per diem rates, taking into account both the effect on fleet size and also on how that fleet is used. Since this integration of the two models has not been carried out, the number of cars that a railroad owns is assumed to be constant throughout each run of the model.

2.5 INPUTS CHOSEN BY SHIPPERS

Decisions made by shippers can influence the operation of the railroad system,and this is recognized by including four inputs over which the shippers exercise control:

- for each origin-desitination pair, two probability distribution of daily demand -- one for the peak season and one for the slack season
- the maximum queue length of demand waiting at each road for empty cars that shippers will tolerate
- the maximum number of days that a unit of demand is allowed to wait for a load
- the probability distribution for the number of days that a shipper or consignee holds a car that is being loaded or unloaded.

At the beginning of each day, a number of units of demand is brought into the model for each of the 100 origin-destination pairs. (Since there are 10 railroads and since any railroad can serve as origin or destination, there are 10x10=100 possible origin-destination pairs.) For each of the origin-destination pairs there is a probability distribution of demand for the slack seasons (first and third quarters) and a different probability distribution for the peak seasons (second and fourth quarters). For example, consider demand for the origin-destination pair (3,2), i.e. demand that originates at road 3 and has road 2 as destination. The number of units of demand that the model creates for a single day during the peak season is 5 with probability 0.1, 6 with probability 0.6, and 8 with probability 0.3. During the slack season the daily demand for this origin-destination pair is 5 with probability 0.5 and 6 with probability 0.5. There are different probability distributions for demand that originates at road 2 and has road 3 as destination. Table 2-1 shows the origin-destination demand that might be created on a typical day. For example, there are 7 units of demand created with road 2 as origin and road 3 as destination; there are 6 units of demand created with road 3 as origin and road 2 as destination. Full details on the manner in which demand is created each day can be found in Section A.4.

If there is a shortage of cars at a railroad and if there is a queue of demand built up at that origin waiting for empty cars, it is assumed that shippers will not allow this queue to grow beyond a maximum length. If demand is created at that origin which would increase the length of the queue beyond its maximum allowed size, then that demand would be destroyed, i.e. it would be removed from the model. The interpretation of a unit of demand being destroyed is that the shipper decides not to send the shipment by rail; the shipper either ships by some other mode or does not ship at all. For example, in the Base Case it is assumed that shippers will not permit the queue of waiting demand at road 4 to exceed 12 units; the other Base Case assumptions are in Section A.4.

If, on a particular day, there is a shortage of cars at a railroad and if demand for which there is no car is held in anticipation of arrival of an empty car, it is assumed

Table 2-1. Units of Origin-Destination Demand
Created on a Typical Day

Destination

Origin	1	2	3	4	5	6	7	8	9	10
1	3	2	2	1	0	0	1	0	0	0
2	4	7	7	2	0	0	1	0	0	0
3	3	6	7	2	0	2	1	0	0	1
4	1	2	2	16	2	1	0	0	0	0
5	0	0	0	1	3	0	0	0	0	0
6	0	0	1	2	0	9	1	0	0	1
7	0	0	1	0	0	1	8	3	0	1
8	0	0	0	0	0	1	2	3	0	0
9	0	0	0	0	0	0	1	0	3	1
10	0	1	1	0	0	1	1	0	1	5

that shippers will not allow the demand to be held over for more than a prescribed number of days. In the Base Case, the maximum number of days that a load can be held over is three. Therefore, if a load of demand has not been loaded into a car within 3 days after that demand is created, then that demand is destroyed.

The final input under shipper control is the number of days that is spent loading or unloading a car. The Base Case assumes that loading or unloading takes 1, 2, or 3 days with respective probabilities 0.55, 0.35, and 0.10. It is assumed that this probability distribution is the same for all railroads, the same for loading as for unloading, and the same throughout the year.

2.6 OTHER INPUTS

There are a number of other inputs to the model that might be collectively termed technical data:

- the distance in miles between each road
- the expected time it takes a car to traverse a link
- the time that a car spends on the sending road's lines when traversing a link
- the cost of hauling a loaded car a mile
- the cost of hauling an empty car a mile
- the distribution at the beginning of the year of cars owned by each road

These inputs are largely self-explanatory, but a few remarks are called for. The distance between roads probably would not be changed on different runs of the model, but it could be if one wanted to redraw the network pictured in Figure 2. The distances are given in Section A.5. For example, in the base case the distance between roads 3 and 4 is 490 miles; the expected transit time for a car going from road 3 to road 4 is 3 days; 1 day of this time is assumed to be on road 3's lines. These transit times do not include any time in which cars are formed into trains. In effect, this amounts to assuming that cars proceed independently to their destinations instead of traveling in trains.

The Base Case cost of hauling a car a mile is 25¢ if the car is loaded and 20¢ if it is empty; these costs are assumed to be constant no matter how many cars are hauled, to be the same for all railroads, and to be the same throughout the year. These cost assumptions are particularly simplistic; it should not be assumed that they would be carried over into future versions of the model. Finally, at the beginning of the year the cars owned by the railroads must be distributed around the network.

2.7 SUMMARY

This Section has described the inputs to the RPM and has indicated what values those inputs take on in the Base Case. The complete details on these inputs and also on their Base Case values are given in Appendix A. A clear understanding of the model inputs is important since the scope of the model is determined by these inputs; the model can estimate the effect on railroad performance of some policy action if and only if that policy action acts through the inputs to the model. It sometimes takes some imagination to figure out how a policy action affects the inputs; but the inputs are designed to sweep in virtually everything that affects railroad performance, so the RPM is capable of generating answers to a wide range of policy questions. Some examples of how different policies act through the inputs are given in Section 5.

3. MODEL OUTPUTS

3.1 INTRODUCTION

Each run of the Railroad Performance Model (RPM) simulates the operation of the national railroad system for one year. Each separate run of the model is based on different values for the inputs such as government, industry, or shipper policies, and one is typically interested in whether the change in government, industry, or shipper policies improves the performance of the railroad system. Unfortunately, there is no one measure of performance that is completely satisfactory from every point of view. Therefore, the model gathers a variety of different measures of performance that might be of interest to the railroads, shippers, government, or other interested parties.

Each measure of performance is called a "statistic." The statistics gathered by the model fall into two broad categories -- summary statistics and detailed statistics. To make it easy to recognize the outputs, each is stated and marked with a black dot. Details about the outputs and the format in which they are displayed are in Appendix B.

3.2 SUMMARY STATISTICS

The summary statistics described in this section are gathered for each railroad individually and also for the nation as a whole.

Since profit-seeking is a major goal of railroads and since the government is also concerned about railroad profit in the current situation of depressed profits for the railroads, the model collects statistics on

- profit.

That is, the model calculates the profit earned by each railroad during the simulated year, and it also calculates the aggregate profit of all the railroads.

Since car utilization statistics indicate the extent to which cars are being utilized and possible areas of improvement, a number of statistics on car utilization are collected for each railroad individually and also nationally. These statistics include the percentage of time that home cars are:

- loaded
- empty
- loaded and on line
- loaded and off line
- loaded and moving
- loaded and standing

- empty and on line
- empty and off line
- empty and moving
- empty and standing.

Also, the numbers (such as the number of days that home cars are loaded) used to calculate these percentages are collected and displayed. Other statistics gathered that deal with car utilization are:

- average car cycle
- percentage of miles traveled by home cars for which the cars are loaded.

Two of the summary statistics indicate the interdependence of railroads and whether a railroad is a net exporter or importer of cars:

- the number of days that home cars are off line per one hundred days that foreign cars are on-line
- number of foreign cars sent away empty as a percentage of the total number of cars loaded.

Two statistics are gathered to indicate the quality of the service received by shippers:

- percentage of demand that is not carried because of an insufficient number of cars
- percentage of demand subject to car shortages, i.e. percentage of demand that must wait for a car.

3.3 DETAILED STATISTICS

The summary statistics just described are calculated from a number of more detailed statistics which will now be described. In order to facilitate description, we will use road A and road B to stand for any of the ten railroads; it might happen that they are the same road. The following statistics are gathered

- the total number of car-loads of demand that arise during the year with A as origin and B as destination
- the total number of loads that are carried from A to B
- the amount of demand from A to B that is not carried because of an insufficient number of cars
- a frequency distribution showing how long demand at each origin waits for cars
- the number of empty cars owned by A that B sends away
- the number of days that cars owned by A are loaded and moving on B's lines
- the number of days that cars owned by A are loaded and standing on B's lines
- the number of days that cars owned by A are empty and moving on B's lines
- the number of days that cars owned by A are empty and standing on B's lines

- the number of loaded miles that cars owned by A travel on B's lines
- the number of empty miles that cars owned by A travel on B's lines
- the number of car shortages on A's lines.

3.4 SUMMARY

The Railroad Performance Model gathers a large number of statistics on the operation of the nation's railroads during the simulated year. When two runs of the model are made, it is possible to see the effect of the assumed difference in inputs of the two runs in either summary form or in great and intricate detail. Therefore, the model provides a great deal of output, and the user can pick and choose the portions that are of interest to him.

4. MODEL LOGIC

4.1 INTRODUCTION

The inputs and outputs have now been listed. The remaining task is to state how the Railroad Performance Model answers the question: When the inputs are given particular values, what values do the output variables take in response? That is, when all the input information about demand, cost, revenue, per diem rates, car service rules, etc. is specified, how will the railroad system perform? The model logic tells how the RPM answers this question. The model logic consists of five components or "modules," each of which is a model in itself. These five modules are:

- Demand Creation Module
- Demand Servicing Module
- Unserviced Demand Module
- Linehaul Module
- Allocation of Empties Module.

Since each module is a model in itself, it also has inputs, outputs, and logic. Just as the RPM is being described in terms of its inputs, outputs, and logic, each module will be described in the same way. However, there are some new features since each module is part of a larger module, i.e. the RPM. Each module's inputs are divided into two types: exogenous and endogenous. An exogenous input to a module is an input whose value does not vary over the course of the simulation year; for example, the per diem rate is an exogenous input (to the Empty Car Allocation Module) since the per diem rate is constant over the year. The only variables that can be exogenous inputs to a module are those variables listed in Section 2 that are inputs to the RPM. An endogenous input to a module is an input that depends on the operation of the model and, thus, can vary over the course of the simulation year. For example, one of the inputs to the Empty Car Allocation Module is the number of empty cars that a road has on hand on a particular day; this number is not exogenously given; it depends on what has happened in the model up to that particular day, and it will probably change from day to day. Therefore, the number of empty cars that a road has on hand is an endogenous input.

Each module's outputs are divided into two types: endogenous and statistical. An endogenous output of a module is an output that is passed to another module to serve as an endogenous input. For example, the number of empty cars that a road has on line is an endogenous output of the Demand Servicing Module that serves as an endogenous input to the Empty Car Allocation Module. A variable is an endogenous output of one module if and only if it is an endogenous input to another module. Statistical output refers to the information collected about the model's operation; this information is processed and used to calculate the output of the RPM. Throughout this chapter the statistical output will be displayed in tables but not explicitly explained since the discussion in Section 3 makes it self-explanatory.

Each of Sections 4.2 through 4.6 describe the inputs, outputs, and logic of one module. Since each module is called into operation every day, the inputs and outputs refer to one particular day. Once the modules have been described, Section 4.7 ties them all together into the Railroad Performance Model.

The section describing each module begins with a table that gives the module's inputs and outputs; the reader is urged to study these tables carefully.

4.2 DEMAND CREATION MODULE

Table 4-1. Inputs and Outputs of the Demand Creation Module

Input: Exogenous ● the season ● for each origin-destination pair, the probability distributions of daily demand for the peak season and for the slack season Endogenous ● none
DEMAND CREATION MODULE
Output: Endogenous ● 100 origin-destination demands Statistical ● amount of origin-destination demand created

The exogenous inputs to the Demand Creation Module on a particular day are the season (which is either slack or peak) and the probability distributions for demand between each of the 100 origin-destination pairs. Each day this module draws a random number which, along with the probability distributions, is used to generate the endogenous output of

100 origin-destination demands such as the ones given in Table 2-1. The exact process by which the day's demands are created is described in Section A.4.

4.3 DEMAND SERVICING MODULE

Table 4-2. Inputs and Outputs of the Demand Servicing Module

Input: Exogenous • rules that determine which demand is loaded first • car service rules specifying into which foreign cars a load may legally be placed • rules by which a road decides which particular car to load a unit of demand into Endogenous • new demand for each origin-destination pair • amount of held-over demand • stock of empty cars at each road
DEMAND SERVICING MODULE
Output: Endogenous • loaded cars • unserviced demand • new stock of empty cars Statistical • number of origin-destination loads carried • number of days each road's cars are loaded and standing • number of loads carried in each road's cars

It is the job of the Demand Servicing Module to load demand into empty cars, insofar as is possible. Endogenous inputs to this module are the stock of empty cars at each road and also the number of units of demand that require a car, broken down by origin and destination. The Demand Servicing Module first services the held-over demand.' This means that it takes a unit of demand that has been held over from the previous day and scans the stock of empty cars to find a car to load this demand into. If a suitable car exists, then a random number is drawn to determine how many days it takes to load the car. After servicing held-over demand, this module services the new demand that has been created on the day in question. Thus, after the Demand Servicing Module has finished the day's operation, it has produced the endogenous inputs of loaded cars, empty cars for which there is no demand, and demand for which there is no empty car. The loaded cars are passed to the Linehaul Module; the empty cars that are not loaded are passed to the Empty Car Allocation Module; the demand that is not loaded into a car is passed to the Unserviced Demand Module.

4.4 THE UNSERVICED DEMAND MODULE

Table 4-3. Inputs and Outputs of the Unserviced Demand Module

Input: Exogenous • the maximum amount of waiting demand that shippers will tolerate at each road • the maximum number of days that shippers will allow demand to wait for a car Endogenous • the amount of unserviced demand at each road
UNSERVICED DEMAND MODULE
Output: Endogenous • held-over demand Statistical • amount of demand destroyed at each road because of lengthy queues • amount of demand destroyed at each road after having gone unserviced for three days • distribution of waiting times for demand at each road

Unserviced demand is demand that a road has not been able to load into a car. The Unserviced Demand Module receives unserviced demand from the Demand Servicing Module and performs the following steps. First, if a unit of demand has waited the maximum allowed number of days without being loaded into a car, then it is destroyed, i.e. removed from the model. Second, if a unit of demand would cause the queue of demand waiting at a road to exceed a specified number, which is interpreted to be the longest queue that shippers will tolerate, then that unit of demand is destroyed. Third, any unserviced demand that is not destroyed is held over until the next day and then passed back to the Demand Servicing Module so that another attempt can be made to load it. This module collects the statistical output listed in Table 4-3.

4.5 THE LINEHAUL MODULE

Table 4-4. Inputs and Outputs of the Linehaul Module

Input:	Exogenous
	• expected transit time on each link
	• rules that govern routing of cars
	• number of days spent on the lines of the sending road when traversing a link
	• probability distribution for unloading time
	Endogenous
	• loaded cars
LINEHAUL MODULE	
Output:	Endogenous
	• additions to the stock of empty cars
	Statistical
	• number of days cars are loaded and moving
	• number of loaded miles traveled
	• number of days cars are loaded and standing

The endogenous input to the Linehaul Module is the stream of just-loaded cars from the Demand Servicing Module. The Linehaul Module determines the links that a loaded car will travel and draws a random number to calculate the number of days that the car requires to traverse each link. That is, the Linehaul Module takes the loaded car through the network one link at a time from origin to destination at the speed implied by the model inputs and random factors. When the car reaches its destination, the Linehaul Module draws a random number to determine the number of days it takes to unload the car; after the car is unloaded, it is placed in the destination road's stock of empties.

4.6 THE EMPTY CAR ALLOCATION MODULE

Table 4-5. Inputs and Outputs of the Empty Car Allocation Module

Input:	Exogenous • the maximum number of empties that each road will hold • the decision rule used by each road in deciding which empties to send away Endogenous • the stock of empties held by each road
	EMPTY CAR ALLOCATION MODULE
Output:	Endogenous • changes in the location of empty cars Statistical • the number of days cars are empty and moving • the number of empty foreign cars sent away by each road

After all of the day's other activities are over, the Empty Car Allocation Module decides what each road does with its stock of empties on hand. The actual number of empties on hand is compared to the maximum number of empties that the road desires to hold. If the number actually held exceeds this maximum number, then the excess foreign empties that are to be sent away are chosen. These cars are routed over the link that takes them toward their home lines; a random number is drawn to determine how many days it takes each car to traverse this link. After the car has transversed this one link, it is placed in the stock of empties of the receiving road, which is not necessarily its owner. Thus, the endogenous output of this model is a change in the distribution of empty cars as empties are shifted from one road to another.

4.7 SUMMARY OF THE MODEL LOGIC

Previous sections in this chapter have described what each module does when called by the RPM. In order to show how these modules are tied together into a unified whole, we will work through the simulation of a typical day for a typical railroad. In this way we will show the order in which the RPM calls the modules and the way that variables are passed from one module to another. The discussion is organized around Figure 3, which shows the modules and the endogenous variables passed between them. To avoid cluttering the diagram, only the endogenous inputs and endogenous outputs of each module are shown.

Consider now one typical day on one typical railroad. The day begins with four endogenous variables that have been generated by the past workings of the model: the amount of held-over demand, the stock of held-over empty cars, the number of newly arrived empty cars, and the cars that have just been loaded and are ready to begin linehaul. Exactly where these variables come from will be seen as the discussion progresses. On a typical day the RPM goes through seven steps.

a. The Linehaul Module checks the loaded cars that arrive at this railroad on this day. Those that have not yet reached their destination are routed over the next link they

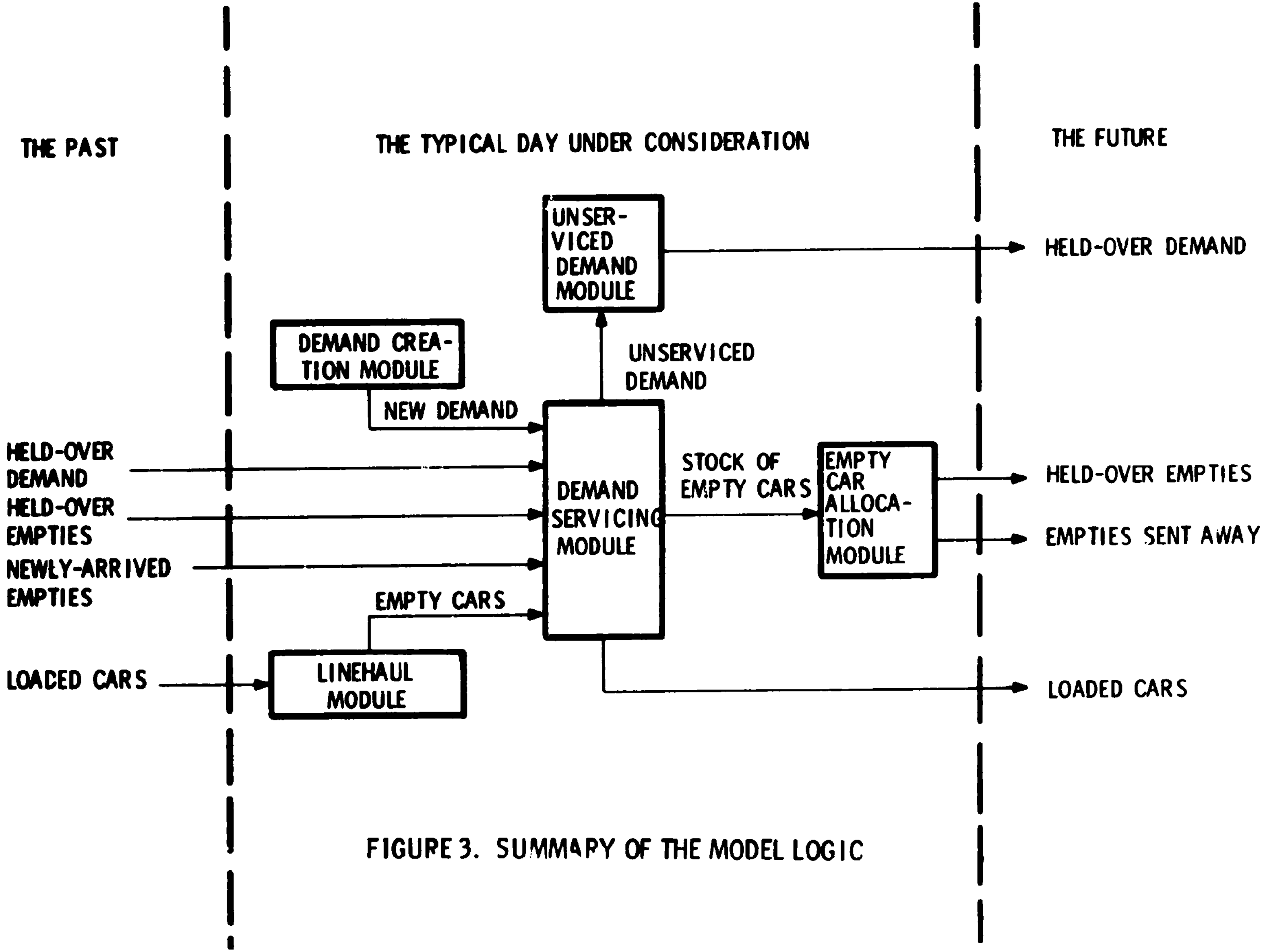

FIGURE 3. SUMMARY OF THE MODEL LOGIC

are to traverse. Those that have reached their destination are sent to the consignee to be unloaded.

b. The stock of empties is created. To do this, start with the stock of empties that has been held over from the previous day. Add to this any newly-arrived empties and any cars that will be unloaded on this day. Thus, it is assumed that all cars that will be empty during the day are available at the beginning of the day.

c. The held-over demand is loaded into this stock of empty cars, insofar as is possible, by the Demand Servicing Module. Any demand not loaded is sent to the Unserviced Demand Module. The loaded cars are sent to the Linehaul Module, but this is in the future since it takes at least one day to load a car.

d. The Demand Creation Module creates the new demand for the day and passes it to the Demand Servicing Module.

e. The new demand is serviced by the Demand Servicing Module; note that held-over demand is given priority over the new demand. Any unserviced demand is sent to the Unserviced Demand Module. Loaded cars are sent as a future input to the Linehaul Module. Cars that have no demand loaded into them are passed to the Empty Car Allocation Module.

f. The Unserviced Demand Module either destroys the unserviced demand or holds it over as an input to the next day's operation of the Demand Servicing Module.

g. The Empty Car Allocation Module either holds the empty cars where they are or sends some of them away. After a journey of one or more days, these cars become newly arrived empties and are an input into the Demand Servicing Module.

These seven steps are then repeated for the rest of the railroads. This completes the discussion of how the RPM simulates a single day's operation. Since the simulation of this day produces the four endogenous inputs that are needed for the next day's simulation, the next day can now be simulated. Thus, the RPM steps through the year simulating one day at a time until 364 days have been simulated, the statistics gathered daily are processed to produce the annual statistics that comprise the RPM output, and the simulation stops.

5. EXAMPLE APPLICATIONS OF THE MODEL

5.1 INTRODUCTION

Modeling can be broken down into two stages--specification and application. The specification stage consists of stating the model inputs, the model outputs, and the model logic; the preceding chapters have performed this stage. The application stage consists of making specific assumptions about the values taken on by the input variables and then of calculating the values that result for the output variables. This section deals with the application stage. A sequence of different assumptions about input values are made that correspond to different scenarios of policy interest. The RPM then calculates the resulting values of the outputs by the method of simulation. Appendix C discusses the advantages of using the method of simulation in a model such as the RPM.

A variety of different applications are made to illustrate the wide range of policy questions that the Railroad Performance Model can address. Section 5.2 describes the model's Base Case. Section 5.3 shows how the performance of the railroad system is affected if per diem rates are changed. This case is analyzed in considerably more detail than the other cases to bring out a number of different aspects of the model. Section 5.4 indicates the effect of a change in car service rules on railroad performance.

Section 5.5 investigates the effect of a change in the time it takes to load or unload a car; this can be interpreted as analyzing the effect of a change in the demurrage system. Section 5.6 examines the effect of extraordinarily high and low demand on railroad performance. Section 5.7 remarks on the cost of running the RPM.

Throughout the chapter selected output statistics will be presented as the need for them arises. Appendix K contains the summary output for 18 runs of the model; the more detailed output is available from the author. Exactly what the more detailed output consists of is spelled out in Appendix B; the entire output, both summary and detailed, for the Base Case is displayed in Appendix J. The runs are numbered to make it easier for the reader to keep track of them.

We establish the convention for this chapter that when we speak of the railroad system, we are talking about the "model" railroad system as specified in the RPM rather than about the real railroad system that is out there operating in the real world. For example, the statement "Aggregate railroad profit rises when the daily per diem rate is raised from $5 to $6" is understood to be true for the RPM but not necessarily true for the real world. This convention is necessary because, as explained in Section 1.6, the current, preliminary version of the RPM is not necessarily a reliable predictor of what would happen in the real world. Nevertheless, even though we cannot say with assurance say that the conclusions about the operations of the RPM are necessarily true for the real world, we can say that those conclusions might hold for the real world. In other words, the RPM suggests what might plausibly be true in the real world. Moreover, the analysis in this section demonstrates the types of analysis that could be carried out if an improved and reliable version of the RPM were available.

One question about the RPM is: How stable is the output? The RPM contains three categories of random variables: linehaul transit times, loading and unloading times, and daily demands. The output of the RPM for any one run depends on the particular stream of random numbers that are drawn during that run. Would the output be greatly affected if a different stream of random numbers were used? A qualified answer is: The output is relatively insensitive to the particular stream of random numbers used. An explanation of both the argument supporting this answer and also the significance of this answer can be found in Appendix D. It should be noted that it was possible to write the computer program so that the daily demands, though randomly generated, are exactly the same for the runs mentioned in Sections 5.2 through 5.5. This feature strengthens the inference that changes in output are due to changes in inputs rather than to random variations. This point is explained further in Section D.3.

5.2 THE BASE CASE

The run of the RPM in which the inputs are given the values corresponding to the status quo is termed the Base Case, which is numbered Run 1. The Base Case is important because in each application of the model an alternative to the status quo is represented by changing one or more of the Base Case values of the inputs. The alternative to the Base Case that is being studied at any one time is called the Test Case. The output of the Base Case and Test Case are compared and any difference is assumed to be the effect of changing the values of the inputs. Since the applications in this section are only examples, the output that receives most of the emphasis is aggregate railroad profit. Aggregate railroad profit is used because it is of considerable importance and because it is a single number that is easy to use as an illustration; it should not be concluded that aggregate railroad profit is the only important measure of railroad performance.

5.3 EFFECTS OF A CHANGE IN THE PER DIEM RATE

5.3.1 Qualitative Effects of a Change in the Per Diem Rate

The Base Case value for the (daily) per diem rate is $5.00. Section 5.3.2 discusses the quantitative effects of raising that rate to $6.00; then Section 5.3.3 investigates the quantitative effects of raising the rate to $7.00, $8.00, $9.00, and $10.00. However, before discussing these quantitative effects, we need to outline the qualitative effects that the RPM allows.

The two types of qualitative effects that can result from a rise in the per diem rate are termed operational effects and distributional effects. Operational effects are defined as changes in the model outputs brought about by a change in operating decisions. The only immediate effect on operating decisions caused by a rise in the per diem rate is that railroads will send more foreign empties away. However, sending away more empties can cause repercussions that ramify through the network. In particular, there are three possible effects on aggregate railroad profit. First, as more foreign empties are sent away, an added cost is incurred in transporting these empties. Second, if the cars are sent to areas where there is excess demand, then more loads are carried and aggregate profit increases. Third, if the cars are more likely to be used by the roads that send them away rather than by the roads that receive them, then this would tend to decrease the number of loads carried and, thus, to decrease aggregate railroad profit.

It should be noted that in the current version of the RPM the only way that a rise in the per diem rate can affect railroad operations is by affecting the number of empty cars each railroad is willing to hold. In the real world there are other channels through which a change in the per diem rate might work (e.g. by affecting the decision on which cars to load particular units of demand into), but these other channels do not appear in the current version of the RPM.

The other type of effect that a rise in the per diem rate can have is termed the distributional effect. In order to see what the distributional effect is, suppose just for this paragraph that a rise in the per diem rate has no effect on operational decisions. That is, suppose that railroad operation is identical before and after the rise in the per diem rate; exactly the same number of loads are carried. In this case, aggregate railroad profit would not be affected by the rise in the per diem rate, but the distribution of that fixed aggregate among the individual railroads would be affected. The roads that were net exporters of cars would receive larger per diem payments and their profits would go up. The roads that were net importers of cars would pay out more in per diem payments and their profit would go down. Aggregate railroad profit, however, would be unaffected since whatever one railroad would lose, another railroad would gain. Therefore, we say that the rise in per diem rates has a distributional effect. If we drop the assumption that railroad operation is unaffected by the rise in the per diem rate, then the distributional rate is still present, though it is somewhat obscured by the change in aggregate profit.

In short, the qualitative effect on aggregate profit of a change in operating decisions brought about by a rise in the per diem rate has three components. First, aggregate profit is lowered since a cost is incurred in hauling around empties. Second, aggregate profit might be raised since the roads that receive the empties might originate more loads. Third, aggregate profit might be lowered since the roads that send away the empties might originate fewer loads. The distributional effect has no effect on aggregate profit. Therefore, since one factor works to increase aggregate profit and two factors work to decrease it, a qualtitative analysis cannot determine whether a rise in the per diem rate will increase or decrease aggregate profit; a quantitative analysis is needed.

(Note: It is a fact--both in the real world and in the current version of the RPM--that railroad revenue might go down even if the number of loads carried goes up. Nevertheless, the "number of loads carried" is often used in the discussion where "revenue" would be more appropriate. There are two reasons for this. First, while it is logically possible that loads carried could go one way while revenue went the other, this is unlikely. Second, due to an oversight, the computer program for the current version of the RPM does not print out the figure for revenue.)

5.3.2 Quantitative Effects of a Change in the Per Diem Rate

The Base Case Run of the RPM, designated Run 1, assumes that the value of the daily per diem rate is $5.00. We now compare the output generated by that run of the RPM with the output generated by the Test Case, numbered Run 8, which assumes that the per diem rate is $6.00. In the course of discussion, reference will be made to the summary outputs displayed in Appendix K; reference will also be made to the detailed output, which is only displayed for the Base Case, in Appendix J.

We can begin the analysis of the effect of raising the per diem rate to $6.00 by comparing the profit that results in each case. Table 5-1 gives the profit for each road and for the aggregate of all roads. It is seen that the increase in the per diem rate raises aggregate profit by $194 thousand. The qualitative discussion in the previous section implies that since profit rises, it must be true that the number of loads originated also rises. This statement can be verified by looking at Table 5-2; 45,190 loads are originated in the Base Case and 45,394 in the Test Case, Not only does the increase in the per diem rate help the railroads (in the sense of aggregate railroad profit being raised), but it also helps shippers. One way to see this is to note that more of shippers' demands for railroad services are met since more

Table 5-1. Profit for Each Road (in thousands of dollars)

Road	Base Case	Test Case	Change
1	734	738	+4
2	4315	4342	+27
3	2237	2205	-32
4	3340	3349	+9
5	469	470	+1
6	2034	2055	+21
7	3455	3510	+55
8	523	542	+19
9	862	885	+23
10	3382	3451	+69
Total	21,353	21,547	+194

Table 5-2. Number of Loads Originated

Road	Base Case	Test Case	Change
1	2927	2922	0
2	7358	7405	+47
3	7619	7707	+88
4	8574	8579	+5
5	1395	1395	0
6	4913	4912	-1
7	5256	5259	+3
8	2013	2026	+13
9	1667	1677	+10
10	3473	3512	+39
Total	45,190	45,394	+204

loads are carried; another indicator is the drop in the incidence of car shortages from 8 percent in the Base Case to 4 percent in the Test Case.

However, in many cases one is not content to know just whether aggregate railroad profit is affected; he will also be interested in how the profit of each railroad is affected by the policy change. Table 5-1 shows that the profit of every railroad except for road 3 rises. In order to illustrate the use of the model, we will analyze in detail the reason why railroad 3's profit declines even though the profit of every other railroad rises. One might think that the explanation of road 3's deviant response would run as follows: "Since aggregate railroad profit rose because more loads were originated, it must be true that the number of loads originated by road 3 went down; or perhaps the number of loads went up, but not by enough to offset the increased cost of transporting empties." While this is an attractive speculation, it must be rejected. As Table 5-2 shows, the number of loads originated by road 3 did not decline; in fact, what this table shows is the parodoxical result that the number of loads originated increased for road 3 by <u>more</u> than for any other road. Therefore, we must look elsewhere for the explanation for the fall in road 3's profit.

We can take the following comprehensive approach. When the per diem rate rises, the effect on road 3's profit can be divided into four components:

- change in profit from hauling more or fewer loads, as the case may be
- decrease in profit due to the greater number of empty car miles
- change in the daily per diem payments received and paid
- change in the mileage per diem payments received and paid.

Each of these components will now be discussed. As the discussion proceeds, the entries in Table 5-3 will be explained.

Table 5-3. Components of Change in Railroad 3's Profit (Thousands of dollars)

Component	Change in Profit
Revenue from extra loads	+22
Cost of extra transport of empties	- 5
Daily per diem	-44
Mileage per diem	- 6
Total	-33

First, consider the change in the revenue that road 3 earns from hauling loaded cars. The number of miles that loaded cars travel on road 3's lines rises in the Test Case by 29,470 miles (= 2,820,700 - 2,791,230). Since it is assumed that the revenue, net of cost, earned per loaded car mile is 75¢, it follows that road 3 earns an added revenue of 22 thousand dollars (= 29,470 x 0.75) in the Test Case. This amount is entered in Table 5-3.

Second, the number of empty miles that cars travel on road 3's lines increases by 24,800. Since the cost to road 3 is assumed to be 20¢ per car-mile, this means that profit is decreased by $5 thousand (= 24,800 x .2). This amount is entered in Table 5-3.

Third, it can be calculated, though the calculations are not shown here, that in the Base Case the amount of daily per diem charges received by road 3 exceeded the amount paid by $54,045 (= $150,895 - 96,850). In the Test Case, the net receipts fell to $10,014 (= $144,060 - 134,046). Therefore, the effect on profit of the change in net receipts of daily per diem payments is a decrease of $44,031 (= $54,045 - 10,014). This amount is entered in Table 5-3.

Fourth, in the Base Case the mileage per diem payments received is a net of $94,007; in the Test Case this falls to $87,817. Therefore, the decrease in road 3's net mileage per diem receipts in the Test Case is $6190. This amount is entered in Table 5-3.

We can now summarize, using the concepts of operational and distributional effects introduced in the preceding section. When the per diem rate is raised, more foreign empty cars are sent home by all roads. In particular, the number of foreign empties sent home by road 3 rises from 0 to 21; the number of road 3's cars which are sent back rises from 630 to 823. This added movement of empties adds $5 thousand to road 3's cost. However, in the Base Case road 3 was plagued with car shortages; 10 percent of the loads originating at road 3 had to wait at least one day for a car; 88 loads were not loaded at all. In the Test Case road 3 has more empty cars available, and this results in car shortages being eliminated and in revenue being increased by $22 thousand. However, road 3 had so many cars on line that not all could be loaded; the number of days that home cars are on line and idle rose from 3208 in the Base Case to 8837 in the Test Case, In large part, the home cars that are on line and idle in the Test Case were off line earning per diem payments in the Base Case. The Test Case, thus, leads to a decrease of $44 thousand in road 3's collection of daily per diem charges and a decrease of $6 thousand in mileage per diem charges. In short, if we consider only the operational effects, road 3 is helped by the rise in per diem rates since the increase is revenue more than compensated for the increase in the cost of hauling empties. But when considering one railroad, we must take into account the distributional effects since they do not cancel out as they do when considering the railroads as a whole. We see that the drop in per diem receipts overwhelms the beneficial operational effects, so road 3 turns out to suffer from the rise in per diem rates. The reason why only road 3 suffered a fall in profit in the Test Case is because, with the exception of road 9, only road 3 had a major influx of home cars that were sent back by other roads. Since this is only an example rather than an exhaustive analysis, we will cut the analysis off here; it is left as an exercise for the interested reader to figure out why road 9's profit rose rather than fell.

This example has shown not only how the outputs of the RPM communicate to the user of the model the major effects of a policy change but also how the detailed outputs can be used to track down an explanation of why the observed effects came about. The process of tracing out these effects can help one appreciate some of the nuances of the railroad system and can build up one's intuition about how that system operates.

5.3.3 What is the Optimal Per Diem Rate?

Since there are many different per diem rates that could be chosen and since different rates have different implications for the performance of the railroad system, a question that naturally arises is: What is the optimal per diem rate? This question cannot be definitively answered here since there is no generally accepted criterion for deciding what is optimal [see Appendix G and Oiesen, 1976a, pp. 16-19]. What can be done here is to illustrate how the RPM can be used to generate the type of information that would be needed to pick out the optimal per diem rate once one had chosen a criterion.

For concreteness, concentrate on how aggregate profit responds to changes in the per diem rate. Six runs of the RPM have been done for different per diem rates; otherwise, they all embody the Base Case assumptions. Table 5-4 lists the numbers assigned to these runs, the per diem rate assumed for each run, the aggregate profit that results, and the number of loads carried by the railroads. Figure 4 graphs the aggregate profit as a function of the per diem rate; line segments are used to connect the six computed points of this function.

When the per diem rate is changed from $5.00 to $6.00 or from $7.00 to $8.00, then aggregate profit rises. That is, the increase in revenue generated by the greater number of loads carried more than offsets the cost of the increased transport

Table 5-4. Various Per Diem Rates and Their Implications

Run	Per Diem Rate	Profit(1000's)	Loads Carried
1	$5	$21,353	45,190
8	$6	$21,547	45,394
9	$7	$21,522	45,534
10	$8	$21,629	45,654
11	$9	$21,622	45,688
12	$10	$21,620	45,683

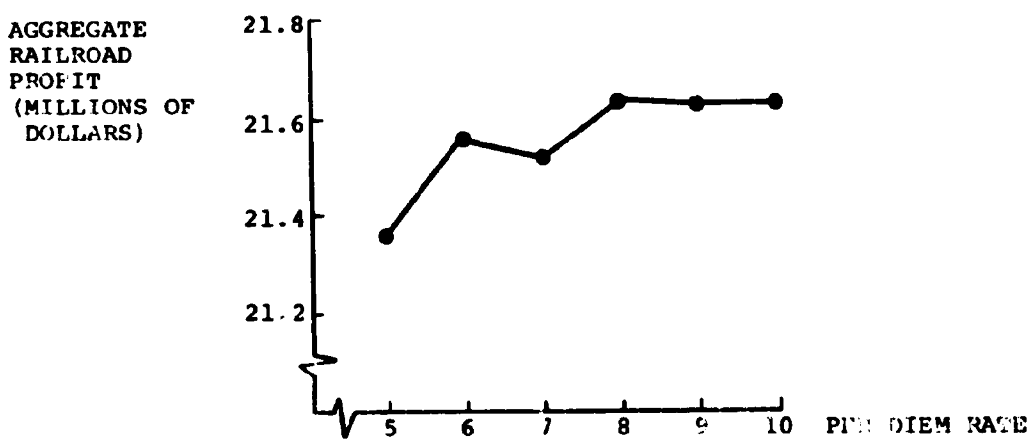

FIGURE 4. PROFIT AS A FUNCTION OF THE PER DIEM RATE

of empty cars. When the per diem rate is raised from $6 to $7 or from $8 to $9, the number of loads carried rises, but the resulting added revenue is insufficient to offset the added cost of hauling empties, so the aggregate profit falls. When the per diem rate is raised from $9 to $10, there is so much shuffling of empties that slightly fewer loads are carried; the resulting drop in revenue, compounded by the increased cost of hauling empties, causes aggregate profit to fall.

In short, if the goal is to choose the per diem rate that maximizes aggregate profit, then it appears that $8 is a good candidate for the optimal per diem rate. However, since the function that relates aggregate profit to the per diem rate is evidently somewhat complicated, further analysis would be necessary before one could have confidence in this conclusion. (Note: The author is not advocating that the objective should be to maximize aggregate profit; this objective is only used as an example.)

5.4 EFFECT OF A CHANGE IN CAR SERVICE RULES

When one railroad has on its lines a car belonging to another railroad, the car service rules specify the regulations that the first railroad must observe in dealing with the foreign car. It should be emphasized that the car service rules are not just an abstract concept; they are widely seen as an effective policy tool, and they are actually used to try to bring about the desired amount of cooperation among railroads. The importance of car service rules is brought out by a recent issue of Trafiic World which describes the Interstate Commerce Commission's rationale for a temporary change in car service rules:

> In ordering changes in present regulations, the Commission said that the freight car shortage is "impeding both the domestic and export movements of agricultural, mineral, forest, and manufactured products and other commodities."
>
> The Commission described as "ineffective" the present car service rules, regulations and practices of railroads governing the use, supply control, movement, distribution, exchange, interchange, and return of freight cars to meet the requirements of shippers [Traffic World, 1975, p. 46].

The point is that the idea of adopting alternative car services rules is a live issue, and it would be useful to have a method such as the RPM that could predict the effect of alternative car service rules on railroad performance.

The Base Case assumption about car service rules has two aspects. First, a road can load a unit of demand into any empty foreign car as long as the loaded car is not sent away from its home lines. Second, a road can hold onto an empty car as long as it wishes. We now investigate two different alternatives to the Base Case car service rules; each one of these alternatives modifies one of these aspects of the Base Case.

The first alternative, designated Run 13, assumes that a load can only be legally loaded into a car belonging to either the destination road or the originating road. This alternative might be advocated by one who thought that the problem was that cars were not being returned to their owners quickly enough and that this alternative would remedy the problem. The RPM can be used to determine whether this view constitutes a correct assessment of the problem. Table 5-5 gives the key data from the output. It is seen that

Table 5-5. Comparison of Alternative Car Service Rules

Run	Aggregate Profit (1000's)	Loads Carried	Percentage of time empty and standing
Base Case(1)	$21,353	45,190	29
Test Case (13)	$19,353	42,344	34

the change in car service rules lowered the aggregate profit by $2 million, or about 10 percent. The reason for the drop in profit can be inferred from other data displayed in the output. Many units of demand that were loaded into foreign cars in the Base

Case were not loaded in the Test Case because of the restrictive car service rules. Thus, out of the total of 45,700 units of demand that were created, the number loaded fell from 45,190 in the Base Case to 42,344 in the Test Case. These foreign cars then stood idle since there was no demand suitable for them to carry, and the percentage of time that cars were empty and standing rose from 29 to 34 percent. For this reason, this first alternative set of car service rules caused aggregate profit to fall. (In fact, as the detailed output in Appendix K shows, the profit fell for every road except road 8.) One problem with the reasoning used by the advocate of this alternative that is uncovered by the RPM is that there is no provision for getting the empty cars back to home lines. This finding of the RPM, one might say, is obvious; however, in situations more complicated that this example alternative, things might be more complicated so that the effect of a policy change is not at all obvious. It is in these cases that the RPM can be of value.

The second alternative set of car service rules to be examined here leaves intact the Base Case assumptions about which foreign cars demand may be loaded into; the change is that a road is not allowed to hold any empty foreign cars. In other words, this alternative, designated Run 19, alters the Base Case by requiring that all foreign empties be sent away at the end of every day. Again, one might advocate such an alternative if he thinks that railroad performance could be improved if cars were more speedily returned to their owners. The output from the Base Case and this new Test Case shows that this change in car service rules does indeed increase aggregate profit--from $21,353 thousand to $21,620 thousand. A somewhat roundabout route will be taken in explaining the significance of this result.

Section E.3.5 argues that car service rules and the per diem rate are policies that both work toward the same goal--to achieve the desired amount of cooperation among railroads. That both policies work toward the same goal is brought out by the following theorem. ("Railroad operations" is used as a shorthand term to cover the activity of cars, e.g. being loaded, moving, standing idle. This means that, in the context of the RPM, railroad operations include everything except for those quantities that are measured in dollars.)

Theorem: Railroad operations are <u>exactly</u> the same in the following two situations:

a. the Base Case is altered by changing the daily per diem rate from $5 to $10;

b. the Base Case is altered by replacing the assumption that a road can hold foreign empties as long as it wishes with the assumption that all foreign empties are sent away at the end of each day.

How does one prove such a theorem? One could simulate the two situations with the RPM and see if the two simulations yielded the same output (except for the output on profit). However, the theorem is more general than this. It says that all possible pairs of simulations of these two situations yield identical railroad operations, where a "pair" of simulations means that the same sequence of random numbers is used to simulate each of the two situations.

The operation of the railroad system will be the same in two situations if those factors that affect operation are the same in the two situations. The factors that affect operations are:

- the random factors
- the decision rules used by decision-makers
- the technical relationships (e.g. transit times) that determine what effects the random factors and decisions will have.

The criterion of proof that is offered is: The operation of the railroad system will be the same in two situations if these three factors are the same in both situations. This criterion allows a proof to be constructed.

Proof: First, consider the random factors. Since the random factors that influence linehaul transit times, loading and unloading times, and daily demands are not a function of either the per diem rate or the car service rules, the random factors are identical in the two situations.

Second, consider the decision rules. Section A.3 spells out for each railroad the decision rule that gives the maximum number of empty cars that that railroad wishes to hold as a function of the per diem rate. When the per diem rate is set at $10, then the decision rule for every railroad is to hold no foreign empties. (The reader will not understand this unless he has read Section A.3.) This is the same decision rule that each railroad is compelled to follow under situation b); the only difference is that situation b) states explicitly what the decision rule through be, whereas situation a) induces this decision rule through an economic incentive. Therefore, these two situations lead to the same decision rules on sending away foreign empties. Inspection of the other assumptions reveals that no other decisions depend on per diem rates or car service rules. Thus, these two situations lead to identical decision rules.

Third, consider the technical relationships. Inspection of the model logic show that no technical relationship depends on the per diem rates or car service rules except for the technical relationship that governs the amount of per diem charges paid from one road to another. Since the amount of per diem paid affect profit but not railroad operations, none of the technical relationships that affect railroad operations is affected. This completes the proof. Q.E.D.

Several remarks on this theorem are in order.

First, this theorem is significant not because of the exact equality of railroad operations in the two situations since the exact equality is an accident of the model logic and Base Case inputs. Rather, the significance lies in showing that the per diem rate and car service rules are two instruments to be used in pursuing the goal of satisfactory railroad performance and that these two instruments are partial substitutes for each other.

Second, though this theorem proves the equality of railroad operations and, hence, by implication, of aggregate railroad profit in the two situations, the distribution of that aggregate among the ten railroads is different in the two situations. Table 5-6 shows the profit earned by

Table 5-6. Profit in Runs 12 and 19
(thousands of dollars)

Road	Alternative Car Service Rules (19)	Per Diem Rate Equals $10 (12)	Difference (19)-(12)
1	776	753	23
2	4333	4359	-26
3	2182	2190	- 8
4	3317	3319	- 2
5	481	473	8
6	2077	2086	- 9
7	3545	3483	62
8	538	551	-13
9	883	890	- 7
10	3488	3515	-27
Total	21,620	21,620	0

each road in the two situations. It is seen that even though aggregate railroad profit is the same, its distribution is not. Some roads are better off in one situation, some in the other. This difference flows from the difference in per diem payments among roads in the two situations. In particular, those roads that are net exporters of cars are better off under the higher per diem rate; those that are net importers of cars are better off under the alternative car service rules.

Third, an example of the way that car service rules and the per diem rate work in tandem to affect railroad performance can now be explained. Suppose that the alternative car service rules are adopted; the aggregate railroad profit will then be $21,620 thousand. Exactly how this aggregate profit is split among the railroads can then be affected by the per diem rate that is chosen. That is, if a higher per diem rate is chosen, then the profit is shifted toward those railroads that are net exporters of cars. Any of the profit figures that are between those shown in Table 5-6 could be achieved. For example, if a per diem rate of $7.50 were chosen along with the alternative car service rules, then each road's profit would be the average of the two figures shown in Table 5-6. This shows how these two policies are complementary and can be used together to achieve desired railroad performance.

Fourth, because the effect on railroad performance of choosing a particular level of the per diem rate depends on the car service rules in effect, and vice-versa, both policies should be chosen at the same time instead of one after the other. That is, if the best per diem rate is chosen, subject to car service rules being held constant, and if the best car service rules are then chosen, subject to the per diem rate being held constant at the level just chosen, then the per diem rate and car service rules which individually are best might not be best together; this type of sequential decision-making is called sub-optimization. Therefore, in theory, gains might potentially be realized if per diem rates and car service rules were considered together instead of separately, as they have been in the past for the most part. Whether large gains could be achieved in practice is an open question. An improved version of the RPM could throw light on this question.

5.5 EFFECT OF A CHANCE IN THE DEMURRAGE SYSTEM

One policy change often discussed is a change in the demurrage system [see Reebie Associates, 1972]. The demurrage system specifies how many free days shippers and receivers of cars are allotted to load and unload cars, and it also specifies the dollar penalties paid by shippers and receivers if they hold cars for more than the allotted number of days. The policy change that is usually mentioned is a tightening of the demurrage system that will cause shippers and receivers to hold cars for less time; the alleged benefit is that the railroads will have use of their cars for a greater amount of time, and this will allow them either to take in more revenue or to cut their investement in cars.

Since a change in the demurrage system affects railroad operations by changing the amount of time that cars spend being loaded or unloaded, a change in the demurrage system is modeled in the RPM by changing the probability distribution for loading and unloading time. The Base Case assumption is that the number of days taken to load or unload a car is 1,2, or 3 days with respective probabilities .55, .35, and .10. As a Test Case, designated Run 14, assume that the demurrage system is changed so that the loading or unloading takes 1 or 2 days with respective probabilities .75 and .25. (It should be emphasized that these probabilities are not calculated by or provided by the RPM. These probabilities must be furnished by the user of the RPM; the user might get the probabilities from empirical data or from a model that is

designed to yield such probabilities as outputs.)
Demurrage payments are not reflected in the current version of the RPM.

Table 5-7. Effect of a Change in Demurrage Rates

Run	Aggregate Profit (1000's)	Loads Carried
Base Case(1)	$21,353	45,190
Test Case(14)	$21,656	45,525

As Table 5-7 shows, things do work out as expected. When the demurrage system is tightened, the aggregate profit and the number of loads carried both increase.

This example application of the RPM has shown how the effect of a change in the demurrage system can be predicted by the RPM even though the demurrage system is not a direct input to the model. This example can be generalized. When one wants to predict the effect of a policy change on railroad performance, he must first decide how that policy change will affect the inputs to the RPM; once that is done, the RPM can be used to generate the desired predictions. Section 6.3 elaborates on this point.

It should also be pointed out that in this particular application the RPM only tells half the story; it only predicts the effect of a change in the demurrage system on the railroads and says nothing about the effect on shippers (except that more loads are carried). A decision-maker would presumably take into account both the gain to the railroads and also the loss or inconvenience to the shippers before deciding whether a change in the demurrage system was a good idea.

5.6 EFFECT OF CHANGES IN DEMAND

There are two reasons why one might want to use the RPM to investigate the effect of changes in demand. First, there are government policies (such as macroeconomic policy or changes in regulation of railroads or of other modes) that can affect demand, so one might want to use the RPM to predict the effect that these policies would have on railroad performance and to determine if any policy change (e.g. of per diem rates or car service rules) would be needed in response. Second, since one does not know for sure what the future level of demand will be when considering a policy, one might want to do a sensitivity analysis to determine how sensitive the railroad performance yielded by a policy is to variations in demand. Table 5-8 contains hypothetical numbers that have been made up to show why a sensitivity analysis might be valuable. Suppose that A and B are two alternative policies

Table 5-8. Hypothetical Aggregate Profit Resulting from Different Combinations of Policies and Levels of Demand

	State of Demand		
Policy	Low	Average	High
A	10	21	22
B	19	20	21

under consideration. If the policies are compared when demand is average, then policy A shows a slightly higher aggregate profit, and one might conclude that A is the better policy

However, when it is realized that demand might well be low and that policy A yields a much lower aggregate profit when demand is low, this finding calls into question the conclusion that A is the better policy. In short, sensitivity analysis such as this can be valuable because it uncovers information about alternative policies that can than be valuable to a decision-maker.

Table 5-9 is analogous to Table 5-8, except that Table 5-9 contains information generated by runs of the RPM. The two alternative policies considered are setting the per diem rate at $5 or $10. The heading "slack" means that the

Table 5-9. Aggregate Profit Resulting from Different Levels of Demand and Different Per Diem Rates

	State of Demand		
Policy	Slack	Average	Peak
$ 5.00	18,802 (15)	21,353 (1)	23,296 (16)
10.00	18,985 (17)	21,547 (12)	24,055 (18)

slack season level of demand is assumed to exist for the entire year; "Peak" means that the peak season level of demand exists for the entire year. "Average" means that the Base Case assumptions hold, i.e. demand is slack in the first and third quarters and peak in the second and fourth. The aggregate railroad profit is shown in Table 5-9 for each level of demand and for each per diem rate. The numbers in parentheses refer to the run number that generated the profit figures. The differences in the results, while significant, are not as dramatic as in the hypothetical example; however, finding out that there is no joker in the deck can be useful for a decision-maker.

5.7 REMARKS ON THE COMPUTER

An Amdahl 470 V/6 computer was used for the runs reported in this paper. The Base Case run took 3.3 minutes; other runs took approximately the same time. At a cost of $25 per minute, this means that a typical run of the current version of the RPM costs between $80 and $85. Appendixes I and J contain documentation of the computer program.

5.8 SUMMARY

This section has given a number of examples of how the RPM can be applied. Rather than recapitulate the applications, this summary will restate in a general form the lessons that have been learned about how the RPM can be useful to decision-makers and researchers. The exposition proceeds by answering three questions:

- What government and industry policies can the RPM be used to investigate?
- What types of questions can the RPM answer about those policies?
- How can the RPM aid the process of developing new policies?

What policies can the RPM be used to investigate? The general answer to this question is: The RPM can investigate any policy that exercises its effect through the model inputs. Since the RPM has been constructed so that virtually all policies work through its inputs, a very wide range of policy alternatives can, in principle, be investigated.

From the point of view of the RPM there are two different types of policies. One type of policy is represented directly in the inputs of the RPM. The per diem rate is an example of this type of policy since it is both a model input and a policy. The second type of policy is one which affects inputs but which is not itself an input. The demurrage system is an example of such a policy since the demurrage system is not a model input; the demurrage system affects railroad operations through its effect on the input of loading and unloading time. The distinction between these two types of policies is important because it is easier to apply the RPM to the first type of policy. That is, in order to investigate the effect of a change in the per diem rate, all that needs to be done is to change the value of the per diem rate input. But in order to investigate the effect of a change in the demurrage system, one must first determine how the new demurrage system affects the loading and unloading times--and this could be a non-trivial task. Section 6.3 discusses this topic further.

What types of questions can the RPM answer about those policies? The general answer to this question is: When particular values are assumed for the inputs, the RPM can predict the values of the outputs that will result. More specifically, there are two types of answers that the RPM can yield. The first type of answer is a prediction of the most likely effect of a policy or of a set of policies. There are a number of ways in which one or more inputs could be changed and one or more runs of the RPM made to estimate the most likely effects of these changes. Perhaps a single alternative value for some input would be tried. Perhaps a sequence of different values for an input would be run so that railroad performance could be expressed as a function of this input. Perhaps two inputs would be changed on the same run to investigate their joint effect.

The second type of answer that the RPM can yield is a prediction of the sensitivity of railroad performance to variations in some input. Section 5.6 contains an example of how the RPM can be used to analyze the sensitivity of output to changes in demand. If the decision of what policies to adopt were to be analyzed using the theory of decision-making under uncertainty, a sensitivity analysis using the RPM could provide the probability distributions over outputs that this theory would require. This topic is discussed further in Appendix G.

<u>How can the RPM aid the process of developing new policies?</u> The user obviously cannot use the RPM to investigate the effects of a policy until he has a particular policy in mind; nevertheless, the RPM can be used to jog his imagination and to help him think up new policies.

To see how the RPM can be used to develop new policies, suppose there is some particular policy whose effect the user wants to investigate. Before the RPM is run with this policy, the user typically has two types of expectations about what the output of that run will show. First, he anticipates that various aggregates will behave in certain ways; e.g., he might think that railroad profit will increase. Second, he anticipates that there will be a specific reason why the anticipated effect will occur, e.g. he might think that railroad profit will increase because more loads will get carried. When the RPM is run to investigate the effect of this policy, the user can look at the output to verify his conjectures. He can look at the aggregate output to see if the policy had the anticipated effect; that is, he can look to see if profit did, indeed, rise. If it did, then he can look at the more detailed output to see if profit rose for the reason that the user had postulated. Either of these expectations might fail to be fulfilled. It might be that profit failed to rise; or if profit did rise, perhaps it rose for some reason other than an increase in the number of loads carried. In either case, the user will then want to examine the detailed output so that he can find out why profit behaved as it did. Once the user has determined why the unexpected happened, then perhaps he can exploit that knowledge to construct a different and more appropriate policy.

In short, the RPM can be used both as a check on intuition and as a tool to build up intuition. The RPM can be used to check one's intuition both on how aggregates respond to policy changes and also on the reasons why aggregates respond as they do. Examining the detailed output and tracing through the effects of a policy change can build up one's intuition about how railroads work and about the channels through which policies exert influence, and it is this augmented intuition that enables the user to conceive of new policies. It is a paradox of modeling that while a model like the RPM is written in mathematics and admits of no vagueness, the benefit derived from using the model largely results from its effect on that subjective factor known as intuition. This, then, explains how the RPM can aid the process of arriving at appropriate policies.

6. EVALUATION OF THE MODEL

6.1 INTRODUCTION

There are three types of information that the Railroad Performance Model (RPM) can provide to a decision-maker or a researcher. First, it yields quantitative information. That is, the RPM calculates the numerical values that result for the outputs (which measure railroad performance) if specific values are assumed for the inputs (which reflect government, railroad, and shipper policies). Second, it provides qualitative information about the effect of a change in the model inputs. For example, if an input (e.g. the per diem rate) is changed, then the model predicts whether outputs (e.g. railroad profit) will increase or decrease. Third, the model provides qualitative information about how railroads work and about the mechanisms through which government policies (or other inputs) exercise an effect on the railroad system. Examples of this type of information were given in Section 5. All three types of information can be useful and valuable. This section is largely concerned with the accuracy and reliability of the information provided both by the current version of the RPM and also by any future, improved version.

The first point is that the specific numbers that are generated by the current version of the RPM are not to be trusted. The numerous simplifying assumptions make it difficult to place any faith in the numbers, especially since some of the numbers (such as average car cycle) conflict with available evidence. Moreover, it is difficult to give a meaningful interpretation to some of the numbers. For example, how does one interpret the Base Case aggregate railroad profit of $21.35 million in light of the assumption that there are only 1000 cars and remembering that the profit calculation does not explicitly take fixed costs into account? In short, some of the numerical output of the current version of the RPM is difficult to interpret, and some of that which can be interpreted is inaccurate.

The second point is that while there is no assurance that the qualitative information provided by the current model is accurate, there is good reason to consider it to be plausible. That is, a qualitative prediction of the model discussed in Section 5.3 is that raising the per diem rate from $5.00 to $6.00 would raise aggregate railroad profit. There is certainly no guarantee that this prediction would hold true in the real world, but it is certainly plausible that it might. If someone argued that a rise in the per diem rate would never, under any circumstance, raise aggregate railroad profit, then the RPM gives a refutation to this argument by showing that there are circumstances under which profit would rise. Moreover, when the RPM output is examined to determine the mechanism through which the rise in the per diem rate increased profit (as was done in Section 5.3.2), this qualitative information is a plausible explanation; perhaps things really work that way, though there is no guarantee that they do.

Therefore, one source of value of the current version of the model is that it points out how the railroad system might operate. But there is another, and probably more important, way in which the current version is valuable -- it points the way to an improved version that can better provide all three types of information. That is, the approach embodied in the current version can be elaborated in order to construct another, improved version. This section describes the problems that would be encountered in developing an improved version and the benefits that would be reaped if an improved version were successfully completed.

The organization of this chapter is as follows. Section 6.2 gathers together many of the assumptions of the current version of the model. This display of the numerous simplifications all together should convince the reader that no trust should be placed in the reliability of the current model. Section 6.3 shows how an improved version of the RPM could serve as a framework that could organize and simplify much of railroad research. Section 6.4 lists various attractive features possessed by the RPM. Section 6.5 discusses two possible obstacles that could hinder further development of the RPM. Section 6.6 discusses weaknesses in the current model and directions in which further development might proceed. Section 6.7 contains a few final remarks.

6.2 RECAPITULATION OF THE MODEL'S ASSUMPTIONS

Since the main assumptions made by the current version of the RPM have been scattered through several chapters and appendixes, they are collected here so that the reader can more easily appreciate the simplifications that have been made.

<u>Background Assumptions</u>

- There are 10 railroads in the country.
- Each railroad has one yard.
- There is one car type.
- There are 1000 cars in the country.
- There is one commodity type.
- There are two seasons -- slack and peak.
- Only full car-loads are carried.
- Cars move independently, not in trains.
- Car service rules are always observed.
- Car service rules apply equally to all cars.

<u>Assumptions About Decision Rules</u>

- The probability distribution of demand for each origin-destination pair is the same for each day during a season.
- Shippers withdraw a unit of demand if the queue of demand waiting for empty cars at a railroad exceeds a specified number.

- Shippers withdraw a unit of demand that is forced to wait more than a specified number of days for an empty car.
- Railroads follow set rules for deciding which empty cars to load demand into, and these rules do not change during the year.
- Each railroad picks the maximum number of empty cars to hold on line each day; this number depends on the daily per diem rate but not on the owner composition of empty cars on line or on any other variable in the model.

Assumptions About Other Inputs

- Per diem rates do not change during the year.
- Car service rules do not change during the year.
- The revenue earned by hauling a loaded car a mile is constant throughout the year and for all railroads and does not depend on any variable in the model.
- The cost of hauling a loaded car a mile and the cost of hauling an empty car a mile are constant throughout the year and for all railroads and do not depend on any variable in the model.
- The probability distribution of the time required to load a car is the same as for the time required to unload a car, and this distribution is the same for all railroads and the same throughout the year.
- The probability distribution of the transit time required to traverse a particular link is the same throughout the year.

Assumptions About Outputs

- A car is considered to be loaded and standing during the entire time it is being unloaded.
- Profit consists only of the variable cost and revenue stemming from car movements.

6.3 THE RPM AS A UNIFYING RESEARCH FRAMEWORK

One role that the RPM can fulfill is that of a unifying framework that organizes rail research. The basis of this claim is that an improved version of the RPM would include as inputs all factors that significantly affect the operation of the railroad system; thus, the effect of any policy on railroad performance can be predicted if it can be determined how that policy would affect the model inputs. This is illustrated in Figure 5.

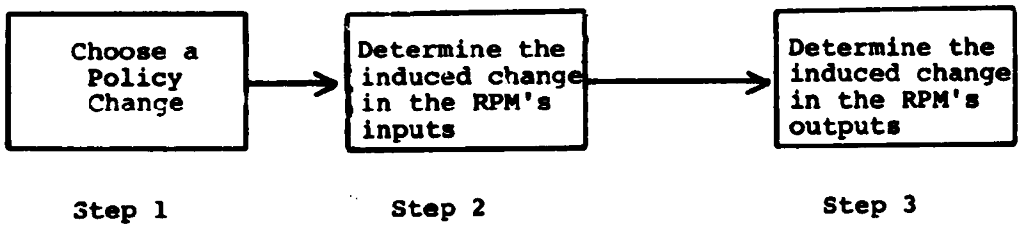

FIGURE 5. THE UNIFIED RESEARCH FRAMEWORK

The general outline of railroad research would have three steps.

<u>Step 1</u>: Choose a policy change (or some type of change) that is to be investigated. For example, the policy change might be to raise the per diem rate, to change the demurrage system, or any number of other things.

Step 2: Determine the change in the RPM's inputs that would be induced by this policy change. If the per diem rate is raised from $5 to $6, then Step 2 is trivial since the per diem rate is both a policy and also an input to the RPM. However, Step 2 is not trivial in the example of changing the demurrage system since the demurrage system is not an input into the RPM. The demurrage system affects railroad operation, it is claimed, by changing the loading and unloading times for cars. Therefore, in this example Step 2 would consist of determining how a specified change in the demurrage system would affect loading and unloading times.

Step 3: Determine the change in the RPM's outputs that would be induced by the change in inputs. This step consists of running the RPM with the new input values as determined by Step 2; the model output is then examined to determine the desirability of the proposed policy change.

In order to bring out the consequences of the RPM serving as a unified framework for railroad research, suppose for this paragraph that an improved, accurate version of the RPM were completed and that we had confidence in it. Then many policy options such as changing per diem rates or car service rules could be immediately investigated since these policies are inputs to the model. Moreover, the research task of investigating the effects of other policy options would be greatly simplified. A researcher would be handed a list containing the RPM's inputs and g. 'n the instructions:

> Determine how the different policy options you are researching affect the RPM's input variables.

The researcher need only concern himself with this task; the RPM will do the rest. In other words, the researcher is only responsible for Steps 1 and 2; the RPM carries out the highly complicated Step 3. Without the RPM, the researcher must perform all three tasks. This is a Herculean assignment, and any number of research tasks have foundered on it. An improved version of the RPM, therefore, would represent not only a unifying framework for railroad research but also a dramatic simplification that could greatly increase the quality of that research.

6.4 ATTRACTIVE FEATURES OF THE RPM

This section describes five features of the RPM which are not present in all railroad models and which, in the author's opinion, enhance its usefulness. (Appendix F contains a more explicit comparison of the RPM with other models.) These features to be discussed are present in the current version, but a future version of the model could better take advantage of them.

First, the RPM recognizes the importance of decisions. Decisions play a key role because the railroad system does not operate automatically or in some mechanical way. That is, the railroad system is not like a ball rolling down an inclined plane whose behavior is governed solely by laws of science. The movement of cars and other aspects of railroad operations are largely governed by decisions made by humans -- by government, railroads, and shippers. Decisions are important not only because they shape railroad operations but also because it is by changing decisions that many policies affect railroad performance. Therefore, a model that is to be useful for policy analysis must pay close attention to decisions.

The RPM incorporates a great deal of detail on decisions by having each railroad make many decisions every day.

These decisions depend on the level and composition of demand, the location of cars, the owner composition of cars, the per diem rate, and other things. Therefore, the model does not assume that the railroad system operates in some mechanical way. Rather, the system operates adaptively, responding to the current state of things. In short, the RPM gives full recognition to the importance of decisions in shaping railroad operation and allows these decisions to respond flexibly to the environment in which the decision is made.

Second, the RPM is not wedded to any one particular theory of decision-making. In the economics literature it is usually assumed that firms (including railroads and shippers) make the decisions that maximize profit. The RPM is consistent with but not tied to this assumption; the RPM embodies a more general theory of decision-making. The RPM assumes that the railroads (and shippers) follow certain decision rules, but there is no assumption as to whether these decision rules are derived from profit maximization. The idea behind these decision rules is that they try to capture the actual decisions that railroads make (or would make), whether or not these decisions are based on profit maximization. Therefore, if railroads really do maximize profit, then this should be built into the decision rules. But if railroads do something else, then the decision rules should be constructed to reflect this. What this means is that if the decision rules were successfully modeled, then the RPM would be able to accept these rules as input; and, given the importance of decisions, this would be an important step toward an accurate and reliable model.

Third, the RPM models the railroads in an intermediate level of detail. Generally, more detail is good for a model because it expands the model's inputs and outputs; more detail is bad because it makes the model more unwieldy. A model should have the amount of detail that allows it to answer the policy questions of interest but not so much that it is too big to use. A case can be made that the RPM is cast at the best level of detail. On the one hand, the RPM is detailed enough to have a large number of inputs; this allows it to address a large number of policy questions. If there were less detail, the model would not be able to say anything anout the effect of changes in the per diem rate or car service rules. On the other hand, if there were more detail, then one might well get bogged down when using the model, and it would not be a practical tool. Thus, the RPM is written at the level of detail that seems to be the best compromise between the lack of scope caused by insufficient detail and the unwieldiness caused by excess detail. The next section discusses this topic further.

Fourth, the RPM takes full account of the interdependence among railroads. This is done by including many railroads in the model and by explicitly modeling the car and commodity flows between them. Explicitly modeling these interdependencies, or system effects, is a big step toward accurate modeling; and it is essential if the model is going to say anything about the effect of changing per diem rates or car service rules since these policies are designed to cope efficiently with the interdependence of railroads. Appendix F goes into this topic in more detail.

Fifth, the RPM has a strong methodological foundation. As modern research has made more use of computers and sophisticated mathematical methods, it has become harder to keep the focus on the substance of the system being modeled rather than on the techniques themselves. It is too easy of the techniques to take over and to dictate the research strategy, even at the cost of substance. A good deal of effort has gone into protecting the RPM from this type of problem. The two papers [Oiesen, 1976a and Oiesen, 1976b], which were cited frequently in Section 1 and on which much of this report is directly or indirectly based, are largely an outgrowth of thinking on the type of modeling approach appropriate to answering the type of questions that the RPM addresses. Therefore, this report avoids common methodological problems such as confusing inputs and outputs, reversing the direction of causation, or failing to recognize the role played by decisions.

This completes the discussion of the main features of the RPM that commend it. Of course, it is largely a matter of opinion whether a particular feature is a blessing or a curse. One person's strong methological foundation is another person's pool of quicksand. This section has tried to lay out the attractive features so that the reader can decide their value for himself.

6.5 OBSTACLES HINDERING FURTHER DEVELOPMENT OF THE RPM

Can the RPM really be improved so that it can make reliable predictions and can serve us a framework for railroad research? Perhaps it can, but there are two nagging problems which prevent one from quickly and confidently answering this question with a "YES."

The first problem is that there might be no suitable level of detail at which the model can be pitched. On the one hand, as pointed out above, as more detail is added to a model, it gains in accuracy (since greater precision is possible) and also in scope (since a wider range of inputs and outputs is possible). Since some minimum amount of accuracy and scope will be deemed necessary, there will be some minimum amount of detail that is needed in the model if it is to be useful. On the other hand, as more detail is incorporated into the model, it might lose its appeal because the input data is too extensive to be prepared, because the knowledge to model the details is lacking, or because the model is too expensive to run. There will be some maximum amount of detail that can be handled if the model is to remain useful. Therefore, the possibility exists that the minimum detail needed for usefulness might exceed the maximum amount of detail that can be tolerated. For example, it might be the case that if decisions are modeled in enough detail to allow accurate predictions, then such a mass of input data is required to support this detail that it cannot be accurately gathered and that, thus, the hoped-for accuracy is not achieved. Whether this discouraging possibility is true for the RPM is not known; all that can be said is that it cannot be ruled out.

The second problem is that it might turn out that the various decision rules which are explicitly modeled in the RPM might defy modeling. Each decision rule that is an input to the RPM assumes that if the same, identical conditions occur twice, then the railroad (or shipper) will make the same decision each time. There are two snags on which modeling of these decision rules could get hung up. First, the decision rule could be unstable, i.e. the railroad might make different decisions even if identical situations are repeated. Second, even if the decision rule is stable, it might be so complicated that the modeler cannot discover it.

In order to explain these snags further, it will be instructive to compare a social science model (such as the RPM) with a natural science model. In the natural sciences, it is widely accepted that the laws governing phenomena are constant; e.g., given particular conditions, falling bodies always behave in the same way. One does not have to worry about the laws of physics changing or about the gravitational constant taking on one value in the first quarter and a different value in the second quarter. The stability of these physical laws has allowed scientists to discover many of them. In contrast, in a social science model there is more instability in the "laws" (or decision rules), since humans are not as reliable as the molecules of a perfect gas. It might be that the instability is so great that there is nothing systematic to model. Even if the instability is at an acceptable level so that there is a "law," this instability makes it harder for the modeler to discover what the law is. This difficulty usually is compounded by the inability to perform worthwhile controlled experiments in the social sciences. Therefore, the combination of possibly unstable laws and the difficulty of discovering whatever stable laws there might be are problems that could potentially torpedo any effort to develop a useful version of the RPM.

In summary, the point of this section is not that further development of the RPM would be fruitless. In the author's opinion, a good working hypothesis is that the problems mentioned in this section are not serious; the possibility of these arguments being true should not be allowed to paralyze research that could potentially have a large payoff. Nevertheless, there is no ironclad guarantee that further research would have the payoff that it seems to promise. One would be a Pollyanna if he did not recognize that these problems might possibly hamper future research. There are limits even to what computers can do.

6.6 POTENTIAL FUTURE DEVELOPMENT OF THE RPM

Sections 6.3 - 6.5 have discussed the main advantages and disadvantages that would be gained or encountered if the RPM were developed further. This section is written at a less grandiose level. It describes some of the shortcomings of the current version of the model and uses this discussion as a springboard for outlining specific areas of the model that could be developed. Appendix H contains an abstract statement of the essential features that an improved version would exhibit.

There are three grounds on which one might criticize the current version of the model. First, some phenomena are excluded. For example, since there is only one yard per road, the problem of how to distribute the empties on a road's lines does not arise. Also, since cars are assumed to move independently, blocking and scheduling problems do not arise. A final example is that pool cars and assigned cars cannot be handled by the model since all cars are assumed indistinguishable.

The second ground for criticism is that the model contains qualitative inaccuracies. For example, a good case can be made that the cost of hauling a loaded car a mile is not constant; it depends on factors such as the level of demand, where it is being hauled, and others. Thus, the assumption that the cost of hauling a car a mile is constant is qualitatively inaccurate.

The third ground for criticism is that even if the qualitative assumptions are correct, the wrong quantitative values might be used. For example, if the qualitative assumption that "The probability distribution of demand for each origin-destination pair is the same for each day during a season" is correct, the wrong probability distribution might be input to the model; i.e. an inaccurate quantitative assumption is made.

Future work on the RPM would consist of altering the model (including consideration of programming language) so as to include additional phenomea, to improve the qualitative assumptions, and to improve the quantitative assumptions. The particular direction taken would be the one that was deemed to contribute the most to increasing the usefulness of the model in light of the policy questions considered most important.

We can be slightly more specific about what the next stage in the development of the RPM might be. The first step would be to pick out a geographical area to model. Ideally, there would be a significant amount of interlining among railroads in this area and a negligible amount between railroads inside the area and railroads outside the area. This area might be the entire country. Once the network is picked, one can then attempt to improve the model so as to circumvent the criticisms lodged against it. Consider the three types of criticism.

First, the model could be altered so it could include new phenomena. One way to include new phenomena would be to relax some of the assumptions listed in Section 6.2. For example, the number of yards operated by each railroad could be increased, the number of commodity types could be increased, the number of car types could be increased, etc. There are also some phenomena not mentioned in the assumptions that could be added, e.g. competition among railroads.

Second, the qualitative assumptions of the model could be altered. A leading candidate for improvement here is the way that cost is modeled. Also, the range of variables that decisions depend on should be expanded. For example, the number of empties that a road wants to hold should be a function not only of the per diem rate but also of the anticipated demand and also perhaps of other variables. For another example, the decision rule on which cars to load which demand into should probably be a function of the per diem rate instead of a constant as it is in the current version of the model.

Third, the data needed by the improved version of the model would have to be gathered. Exactly what data would be needed cannot be specified in advance; it depends on how the model is changed.

In short, the idea is that the RPM can be improved in stages. After each stage, a decision can be made as to whether further development is warranted. The specific improvements to be included in the next stage of development might well -- but need not necessarily -- be from those mentioned above. The improvements included would be determined by conferring with possible users of the model to determine which improvements would throw the most light on questions of interest.

6.7 CONCLUSION

There are many new policies that are proposed with the aim of improving the performance of the railroad system. Our unaided intuition is often insufficient to tell us which of these proposed policies would work and which would not -- for the plain reason that the railroad system is so complicated. There are many different decision-makers making many different decisions that affect the operation of the railroad system. Moreover, the entire railroad system is tied together so that events in one sector ripple through the system causing effects -- sometimes unexpected -- in other sectors. In order to deal with this complexity, a model of the nation's railroad system has been developed.

The model has promise both in the range of policies it can address and also in the apparent soundness of its approach. The goals of the model are to provide accurate predictions of the effects of policy changes and to develop our intuition so that we can think of better policies. Whether or not the model can be developed sufficiently to meet these goals remains to be seen. In the author's opinion, while there is some question about the workability of a more sophisticated version of the Railroad Performance Model, the large potential payoff to having an accurate model with the scope of the RPM seems to make its further development a worthwhile, though risky, investment.

APPENDIXES

A. INPUT DESCRIPTION AND FORMAT

A.1 INTRODUCTION

This appendix, which is written parallel to Section 2, gives a complete description of the manner in which the inputs are structured, gives the values that are assumed for the inputs for the Base Case, and explains where those assumed values came from. When possible, the assumed input values are based on 1974 data. The reader should be warned that the assumed inputs are not slavishly realistic. Since the current version of the RPM is designed to be a demonstration model rather than a model to be immediately used, it was not deemed desirable to put much of the limited resources available into assembling data. Therefore, much of the input data is, quite justifiably, based on judgment and a desire to maintain consistency within the model rather than on meticulous data search and processing. Thus, this appendix strives to make clear what input data is used in the Base Case, but there is no pretense that this data is accurate.

In this and other appendixes the variables will be labelled with the symbol given to them in the computer program. This will put the interested reader in a position to understand the program; these symbols should not cause any problem to the reader unfamiliar with GPSS.

A.2 INPUTS CHOSEN BY THE GOVERNMENT

In the Base Case the per diem (or car hire) charge per day is assumed to be

XH$PDCPD = $5.00.

The per diem charge per mile is assumed to be

XH$PDCPM = $0.05.

These values are rough averages taken from the schedule of per diem rates [Association of American Railroads, 1974, p.12].

The revenue per loaded car mile is assumed to be

XH$RPLCM = $1.00.

This figure is used since, according to the Association of American Railroads [1975a, pp. 33,42], the average revenue per ton-mile is about 2¢ and since the average number of tons carried per car, weighted by the length of haul, is about 50. Therefore, 2¢x50 = $1.00.

The car service rules are represented by two separate inputs. The first is the number of feasible owners matrix, MB12, which is shown in Table A-1. If a load of demand has origin i and destination j, the (i,j)th element of this matrix contains the number of owning railroads into whose cars the car service rules would allow railroad i to load this demand. For example, in the Base Case if there is a

Table A-1

Number of Feasible Owners Matrix
(MB12)

Destination

Origin	1	2	3	4	5	6	7	8	9	10
1	10	10	10	10	5	9	9	7	7	8
2	2	10	9	5	5	6	7	6	6	7
3	3	3	10	3	3	4	6	4	5	6
4	4	4	5	10	2	4	7	6	7	5
5	5	5	7	10	10	7	8	7	7	6
6	6	6	6	6	3	10	6	6	5	3
7	4	4	4	3	3	2	10	2	4	4
8	4	4	5	5	5	4	5	10	3	3
9	6	6	8	7	6	6	9	8	10	2
10	9	9	9	9	5	5	9	6	3	10

load of demand with road 3 as the origin and road 4 as the destination, the number of feasible owners matrix states that the car service rules allow this demand to be loaded into the cars of only three roads. It remains to specify what those three roads are; it is convenient to postpone this until the next section.

A.3 INPUTS CHOSEN BY THE RAILROADS

The order in which demand is serviced is governed by the Demand Priority Matrix, MB19, shown in Table A-2. Row i gives the reverse of the order in which demand originating at road i is serviced. For example, on a given day, road 3 first attempts to service demand destined for road 3, then demand destined for road 2, then demand destined for road 1, then demand destined for road 4, etc.

Once a road has decided which demand should next be serviced, the decision on which of the empty cars it should be loaded into is governed by the car choice matrices, MB1,...MB10, which are shown in Tables A-3 through A-12. Suppose road i has a load of demand with destination j that it would like to put into an empty car. Row j of the car service matrix for road i, MBi, contains the numbers of the roads whose cars the car service rules allow this demand to be loaded into. For example, demand with road 3 for an origin and road 4 for a destination could be loaded into cars of roads 5,3, or 4; this is seen by looking at row 4 of MB3. The zeroes in these matrices are of no significance. The matrices also indicate road i's preferences as to which car it would like to place a load into; these matrices are designed so that the desirability of a car owned by an owner increases to the right. For example, road 3 first tries to load the demand destined for road 4 into a car owned by road 4; if no car owned by road 4 is available, then road 3 would like to load the demand into a car owned by road 3; if no car owned by road 3 is available, then

Table A-2

Demand Priority Matrix

(MB19)

Origin \ Destination	1	2	3	4	5	6	7	8	9	10
1	10	9	8	6	5	7	4	3	2	1
2	10	9	8	6	5	7	4	1	3	2
3	5	9	8	10	7	6	4	1	2	3
4	10	9	8	7	1	6	5	2	3	4
5	10	9	8	7	1	6	3	2	4	5
6	5	9	8	2	1	4	3	10	7	6
7	5	9	4	2	1	6	3	10	8	7
8	5	9	4	2	1	10	3	6	7	8
9	5	3	6	2	1	8	4	7	10	9
10	5	4	8	1	2	3	6	9	7	10

Table A-3

Car Choice Matrix for Railroad 1

(MB1)

Destination Railroad	Owning Railroad: 1	2	3	4	5	6	7	8	9	10
1	10	9	6	8	7	5	4	3	2	1
2	10	9	6	8	7	5	4	3	1	2
3	10	9	6	8	7	5	4	2	1	3
4	10	9	8	7	6	5	3	2	1	4
5	2	3	4	1	5	0	0	0	0	0
6	2	3	4	5	8	7	10	1	6	0
7	2	3	4	6	8	9	10	1	7	0
8	2	3	7	9	10	1	8	0	0	0
9	2	3	7	8	10	1	9	0	0	0
10	2	3	8	7	6	9	1	10	0	0

Table A-4

Car Choice Matrix for Railroad 2

(MB2)

Owning Railroad

Destination Railroad	1	2	3	4	5	6	7	8	9	10
1	2	1	0	0	0	0	0	0	0	0
2	10	9	8	7	6	5	4	3	1	2
3	10	9	8	7	6	5	4	2	3	0
4	3	6	5	2	4	0	0	0	0	0
5	3	6	4	2	5	0	0	0	0	0
6	3	4	7	10	2	6	0	0	0	0
7	3	6	8	9	10	2	7	0	0	0
8	3	7	10	9	2	8	0	0	0	0
9	3	7	8	10	2	9	0	0	0	0
10	3	8	7	6	9	2	10	0	0	0

Table A-5

Car Choice Matrix for Railroad 3

(MB3)

Destination Railroad \ Owning Railroad	1	2	3	4	5	6	7	8	9	10
1	2	3	1	0	0	0	0	0	0	0
2	1	3	2	0	0	0	0	0	0	0
3	10	9	8	7	6	5	4	1	2	3
4	5	3	4	0	0	0	0	0	0	0
5	4	3	5	0	0	0	0	0	0	0
6	10	7	3	6	0	0	0	0	0	0
7	8	9	10	6	3	7	0	0	0	0
8	9	7	3	8	0	0	0	0	0	0
9	7	8	10	3	9	0	0	0	0	0
10	8	7	6	9	3	10	0	0	0	0

Table A-6

Car Choice Matrix for Railroad 4

(MB4)

Destination Railroad	Owning Railroad 1	2	3	4	5	6	7	8	9	10
1	2	3	4	1	0	0	0	0	0	0
2	3	1	4	2	0	0	0	0	0	0
3	2	8	7	4	3	0	0	0	0	0
4	9	10	1	2	3	8	7	6	5	4
5	4	5	0	0	0	0	0	0	0	0
6	10	7	4	6	0	0	0	0	0	0
7	10	9	8	3	6	4	7	0	0	0
8	9	6	7	3	4	8	0	0	0	0
9	3	8	7	6	10	4	9	0	0	0
10	7	6	9	4	10	0	0	0	0	0

Table A-7

Car Choice Matrix for Railroad 5

(MB5)

Owning Railroad

Destination Railroad	1	2	3	4	5	6	7	8	9	10
1	4	3	2	5	1	0	0	0	0	0
2	4	3	1	5	2	0	0	0	0	0
3	4	1	2	7	8	5	3	0	0	0
4	3	2	1	6	7	8	9	10	5	4
5	4	3	2	1	6	7	8	10	9	5
6	4	7	8	9	10	5	6	0	0	0
7	4	3	6	8	9	10	5	7	0	0
8	4	3	6	7	9	5	8	0	0	0
9	4	6	8	7	10	5	9	0	0	0
10	4	7	6	9	5	10	0	0	0	0

Table A-8

Car Choice Matrix for Railroad 6

(MB6)

Owning Railroad

Destination Railroad	1	2	3	4	5	6	7	8	9	10
1	4	7	3	2	6	1	0	0	0	0
2	4	7	3	1	6	2	0	0	0	0
3	7	8	2	1	6	3	0	0	0	0
4	3	2	1	5	6	4	0	0	0	0
5	4	6	5	0	0	0	0	0	0	0
6	9	8	3	2	1	5	10	7	4	6
7	8	3	2	1	6	7	0	0	0	0
8	8	3	2	1	6	8	0	0	0	0
9	7	8	10	6	9	0	0	0	0	0
10	9	6	10	0	0	0	0	0	0	0

Table A-9

Car Choice Matrix for Railroad 7

(MB7)

Owning Railroad (columns 1–10); Destination Railroad (rows 1–10)

Destination Railroad	1	2	3	4	5	6	7	8	9	10
1	3	2	7	1	0	0	0	0	0	0
2	3	1	7	2	0	0	0	0	0	0
3	2	1	7	3	0	0	0	0	0	0
4	5	7	4	0	0	0	0	0	0	0
5	4	7	5	0	0	0	0	0	0	0
6	7	6	0	0	0	0	0	0	0	0
7	6	4	5	3	8	2	1	9	10	7
8	7	8	0	0	0	0	0	0	0	0
9	8	10	7	9	0	0	0	0	0	0
10	6	9	7	10	0	0	0	0	0	0

Table A-10

Car Choice Matrix for Railroad 8

(MB8)

Owning Railroad

Destination Railroad	1	2	3	4	5	6	7	8	9	10
1	3	2	8	1	0	0	0	0	0	0
2	3	1	8	2	0	0	0	0	0	0
3	2	1	4	8	3	0	0	0	0	0
4	3	7	5	8	4	0	0	0	0	0
5	3	7	4	8	5	0	0	0	0	0
6	3	7	8	6	0	0	0	0	0	0
7	6	4	5	8	7	0	0	0	0	0
8	7	3	6	9	10	4	5	2	1	8
9	8	10	9	0	0	0	0	0	0	0
10	8	9	10	0	0	0	0	0	0	0

Table A-11

Car Choice Matrix for Railroad 9

(MB9)

Destination Railroad \ Owning Railroad	1	2	3	4	5	6	7	8	9	10
1	8	7	3	2	9	1	0	0	0	0
2	8	7	3	1	9	2	0	0	0	0
3	8	7	2	1	4	5	9	3	0	0
4	8	7	3	6	5	9	4	0	0	0
5	8	7	6	4	9	5	0	0	0	0
6	10	7	4	5	9	6	0	0	0	0
7	8	6	3	4	5	2	1	9	7	0
8	7	3	2	1	4	5	9	8	0	0
9	5	4	1	2	3	6	7	8	10	9
10	9	10	0	0	0	0	0	0	0	0

Table A-12

Car Choice Matrix for Railroad 10

(MB10)

Owning Railroad

Destination Railroad	1	2	3	4	5	6	7	8	9	10
1	8	7	6	5	4	3	2	10	1	0
2	8	7	6	5	4	3	1	10	2	0
3	8	7	6	5	4	2	1	10	3	0
4	8	7	6	3	2	1	5	10	4	0
5	7	6	4	10	5	0	0	0	0	0
6	7	4	5	10	6	0	0	0	0	0
7	8	6	4	5	3	2	1	10	7	0
8	7	3	2	1	10	8	0	0	0	0
9	10	8	9	0	0	0	0	0	0	0
10	9	6	7	8	3	4	5	2	1	10

road 3 would like to load the demand into a car owned by road 5; if no car owned by road 5 is available, then efforts to load that demand cease since there is no suitable car available into which to load this demand. This demand, therefore, is sent to the Unserviced Demand Module.

These car choice matrices are derived in two steps. First, the cars into which a load can legally be placed are found by applying the car service rule that a foreign car cannot be loaded and sent away from its home lines to the network in Figure 2. Second, the ordering of roads in each row is done according to the rules explained in Section 2.4.

Once a car is loaded at origin i for destination j, road i must decide what link of track that car will be sent over. The choice made in the Base Case is given in the next road matrix MB16, which is in Table A-13. If a car is at road i and its eventual destination is road j, then the $(i,j)^{\underline{th}}$ element of this matrix gives the next road to which the car is sent.

The maximum number of empty cars that road i is willing to hold is expressed by a function FNi which has the per diem rate XH$PDCPD as its argument. The per diem rate is allowed to range from $1.00 to $10.00. The ten functions are

$$FNi = n_i - (n_i/10) \cdot XH\$PDCPD, \; i=1,\ldots,10,$$

where n_i is the number of cars owned by road i. Since there is no data bearing on these functions, the specific form chosen was picked for convenience.

Table A-13

Next Road Matrix
(MB16)

Location of Car \ Final Destination	1	2	3	4	5	6	7	8	9	10
1	1	2	2	2	2	2	2	2	2	2
2	1	2	3	4	4	3	3	3	3	3
3	2	2	3	4	4	7	7	8	8	7
4	2	2	3	4	5	6	7	7	7	6
5	4	4	4	4	5	4	4	4	4	4
6	7	7	7	4	4	6	7	7	10	10
7	3	3	3	4	4	6	7	8	9	10
8	3	3	3	7	7	7	7	8	9	9
9	8	8	8	7	7	10	7	8	9	10
10	7	7	7	6	6	6	7	9	9	10

If the number of empties that a road desires to hold is exceeded by the number it actually holds, then the disposition of foreign empties matrix, MB18, shown in Table A-14, governs the order in which empties are sent away. Row i of this matrix contains the reverse of the order in which road i would send empties away. For example, suppose that road 3 has more empties than it desires. It first sends away empties owned by road 10; if after sending away all the empties on its lines owned by road 10 it still has too many empties, then it sends away empties owned by road 9; empties owned by roads 5,6,1,2,4,8, and 7 go next. These orderings are based on the rule stated in Section 2.4.

The input that declares how many cars are owned by each railroad will be described below in Section A.5.

Table A-14

Empty Car Disposition Matrix
(MB18)

Empty Cars Ranked in Order of Desirability

Road Disposing of Empties	1	2	3	4	5	6	7	8	9	10
1	2	3	4	5	7	8	6	9	10	
2	1	3	4	5	7	8	6	9	10	
3	7	8	4	2	1	6	5	9	10	
4	5	3	7	6	2	1	8	10	9	
5	4	6	7	1	2	3	8	10	9	
6	7	4	10	5	8	3	2	1	9	
7	3	8	6	4	10	9	5	2	1	
8	7	3	9	10	6	4	5	2	1	
9	10	8	7	6	3	4	5	2	1	
10	9	6	7	8	3	4	5	2	1	

A.4 INPUTS CHOSEN BY SHIPPERS

The method by which daily origin-destination demand is created is central to the model and will be explained in detail. It is assumed that there are only three levels of daily demand -- low, average, and high. These three levels of demand are shown in matrices MB13, MB14, and MB15, respectively, in Tables A-15 to A-17. The interpretation of these matrices is as follows. If demand is low on a particular day, then the origin-destination demands shown in the low daily demand matrix are created. For example, there will be 2 units of demand created with road 7 as the origin and road 8 as the destination. Whether demand is low, average, or high on a particular day depends on the season and on a random number drawing. The peak season is the second and fourth quarters; the slack season is the first and third quarters. The probability of demand being low, average, or high in a particular season is shown in Table A-18. The peak season probabilities are stored in the function that the computer program calls FN12; the slack season probabilities are stored in the function FN11. The relative magnitudes of aggregate low, average, and high demands are based on judgment. The relative sizes of the specific origin-destination demands are based very roughly on carload waybill statistics (U.S. Department of Transportation, 1975, p. 1 of Appendix B). It should be stressed that no fine-tuning has gone into the demand input data used here.

Table A-15
Low Daily Demand Matrix
(MB13)

Destination

Origin

	1	2	3	4	5	6	7	8	9	10
1	2	2	1	1	0	0	0	0	0	0
2	3	6	5	2	0	0	1	0	0	0
3	2	5	5	2	0	1	2	0	0	1
4	1	1	1	13	1	1	1	0	0	0
5	0	0	0	1	2	0	0	0	0	0
6	0	0	0	2	0	7	1	0	0	1
7	0	0	1	0	0	2	6	2	0	1
8	0	0	0	0	0	0	2	2	0	0
9	0	0	0	0	0	0	0	0	2	1
10	0	0	0	0	0	1	1	0	1	4

Table A-16

Average Daily Demand Matrix

(MB14)

Destination

Origin	1	2	3	4	5	6	7	8	9	10
1	3	2	2	1	0	0	1	0	0	0
2	4	7	7	2	0	0	1	0	0	0
3	3	6	7	2	0	2	1	0	0	1
4	1	2	2	16	2	1	0	0	0	0
5	0	0	0	1	3	0	0	0	0	0
6	0	0	1	2	0	9	1	0	0	1
7	0	0	1	0	0	1	8	3	0	1
8	0	0	0	0	0	1	2	3	0	0
9	0	0	0	0	0	0	1	0	3	1
10	0	1	1	0	0	1	1	0	1	5

Table A-17

High Daily Demand Matrix

(MB15)

Destination

Origin	1	2	3	4	5	6	7	8	9	10
1	3	3	2	1	0	0	0	0	0	0
2	5	9	9	2	0	1	0	0	0	1
3	3	8	9	2	0	1	1	0	0	1
4	2	3	3	21	2	1	0	0	0	0
5	0	0	0	1	3	1	0	0	0	0
6	0	1	1	1	0	12	1	0	0	1
7	1	1	3	0	0	1	11	3	0	1
8	0	0	0	0	0	1	3	3	0	1
9	0	0	0	0	0	0	1	0	4	2
10	1	1	1	0	0	1	2	1	2	7

Table A-18

Probability of a Particular Level of Demand Occurring

	Peak Season	Slack Season
Low	0.1	0.5
Average	0.6	0.5
High	0.3	0.0

The maximum number of units of demand that shippers will allow to queue up at each railroad is:

XB1 = 4	XB6 = 6
XB2 = 10	XB7 = 7
XB3 = 10	XB8 = 3
XB4 = 12	XB9 = 3
XB5 = 2	XB10 = 4

These numbers are based on judgment.

It is assumed that it takes 1,2, or 3 days to load or unload a car with respective probabilities 0.55, 0.35, and 0.10. These values are stored in the loading and unloading time function FN$LULT. These values are based on an examination of the distribution exhibited in Reebie Associates [1972, p.59].

A.5 OTHER INPUTS

The relevant mileages can be obtained from the distance matrix, MH2, shown with the Base Case values in Table A-19. This matrix is interpreted in the following way. The cells containing dashes are not directly connected by a rail link. Suppose $i \neq j$ and that roads i and j are connected by a rail link. Then the $(i,j)^{th}$ element is the number of miles that a car travels on road i's lines when traveling between i and j. The $(j,i)^{th}$ element gives the number of miles on j's lines, and the sum of these two elements gives the total distance between roads i and j. These distances are short-line distances from the Rand-McNally Railraod Atlas [1971,pp. 4-5, 62]. If i=j, then the diagonal element is half the distance of an intraline haul on road i's lines. These distances are based on judgment and the railroad atlas.

The expected transit time in days for a car traveling on a link can be obtained from the next link transit time matrix, MB11, in Table A-20. Suppose a car is located at road i and suppose that its eventual destination is road j. The next road matrix MB16 described above states what link the car will travel on next; the $(i,j)^{th}$ element of the next link transit time matrix gives the expected transit time in days to traverse this link.

Table A-19

Distance Matrix
(MH2)

Receiving Road

Sending Road	1	2	3	4	5	6	7	8	9	10
1	50	200	-	-	-	-	-	-	-	-
2	150	200	300	916	-	-	-	-	-	-
3	-	200	110	200	-	-	170	170	-	-
4	-	325	490	200	350	459	512	-	-	-
5	-	-	-	366	158	-	-	-	-	-
6	-	-	-	365	-	200	450	-	-	470
7	-	-	284	100	-	260	225	445	900	710
8	-	-	400	-	-	-	130	175	680	-
9	-	-	-	-	-	-	1278	1055	250	350
10	-	-	-	-	-	1225	1390	-	625	250

Table A-20

Next Link Transit Time Matrix
(MB11)

Final Destination

Location of Car	1	2	3	4	5	6	7	8	9	10
1	2	2	2	2	2	2	2	2	2	2
2	2	2	2	4	4	2	2	2	2	2
3	2	2	2	3	3	2	2	2	2	2
4	4	4	3	2	3	3	2	2	2	3
5	3	3	3	3	2	3	3	3	3	3
6	2	2	2	3	3	2	2	2	4	4
7	2	2	2	2	2	2	2	2	5	5
8	2	2	2	2	2	2	2	2	4	4
9	4	4	4	5	5	3	5	4	2	3
10	5	5	5	4	4	4	5	3	3	2

For example, suppose a car is at road 7 and its eventual destination is road 2. The (7,2)th element of the next road matrix says that that car will next travel to road 3; the (7,2)th element of the next link transit time matrix says that it is expected that it will take 2 days to travel between roads 7 and 3. The number of days that it takes a car to travel between two roads will not always be the number specified in the next link transit time matrix since these numbers are expected rather than actual values. The model assumes that if the expected transit time is t days, then the actual transit time will be either t-1, t, or t+1 days, each with probability one-third. The numbers in the next link transit time matrix are derived in the following way. Assume that loaded cars continuously travel 16.7 mph when on roads 1,2, and 3; 18.1 mph when on roads 4 and 5; and 22.7 mph when on roads 6,7,8,9, and 10. These speeds are taken from the Association of American Railroads [1975b, p.3]. The distances implied by the distance matrix are divided by the appropriate speed to yield transit time in hours. This is rounded off to the nearest day; one day is added to allow for miscellaneous delays, and this is the number appearing in the next link transit time matrix.

If a car travels from road i to adjacent road j, element (i,j) of the time on sending road's lines matrix, MB17, Table A-21, tells how many days are spent on road i's lines. The number of days on road j's lines can then be calculated by residual since the total transit time is calculated in the manner described in the previous paragraph; all of the variation in transit time is absorbed by the receiving road.

The cost of hauling a loaded car one mile is assumed to be

XH$CPLCM = 25¢.

The cost for hauling an empty car one mile is assumed to be

XH$CPECM = 20¢.

These figures are based very loosely on work done at the Transportation Systems Center; but, as the text emphasizes, these figures are not to be taken seriously.

The Base Case distribution of cars at the beginning of the simulation is given in the cars matrix, MH1, in Table A-22. This matrix is 10X11. The (i,j)th element, for $j \leq 10$, is the number of empty cars on road i's lines that are owned by road j. The (i,11)th element is the number of empties on road i's lines, i.e. the sum of the first ten elements in row i. Not shown in Table A-22 is the sum of the elements in column j, which is the total number of cars owned by road j. The relative sizes of the fleets of different roads is based loosely on the Association of American Railroads [1975, p.2]. At the beginning of the year, all cars are assumed to be empty. Unlike the other inputs, the cars matrix is modified as the year progresses so that the number and owner composition of empties held by each

Table A-21

Time on Sending Road's Lines Matrix
(MB17)

Sending Road \ Receiving Road	1	2	3	4	5	6	7	8	9	10
1	1	1	-	-	-	-	-	-	-	-
2	1	1	1	2	-	-	-	-	-	-
3	-	1	1	1	-	-	1	1	-	-
4	-	1	2	1	1	2	1	-	-	-
5	-	-	-	1	1	-	-	-	-	-
6	-	-	-	1	-	1	1	-	-	1
7	-	-	1	1	-	1	1	1	2	2
8	-	-	1	-	-	-	1	1	2	-
9	-	-	-	-	-	-	3	2	1	1
10	-	-	-	-	-	3	3	-	2	1

Table A-22

Cars Matrix

(MH1)

Owner

Location of Empty	1	2	3	4	5	6	7	8	9	10	11
1	20	30	20	7	0	0	0	0	0	0	77
2	14	56	50	11	0	2	2	0	0	3	138
3	8	55	56	14	0	5	4	2	2	3	149
4	3	15	15	125	6	9	4	2	1	3	183
5	0	0	0	11	18	0	0	0	0	0	29
6	0	3	5	7	2	76	6	5	0	6	110
7	0	3	4	1	0	6	66	18	6	14	118
8	0	0	0	1	0	0	17	24	5	3	50
9	0	0	0	1	0	0	2	2	30	12	47
10	0	3	3	1	0	5	8	3	12	64	99

road varies during the year. In the runs of the model reported in Section 5, the simulation was run for 13 months; the statistics reported are those gathered in the last 12 months of the simulation. The statistics gathered during the first month were discarded because they are tainted by the assumption that all cars were empty at the beginning of the year.

A.6 SUMMARY

The name of the inputs and their symbols in the computer program will now all be written down in one place for reference.

Inputs controlled by the government

- per diem charge per day, XH$PDCPD
- per diem charge per mile, XH$PDCPM
- revenue per loaded car mile, XH$RPLCM
- number of feasible owners matrix, MB12

Inputs controlled by the railroads

- demand priority matrix, MB19
- car choice matrices, MB1,...,MB10
- next road matrix, MB16
- maximum number of empties a road will hold, FN1,...,FN10
- disposition of foreign empties matrix, MB18
- cars matrix, MH1

Inputs controlled by shippers

- low, average, and high daily demand matrices, MB13, MB14, and MB15
- maximum length of the queue of demand waiting for cars that shippers will allow, XB1,...,XB10
- maximum number of days that a load can be held over
- days spent loading or unloading, FN$LULT
- the probability of demand being low, average, or high in the slack or peak season, FN11 and FN12, respectively.

Other inputs

- distances between roads matrix, MH2
- expected transit time between roads matrix, MB16
- time on sending road's lines matrix, MB17
- cost per loaded car mile, XH$CPLCM
- cost per empty car mile, XH$CPECM
- initial distribution of cars matrix, MH1

B OUTPUT DESCRIPTION AND FORMAT

B.1 INTRODUCTION

This appendix gives a detailed description of the output of the Railroad Performance Model and explains how the output data is displayed in the computer print-out. It is necessary to read this appendix in order to be able to read the computer output. The output will be discussed in four sections under the headings of the DATA matrix, the ADATA matrix, the basic information matrices, and the waiting time tables. The first two of these headings correspond to the summary statistics described in Section 3.2; the last two correspond to the detailed statistics of Section 3.3.

B.2 THE DATA MATRIX

The DATA matrix contains a number of summary statistics, all but one of which is presented in percentages or some other normalized form in order to bring out their significance. In the computer program, this matrix is referred to by either of two symbols -- MX$DATA or MX11. This matrix is 11x17. Row i, i=1,...,10, contains data for railroad i. Row 11 contains data for the nation as a whole. We will explain the data in the row for railroad i by working through the columns one at a time. The minor changes in wording needed for row 11, which contains aggregate data, will not be spelled out.

1. Profit for road i. This column contains the year's profit for railroad i, measured in dollars. However, it should be emphasized that the following somewhat flawed definition of profit is used:

profit = revenue that road i receives from moving loaded cars on line
- cost to road i of moving loaded cars on line
- cost to road i of moving empty cars on line
+ car hire payments received by road i
- car hire payments paid out by road i.

The flaw in this definition is that the only costs that are included are the variable costs incurred in moving cars.

Fixed costs such as overhead are not included.

2. The percentage of time that road i's cars are loaded. In calculating this statistic, it is assumed that cars are loaded during the entire time that they are being loaded or unloaded.

3. The percentage of time that road i's cars are empty.

4. The percentage of time that road i's cars are loaded and on line.

5. The percentage of time that road i's cars are loaded and off line.

6. The percentage of time that road i's cars are loaded and moving.

7. The percentage of time that road i's cars are loaded and standing.

8. The percentage of time that road i's home cars are empty and on line.

9. The percentage of time that road i's cars are empty and off line.

10. The percentage of time that road i's cars are empty and moving.

11. The percentage of time that road i's cars are empty and standing.

12. The percentage of miles traveled by road i's cars

for which the cars are loaded. This statistic is calculated by dividing the number of loaded miles traveled by road i's cars by the total number of miles traveled by road i's cars.

13. The percentage of demand originating at road i that is lost because of insufficient cars. This statistic is calculated by taking the number of units of demand during the year that both originate at road i and do not get loaded into a car (i.e. are destroyed) and dividing it by the number of units of demand that originate at road i during the year.

14. The number of days that road i's cars are off line per 100 days that foreign cars are on road i's lines. If this statistic is greater than 100, then road i is a net exporter of cars.

15. Number of empty foreign cars sent away by road i during the year as a percentage of the number of cars loaded by road i.

16. The average car cycle for road i. This statistic is calculated by taking the total number of days that road i's cars are either loaded or empty and dividing by the number of loads carried in road i's cars.

17. Frequency of car shortages at road i. This statistic gives the number of loads of demand with road i as origin that experience a car shortage (i.e. are not loaded into a car on their first day in the model) as a percentage of the total number of loads of demand created with road i as origin.

This completes the description of the significance of each of the 17 columns of the DATA matrix.

B.3 THE ADATA MATRIX

The ADATA matrix also contains summary statistics, but these are in absolute (or non-normalized) form instead of in percentages. In the computer program this matrix is referred to by either of two symbols -- MX$ADATA or MX7. This matrix is 11X17. Row i, i=1,...,10, contains data for railroad i. Row 11 contains data for the nation as a whole. As in the preceding section, we will explain the columns of this matrix for railroad i, leaving the reader to supply the interpretation for row 11.

1. Total car days for road i's cars. This is the total number of days that road i's cars are either moving or standing. This number is very close to 364 times the number of cars owned by road i, but not exactly because of a transition slippage that occurs at the beginning and the end of the year.

2. The number of days that cars owned by road i are loaded and moving.

3. The number of days that road i's cars are loaded and standing. It is assumed that a car is loaded and standing during the entire time that it is being loaded or unloaded and at no other time.

4. The number of days that road i's cars are empty and moving.

5. The number of days that road i's cars are empty and standing.

6. The number of days that road i's cars are loaded and on line.

7. The number of loaded miles traveled by road i's cars.

8. The number of days that road i's cars are empty and on line.

9. The number of empty miles traveled by home cars.

10. The number of units of demand originating at road i that are destroyed because of insufficient cars.

11. The number of units of demand that originate at road i.

12. The number of days that road i's cars are off line.

13. The number of days that foreign cars are on road i's lines.

14. The number of empty foreign cars that road i sends away.

15. The number of units of demand originating on road i that get loaded.

16. The number of loads carried in cars owned by road i.

17. The number of car shortages at road i.

This completes the description of the significance of each of the 17 columns of the MX$ADATA matrix.

B.4 BASIC INFORMATION MATRICES

The matrices to be defined now contain the basic elements of data that are collected while the model is running and that are used to calculate the DATA and ~DATA matrices. These matrices are all 10X10. The following paragraphs will first give the symbol(s) assigned to each matrix in the computer program, next give a short, intuitive name for the matrix, and finally give a detailed explanation of the meaning of the (i,j)th element of the matrix.

MX$DMAND or MX8: The demand matrix. The (i,j)th element is the number of units of demand that are created during the year with origin i and destination j.

MX$LOADS or MX10: The loads carried matrix. The (i,j)th element is the number of loads with origin i and destination j that are actually carried during the year.

MH$DESTQ: The immediate destruction matrix. The (i,j)th element gives the number of units of demand with origin i and destination j that are immediately destroyed after being created because the queue of waiting demand at road i is already full when this demand is created.

MH$DESTW: The delayed destruction matrix. The (i,j)th element gives the number of units of demand with origin i and destination j that are destroyed after waiting unsuccessfully for three days for an empty car.

MX$DLM or MX1: The days loaded and moving matrix. The (i,j)$\underline{th}$ element is the number of days that cars owned by road i are loaded and moving on road j's lines.

MX$DLUL or MX2: The days loading or unloading matrix. The (i,j)$\underline{th}$ element is the number of days that cars owned by road i are being loaded or unloaded on road j's lines. This is also assumed to be the number of days that i's cars are loaded and standing on j's lines.

MX$DEM or MX3: The days empty and moving matrix. The (i,j)$\underline{th}$ element is the number of days that i's cars are empty and moving on j's lines.

MX$DES or MX4: The days empty and standing matrix. The (i,j)$\underline{th}$ element is the number of days that i's cars are empty and standing on j's lines.

MX$LMILE or MX5: The loaded miles matrix. The (i,j)$\underline{th}$ element is the number of miles that i's cars travel on j's lines while loaded.

MX$EMILE or MX6: The empty miles matrix. The (i,j)$\underline{th}$ element is the number of miles that i's cars travel on j's lines while empty.

MX$SENT or MX9: The sent matrix. The (i,j)$\underline{th}$ element is the number of empty cars owned by j that road i has sent away because it did not want them.

B.5 WAITING TIME TABLES

The output also includes tables of waiting time distributions at each road. These tables are named WAIT1, WAIT2,...,WAIT9, WAI10, and WAITN, one for each of the ten roads and one for the nation as a whole. These tables show the number of units of demand at each road that waited 1,2, or 3 days. Various other statistics are also given, e.g. mean waiting time.

B.6 SUMMARY

The names of the outputs and their symbols in the computer program will be collected here for reference.

Summary Outputs

- DATA matrix, MX$DATA or MX11
- ADATA matrix, M$ADATA or MX7

Detailed Outputs

- demand matrix, MX$DMAND or MX8
- loads carried matrix, MX$LOADS or MX10
- immediate destruction matrix, MH$DESTQ
- delayed destruction matrix, MH$DESTW
- days loaded and moving matrix, MX$DLM or MX1
- days loading or unloading matrix, MX$DLUL or MX2
- days empty and moving matrix, MX$DEM or MX3
- days empty and standing matrix, MX$DES or MX4
- loaded miles matrix, MX$LMILE or MX5
- empty miles matrix, MX$EMILE or MX6
- sent matrix, MX$SENT or MX9.
- waiting time tables, WAIT1,...,WAI10, WAITN

C. THE NATURE OF SIMULATION MODELS

A few brief remarks on the nature of simulation models will be included here since the author feels that there is widespread misunderstanding about the difference between simulation and analytic models and that there is among many modelers an unjustified disdain for simulation models. This appendix tries to clear up this misunderstanding and to combat the idea that simulation models are an inferior breed of model. In fact, it is argued that in a large class of important cases, simulation models are better than analytic models.

Section 2-4 describe the RPM's inputs, outputs, and logic. These sections describe the behavioral and technical assumptions that are made about how the railroad system operates. The point to make is that these sections could easily have been written so that the reader could not tell whether the RPM is an analytic or a simulation model. That is, it is quite possible that an analytic model and a simulation model could share the same assumptions. What distinguishes these two types of models is the method by which the outputs are calculated and the nature of the outputs.

To explain these assertions assume for simplicity that the only output is aggregate railroad profit, which we will call "profit." Once values are specified for the inputs, these is no unique value of profit that will result, because the model contains random variables. (Daily demand, transit, times, and loading and unloading times are random in the RPM.) There will be a probability distribution for profit. For example, there is some probability that profit will be less than $20 million, some probability that profit will be between $20 and $21 million, some probability that profit will be between $21 and $22 million, etc. An analytic model would solve either for this probability distribution or for some of its characteristics (e.g. its mean). The main problem with an analytic model is that it is often difficult to solve for this probability distribution. It can safely be stated that it is impossible, given current and forseeable mathematical techniques, to solve the RPM for this probability distribution or for its mean.

If one abandons hope for solving for this probability distribution or for its mean, then he might settle for a single drawing from this distribution. A simulation model provides this single drawing. In a model like the RPM where there are numerous independent random occurrences, there is reason to believe that this single drawing will be a good approximation to the mean of the distribution. Evidence for this is given in Appendix D.

In summary, three things should be emphasized. First, the assumptions underlying an analytic model might well be <u>exactly</u> the same as the assumptions underlying a simulation model. Second, an analytic model, <u>if</u> it can be solved, yields the desired probability distribution or some of its characteristics; a simulation model yields one drawing from this distribution, and there is usually no obstacle to calculating this drawing. Third, the one drawing yielded by a simulation model will in some cases (such as the RPM) be a good estimate of the mean of the distribution.

These considerations lead to the following question. Suppose we have a complicated set of assumptions (such as those of the RPM). Should an analytic or a simulation model be used? If an analytic model can be solved at reasonable expense, then an analytic model would be better because it would yield more information about the output than a simulation model. However, since a complicated system is being modeled, it is likely that an analytic model could not be solved. When it cannot be solved, what typically happens is that the modeler introduces simplifying assumptions until the analytic model can be solved, say, for the mean of the distribution. However, in models like the RPM, a simulation approach yields a good approximation to the mean of the distribution, but the simplifying assumptions are not needed. In other words, a simulation model would be able to provide answers of approximately the same quality as an analytic model, but the simulation model could handle a much richer set of assumptions. Therefore, the presumption is that for complicated models like the RPM, a simulation model is better than an analytic mode.

(Further discussion of some of the material in this appendix and of related matters can be found in Olesen [1976b, esp. pp. 35-9].)

As a concluding conjecture, the author predicts that models having the same general form as the RPM will gain greatly in popularity in the near future. This general form consists of two parts. First, a number of static,analytic submodels of decision-makers, technical processes, or market interactions determine what happens at each point in time. These analytic submodels are called "modules" in this report. Second, the method of simulation is used to hook these static submodels together over time to form a dynamic model. A recent example of this general form being used in a large macroeconomic model is Fair [1974, esp. pp. 12-13,16].

D. RANDOMNESS AND THE STABILITY OF MODEL OUTPUT

D.1 INTRODUCTION

Appendix C points out that when the assumptions for a run of the RPM are specified, then these assumptions imply a probability distribution for the model outputs. The mathematical problem of finding this distribution or its mean cannot be solved, so we use a simulation model to take a drawing from this distribution. This appendix discusses the question of how much difference there is likely to be between different drawings from this distribution. The only model output considered is aggregate railroad profit.

The point at issue and its significance can be stated in the following way. On the one hand, suppose that, given a set of assumptions for one run of the model,the probability distribution for profit is very spread out. This means that if different runs of the model are made under these assumptions (i.e. different streams of random numbers are used), then the profit calculated by the model would probably jump around wildly. This behavior would largely destroy the usefulness of the model. On the other hand, if the probability distribution is tightly bunched, then successive runs would yield profit figures that displayed little variation. This stability in output would greatly enhance the usefulness of the model; it would,as Appendix C argues, make the simulation model virtually as good as a model with the same assumptions that could be solved analytically for the mean of the distribution.

The RPM has three sources of randomness -- linehaul transit times, loading and unloading times, and daily demand. Section D.2 investigates the stability of profit when all three sources of randomness are allowed to vary; Section D.3 investigates the stability when only the linehaul transit times and the loading and unloading times vary.

D.2 STABILITY OF OUTPUT WHEN ALL SOURCES OF RANDOMNESS VARY

In order to investigate the degree to which profit fluctuates on different runs, four runs were made. These runs, numbered 1,5,6, and 7, all embody the Base Case assumptions; they differ only in the stream of random numbers used. The aggregate railroad profit for each run is given in Table D-1. It is seen that the differences between the profit

Table D-1. Variation in Profit Caused by Random Factors

Run	Aggregate profit (in millions)
1	$21.35
5	21.60
6	21.25
7	21.64

figures are not major. The difference between the highest and lowest figures as a percentage of the lowest is 1.83 percent. That this percentage difference is relatively small is not unexpected; since nearly 150,000 independent random events occur in each run of the RPM, a loose application of the law of large numbers leads one to expect this small percentage difference.

The conclusion is that the output does seem to be relatively stable and not too sensitive to random variations. However, two qualifications should be noted. First, only four runs were performed, so a small sample error could be present. Second, the less aggregated outputs are less stable than the aggregate railroad profit. The interested reader can peruse some of these less aggregated outputs in the output listings in Appendix K. Both of these qualifications also apply to the conclusions in the next section.

D.3 STABILITY OF OUTPUT WHEN DEMAND DOES NOT VARY

While the amount of variation in profit displayed in the previous section might seem minor, it would be nice -- and in some cases crucial -- to reduce this variation further. One way to reduce this variation is to take advantage of the fact that GPSS generates what are called pseudorandom numbers [see Schriber, 1974, pp. 12-15 or Gordon, 1969, p.95]. The use of pseudorandom numbers allows daily demand to be generated "randomly" during a single run while at the same time allowing identical daily demands to be generated on successive runs. This means that demand can be "controlled for" so that variations in output on successive runs are not caused by random variations in demand. Therefore, any differences in output between two runs is caused either by a difference in inputs or by random variation in transit times or in loading and unloading times -- not by random variation in demand.

The amount of variation in profit that can be caused by variations in transit times and in loading and unloading times is investigated in Runs 1-4, which control for demand. The profit figures generated by these runs are displayed in Table D-2. It is seen that the variation in profit figures

Table D-2. Variation in Profit Caused by Random Factors

Run	Aggregate profit (in millions)
1	$21.35
2	21.34
3	21.32
4	21.32

is considerably smaller than the variation reported in the preceding section. The difference between the highest and lowest figures as a percentage of the lowest figure is .0014 percent. This means that when demand is controlled for -- as it is in every run except for Runs 5-7 and 15-18 -- the profit figure exhibits virtually no sensitivity to randomness. Since all of the runs (except 15-18) described in Section 5 control for demand, we can have a great deal of confidence that the changes in outputs reported there do indeed flow from the changes in inputs rather than from random variation. This conclusion is subject to the two qualifications mentioned at the end of the preceding section.

(Since Runs 1-7 all embody the Base Case assumptions, there is no compelling reason why one rather than another should be designated as the "official" Base Case run. Run 1 is so designated only because it uses the default sequence of pseudorandom numbers provided by GPSS. All runs other than Runs 2-7 use the default random numbers.)

E. SYSTEM EFFECTS, EXTERNALITIES, AND RAILROAD PERFORMANCE

E.1 INTRODUCTION

Because cars flow between railroads, decisions made by one railroad affect other railroads; these effects transmitted through interlined cars are called system effects. The existence of system effects implies that some coordination of the actions of the railroads is necessary if the railroad system is to operate efficiently. Section E.2 explains in detail what system effects are and what they imply about the accuracy of models containing one railroad relative to the accuracy of models containing more than one. Section E.3 then discusses why these system effects give rise to what economists call an externality. This section explains what an externality is, why it can lead to inefficiency, and what can be done to counteract it. In sum, this appendix shows that a model with many railroads is sometimes needed to give reliable predictions and that reliable predictions can be of significant value in light of the externalities generated by railroad operations.

E.2 SYSTEM EFFECTS

If each railroad were a self-contained entity, then there would be no reason for a model to contain more than one railroad. That is, if the decisions taken by a railroad (any by the shippers served ... that railroad) affected only that one railroad, then there would be no interdependence among railroads and, consequently, no need to model more than one railroad at a time. However, railroads usually are not self-contained because loaded and empty cars flow among them. Therefore, decisions made by one railroad can alter the flow of cars among railroads and, thus, have an effect on other railroads. The term system effects will be used to describe these effects that are spread from one railroad to another via changes in the flow of interlined cars.

This concept of system effects needs to be spelled out in more detail. For concreteness, suppose that there are only two roads, A and B. Suppose further that we are only interested in modeling road A, i.e. we want to predict what the effect would be on Railroad A is a change were to occur. This change might be in government, railroad, or shipper policies or in anything else that affects road A. Two cases will be distinguished according to whether the change immediately affects just railroad A or both railroads.

Case I: Consider a change that immediately affects only decisions made by Road A. For example, the change might be that road A decides to adopt new decision rules for matching cars to demand or for allocating empty cars. These changes would have the immediate effect of altering decisions made by road A. Road A would perhaps load different cars, alter decisions on which demand to load when there is a car shortage, or send different foreign empties away. These immediate effects on A are called first-round effects.

There are various ways that these altered decisions might have an effect on road B. Perhaps more or less of A's cars will come loaded onto B's lines; perhaps more or less of B's cars will come loaded onto B's lines from A's lines; perhaps more or less of B's cars will come empty onto B's lines from A's lines. When any of these things happen, there will be an initial effect, e.g. if more loaded cars come onto B's lines, then B will probably collect more revenue; these effects are largely effects to which A subjects the passive B; B does not have much choice about them.

Once the cars are unloaded, however, then B's stock of empty cars is altered and B must decide what to do with these empty cars, e.g. which should it load, which should it hold where they are terminated, which should be sent elsewhere?

The decisions that B makes have effects on B such as changing the number of loads originated, the number of empty car-miles traveled, or the amount of per diem payments paid. The total effect on B includes both the effects to which B is passively subjected and also the effects which are the results of B's altered decisions; these effects will be called the second-round effects. B's altered decisions, however, will not only affect B but also alter the flow of empty and loaded cars going to A. We can now repeat the analysis of the second-round effects. A will first be passively affected to some degree; then, as A's stock of empties changes, A's decisions are altered, and these altered decisions lead to further effects on A. These effects on A will be termed third-round effects. The reader can imagine the fourth-round effects, fifth-round effects, etc. that would follow.

We have seen how the change under consideration has an immediate, first-round effect on A. This change then has other effects on A and B which can be collectively termed higher-round effects. These higher-round effects constitute the system effects. That is, these higher-round effects occur only because the railroads are interdependent. If there were no flow of cars between railroads, then there would be only a first-round effect and no higher-round effects.

The implications for modeling of the existence of these higher-round, system effects will now be explained. Suppose we want to have a super-accurate model that will predict the total effect of the change on road A. Then we must have a model that includes not only road A but also road B since we must model B's decisions in order to figure out what the total effect is on A. However, we are probably willing to settle for something less than a super-accurate model. Modeling inevitably involves simplifications that assume away certain effects; the hallmark of good modeling is assuming away the effects that are unimportant and keeping in the model the effects that are important. In the present case, since we are studying a change that only affects A directly, we might decide that the higher-round effects are relatively unimportant and can be safely omitted from the model. That is, we would be content with a model that contained road A but no other roads. This model would not be super-accurate; but if the higher-round effects are indeed minor, then it would be accurate enough for our purposes. This simplification is usually made when a single railroad is being studied; Sections F.3 and F.4 mention some models that make this simplification.

Case II: Consider a change that immediately affects decisions made by both railroads. For example, changes in the per diem system, car service rules, or demurrage system might alter the decisions made by both A and B. Insofar as the change has a first-round effect and alters road A's decisions, the process by which higher-round decisions follow in train is the same as that described for Case I. The difference in Case II is that there can now be immediate, first-round effects on B's decisions. This means that there will be a second-round effect on A, and so forth. The point is that in Case II there are many more higher-round effects, so a model that assumes them away and only contains road A will pay a heavier penalty in terms of loss of accuracy than would be paid in a Case I situation. In fact, since policies like per diem rates and car service rules presumably exert their effect by altering flows of cars between railroads, one cannot avoid the conclusion that a model must include both roads if it is to be used to analyze changes in these policies.

This section can be summarized by considering the question: Should a model with one railroad or a model with many railroads be used? The answer to this question depends on the relative importance of two conflicting considerations. The first consideration is that because there is interlining of cars, there exist system effects. That is, a change that affects one railroad will be transmitted through the railroad system and affect other railroads. This consideration implies that a many-railroad model has an advantage since it can include the system effects that cannot be included in a one-railroad model. The second consideration is that it is easier to build n one-railroad models than one n-railroad model. This is an advantage of one-railroad models. How does one reconcile these opposing considerations?

On the one hand, if a particular change is judged to have no significant system effects, then the first consideration is irrelevant and a one-railroad model is appropriate. On the other hand, if a change has important system effects, then a model of a single railroad would probably lose so much accuracy that it would be on little or no value. Therefore, only a many-railroad model could provide a suitable level of accuracy; but a many-railroad model could do so only if the inherent difficulty of developing such a model could be overcome. In short, the decision in this case is not between a one-railroad model and a many-railroad model but rather between a many-railroad model and no model at all.

The twin rationale for constructing the RPM, which is a many-railroad model, is the fact that many policy questions involve significant system effects and can only be answered by a many-railroad model and the further fact that, as Section F.2 argues, there is apparently no existing many-railroad model that can handle these questions. The RPM, then, is an exploratory model that investigates the question of whether a many-railroad model can be developed that provides the desired degree of accuracy.

E.3 EXTERNALITIES

E.3.1 Introduction

Over the last few decades economists have studied what are known as externalities. This section defines the concept of an externality (Subsection E.3.2), shows how the presence of an externality can lead to inefficiency (Subsection E.3.3), and discusses ways of dealing with externalities (Subsection E.3.4). Subsection E.3.5 then argues that the system effects discussed in Section E.2 are a form of externality and can lead to an inefficiency. By recognizing that these system effects are a form of externality, the knowledge and intuition that economists have developed for dealing with externalities becomes relevant to the railroads.

E.3.2 What is an Externality?

This subsection states a definition of an externality and gives a few examples that bring out the essential features of externalities. For convenience, we let dm stand for "decision-maker;" thus, dm might stand for an individual, a corporation, on any other entity that makes decisions.

We will use the following definition.

Definition: An externality occurs if one dm makes a decision that affects another dm, as long as that effect is not a consequence of a market transaction between those two dm's.

It should be noted that economists have had a great deal of trouble formulating an airtight definition of an externality. For a verbal discussion of some of the problems, see Baumol and Oates [1975, pp. 16-18]. For a mathematical discussion, see Buchanan and Stubblebine [1962]. Both of these discussions have their flaws.

Now for some examples. Suppose a train passes through a residential neighborhood every night and disturbs the residents with its noise. By deciding to run this train, the railroad affects the well-being of the residents. The effect is not a consequence of a market transaction since the railroad presumably has not paid the residents for the right to run this train. Therefore, running this train is an example of an externality. For another example, suppose a train passes through an urban area; whenever it crosses a road, automobiles have to stop and wait for it. Thus, whenever the railroad decides to run this train, there will be effects on the well-being of the motorists. Since the motorists are not compensated for waiting, this is another example of an externality. Both of these examples are said to be negative externalities since the decisions made by the railroads decrease the well-being of the affected parties, but there can also be positive externalities that benefit those affected parties; an example will be given in Section E.3.5.

To further illuminate the definition, an example will be given of something that is not an externality. Suppose a railroad hires an employee; that is, the railroad decides to hire the employee and the employee decides to work for the railroad. Presumably, these decisions benefit both the railroad and the worker; therefore, one might think that this is a positive externality. However, this is not a positive externality since the hiring is a market transaction, which the definition excludes from being an externality.

E.3.3 Why are Externalities Important?

The reason why externalities are of interest is that they often impair efficiency. To see why this is so, suppose that a dm is part of a system (such as the railroad system) and that its decisions affect other dm's in the system. Presumably when making decisions this dm gives heavy weight to its own interests and little or no weight to the interest of other dm's in the system. This might well lead to the paradox that even though each dm pursues its own interest, each dm ends up worse off than if the dm's had cooperated and taken each others' interests into account. For example, consider a system that contains two railroads A and B. Suppose that A has to choose between two decisions a_1 and a_2 and that B has to choose between two decisions b_1 and b_2. Suppose further that decisions a_1 and a_2 are equally attractive to A, and it chooses a_1. Suppose further that decisions b_1 and b_2 are equally attractive to B, and it chooses b_1. However, decisions made by one road can have effects on the other road. Suppose that if road A took decision a_2, then road B would benefit greatly; and if road B took decision b_2, then A would benefit greatly. Therefore, both railroads could be better off if they switched their decisions to a_2 and b_2. This example indicates how the presence of an externality can lead to inefficiency since one railroad does not take into account the effects of its decisions on other roads; by coordinating decisions everybody can be made better off. It might be that nothing can be done that would bring about the coordination that would remedy this inefficiency, but it might be that there are policies that would be successful. In short, externalities are important because they can lead to inefficiency, and studying externalities can suggest policies to deal with that inefficiency.

E.3.4 What Can be Done About an Externality?

Economists have recognized five general types of policies that might be used to compensate for an externality and to increase efficiency. The first policy is to use the price system. For example, the government can levy a tax on an undesirable activity like polluting and thus give the polluting dm an economic incentive to reduce his activity. The second policy is to issue commands that specify how a private dm must act. For example, the government might degree that certain activities (such as ones that produce a particular pollutant) be outlawed. The third policy is to encourage negotiation by the affected parties; in this way, the dm causing the externality is made aware of the interests of others and perhaps offered an economic incentive (e.g. a bribe) to act in accord with those interests. The fourth policy is to expand the scope of the dm's decisions so that the externality is "internalized." That is, if dm A makes a decision that affects dm B, then A and B might be merged into one decision-maker. This expanded dm can then take into account the effect of decisions on the joint interests of A and B. The fifth policy is for the government to take over and run things. The idea here is that, in principle, the government can take all legitimate interests into account when deciding what decisions to take. It should be emphasized that these five general types of policies are nothing more than potential ways of dealing with an externality; there is no guarantee that even one of them will work in a particular case.

E.3.5 Externalities and Railroads

The foregoing discussion of externalities will now be applied to railroads. For expositional purposes, assume just for this paragraph that there are no per diem rates, no car service rules, and no constraints on how a railroad treats foreign cars on line. If road A loaded one of its own cars and sent that loaded car to road B, then road B would get free use of that car. That is, B would benefit from A's decision to send a car onto B's lines; this is a positive externality. If there really were no constraints on how B treated A's car, then there's no telling what B might do with it. B might hold on to it for two years waiting for a load, maybe convert it into a restaurant, or perhaps load it and send it to Australia. Therefore, we can see two possible sources of inefficiency in this case. First, A might not load freight that would cause its cars to pass onto B's lines. Second, if B did receive A's cars, it might treat them in a selfish or sloppy manner. For both these reasons, we expect the number of loads carried to be less than it would be if A and B were well-coordinated. Thus, we would expect that the railroads or government would take steps to compensate for this externality and to bring about cooperation in order to increase efficiency. In fact, it is possible to interpret much of railroad history as a trial and error search for ways to deal with the externality caused by interlining.

Consider the five general methods listed above for dealing with an externality and how these methods have been used by the railroads. First, the per diem rates represent the use of prices to regulate decisions since raods must decide whether they want to send a foreign car home or hold it and pay the per diem rate. A more extreme use of the price system is proposed by Rastatter and Snow [1970, pp. 121-3] who suggest that per diem rates should be controlled solely by market forces and should be allowed to fluctuate freely. Second, car service rules are commands that tell railroads certain things that they must do with foreign cars. Third, negotiations appear in such things as general manager's agreements where one road gives another permission to violate the car service rules. Fourth, the Railbox Corporation is a consortium of railroads that owns cars that are free-running and have no one road as a home road. This is an experiment that for some cars internalizes the externality since these cars are jointly owned by a number of railroads rather than by one railroad. Fifth, there are some who think that the best policy would be for the government to nationalize the railroads.

In sum, interlining leads to system effects and, thus, to an externality. This externality, if untreated, would have led to a serious inefficiency in railroad operation. Thus, all five of the general methods of dealing with an externality have either been used or proposed. The policies currently followed have evolved largely through trial and error. Since it is not feasible to do a large number of trial and error experiments, many reasonable policies have not been tried; therefore, there is no assurance that the current policies are the best. Moreover, the trial and error method of finding policies does not tell one how policies should be altered as the circumstances change.

An alternative to the traditional trial and error procedure is to use a model to find attractive policies. Economists have long been engaged in modeling that is designed to find the "optimal" policies that bring about the desired amount of cooperation when externalities exist. These efforts enable one to understand many of the issues involved in finding optimal policies, but immediate application of the standard techniques is forestalled by the complexity introduced by the many different decisions and decision-makers involved and by the intricate way in which the different decisions interact. The RPM deals with this complexity by using the method of simulation. It simulates a trial and error approach by assuming different policies on different runs. Since the RPM is a model rather than the real world, a large number of policy alternatives can be tried. This means that once the inefficiency caused by externalities has been recognized, the user can experiment with a number of proposed policy alternatives in order to find the one that yields the most satisfactory railroad performance.

E.4 SUMMARY

To summarize, this appendix has discussed system effects, the externalities caused by these system effects, the policies that can deal with these externalities, and the role that a model like the RPM could play in arriving at a policy choice. We have seen how a decision taken by one railroad can affect other railroads via the system effects that are transmitted through interline car flows. The presence of system effects means that inefficiency can arise because a railroad making a decision either will not or can not take into account the effects of that decision on other roads. There are five potential types of policies that can deal with this inefficiency. Isolating an appropriate policy is a diffcult task; the RPM can help in this task since it is a many-railroad model that explicitly models the flow of cars between roads. Therefore, the justification for the RPM can be stated in a single sentence: The RPM is potentially useful becuase interlining leads to inefficiency, because policies can reduce that inefficiency, because the appropriate policies are hard to identify, and because the RPM can help to find them.

F. COMPARISON OF THE RPM WITH OTHER MODELS

F.1 INTRODUCTION

There exist a large number of models that deals with some aspect of the railroad system. The purpose of this appendix is not to describe this host of models in detail but rather to compare and contrast them to the RPM at a general level. The comparison is mainly in terms of the range of questions that the various models are able to answer. The reader wanting a more systematic exposition of a number of these models is referred to Baker [1976].

This section is organized around two distinctions. The first distinction is between models that include only one railroad and models that include more than one. This distinction is important since the system effects that are discussed in Sections 1.8 and E.2 cannot be handled by a model that contains only one railroad.

The second distinction is between positive and normative models. A positive model is a model that tries to predict what will happen under specified conditions. For example, a positive model of a railroad might predict the effects of alternative decisions on that railroad's profit, on the amount of demand that is serviced, or on the number of car-days used to service a fixed level of demand. A normative model determines the "optimal" decision, i.e. the decision that best fulfills some specified criterion. That is, a normative model not only predicts the effects that different decisions would have but also picks out the decision that would yield the most desired effects. For example, a normative model of an individual railroad might be used to find the decision that maximizes profit, or maximizes the amount of demand that is serviced, or minimizes the number of car-days used to service a fixed level of demand. In principle, a normative model does more than a positive model since it both predicts the effects of each decision (which a positive model does) and also evaluates those effects and calculates the decision that is deemed "best" (which a positive model does not do). In practice, however, normative models are often subject to two difficulties. First, it might be difficult to state what criterion should be used to decide which decision is best. Second, the model might be too complicated to solve for the best decision; the discussion in Appendix C on the frequent inability to solve analytic models applies to normative models, which are usually analytic models.

Since railroads are classified according to whether they contain one or more railroads and according to whether they are positive or normative, there are four classes of models. These four classes, in order to importance to this appendix, are:

- positive models of more than one railroad
- positive models of a single railroad
- normative models of a single railroad
- normative models of more than one railroad.

These four classes will now be discussed.

F.2 POSITIVE MODELS OF MORE THAN ONE RAILROAD

F.2.1 Description of these Models

We first discuss positive models containing more than one railroad -- the class of models to which the RPM belongs. This subsection describes the two other models in this class of which the author is aware. For brevity, these two models are called the Queen's model and the FRA network model.

The Queen's model, as described in Petersen and Fullerton [1975], consists of three types of submodels. The first type of submodel is a positive model of a single link. Inputs to this component include the number of tracks on this link, the features of the link such as the signalling and control system, the traffic on this link, and the time a car takes to traverse this link if there is no congestion. The output is the actual transit time over this link, which equals the uncongested transit time plus any delays that result from trains meeting or overtaking each other on this link. The second type of submodel is a model of a single yard. Inputs include the physical characteristics of the yard, the rules used in handling cars, and the traffic through the yard. The main output is the average throughput time for cars.

The first two types of submodels predict the time a car takes to traverse a link or pass through a yard, given the amount of traffic and other inputs. The third submodel integrates the first two into a model of a railway system. In this system model a set of yards and links is assumed, and the inputs for the yard and link models are specified. Further, another input that must be specified is traffic for the system as a whole. The system model calculates the routings that minimize the number of car-days needed to carry the specified amount of traffic. It is assumed that there are enough empty cars available to carry all the traffic.

The FRA network model consists of a network, a file containing information about the links in the network, and a battery of computer programs. The network contains about 25,000 links and 15,000 nodes, though not all of them would be used in any one application of the model. The information file about each link gives information such as the length of the link and the number of tracks. There are a number of different computer programs (or models); discussion here will be confined to the main program, which is the traffic assignment program [IBM, 1975].

Input to the traffic assignment program includes a subset of the network, information about the links, a level of traffic and a definition of "impedance." Traffic is then routed so that impedance is minimized. Impedance can be defined to be distance, time, cost, or whatever seems appropriate and feasible. The model is static; the traffic assignment is typically for a year's traffic at a time.

F.2.2 Comparison of these Models with the RPM

In comparing the Queen's model and the FRA network model to the RPM, two considerations are of prime importance:

- What questions can each model answer?
- How accurately can it answer those questions?

Four issues will be discussed that bear on these considerations.

First, the Queen's model and the FRA model both assume that freight is always carried; the availability of empty cars is never a binding constraint. In fact, it seems fair to say that these two models do not recognize the concept of an empty car. Moreover, these models do not distinguish between home and foreign cars. This means that in principle these models cannot answer questions about allocation of empties, freight car shortages, and policies such as per diem rates and car service rules. By "in principle" we mean that there is apparently no alternation of these models short of completely changing them that would allow them to address questions about these topics.

The inability of these two models to deal with these topics is significant since many policy questions involve these topics. For example, for many years freight car shortages have been a persistent and nagging problem. Policies are often discussed that are designed to deal with them, as illustrated by the quotation from the Interstate Commerce Commission in Section 5.4. Moreover, numerous Congressional hearing have been held on this problem [e.g. U.S. Senate, 1971]. In addition to this revealed concern over these topics, Appendix E provides the theoretical reason why these are important topics for a many-railroad model to cover. In short, one critical advantage of the RPM is its ability to explicitly handle empty cars, empty car flows among railroads, and policies that affect car movements.

Second, the RPM gives a balanced emphasis to the numerous decisions made by railroads and shippers, whereas the other two models are unbalanced in the sense that they place most of their emphasis on the routing decision. Both of these models go through a complicated optimization to determine what routes loaded cars will take, but other decisions are either omitted entirely (such as decisions concerning empty cars) or treated sketchily (such as, in the Queen's model, the decision on how to schedule trains). In the author's opinion, this gives the routing decision more importance than it deserves.

Third, the RPM can incorporate daily fluctuations in demand, whereas the other two models cannot. The Queen's model is a "steady state" model that assumes that demand does not vary from day to day. The FRA model is even coarser since it assigns a year's traffic all at once and does not recognize "days", much less daily or even seasonal variation in demand. This point is of importance since it seems likely that some of the difficulties of freight car management stem from the irregularity and unpredictability of demand.

Fourth, there are some ways in which these two models are superior to the RPM. In particular, the Queen's model expresses the time it takes a car to pass over a link or through a yard as a function of various relevant factors. In contrast, the current version of the RPM assumes a probability distribution for the transit time over a link that is not a function of anything; and the current version completely ignores delays in yards. (Note: A working version of the RPM that is more highly developed than the "current" version described in this report does include yard delays.) The point to make here is that this disadvantage of the RPM is not inherent; this disadvantage could be removed if the RPM were modified to include the Queen's link and yard models. Integrating these components of the Queen's model into the RPM probably would not be too difficult since they express delay as an analytic function of the relevant inputs.

In summary, as Section E.2 emphasizes, the only reason why we want a model containing more than one railroad is so the system effects can be modeled. Recall that system effects are caused by the flow of loaded and empty cars among roads. Only the RPM models empty car flows. All three models model the loaded car flows; but since the loaded car flows that occur depend on stocks of empty cars, it is a reasonable conjecture that the RPM could better predict loaded car flows. Thus, since the RPM could apparently better model the flows of loaded and empty cars among railroads, it could apparently better model the system effects -- which is the raison d'etre of a many-railroad model. Moreover, only the RPM could answer questions about policies such as per diem rates and car service rules that are designed to deal with system effects. Therefore, to return to the two considerations listed at the beginning of this subsection, the conclusion is that the RPM could answer a much wider range of relevant policy questions and that, for those questions that all the models can answer, an improved version of the RPM could apparently answer them most accurately. This conclusion, however, is nothing more than a conjecture as long as the RPM has not been elaborated and validated.

F.3 POSITIVE MODELS OF A SINGLE RAILROAD

F.3.1 Description of these Models

A number of positive models of individual railroads have been constructed that are designed to provide information useful to decision-makers. Nine of these models are discussed in Baker [1976, Section 3]. A typical model in this class and perhaps the best known is the AAR network simulation model [Midwest Research Institute, 1971]. These models typically have very detailed inputs such as the exact schedules of trains and the resources available in each yard. The model logic usually tries to reproduce actual behavior in great detail. In short, these models try to predict the effect of a change in a single railroad's policies on that railroad, and these predictions are usually based on a very detailed characterization of that railroad's operations.

F.3.2 Comparison of these Models with the RPM

The only inherent difference between the RPM and these models is that the RPM can handle system effects and these one-railroad models cannot. (Recall that system effects consist of the effects that one railroad has on other roads). This means that if a policy with significant system effects is being investigated, then the RPM rather than the one-railroad models would be the appropriate investigative tool. It is interesting to note that if there were a positive model for each road and if these were all simulation models written at the same level of detail, then they could be hooked together to form a version of the RPM. "Hooking them together" would consist of specifying how loaded and empty cars would flow between the roads.

While the only necessary difference between the RPM and these one-railroad models is in the treatment of system effects, in practice there are two other differences. First, a model that deals with only one road can go into much more detail than the RPM. This is appropriate since the one-railroad models are designed to guide the micro decisions of railroads while the RPM is not. Second, the range of phenomena allowed varies from model to model. For example, the AAR model does not recognize the existence of empty cars; it is assumed that there are enough cars to carry demand, whatever demand is. Thus, phenomena such as matching demand with empties and allocation of empties that are treated in detail in the RPM do not even appear in the AAR model (and in many of the other models). Moreover, per diem rates and car service rules usually do not enter into these models.

In short, the RPM and the positive, one-railroad models should for the most part be viewed not as incompatible, competing models but rather as models that are designed to answer different types of questions. The one-railroad models are more fitted to investigating very detailed problems and in providing guidance to single railroads, but these models are not suited to investigating changes in government policies or any type of a change that has system effects. Thus, the RPM sacrifices detail in order to gain scope; presumably, for the applications to which the RPM is put, the gain in scope outweighs the loss in detail.

F.4 NORMATIVE MODELS OF A SINGLE RAILROAD

F.4.1 Description of these Models

There are a number of models of a single railroad that are designed to calculate the decision that in some sense is optimal for a single railroad. The decision that most of these models deal with is the treatment of empty cars, though some of them deal with scheduling or routing trains. A number of models of this type are described in Baker [1976, Section 5]. A model used by the Southern Railroad can be used to illustrate this type of model. The road is divided into 43 districts. Input into the model includes the supply and demand for empty cars in each district, information about the costs of moving an empty car, and information on the benefits of loading a unit of demand. The model is a linear programming model that determines what flows of empty cars should occur in order to maximize the difference between benefits and costs.

F.4.2 Comparison of these Models with the RPM

There are two different ways to compare a one-railroad, normative model to the RPM. First, a normative model calculates what, in some sense, a railroad should do. The decisions that a railroad should take might well differ from those that it actually takes, so it is not possible to hook together normative models of individual roads to form a version of the RPM since the RPM is a positive model that tries to reproduce actual behavior (and it would not be possible even if the RPM were a normative model).

Second, since the RPM is a positive model, it addresses different questions than a normative model. However, Appendix G shows how the RPM could be extended to a normative model. If this were done, the difference between the normative RPM and the one-railroad models would be that the RPM could take system effects into account. For example, the RPM would recognize that a decision by road A would affect road B and that this system effect would be reflected back to road A.A one-railroad model could not incorporate this system effect that road A's decision has on road A. Moreover, a normative version of the RPM could address questions about decisions made at a higher level than the individual railroad, e.g. decisions on per diem rates and car service rules.

F.5 NORMATIVE MODELS OF MORE THAN ONE RAILROAD

The author is not aware of any serious attempt to develop a normative model of more than one railroad. There are both theoretical and computational obstacles to the development of such a model. The theoretical obstacle is that any normative model must have an objective function that is to be optimized and there is no obvious candidate for this objective function. The practical obstacle is that if the model were anywhere near as complicated as the RPM, it would be exceedingly difficult to solve for the optimal decision. In short, these theoretical and practical obstacles seem to be the reasons why no normative model of more than one railroad exists, and they are also sufficient reasons why no one should agitate for such a model. If, despite these remarks, the reader would like to see an outline of what such a model might look like, he can turn to Appendix G.

G. THE RPM IN A DECISION-THEORETIC CONTEXT

The RPM, as described in this report, is a positive model; that is, the RPM is designed to predict the effects of various actions. A normative model not only predicts the effects of actions but also singles out the best (or optimal or most preferred) action. This appendix shows how the RPM could be the basis of a normative model. This appendix also expands the discussion in Section 1.7 on the relationship between the RPM and the decision problem faced by a decision-maker. The discussion draws on Oiesen [1976a, Appendix One]. To avoid needless complication, this appendix assumes that there are no random factors.

Let I be the set of values that the RPM's inputs could take on and let O be the set of values that the outputs could take on. If there are n inputs and m outputs, then each element of I is an n-vector and each element of O is an m-vector. (Note that I and O are not the sets of inputs and output variables; rather, I and O are the sets of values that the input and output variables could take on.) If a value $I' \in I$ is picked for the inputs and the RPM is then run, the RPM calculates a value O' for the outputs. In this way, the RPM associates a unique output value with each input value. Therefore, the RPM implicitly defines a function f with I as its domain and O as its range. Symbolically, this is written $f: I \rightarrow O$. In effect, developing the RPM amounts to specifying the input variables, the output variables, and the function f.

Suppose that a reliable version of the RPM is ready for use; we will sketch out how the RPM could be used to construct a normative model. Suppose there is a set of policies that we would like to use the RPM to investigate. Suppose I* is a set of input values that corresponds to the set of policies. That is, I* is a subset of I, and each element of I* is the input value that represents one of the policies under consideration. Let the set O* be the set of feasible output values; that is, each element of O* could be attained by choosing one of the policies in I*. Symbolically, $O^* = \{O_1 \epsilon O: f(I_1) = O_1 \text{ for some } I_1 \epsilon I^*\}$. That is, O* is the image of I* under f.

We must next assume that the decision-maker whose job it is to choose a policy from I* has preferences over O*. That is, we assume that for any two elements in O*, he can say that he prefers one, prefers the other, or is indifferent. Let the function $\emptyset: O^* \rightarrow R$ represent these preferences, where R represents the real line. That is, if the decision-maker prefers O_1 to O_2, then $\emptyset(O_1) > \emptyset(O_2)$.

We can now write the decision problem faced by this decision-maker as

$$\max_{I \epsilon I^*} \emptyset\, [f(I)].$$

The components of this decision problem are I*,O*, f, and Ø. The relationship between the components is shown in Figure 6. For each element in I*, the function f determined by the RPM picks out the value of O* that results, and the

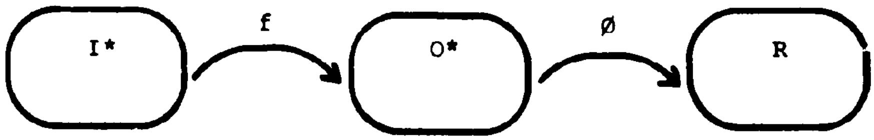

FIGURE 6. ELEMENTS OF THE DECISION PROBLEM

function Ø then associates a real number or "utility" with this value of O*. This utility is, in effect, associated with the value in I* by the composite function Ø(f). In this way, a utility is associated with each of the policies in I*. The policy in I* with the highest utility is the most preferred decision; that is, this policy is the one that should be adopted. In this way the RPM can be extended into a normative model that determines the optimal decision.

Recall that Section 1.7 stated that a government decision-making process ideally has the following four steps. First, decide what the set of possible policies is. In the formal decision problem just stated, this first step amounts to determining the set I*. Second, decide what the variables of interest are. In the decision problem, this second step corresponds to stating what the output variables are. Third, determine how the variables of interest respond to the different policies. The function f performs this step. Fourth, of the feasible values (i.e. O*) for the variables of interest (i.e. the output variables), find the most preferred value. The function Ø states the preferences that allow this fourth step to be carried out. Therefore, the formal decision problem stated here shows how the four steps in the ideal decision-making process were arrived at. In brief, I*, the output variables, f, and Ø completely define the decision pr 'lem, so the fcur steps amount to determining these four thinc.

The reader is perhaps wondering: How operational is all this? Note that any version of the RPM give the input variables, the output variables, and the function f. When a range of policies is picked for investigation, this gives--or comes close to giving--I*. Thus, the RPM yields three ot the four components of the decision problem. The only missing component is Ø, which states the decision-maker's preferences. In the author's opinion, there is no way to systematically and objectively say very much about preferences. [See Olesen, 1976a, pp. 16-19.] Preferences deai with ethical rather than technical matters. The most that can be expected from a model is technical information; it is up to the decision-maker to take the last, ethical step that is needed. It is the decision-maker's job to peruse the outputs that result from different values of the inputs and to decide which inputs, i.e. which policies, are most desirable.

In closing, a view that conflicts with the one in the previous paragraph will be called to the reader's attention. A new book by Keeney and Raiffa [1976] argues that it is possible for technical analysis to say something about preferences. To give a flavor of their argument, two paragraphs will be quoted that discuss the typical sequence of events that occur when a complicated model is developed.

Several person-years of effort will be utilized developing, modifying, and verifying an elaborate simulation model that outputs the possible levels of several indicators of interest resulting from any particular policy. Perhaps the output is synthesized in terms of a few graphs or tables and a summary report is written for the decision maker. This decision maker then struggles for perhaps a week with the implications of the alternatives and then chooses an alternative. The score: person-years on the uncertainty side of the problem, a week on the preference side. We feel that the shifting of a little effort--perhaps only a few person-months--to the preference aspects could lead to significantly improved decision making in many situations. In this book, we suggest how you might constructively use more effort on the preference aspects of analysis.

An illustrative example can help set the stage. A decision-making unit must make a policy choice in a complicated environment. Imagine that the problem is so complicated that a computer-based simulation model is designed such that for each policy choice under review, a scenario can be generated that indicates how the future might unfold in time. Now suppose that the analyst effectively summarizes the relative desirability of any future scenario not by a single number but, let us say, by a dozen well-chosen numbers: some reflecting costs, others reflecting benefits. Since these output performance numbers may simultaneously deal with economic, environmental, social, and health concerns, these summarizing indices will, in general, be incommensurable units. To complicate matters, suppose that stochastic elements are involved in the simulation so that, for a single policy choice being investigated, repeated simulation runs result in different sets of summary performance measures. The joint probability distribution of these performance measures as made manifest through repeated realizations of the simulation will, in general indicate that these 12 measures are probabilistically dependent. Now assume you are a harassed decision maker sitting in front of an output display device deluged with a mountain of con-

> flicting information. You are confused. What should you do? How can you sort out the issues and start thinking systematically about your choice problem: which policy should you adopt in the real setting? We believe this book addresses your problem and has something constructive to say about it that is not merely platitudinous. (pp. viii-ix, emphasis in original)

Since the author just discovered this book, no evaluation of its argument can be given now; all that can be done is to call it to the reader's attention.

H. A GENERAL MODEL OF RAILROAD PERFORMANCE

Sections 2 through 4 and Appendixes A and B specify every detail of the current version of the RPM, and this obscuring mass of detail makes it difficult to discern the essential features of the model. Therefore, this appendix states a generalized version of the RPM that clears away the tangle of detail and exposes the essential features of the current model. Moreover, it is expected that these features would carry over to any improved version of the model that might be developed.

To make the essential features stand out distinctly, this appendix assumes that there are no random factors. Parenthetical remarks indicate how things would be altered if random factors were allowed. Except for the randomness, the current version of the RPM is a special case of the general model of this appendix; any improved version of the RPM probably would also be a special case of this general model.

The general model will be explained by discussing its inputs, outputs, and logic. The inputs to the general model consist of three components. The first component is the structural assumption such as the number of railroads, the number of yards each railroad has, the number of car types, and the number of commodity types. The second component is the decision rules followed by railroads, shippers, government, and any other decision-makers appearing in the model. Railroads have decision rules for things like how to match cars with demand, how to route cars, how to treat home and foreign empties, and how many cars to buy. Shippers have decision rules for things like how many cars to demand, how to treat unserviced demand, and how long to hold on to cars during loading and unloading. Let d(·) stand for all these decision rules. That is, d(·) is a vector containing the decision rules that govern the decisions that are made. The symbol "d(·)" is used since the decision rules are functions; that is, the decisions that are made at a particular time are a function of the state of the railroad system at that time. The third component of inputs is everything else that independently affects railroad performance. This third component might include the weather, the initial state of the railroad system, and other miscellaneous things. Let I represent the first and third components of inputs. Thus, (I, d(·)) constitutes the complete set of input variables.

There is very little to say in general about the output variables except that these variables measure the performance of the railroad system from the point of view of the railroads, shippers, general public, government, and any other interested parties. Let O stand for the set of output variables.

The logic of a model is, in general, a function that maps from the input variables to the output variables. That is, given a value for the input variables, the model logic is a function that determines the value that the output variables will take on. In order to state the model logic, three concepts must be explained. The first concept is the state of the railroad system. The state of the railroad system is defined to be a description at a point in time of all relevant aspects of the railroad system. ("Relevant aspects" means those things that have a bearing either on decisions or on output.) We can think of the state of the railroad as being of two parts. One part is assumed to be the same from day to day; this part consists of yards, links of track, etc. The other part consists of things that can change from day to day. The things that can change from day to day include things like:

- the number of empty cars, broken down by location, owner, type, and, if moving, arrival date at next location
- the number of loaded cars broken down by location, owner, type of car, type of commodity carried, destination, and arrival date at next location
- the number of units of new and waiting demand broken down by type of commodity, origin, and destination.

There could be other things that could change from day to day, depending on the specific assumptions made. For example, if labor is explicitly modeled and if the number of employees can vary from day to day, then the number of employees would be included in the state of the railroad system. Let the symbol s_t represent the state of the railroad system at day t; thus, s_t is a complicated variable that describes all relevant features of the railroad system on day t. No attempt will be made here to say what s_t might look like; it might be a set of matrices or something more complicated. Note that s_t includes information about the future such as: A particular car will be arriving empty at a particular yard on day t+1.

The second needed concept is the transition function. If we let $\emptyset$ be the transition function, then we write

$$s_{t+1} = \emptyset\ [s_t,\ d\ (s_t),\ I].$$

This is the "transition equation" or the "equation of motion" of the railroad system. It is assumed that the specific decisions taken by railroads and shippers on day t depend on the state of the railroad system, so we write $d(s_t)$. This means that if the state of the railroad system is exactly the same on two different days, then the same decisions are taken on those two days. (More generality could be included by allowing $d(\cdot)$ to vary over time to reflect learning or something, but this complication is here suppressed.) This means that decisions do not depend on anything in addition to s_t. It does not mean that a particular decision must be sensitive to every part of s_t; in fact, most decisions will not depend on all of s_t.

The transition equation says that if we start with a state s_t, then the decisions taken by railroads and shippers on day t will be $d(s_t)$; the state s_t, the decisions $d(s_t)$, and the inputs I then jointly determine s_{t+1}, the state on the next day. (If there were random elements, then the transition function would determine a probability distribution for s_{t+1} rather than a single value.) Since the function $d(\cdot)$ and the values of the inputs I are fixed throughout the year, this means that, in effect, each day's state determines the next day's state. In this way, the railroad system bootstraps its through time, moving from one day to the next, with the precise path it takes governed by the decisions taken each day.

The third needed concept is the output function. Let $s = (s_0, s_1, \ldots, s_T)$ be the vector of states that occur during the simulation period. The output function $f(\cdot)$ is then a function that associates a value of the output variables with a value of s, i.e.

$$O = f(s).$$

(This is a slight abuse of notation since O is being used both for the set of output variables and also for the values taken on by these variables; this should cause no confusion.) The interpretation of this equation is as follows. The vector s is a complete description of what happened during the simulation. The output function merely extracts the desired information from s. For example, if profit is one of the output variables, the output function calculates the profit that results from any particular vector s. (If there were random elements, the output function would determine the probability distribution for the outputs, or perhaps characteristics of this distribution, rather than a particular value.)

The output function can now be rewritten to yield the model logic. The transition equation implies that s_i, $i = 0, \ldots, T$, is a function of s_0, $d(\cdot)$, and I. Therefore, the last equation implies that there exists a function $f^*(\cdot)$ that associates a value of the output variables with each value of the triple $(s_0, d(\cdot), I)$, i.e.

$$f^*(s_0, d(\cdot), I) = O.$$

Recall that s_o, $d(\cdot)$, and I are inputs. Thus this last equation expresses the outputs as a function of the inputs. The function $f^*(\cdot)$, therefore, is the model logic. (If there were random elements, then $f^*(\cdot)$ would determine not specific values for O but a probability distribution or characteristics of that probability distribution.)

This completes the discussion of the inputs, outputs, and logic of the general model. Three brief remarks are in order. First, at a very general level, this model has a great deal in common with a model described by Winter [1964, pp.245-7]. The mathematical statement is closely related to the axiomatic definition of a dynamical system in Kalman, Falb, and Arbib [1969, pp.5-6]. Second, this general model can, in principle, be "solved" either analytically or by simulation. The statement of the model allows either approach; Appendix C discusses this topic further. Third, except for the randomness, the current version of the RPM is a special case of this general model.

In summary, a railroad performance model is completely specified when we have chosen its input variables I and $d(\cdot)$, its output variables O, and its logic $f^*(\cdot)$. Since the function $f^*(\cdot)$ is very complicated, we are not able to specify it directly. Therefore, we must specify the transition function $\phi(\cdot)$, the output function $f(\cdot)$, and how the state of the railroad system s_t is measured; these three entites allow the function $f^*(\cdot)$ to be calculated, one point at a time. Thus, when the RPM is run, what is happening is that one point of the function $f^*(\cdot)$ is being calculated. That is, specific values are picked for the inputs; the RPM works through time one day at a time, calculating what decisions are made and how these decisions, acting through the transition function, change the state of the railroad system. After all the daily states have been calculated, the output function is called to compute the values that the output variables take on; thus, specific values of the output variables are associated with specific values of the input variables, and one point of the function $f^*(\cdot)$ has been calculated. This paragraph, then summarizes the essential features of a railroad performance model. The research task is to specify these features so that a useful model results.

I. DESCRIPTION OF THE COMPUTER PROGRAM

I.1 INTRODUCTION

The purpose of this appendix is to describe how the computer program is organized and to put the reader in a position to understand the program. Section I.1 contains a list of the symbols used in the program. Section I.2 then describes what each part of the program does. To understand this appendix, the reader should be familiar with GPSS V, the language in which the program is written

It should be emphasized that the only thing the computer program does is to perform the calculations that Sections 2 through 4 and Appendixes A and B say should be performed. That is, these sections and appendixes completely specify the substance of the RPM; the only remaining task is the elementary--though tiresome--one of performing the required calculations. This computer program carries out the required calculations.

I.2 DICTIONARY OF SYMBOLS

This section lists in alphabetical order the symbols used in the program. If the symbol stands for an input or output, this is noted so that the reader can turn to Appendix A or B for a more detailed description of this symbol's meaning.

FN1,...,FN10 (input): Expresses as a function of the per diem rate the maximum number of empty cars that each road wishes to hold.

FN11 (input): Depending on the random number drawn, takes on one of the values 13,14, or 15 to indicate that demand is low, average, or high, respectively, on a particular day in the slack season.

FN12 (input): Depending on the random number drawn, takes on one of the values of 13,14, or 15 to indicate that demand is low, average, or high, respectively, on a particular day in the peak season.

FN$LULT (input): Determines the number of days it takes to load or unload a car as a function of a random number.

MB1,...,MB10 (input): The car choice matrices.

MB11(input): The transit time matrix.

MB12 (input): The number of feasible owners matrix.

MB13 (input): The low daily demand matrix.

MB14 (input): The average daily demand matrix.

MB15 (input): The high daily demand matrix.

MB16 (input): The next road matrix.

MB17 (input): The time on sending road's lines matrix.

MB18 (input): The disposition of foreign empties matrix.

MB19 (input): The demand priority matrix.

MH1 (input): The cars matrix.

MH2 (input): The distance matrix.

MH$DESTW (output): The delayed destruction matrix.

MH$DESTQ (output): The immediate destruction matrix.

MX$ADATA (output): The ADATA matrix, summary output in raw form.

MX$DATA (output): The DATA matrix, summary output in normalized form

MX$DEM (output): The days empty and moving matrix.

MX$DES (output): The days empty and standing matrix.

MX$DLM (output): The days loaded and moving matrix.

MX$DLUL (output): The days spent loading and unloading matrix, i.e. the days loaded and standing matrix.

MX$DMAND (output): The demand matrix.

MX$EMILE (output): The empty miles matrix.

MX$LMILE (output): The loaded miles matrix.

MX$LOADS (output): The loads carried matrix.

MX$SENT (output): The empty cars sent away matrix.

MX1 (output): Same as MX$DLM.

MX2 (output): Same as MX$DLUL.

MX3 (output): Same as MX$DEM.

MX4 (output): Same as MX$DES.

MX5 (output): Same as MX$LMILE.

MX6 (output): Same as MX$EMILE.

MX7 (output): Same as MX$ADATA.

MX8 (output): Same as MX$DMAND.

MX9 (output): Same as MX$SENT.

MX10 (output): Same as MX$LOADS.

MX11 (output): Same as MX$DATA.

Q1,...,Q10 (output): The number of units of demand at each road waiting for an empty car.

Q$WAITN (output): The number of units of demand in the entire country waiting for an empty car.

V1,...,V32: Variables used, defined in comments in statements 371-435 in the program listing in Appendix J.

WAIT1,...,WAIT9,WAI10 (output): Tables that display the frequency distribution of the number of days that units of demand wait for empty cars at each road.

WAITN (output): Table that displays the frequency distribution of the number of days that units of demand at all roads wait for empty cars.

XB1,...,XB10 (input): XBi is the maximum number of units of demand that shippers will allow to wait for empty cars at road i.

XB11: Takes on the value 11 in the slack demand season and 12 in the peak season.

XB12: Takes on one of the values 13, 14, or 15 to indicate that demand on a particular day is low, average, or high.

XB$TTIME: Expected transit time for traversing the next link.

XB$NROAD: The number of the road that will be reached when the next link is traversed.

XH17: Number of excess empties held by a road.

XH$CPECM (input): Cost per empty car mile.

XH$CPLCM (input): Cost per loaded car mile.

XH$RPLCM (input): Revenue per loaded car mile.

XH1,...,XH10: The maximum number of empty cars that each road desires to hold.

XH11: Used for temporary storage of a number; has many different transient uses throughout the program.

I.3 DESCRIPTION OF THE PROGRAM

This section describes the Base Case program, which is listed in Appendix I. The differences between this program and the programs used for other runs is trivial. Running down the right hand side of the program listing in Appendix J are statement numbers; it is seen that the statements are numbered from 1 to 812. These statement numbers are used to refer to specific portions of the program; "s." and "ss." are used as abbreviations for "statement" and "statements," respectively. Since almost every executable statement in the program is described by a comment, it should not be too hard for the reader to figure out what each individual statement does. Therefore, this section tries to give a big picture view of how the statements fit together.

The program falls into three parts:

- the first group of control cards
- the statements that model railroad operations
- the second group of control cards.

These parts will now be discussed.

The first group of control cards (ss. 1-478). These statements provide information to the GPSS processor and provide the data; they are largely self-explanatory to one familiar with GPSS. Since a large number of transactions are used in the model, the REALLOCATE cards (ss.1-4) reallocate space in primary memory toward transactions and common and away from other GPSS entities. The EQU cards (ss.6-28) are used so that indirect addressing and mnemonic names can both be used. For example, MX1 and MX$DLM are both names for the same matrix. When indirect addressing is necessary, MX1 is the name used since indirect addressing cannot be used with MX$DLM. When indirect addressing is not needed, the more easily understood symbol MX$DLM is used. The matrix initialization statements (ss.69-356) provide the input data given in the matrices in Appendix A. The miscellaneous initialization statements (ss.436-43) provide the constants that are required input. The other statements in the first group of control cards require no comment.

<u>The statements that model railroad operation</u> (ss.479-804). The statements that represent the model logic fall into nine segments that will be discussed in turn. Since the unit of time used in the simulation is one day, each statement refers to what happens on a particular day.

The first model segment (ss.479-92) performs two housekeeping duties. First, recall that the maximum number of empties that a road desires to hold is a function FNi of the per diem rate. It would be wasteful to evaluate FNi every day since its value does not change over the year. Therefore, ss.483-5 evaluate this function once and store the number in permanent locations XH1,...,XH10. Second, this segment regulates the value of the savevalue XB11, giving it a value of 11 when it is the slack season for demand and a value of 12 when it is the peak season. The season is peak during the first thirty days of the simulation, which is the normalization period for which no statistics are kept (see the ninth model segment). Slack and peak seasons then alternate, with each season being 91 days long.

The second model segment (ss.493-506) is the Demand Creation Module. Statement 496 draws a random number. FN11 or FN12, depending on the season, then uses this random number to choose one of MB13, MB14, or MB15 as the matrix of new demand created on this day. Statement 501 creates a transaction for each unit of new demand. Statements 498-500 are arranged so that the order in which these transactions are created corresponds to the order in which the originating road desires to service that demand. Each transaction has 5 byte parameters and 1 halfword parameter. The first byte parameter contains the number of the originating road; the second contains the number of the destination road. Only transient use of the third is made in this segment; none of the other parameters are used in this segment. S.496 is written so that the newly created demand has a priority level of 3. These transactions representing loads of demand waiting for a car are, after being counted by statement 505, passed to the next model segement.

The third model segment (ss.507-524,545-49) is the Demand Servicing Module. This segment receives a stream of transactions representing demand and attempts to load them into cars. Statement 509 stores the maximum number of days that the demand will wait for a car in the fifth byte parameter. SS.510-12, 548 then take the demand transactions one at a time and look for an empty car into which the demand can be loaded. This is done by checking MH1, which is the matrix that keeps track of where the empty cars are, to see if the originating road has an empty owned by a road into whose car this demand can legally be loaded; these legal owners are checked in the order specified in the car choice matrices, MB1,...,MB10. If there is no suitable empty car, then statement 549 sends the demand transaction to the Unserviced Demand Module. If there is a suitable empty car, then loading this demand into this car is simulated by reducing the stock of empties recorded in the MH1 matrix (ss.513-14),storing the number of the owning road in byte parameter 3 (s.511), and collecting some statistics (ss. 519-20). Loading of the car is simulated in ss.521-23. A random number and the loading and unloading time function FN$LULT are used to determine in s.521 the number of days it takes to load the car. S.515 gives the loaded car a priority level of 7 so that when it is unloaded, the empty car will be available when demand is serviced. S.524 passes the newly loaded car to the Linehaul Module.

The Fourth Model Segment (ss.524-44)is the Unserviced Demand Module. S.528 raises the priority of this demand transaction to 5 so that when it is passed back to the Demand Servicing Module, it is serviced after the empty cars are available but before the newly created demand is serviced. Unserviced demand transactions originating at road i are placed in Qi, i = 1,...,10, and also in a "national queue" WAITN. Ss. 529-534 check to see if the demand has been in the queue for the maximum allotted number of days; if so, after some housekeeping, that demand is destroyed, i.e. the transaction is terminated. If not, the demand is put in the queues if it is not already in them (ss. 535-537); but the demand is destroyed if it would cause the length of Qi to exceed XBi, the maximum queue length that shippers will tolerate (ss. 538-42). If the demand transaction gets through the Unserviced Demand Module without being destroyed, it is held for one day (s. 543) and then passed back to the Demand Servicing Module (s. 544).

The fifth model segment (ss. 550-72) is the Linehaul Module. The Linehaul Module receives a stream of just-loaded demand transactions from the Demand Servicing Module. Ss. 553-5 simulate the linehaul of this transaction over one link. S. 553 uses the next link transit time matrix to determine the expected transit time. S. 555 then draws a random number to determine the actual transit time and holds the transaction for that many days of simulated time. Ss. 556-63 collect information on the number of miles and days that this loaded car has just spent on the lines of the sending and receiving roads. S. 564 determines whether this car has another link to travel. If so, then s. 571 places the current location of the car into byte parameter 1, and the car is sent back to s.553 so it can traverse the next link. If not, then the car has reached its destination. S. 565 draws a random number and uses FN$LULT to determine how many days are required for unloading. After the car is unloaded, it is returned to the stock of empties (ss. 568-9), and the demand transaction is terminated.

The sixth model segment (ss. 573-616) is the Empty Car Allocation Module. S. 575 creates a housekeeping transaction with a priority level of 2; this ensures that the last thing that happens in a day is that unwanted empties are sent away. S.577 compares the number of empties that road i actually holds, which is MH(i,11), to XHi, which is the maximum number of empties the road desires to hold. If road i holds undesired empties, ss.579-84 determine which empties will be sent away. Ss.585-95 create a transaction to represent each empty car, and these cars are removed from road i's stock of empties (ss.588-89,596-97). Ss.600-612 then give these transactions a priority of seven and simulate the linehaul of these empties to the next road and collect statistics on what happens. The newly arrived empties are added to the stock of empties at the road where they are now located (ss.613-14), and the transactions representing empty cars are terminated.

The seventh model segment (ss.617-27), after the day's activities are completed, gathers statistics on the number of days that cars owned by each road spend empty and standing on the lines of each road.

The eighth model segment (ss.628-791) is called into action after the simulation is completed to prepare the final output of the model. Since the calculations performed in this segment are both elementary and tedious and since comments scattered through the program indicate exactly what is being calculated, no further remarks are called for here.

The ninth model segment (ss.792-804) stops the model after it has run 30 days and then discards the statistics that have been gathered. The cars matrix MH1 and the distribution of cars around the network, some of them midway in a journey, are not affected by this model segment. This means that after this segment performs its duties, the model is properly initialized and ready for its run of one year to begin. (Note: The comment in s.793 mistakenly labels this segment the "eighth" model segment rather than the ninth. This mistake causes no error in execution since it is in a comment.)

The second group of control cards (ss.805-812). These statements start the model running (s.808), discard the unwanted statistics gathered during the first 30 days that are not discarded by the ninth model segment (s.810) and restart the model for its run of a year (s.811).

J. PROGRAM LISTING FOR THE BASE CASE

This appendix contains the listing from the Base Case Run, including both the program and the complete output. The following material appears in this order:

1) sheet with accounting information (1 page)
2) the program (16 pages)
3) the block count sheet (2 pages)
4) output (16 pages).

```
//RMT51116 JOB 5631,DIESEL..J,REGION=300K,TIME=4                          JOB 4079
// EXEC GPSS,PARM=C
//SYSPRINT DD SYSOUT=A
//SYSIN DD *
IEF142I - STEP WAS EXECUTED - COND CODE 0000

          DATE AND TIME              CPU TIME              REGION (K)       JOB       PROC      STEP      PROGRAM
STEP    BEGUN      ENDED        REQUESTED     USED       REQUESTED  USED     NAME      NAME      NAME      NAME
----    -----      -----        ---------     ----       ---------  ----   --------  --------  --------  --------
   1   09/09/76   09/09/76    10:00:00.00  00:03:19.37     320      300   RMT51116             GPSS      DAG01V
       15:03:09   15:12:22

            STEP STATISTICS AND CHARGES
RESOURCE               COUNT    X   RATE       =   CHARGE
--------               -----        ----           ------
CPU CENTISECONDS  :     19,537 X 1.67X10E-4  =      3.256
OCCUPANCY TIME    :   5061.10E  X 0.0         =      0.000
3330 DISK         :          3 X 6.25X10E-5  =      0.000
LINE PRINTER      :      3,110 X 7.81X10E-6  =      0.024
3330 DISK         :         92 X 6.25X10E-5  =      0.006
3330 DISK         :         43 X 6.25X10E-5  =      0.003
3330 DISK         :          0 X 6.25X10E-5  =      0.000
3330 DISK         :        124 X 6.25X10E-5  =      0.008
3330 DISK         :          0 X 6.25X10E-5  =      0.000
CARD READER       :        819 X 3.91X10E-6  =      0.003
LINE PRINTER      :          0 X 7.81X10E-6  =      0.000
                                                ------------
STEP COST = PRIO RATE X STEP CHARGE =  1.0 X        3.300 =         3.300 M.U. MINUTE(S)

END JOB: RMT51116  5631  DIESEL..J              EXIT = 01  SYSTEM CODE = 000  TERMINATION NORMAL        09/09/76 15:12:22

JOB ACCOUNTING TOTALS: CPU TIME USED = 00:03:19.37       LINES PRINTED =    3,110
                           I/O COUNT =     259           CARDS PUNCHED =        0
                                                         CARDS READ    =      819

                    TOTAL COST   =   3.300 'M.U.MINUTE(S)'

ADJUSTED ACCOUNT BUDGET: MACHINE UNITS USED: PRIO>0 =     20.942      PRIO0 =     0.000
                         MACHINE UNITS LEFT: PRIO3  =      8.414      PRIO2 =     9.700

               ACCUMULATED CHARGE THIS MONTH =     20.942 'MACHINE UNITS'
```

```
*** GPSS V - OS VERSION ***
*** IBM PROGRAM PRODUCT 5734-XS2 (V1M3) ***
                                                              STATEMENT
                                                                NUMBER
REALLOCATE FAC,1,STO,1,QUE,11,LOG,1,TAR,11,AVR,1                     1
REALLOCATE LSV,1,CHA,1,GRP,1,LMS,1,MAC,1,BLO,300,FUN,15              2
REALLOCATE XAC,2500,COM,96000                                        3
REALLOCATE VAR,33,FSV,1,HSV,20,BSV,15,FMS,12,HMS,5,BMS,20            4
```

```
BLOCK                                                                    STATEMENT
NUMBER  *LOC    OPERATION  A,B,C,D,E,F,G,H,I          COMMENTS           NUMBER
                SIMULATE                                                    5
        *                                                                   6
        *       EQU STATEMENTS                                              7
        *                                                                   8
         ULW    EQU         1,PX                                            9
         ULWL   EQU         2,PX                                           10
         LEW    EQU         3,PX                                           11
         LES    EQU         4,MX                                           12
         LRILF  EQU         5,MX                                           13
         FRILF  EQU         6,MX                                           14
         ADATA  EQU         7,PX                                           15
         DMAND  EQU         8,MX                                           16
         SEPT   EQU         9,PX                                           17
         LOADS  EQU         10,PX                                          18
         DATA   EQU         11,PX                                          19
         RPLCM  EQU         12,XH                                          20
         CPLCM  EQU         13,XH                                          21
         CPECM  EQU         14,XH                                          22
         PDCPD  EQU         15,XH                                          23
         PDCPM  EQU         16,XH                                          24
         LUIT   EQU         13,Z                                           25
         NROAD  EQU         13,XB                                          26
         TTIME  EQU         14,XB                                          27
         WAITN  EQU         11,Q                                           28
        *                                                                  29
        *       FIRST GROUP OF CONTROL CARDS                               30
        *                                                                  31
        *                                                                  32
        *       MATRIX DEFINITION STATEMENTS                               33
        *                                                                  34
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INITIAL   MB16(3,1-2),2/MA16(3,3),3/MB16(3,4-5),4
INITIAL   MB16(3,6-7),7/MA16(3,8-9),8/MA16(3,10),7
INITIAL   MA16(4,1-2),2/MA16(4,3),3/MA16(4,4),4/MA16(4,5),5
INITIAL   MA16(4,6),6/MA16(4,7-9),7/MA16(4,10),6
INITIAL   MB16(5,1-4),4/MA16(5,5),5/MA16(5,6-10),'
INITIAL   MB16(6,1-3),7/MA16(6,4),4/MB16(6,5),4
INITIAL   MB16(6,6),6/MA16(6,7-8),7/MB16(6,9-10),10
INITIAL   MB16(7,1-3),3/MA16(7,4-5),4/MA16(7,6),6
INITIAL   MA16(7,7),7/MA16(7,8),8/MA16(7,9),9/MA16(7,10),10
INITIAL   MA16(8,1-3),5/MA16(8,4-7),7/MA16(8,8),8
INITIAL   MA16(8,9),5/MA16(8,10),9/MA16(9,1-3),8/MB16(9,4-5),7
INITIAL   MB16(9,6),10/MA16(9,7),7/MA16(9,8),8/MA16(9,9),9
INITIAL   MA16(9,10),10/MA16(10,1-3),7/MA16(10,4-5),6
INITIAL   MA16(10,6),6/MA16(10,7),7/MA16(10,8-9),9
INITIAL   MA16(10,10),10
INITIAL   MA17(1-2,1-2),1/MA17(2,3),1/MA17(2,4),2
INITIAL   MA17(3,2-4),1/MA17(3,7-8),1/MA17(4,2),1/MA17(4,3),2
INITIAL   MA17(4,4-5),1/MA17(4,6),2/MA17(4,7),1
INITIAL   MA17(5,4-5),1/MA17(6,4),1/MA17(6,6-7),1/MA17(6,10),1
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      INITIAL    MA17(7,3-4),1/MA17(7,6-8),1/MA17(7,9-10),2
      INITIAL    MA17(8,3),1/MA17(8,7-8),1/MA17(8,9),2/MA17(9,7),3
      INITIAL    MA17(9,8),2/MA17(9,9-10),1/MA17(10,6-7),1
      INITIAL    MA17(10,9),2/MA17(10,10),1
      INITIAL    MA18(1,1),2/MA18(2,1),1/MA18(3,1),7/MA18(4,1),9
      INITIAL    MA18(5,1),4/MA18(6,1),7/MA18(7,1),3/MA18(8,1),7
      INITIAL    MA18(9,1),10/MA18(10,1),9/MA18(1-2,2),3/MA18(3,2),8
      INITIAL    MA18(4,2),3/MA18(5,2),6/MA18(6,2),9/MA18(7,2),8
      INITIAL    MA18(8,2),3/MA18(9,2),8/MA18(10,2),6/MA18(1-3,3),4
      INITIAL    MA18(4-5,3),7/MA18(6,3),10/MA18(7,3),6/MA18(8,3),9
      INITIAL    MA18(9-10,3),7/MA18(1-2,4),5/MA18(3,4),2
      INITIAL    MA18(4,4),6/MA18(5,4),1/MA18(6,4),5/MA18(7,4),4
      INITIAL    MA18(8,4),10/MA18(9,4),6/MA18(10,4),8
      INITIAL    MA18(1-2,5),7/MA18(3,5),1/MA18(4-5,5),2
      INITIAL    MA18(6,5),8/MA18(7,5),10/MA18(8,5),6/MA18(9-10,5),3
      INITIAL    MA18(1-2,6),8/MA18(3,6),6/MA18(4,6),1/MA18(5-6,6),3
      INITIAL    MA18(7,6),9/MA18(8-10,6),4/MA18(1-2,7),6
      INITIAL    MA18(3,7),5/MA18(4-5,7),8/MA18(6,7),2
      INITIAL    MA18(7-10,7),5/MA18(1-3,8),9/MA18(4-5,8),10
      INITIAL    MA18(6,8),1/MA18(7-10,8),2/MA18(1-3,9),10
      INITIAL    MA18(4-6,9),9/MA18(7-10,9),1
      INITIAL    MA19(1-2,1),10/MA19(3,1),5/MA19(4-5,1),10
      INITIAL    MA19(6-10,1),5
      INITIAL    MA19(1-8,2),9/MA19(9,2),3/MA19(10,2),4/MA19(1-6,3),8
      INITIAL    MA19(7-8,3),4/MA19(9,3),6/MA19(10,3),8/MA19(1-2,4),6
      INITIAL    MA19(3,4),10/MA19(4-5,4),7/MA19(6-7,4),2
      INITIAL    MA19(8-9,4),2/MA19(10,4),1/MA19(1-2,5),5/MA19(3,5),7
      INITIAL    MA19(4-9,5),1/MA19(10,5),2/MA19(1-2,6),7
      INITIAL    MA19(3-5,6),6/MA19(6,6),4/MA19(7,6),6/MA19(8,6),10
      INITIAL    MA19(9,6),8/MA19(10,6),3/MA19(1-3,7),4/MA19(4,7),5
      INITIAL    MA19(5-8,7),5/MA19(9,7),4/MA19(10,7),6/MA19(1,8),3
      INITIAL    MA19(2-3,8),1/MA19(4-5,8),2/MA19(6-7,8),10
      INITIAL    MA19(8,8),6/MA19(9,8),7/MA19(10,8),9/MA19(1,9),2
      INITIAL    MA19(2,9),3/MA19(3,9),2/MA19(4,9),3/MA19(5,9),4
      INITIAL    MA19(6,9),7/MA19(7,9),2/MA19(8,9),7/MA19(9,9),10
      INITIAL    MA19(10,9),7/MA19(1,10),1/MA19(2,10),2/MA19(3,10),3
      INITIAL    MA19(4,10),4/MA19(5,10),5/MA19(6,10),6
      INITIAL    MA19(7,10),7/MA19(8,10),8/MA19(9,10),9/MA19(10,10),10
      INITIAL    MH1(1,1),20/MH1(1,2),30/MH1(1,3),20/MH1(1,4),7
      INITIAL    MH1(1,11),77/MH1(2,1),14/MH1(2,2),56/MH1(2,3),50
      INITIAL    MH1(2,4),11/MH1(2,6),2/MH1(2,7),2/MH1(2,10),3
      INITIAL    MH1(2,11),138/MH1(3,1),8/MH1(3,2),55/MH1(3,3),56
      INITIAL    MH1(3,4),14/MH1(3,6),5/MH1(3,7),4/MH1(3,8),2
      INITIAL    MH1(3,9),2/MH1(3,10),3/MH1(3,11),109/MH1(4,1),3
      INITIAL    MH1(4,2-3),15/MH1(4,4),125/MH1(4,5),6/MH1(4,6),9
      INITIAL    MH1(4,7),4/MH1(4,8),2/MH1(4,9),1/MH1(4,10),3
      INITIAL    MH1(4,11),183/MH1(5,4),11/MH1(5,5),18/MH1(5,11),29
      INITIAL    MH1(6,2),3/MH1(6,3),5/MH1(6,4),7/MH1(6,5),2
      INITIAL    MH1(6,6),76/MH1(6,7),6/MH1(6,8),5/MH1(6,10),6
      INITIAL    MH1(6,11),118/MH1(7,2),3/MH1(7,3),4/MH1(7,4),1
      INITIAL    MH1(7,6),6/MH1(7,7),66/MH1(7,8),18/MH1(7,9),6
      INITIAL    MH1(7,10),14/MH1(7,11),118/MH1(8,4),1/MH1(8,7),17
      INITIAL    MH1(8,8),24/MH1(8,9),5/MH1(8,10),3/MH1(8,11),50
      INITIAL    MH1(9,4),1/MH1(9,7),2/MH1(9,8),2/MH1(9,9),38
      INITIAL    MH1(9,10),12/MH1(9,11),47/MH1(10,2-3),3/MH1(10,4),1
      INITIAL    MH1(10,6),5/MH1(10,7),8/MH1(10,8),3/MH1(10,9),12
      INITIAL    MH1(10,10),60/MH1(10,11),99
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         INITIAL     MH2(1,1),50/MH2(1,2),200/MH2(2,1),150/MH2(2,2),200
         INITIAL     MH2(2,3),300/MH2(2,4),316/MH2(3,2),200
         INITIAL     MH2(3,3),110/MH2(3,4),200/MH2(3,7),170/MH2(3,8),170
         INITIAL     MH2(4,2),325/MH2(4,3),490/MH2(4,4),200/MH2(4,5),350
         INITIAL     MH2(4,6),459/MH2(4,7),512/MH2(5,4),366/MH2(5,5),150
         INITIAL     MH2(6,4),365/MH2(6,5),200/MH2(6,7),490/MH2(6,10),470
         INITIAL     MH2(7,5),269/MH2(7,4),100/MH2(7,6),260/MH2(7,7),225
         INITIAL     MH2(7,8),445/MH2(7,9),900/MH2(7,10),710
         INITIAL     MH2(8,5),400/MH2(8,7),130/MH2(8,8),175/MH2(8,9),680
         INITIAL     MH2(9,7),1270/MH2(9,8),1055/MH2(9,9),250
         INITIAL     MH2(9,10),350/MH2(10,6),1225/MH2(10,7),1390
         INITIAL     MH2(10,9),625/MH2(10,10),250
*
*        TABLE DEFINITION STATEMENTS
*
 WAIT1 QTABLE      1,0,1,4
 WAIT2 QTABLE      2,0,1,4
 WAIT3 QTABLE      3,0,1,4
 WAIT4 QTABLE      4,0,1,4
 WAIT5 QTABLE      5,0,1,4
 WAIT6 QTABLE      6,0,1,4
 WAIT7 QTABLE      7,0,1,4
 WAIT8 QTABLE      8,0,1,4
 WAIT9 QTABLE      9,0,1,4
 WAT10 QTABLE      10,0,1,4
 WAITN QTABLE      11,0,1,9
*
*        VARIABLE DEFINITIONS
*
 1       VARIABLE    PB2+1
*        V2: THE NUMBER OF DAYS PB1'S CARS ARE ON LINE AND LOADED
 2       VARIABLE    MXSULM(PR1,PR1)+MXSOLW(PR1,PR1)
*        V3:  NUMBER OF DAYS CAR IS MOVING ON LINES OF RECEIVING ROAD
 3       VARIABLE    AC1-PH1-XH11
*        V4:  EXCESS NUMBER OF EMPTY CARS ON ROAD PH1'S LINES
 4       VARIABLE    PH1(PH1,11)-KH*PR1
*        V5:  NUMBER OF DAYS THAT HOME CARS ARE OFF-LINE PER 100 DAYS
*             THAT FOREIGN CARS ARE ON LINE
 5       VARIABLE    100*MX7(PR1,12)/MX7(PR1,'5)
*        V6: THE NUMBER OF DAYS THAT PR1'S CARS ARE ON LINE AND EMPTY
 6       VARIABLE    MXSDFH(PR1,PR1)+MXSDFS(PR1,PR1)
*        V10: THE SUM OF THE ELEMENTS IN THE PR1TH ROW OF MATRIX PR2
 10      VARIABLE    V23+V24+V25+MX*PR2(PR1,10)
 23      VARIABLE    MX*PR2(PB1,1)+MX*PR2(PE1,2)+MX*PB2(PB1,3)
 24      VARIABLE    MX*PR2(PR1,4)+MX*PR2(PR1,5)+MX*PR2(PR1,6)
 25      VARIABLE    MX*PB2(PB1,7)+MX*PR2(PH1,8)+MX*PB2(PR1,9)
*        V12: TOTAL NUMBER OF CAR DAYS FOR ROAD PR1
 12      VARIABLE    MX7(PR1,2)+MX7(PR1,3)+MX7(PR1,4)+MX7(PR1,5)
*        V13: THE SUM OF THE ELEMENTS OF COLUMN PR1 OF MATRIX PR2
 13      VARIABLE    V9+V11+V26+MX*PR2(10,PR1)
 9       VARIABLE    MX*PR2(1,PR1)+MX*PR2(2,PR1)+MX*PR2(3,PR1)
 11      VARIABLE    MX*PR2(4,PR1)+MX*PR2(5,PR1)+MX*PR2(6,PR1)
 26      VARIABLE    MX*PR2(7,PR1)+MX*PR2(8,PR1)+MX*PR2(9,PR1)
*        V14: PERCENT OF TIME THAT ROAD PR1'S CARS ARE LOADED
 14      VARIABLE    100*(MX7(PR1,2)+MX7(PR1,3))/MX7(PR1,1)
*        V15: PERCENT OF TIME THAT ROAD PR1'S CARS ARE IN THE STATE REFERRED TO
*             BY THE PR4TH COLUMN OF MATRIX ADATA
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 15     VARIABLE    100*MX7(PA1,PA4)/MX7(PA1,1)
 16     VARIABLE    (PB4*4)&10
 *      V17: PERCENTAGE OF DEMAND ORIGINATING AT ROAD PA1 THAT IS DESTROYED, OR
 *           FOREIGN CARS SENT AWAY EMPTY BY PB1 AS A % OF THE CARS LOADED AT PB1
 17     VARIABLE    100*MX7(PA1,PB2)/MX7(PA1,PB3)
 *      V18: PERCENTAGE OF MILES TRAVELED BY PB1'S CARS THAT ARE LOADED
 18     VARIABLE    (500*MX7(PA1,7)/(MX7(PA1,7)+MX7(PA1,5)))+2
 *      V19: AMOUNT OF DEMAND WITH ORIGIN PA1 AND DESTINATION PA2
 *           THAT IS DESTROYED
 19     VARIABLE    MHSDEST6(PA1,PA2)+MHSDEST8(PA1,PB2)
 *      V20: NUMBER OF DAYS PA1'S CARS ARE OFF LINE AND IN THE STATE REFERRED
 *      TO BY MATRIX PB2
 20     VARIABLE    V10-MX*PA2(PA1,PA1)
 *      V21: NUMBER OF DAYS FOREIGN CARS ARE ON PA1'S LINES AND IN THE STATE
 *           REFERRED TO BY MATRIX MX*PA2
 21     VARIABLE    V13-MX*PA2(PA1,PA1)
 *      V22: AVERAGE CAR CYCLE FOR ROAD PA1
 22     VARIABLE    MX7(PA1,1)/MX7(PA1,16)
 *      V7: FIRST THREE COMPONENTS OF PROFIT
 7      VARIABLE    (V27+V28+V29)/100
 *      V27: REVENUE MINUS COST FOR LOADED CARS ON HOME LINES
 27     VARIABLE    (XHSRPLCM-XHSCPLCM)*V13
 *      V28: NET CAR HIRE RECEIPTS FOR DAILY CHARGES
 28     VARIABLE    XHSPDCPD*(MX7(PA1,12)-MX7(PB1,13))
 *      V29: NET CAR HIRE RECEIPTS FOR MILEAGE CHARGES
 29     VARIABLE    XHSPDCPM*V30
 *      V30: NET NUMBER OF MILES HOME CARS ARE OFF LINE
 30     VARIABLE    MX7(PA1,7)+MX7(PA1,9)-MX5(PB1,PA1)-MX5(PB1,PA1)
 *      V8: COST OF MOVING EMPTY CARS ON LINE
 8      VARIABLE    XHSCPECM*V13/100
 *      V31:  FILLING IN COLUMN PA3 OF THE ADATA MATRIX
 31     VARIABLE    MXSDATA(PA1,PB6)-MXSDATA(PA1,PB2)
 *      V32:  PERCENTAGE OF DEMAND FOR WHICH NO CAR IS IMMEDIATELY AVAILABLE
 32     VARIABLE    100*MX7(PA1,17)/MX7(PA1,11)
 *
 *      MISCELLANEOUS INITIALIZATIONS
 *
        INITIAL     XHSRPLCM,100/XHSCPLCM,25/XHSCPECM,20
        INITIAL     XHSPDCPD,540/XHSPDCPM,5
        INITIAL     XP1,4/XP2,10/XP3,10/XP4,12/XP5,2/XP6,6
        INITIAL     XP7,7/XP8,3/XP9,3/XP10,4
        INITIAL     MXSDATA(11,14),100
 *      FUNCTION DEFINITIONS
 *
 *      FUNCTIONS 1-10 EXPRESS THE MAXIMUM NUMBER OF EMPTY CARS THAT
 *      A RAILROAD WISHES TO HOLD
 1      FUNCTION    XHSPDCPD,C2
0,53/1000,0
 2      FUNCTION    XHSPDCPD,C2
0,165/1000,0
 3      FUNCTION    XHSPDCPD,C2
0,159/1000,0
 4      FUNCTION    XHSPDCPD,C2
0,173/1000,0
 5      FUNCTION    XHSPDCPD,C2
0,31/1000,0
 6      FUNCTION    XHSPDCPD,C2
0,111/1000,0
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        7     FUNCTION    XH$POCPD,C2
      0.117/1000.0
        8     FUNCTION    XH$PDCPD,C2
      0.56/1000.0
        9     FUNCTION    XH$PDCPD,C2
      0.97/1000.0
       10     FUNCTION    XH$PDCPD,C2
      0.90/1000.0
      *       FUNCTION 11 RANDOMLY DETERMINES WHETHER DEMAND IS LOW, AVERAGE OR HIGH
      *       FOR A DAY IN THE SLACK SEASON
       11     FUNCTION    RN2,D2
      .5,13/1,14
      *       FUNCTION 12 RANDOMLY DETERMINES WHETHER DEMAND IS LOW, AVERAGE OR HIGH
      *       FOR A DAY IN THE PEAK SEASON
       12     FUNCTION    RN2,D3
      .1,13/.7,14/1,15
      *       FUNCTION LULT RANDOMLY CHOOSES THE LOADING OR UNLOADING TIME FOR A CAR
       LULT   FUNCTION    RN3,D4
      .55,1/.9,2/1,3
      *
      *       FIRST MODEL SEGMENT:  MISCELLANEOUS INITIALIZATIONS
      *
 1            GENERATE    1,,,1,10,1PB              CREATE DUMMY TRANSACTION
 2            ASSIGN      1,10,PB                   ASSIGN ROAD NUMBER
 3     BLOKA  SAVEVALUE   PB1,FN$PB1,XH             STORE EACH ROAD'S MAX Q LENGTH
 4            LOOP        1PB,BLOKA                 LOOP THROUGH REST OF ROADS
 5            SAVEVALUE   11,12,XB                  INDICATE PEAK SEASONAL DEMAND
 6            ADVANCE     30                        LET THE NORMALIZATION MONTH PASS
 7     BLK20  SAVEVALUE   11,11,XB                  INDICATE SLACK SEASONAL DEMAND
 8            ADVANCE     91                        LET THE SEASON PASS
 9            SAVEVALUE   11,12,XB                  INDICATE PEAK SEASONAL DEMAND
10            ADVANCE     91                        LET THE SEASON PASS
11            TRANSFER    ,BLK20
      *
      *       SECOND MODEL SEGMENT:  DEMAND CREATION MODULE
      *
12            GENERATE    1,,,,3,5P,,1PH            GENERATE DEMAND-CREATING TRANSACTION
13            SAVEVALUE   12,FN,XB11,XB             PICK HIGH, AVG, OR LOW DAILY DEMAND
14            ASSIGN      1,10,PB                   ASSIGN ORIGINATING ROAD TO PB1
15     BLOK2  ASSIGN      3,10,PB                   STORE RANK OF NEXT DESTINATION ROAD
16     BLOK1  ASSIGN      2,MB19(PB1,PB3),PB        STORE NUMBER OF NEXT DES ROAD
17            SPLIT       MB$XB12(PB1,PB2),BLOK3    CREATE O-D DEMAND
18            LOOP        3PB,BLOK1                 LOOP THROUGH REST OF DESTINATIONS
19            LOOP        1PB,BLOK2                 ASSIGN NEW ORIGIN, UNLESS ALL DONE
20            TERMINATE                             REMOVE DEMAND-CREATING TRASACTION
21     BLOK3  MSAVEVALUE  DMAND+,PB1,PB2,1,MX       COUNT NEW DEMAND JUST CREATED
      *
      *       THIRD MODEL SEGMENT:  DEMAND SERVICING MODULE
      *
22            ASSIGN      5,3,PB                    ASSIGN MAX DAYS LOAD WILL WAIT
23     BLK26  ASSIGN      4,MB12(PB1,PB2),PB        ASSIGN NUMBER OF FEASIBLE OWNERS
24     BLOK4  ASSIGN      3,MB$PB1(PB2,PB4),PB      ASSIGN NEXT CAR OWNER TO BE TRIED
25            TEST G      MH1(PB1,PB3),0,BLOK5      IS A CAR AVAILABLE?
26            MSAVEVALUE  1-,PB1,PB3,1,MH           IF SO, REMOVE FROM STOCK OF EMPTIES
27            MSAVEVALUE  1-,PB1,11,1,MH            IF SO, REMOVE FROM STOCK OF EMPTIES
28            PRIORITY    7                         ASSIGN "TO BE UNLOADED" PRIORITY
29            TEST L      PB5,3,BLK21               WAS DEMAND BEEN IN QUEUE?
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30         DEPART     PR1                          IF SO, THEN REMOVE IT
31         DEPART     WAITN                        REMOVE LOAD FROM NATIONAL QUEUE
32   BLK21 MSAVEVALUE ADATA+,PR3,16,1,MX           SHOW ROAD PASS'S CARS CARRIED A LOAD
33         MSAVEVALUE LOADS+,PR1,PR2,1,MX          SHOW A UNIT OF O-D DEMAND IS LOADED
34         ASSIGN     4,FNBLKLT,PR                 ASSIGN LOADING TIME TO PR4
35         ADVANCE    PR4                          LOAD CAR
36         MSAVEVALUE DLUL+,PR3,PR1,PR4,MX         COUNT DAYS CAR SPENDS BEING LOADED
37         TRANSFER   ,BLK1A                       PASS LOADED CAR TO LINEHAUL MODULE
      *
      *    FOURTH MODEL SEGMENT:  UNSERVICED DEMAND MODULE
      *
38   BLK53 PRIORITY   5                            ASSIGN PRIORITY FOR HELD-OVER DEMAND
39         LOOP       5PR,BLK16                    HAS LOAD LOOKED FOR CAR 3 DAYS?
40         MSAVEVALUE DESTW+,PR1,PR2,1,MH          IF SO, NOTE THAT A LOAD IS DESTROYED
                                                   UNSERVICED DEMAND WAITS THIRD DAY
41         ADVANCE    1                            REMOVE LOAD FROM THE QUEUE
42         DEPART     PR1                          REMOVE LOAD FROM NATIONAL QUEUE
43         DEPART     WAITN                         REMOVE THE LOAD FROM THE MODEL
44         TERMINATE                               HAS THIS LOAD NOT BEEN IN QUEUE YET?
45   BLK16 TEST E     PR5,2,BLOK7                  IF NOT PUT IT IN THE QUEUE
46         QUEUE      PR1                          PUT LOAD INTO NATIONAL QUEUE
47         QUEUE      WAITN                        IS MAX QUEUE LENGTH EXCEEDED?
48         TEST G     Q$PR1,XH$PR1,BLOK7           IF SO, REMOVE IT FROM QUEUE
49         DEPART     PR1                          REMOVE LOAD FROM NATIONAL QUEUE
50         DEPART     WAITN                        NOTE A LOAD IS DESTROYED
51         MSAVEVALUE DESTD+,PR1,PR2,1,MH
52         TERMINATE                               WAIT FOR THE NEXT DAY
53   BLOK7 ADVANCE    1
54         TRANSFER   ,BLK26
      *
      *    THE REST OF THE THIRD MODEL SEGMENT
      *
55   BLOK5 LOOP       4PB,BLOK4                    IF NOT, STORE RANK OF NEXT OWNER
56         TRANSFER   ,BLK53                       PASS DEMAND TO UNSERVICED DEM MODULE
      *
      *    FIFTH MODEL SEGMENT:  LINEHAUL MODULE
      *
57   BLK1A SAVEVALUE  TTIME,MH11(PB1,PB2),XB       STORE EXPECTED TRANSIT TIME
58         ASSIGN     1,AC1,PH                     STORE TIME THAT LINEHAUL BEGINS
59         ADVANCE    XBSTTIME,1                   LINEHAUL
60         SAVEVALUE  NROAD,MH14(PB1,PB2),XB       STORE NUMBER OF DESTINATION ROAD
61         SAVEVALUE  11,MH17(PB1,XBSNROAD),XH     STORE TIME ON SENDING ROAD'S LINES
62         MSAVEVALUE DLH+,PB3,PB1,XH11,MX         INCREMENT DLH FOR SENDING ROAD
63         MSAVEVALUE DLH+,PB3,XBSNROAD,V3,MX      INCREMENT DLH FOR RECEIVING ROAD
64         SAVEVALUE  11,MH2(PB1,XBSNROAD),XH      STORE MILES CAR IS ON SENDING ROAD
65         MSAVEVALUE LMILE+,PB3,PB1,XH11,MX       INCREMENT MILES  ON SENDING ROAD
66         SAVEVALUE  11,MH2(XBSNROAD,PB1),XH      STORE MILES ON RECEIVING ROAD
67         MSAVEVALUE LMILE+,PB3,XBSNROAD,XH11,MX     INCREMENT MILES ON REC. ROAD
68         TEST E     PB2,XBSNROAD,BLK17           HAS CAR REACHED DESTINATION?
69         ASSIGN     4,FNBLKLT,PR                 STORE UNLOADING TIME
70         ADVANCE    PR4                          UNLOAD CAR
71         MSAVEVALUE DLUL+,PH3,PB2,PR4,MX         UPDATE DLUL MATRIX
72         MSAVEVALUE 1+,PB2,PB3,1,MH              ADD CAR TO STOCK OF EMPTIES
73         MSAVEVALUE 1+,PR2,11,1,MH               ADD CAR TO STOCK OF EMPTIES
74         TERMINATE
75   BLK17 ASSIGN     1,XBSNROAD,PB                PUT NEW CAR LOCATION IN PB1
76         TRANSFER   ,BLK1A
      *
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        *       SIXTH MODEL SEGMENT:  EMPTY CAR ALLOCATION MODULE
        *
77              GENERATE    1,,,,2,5PH,1PH              CREATE HOUSEKEEPING TRANSACTION
78              ASSIGN      1,10,PB                     STORE NUMBER OF SENDING ROAD
79        BLK10 TEST G      MH1(PB1,11),XH0PH1,BLOK9    IS THE NUMBER OF EMPTIES EXCESSIVE?
80              SAVEVALUE   17,V4,XH                    STORE EXCESS NUMBER OF CARS PB1 HAS
81              ASSIGN      4,9,PH                      STORE RANK OF FIRST ROAD EXAMINED
82        BLK11 ASSIGN      3,MB18(PB1,PB4),PB          STORE NEXT  OWNER  TO BE EXAMINED
83              TEST G      XH17,MH1(PB1,PB3),BLK13     IS THE NUMBER OF EXCESS EMPTIES ON
        *                                               PB1'S LINES GREATER THAN THE NUMBER
        *                                               OF EMPTIES OWNED BY PB3?
84              SPLIT       MH1(PB1,PB3),BLK12          CREATE TRANSACTIONS TO BE EMPTIES
85              SAVEVALUE   17-,MH1(PB1,PB3),XH         DECREASE NUMBER OF EXCESS CARS
86              SAVEVALUE   11,MH1(PB1,PB3),XH          STORE NUMBER OF CARS SENT AWAY
87              MSAVEVALUE  1,PB1,PB3,0,MH              REDUCE STOCK OF EMPTIES
88              MSAVEVALUE  1-,PB1,11,XH11,MH           REDUCE STOCK OF EMPTIES
89              LOOP        4PH,BLK11                   STORE RANK OF NEXT ROAD TO BE EXAM'D
90              LOOP        1PB,BLK10                   LOOP THROUGH OTHER ROADS
91              TERMINATE
92        BLOK9 LOOP        1PB,BLK10                   CHECK OTHER ROADS
93              TERMINATE
94        BLK13 SPLIT       XH17,BLK12                  CREATE TRANSACTIONS TO BE EMPTIES
95              MSAVEVALUE  1-,PB1,PB3,XH17,MH          REDUCE STOCK OF EMPTIES
96              MSAVEVALUE  1-,PB1,11,XH17,MH           REDUCE STOCK OF EMPTIES
97              LOOP        1PB,BLK10                   LOOP THROUGH OTHER ROADS
98              TERMINATE                               REMOVE DUMMY TRANSACTION
99        BLK12 ASSIGN      2,MB16(PB1,PB3),PB          STORE DESTINATION OF EMPTY CAR
100             PRIORITY    7                           ASSIGN APPROPRIATE PRIORITY TO CAR
101             SAVEVALUE   TTIME,MB11(PB1,PB2),XB      STORE EXPECTED TRANSIT TIME
102             ASSIGN      1,AC1,PH                    STORE TIME THAT LINEHAUL BEGINS
103             ADVANCE     XBSTTIME,1                  LINEHAUL
104             SAVEVALUE   11,MB17(PB1,PB2),XH         STORE NUMBER OF DAYS ON SENDING ROAD
105             MSAVEVALUE  DEM+,PB3,PH1,XH11,MX        UPDATE DEM MATRIX
106             SAVEVALUE   11,V3,XH                    STORE NUMBER OF DAYS ON REC'NG ROAD
107             MSAVEVALUE  DEM+,PB3,PH2,XH11,MX        UPDATE DEM MATRIX
108             SAVEVALUE   11,MH2(PB1,PB2),XH          STORE MILES ON SENDING ROAD
109             MSAVEVALUE  EMILE+,PB3,PB1,XH11,MX      UPDATE EMILE MATRIX
110             SAVEVALUE   11,MH2(PB2,PB1),XH          STORE MILES ON RECEIVING ROAD
111             MSAVEVALUE  EMILE+,PB3,PB2,XH11,MX      UPDATE EMILE MATRIX
112             MSAVEVALUE  1+,PB2,PB3,1,MH             ADD TO STOCK OF EMPTIES
113             MSAVEVALUE  1+,PB2,11,1,MH              ADD TO STOCK OF EMPTIES
114             MSAVEVALUE  SENT+,PB1,PB3,1,MX          UPDATE SENT MATRIX
115             TERMINATE
        *
        *       SEVENTH MODEL SEGMENT:  GATHERING DAILY STATISTICS
        *
116             GENERATE    1,,,,1,2PH                  CREATE RECORD-KEEPING TRANACTION
117             ASSIGN      1,10,PB                     STORE ROAD WHERE EMPTIES ARE LOCATED
118       BLK14 ASSIGN      2,10,PB                     STORE ROAD THAT OWNS EMPTIES
119       BLK15 SAVEVALUE   11,MH1(PB1,PB2),XH          STORE NUMBER OF PB2'S CARS ON PB1
120             MSAVEVALUE  DES+,PB2,PB1,XH11,MX        UPDATE DES MATRIX
121             LOOP        2PH,BLK15                   LOOP THROUGH OTHER OWNERS
122             LOOP        1PB,BLK14                        LOOP THROUGH OTHER LOS
123             TERMINATE                               REMOVE RECORD-KEEPING TRANACTION
        *
        *       EIGHTH MODEL SEGMENT:  FINAL STATISTICS GATHERING AND THE TIMER
        *
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        *       CALCULATE COLUMNS 2-5 OF THE ADATA MATRIX, EXCEPT ROW 11
124             GENERATE  1,,399,,,6PB              GENERATE RECORD-KEEPING TRANSACTION
125             ASSIGN    2,4,PH                    STORE MATRIX NUMBER
126       BLK23 ASSIGN    1,10,PB                   STORE NUMBER OF ROAD
127       BLK22 MSAVEVALUE ADATA,PB1,V1,V10,MX      FILL IN COLS 2-5 OF ADATA MATRIX
128             LOOP      1PB,BLK22                 LOOP THROUGH REST OF ROADS
129             LOOP      2PB,BLK23                 LOOP THROUGH REST OF COLUMNS
        *       CALCULATE COLUMN 6 OF THE ADATA MATRIX, EXCEPT  ROW 11
130             ASSIGN    1,10,PB                   STORE ROAD NUMBER
131       BLK24 MSAVEVALUE ADATA,PB1,6,V2,MX        CALCULATE COL 6 OF ADATA
132             LOOP      1PB,BLK24                 LOOP THROUGH REST OF ROADS
        *       CALCULATE COLUMN 8 OF ADATA MATRIX, EXCEPT ROW 11
133             ASSIGN    1,10,PB                   STORE ROAD NUMBER
134       BLK25 MSAVEVALUE ADATA,PB1,8,V6,MX        FILL IN COL 8 OF ADATA
135             LOOP      1PB,BLK25                 LOOP THROUGH REST OF ROADS
        *       CALCULATE COL 1 OF ADATA MATRIX, EXCEPT ROW 11
136             ASSIGN    1,10,PB                   STORE NUMBER OF ROAD
137       BLK27 MSAVEVALUE ADATA,PB1,1,V12,MX       FILL IN COL 1 OF ADATA MATRIX
138             LOOP      1PB,BLK27                 LOOP THROUGH REST OF ROADS
        *       CALCULATE ROW 11 OF COLS 1-6, 8 OF ADATA MATRIX
139             ASSIGN    2,7,PH                    STORE NUMBER OF ADATA MATRIX
140             ASSIGN    1,8,PH                    STORE COLUMN OF ADATA MATRIX
141       BLK28 MSAVEVALUE ADATA,11,PB1,V13,MX      PUT NATIONWIDE TOTALS INTO ADATA
142             LOOP      1PB,BLK28                 LOOP THROUGH REST OF COLUMNS
        *       CALCULATE COLUMN 2 OF DATA MATRIX
143             ASSIGN    1,11,PB                   STORE ROAD (OR ROW) NUMBER
144       BLK29 MSAVEVALUE DATA,PB1,2,V14,MX        FILL IN COL 2 OF DATA MATRIX
145             LOOP      1PB,BLK29                 LOOP THROUGH REST OF ROADS
        *       CALCULATE COL 3 OF DATA MATRIX
146             ASSIGN    1,11,PB                   STORE ROAD NUMBER
147       BLK52 MSAVEVALUE DATA,PB1,3,100,MX
148             SAVEVALUE  11,MX$DATA(PB1,2),XH
149             MSAVEVALUE DATA-,PB1,3,XH11,MX      FILL IN COL 3 OF DATA MATRIX
150             LOOP      1PB,BLK52                 LOOP THROUGH REST OF ROADS
        *       CALCULATE COLUMNS 4-11 OF THE DATA MATRIX
151             ASSIGN    6,3,PH                    PREPARE TO CALCULATE COLUMNS 8-11
152             ASSIGN    5,4,PH                    SET COUNTING PARAMETER
153             ASSIGN    3,11,PB                   STORE COL TO BE CALCULATED BY RESID
154             ASSIGN    4,4,PH                    STORE COLUMN OF ADATA MATRIX
155             ASSIGN    2,10,PB                   STORE COL TO BE CALCULATED DIRECTLY
156       BLK32 ASSIGN    1,11,PB                   STORE ROAD NUMBER
157       BLK30 MSAVEVALUE DATA,PB1,PB2,V15,MX      DIRECTLY CALCULATE COLUMN OF DATA
158             LOOP      1PB,BLK30                 LOOP THROUGH REST OF ROADS
159             ASSIGN    1,11,PB                   STORE ROAD NUMBER
160       BLK31 MSAVEVALUE DATA,PB1,PB3,V31,MX      FILL IN COLUMN PB3 OF DATA MATRIX
161             LOOP      1PB,BLK31                 LOOP THROUGH REST OF ROADS
162             TEST LE   PB5,3,BLK54               HAVE COLUMNS 8-11 BEEN FILLED?
163             ASSIGN    6,2,PH                       PREPARE TO CALCULATE COS 4-7
164       BLK54 ASSIGN    2-3-,2,PB                 RESET PB2-3 FOR NEXT CALCULATION
165             ASSIGN    4,V16,PB                  SET PB4 FOR NEXT CALCULATION
166             LOOP      5PB,BLK32                 LOOP THROUGH REST OF COLUMNS
        *       CALCULATE COLUMNS 7 AND 9 OF THE ADATA MATRIX
167             ASSIGN    2,5,PH                    STORE NUMBER OF LMILE MATRIX
168             ASSIGN    1,10,PB                   STORE ROAD NUMBER
169       BLK33 MSAVEVALUE ADATA,PB1,7,V10,MX       FILL IN LOADED MILES COLUMN OF ADATA
170             LOOP      1PB,BLK33                 LOOP THROUGH REST OF ROADS
171             ASSIGN    2,6,PH                    STORE NUMBER OF EMILE MATRIX
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172        ASSIGN     1,10,FR                  STORE ROAD NUMBER
173  BLK34 MSAVEVALUE ADATA,PR1,9,V10,MX       CALCULATE EMPTY MILES COLUMN
174        LOOP       1PR,BLK34                LOOP THROUGH REST OF ROADS
175        ASSIGN     1,9,PH                   STORE NUMBER OF COLUMN
176        ASSIGN     2,7,PH                   STORE NUMBER OF ADATA MATRIX
177        MSAVEVALUE ADATA,11,9,V13,MX        PUT TOTAL EMPTY MILES INTO ADATA
178        ASSIGN     1,7,PH                   STORE NUMBER OF COLUMN
179        MSAVEVALUE ADATA,11,7,V13,MX        FILL IN TOTAL LOADED MILES
     *      CALCULATE COLUMN 12 OF DATA MATRIX
180        ASSIGN     1,11,FR                  STORE ROAD NUMBER
181  BLK35 MSAVEVALUE DATA,PR1,12,V18,MX       FILL IN COL 12 OF DATA MATRIX
182        LOOP       1PR,BLK35                LOOP THROUGH REST OF ROADS
     *     CALCULATE COLUMN 10 OF ADATA MATRIX
183        ASSIGN     1,10,FR                  STORE ORIGIN
184  BLK37 ASSIGN     2,10,FR                  STORE DESTINATION
185  BLK36 MSAVEVALUE ADATA+,PH1,10,V19,MX     ADD TO DEMAND DESTROYED
186        LOOP       2PR,BLK36                LOOP THROUGH DESTINATIONS
187        LOOP       1PR,BLK37                LOOP THROUGH ORIGINS
188        ASSIGN     2,7,PH                   STORE NUMBER OF ADATA MATRIX
189        ASSIGN     1,10,FR                  STORE COL NUMBER OF ADATA MATRIX
190        MSAVEVALUE ADATA,11,10,V13,MX       FILL IN TOTAL DEMAND DESTROYED
     *     CALCULATE COLUMN 11 OF THE ADATA MATRIX
191        ASSIGN     2,8,PH                   STORE NUMBER OF DMAND MATRIX
192        ASSIGN     1,10,FR                  STORE ROAD NUMBER
193  BLK38 MSAVEVALUE ADATA,PR1,11,V10,MX      FILL IN DEMAND COL OF ADATA
194        LOOP       1PR,BLK38                LOOP THROUGH REST OF ROADS
195        ASSIGN     2,7,PH                   STORE NUMBER OF ADATA MATRIX
196        ASSIGN     1,11,FH                  STORE COLUMN OF ADATA MATRIX
197        MSAVEVALUE ADATA,11,11,V13,MX       CALCULATE TOTAL DEMAND
     *     CALCULATE COLUMN 13 OF THE DATA MATRIX
198        ASSIGN     1,11,FR                  STORE ROAD NUMBER
199        ASSIGN     2,10,FR                  STORE COL OF ADATA
200        ASSIGN     3,11,PH                  STORE COL OF ADATA
201  BLK39 MSAVEVALUE DATA,FR1,13,V17,MX       FILL IN COL 13 OF DATA MATRIX
202        LOOP       1PR,BLK39                LOOP THROUGH REST OF ROADS
     *     CALCULATE COLUMN 12 OF THE ADATA MATRIX
203        ASSIGN     1,10,FR                  STORE ROAD NUMBER
204  BLK41 ASSIGN     2,4,PR                   STORE MATRIX NUMBER
205  BLK40 MSAVEVALUE ADATA+,PR1,12,V20,MX     INCREMENT COL 12 OF ADATA MATRIX
206        LOOP       2PR,BLK40                LOOP THROUGH OTHER STATES
207        LOOP       1PR,BLK41                LOOP THROUGH OTHER ROADS
     *     CALCULATE COLUMN 13 OF THE ADATA MATRIX
208        ASSIGN     1,10,FR                  STORE ROAD NUMBER
209  BLK43 ASSIGN     2,4,PH                   STORE MATRIX NUMBER
210  BLK42 MSAVEVALUE ADATA+,PR1,13,V21,MX     FILL IN COL 13 OF ADATA MATRIX
211        LOOP       2PR,BLK42                LOOP THROUGH REST OF MATRICES
212        LOOP       1PR,BLK43                LOOP THROUGH REST OF ROADS
     *     CALCULATE COLUMN 14 OF THE DATA MATRIX
213        ASSIGN     1,10,PR                  STORE ROAD NUMBER
214  BLK44 MSAVEVALUE DATA,PR1,14,V9,MX        FILL IN COL 14 OF DATA MATRIX
215        LOOP       1PR,BLK44                LOOP THROUGH REST OF ROADS
     *     CALCULATE COLUMN 14 OF THE ADATA MATRIX, EXCEPT ROW 11
216        ASSIGN     2,9,PH                   STORE NUMBER OF SENT MATRIX
217        ASSIGN     1,10,FR                  STORE ROAD NUMBER
218  BLK45 MSAVEVALUE ADATA,PR1,14,V10,MX      FILL IN COL 14 OF ADATA
219        LOOP       1PR,BLK45                LOOP THROUGH REST OF ROADS
     *     CALCULATE COLUMN 15 OF THE ADATA MATRIX, EXCEPT ROW 11
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220          ASSIGN      1,10,PR                        STORE ROAD NUMBER
221          ASSIGN      2,10,PR                        STORE NUMBER OF LOADS MATRIX
222    BLK46 MSAVEVALUE  ADATA,PR1,15,V10,MX            FILL IN COL 15 OF ADATA MATRIX
223          LOOP        1PR,BLK46                      LOOP THROUGH REST OF ROADS
      *      CALCULATE ROW 11 OF COLUMNS 12-15 OF ADATA MATRIX
224          ASSIGN      2,7,PH                         STORE NUMBER OF ADATA MATRIX
225          ASSIGN      3,4,PR                         SET LOOPING PARAMETER
226          ASSIGN      1,15,PR                        STORE COLUMN OF ADATA MATRIX
227    BLK55 MSAVEVALUE  ADATA,11,PR1,V13,MX            FILL IN COLUMN PR1 OF ADATA MATRIX
228          ASSIGN      1-,1,PR                        DECREMENT COLUMN NUMBER
229          LOOP        3PB,BLK55                      LOOP THROUGH OTHER COLUMNS
      *      CALCULATE COLUMN 15 OF THE DATA MATRIX
230          ASSIGN      1,11,PR                        STORE ROAD NUMBER
231          ASSIGN      2,14,PH                        STORE COLUMN NUMBER
232          ASSIGN      3,15,PR                        STORE COLUMN NUMBER
233    BLK47 MSAVEVALUE  DATA,PR1,15,V17,PX             FILL IN COL 15 OF THE DATA MATRIX
234          LOOP        1PR,BLK47                      LOOP THROUGH REST OF ROADS
      *      CALCULATE ROW 11 OF COLUMN 16 OF THE ADATA MATRIX (ROWS 1-10 ARE
      *      CALCULATED IN THE DEMAND SERVICING MODULE)
235          ASSIGN      2,7,PH                         STORE NUMBER OF ADATA MATRIX
236          ASSIGN      1,16,PR                        STORE COLUMN NUMBER
237          MSAVEVALUE  ADATA,11,16,V13,PX             FILL IN NUMBER OF LOADS CARRIED
      *      CALCULATE COLUMN 16 OF THE DATA MATRIX
238          ASSIGN      1,11,PR                        STORE ROAD NUMBER
239    BLK49 MSAVEVALUE  DATA,PR1,16,V22,MX             FILL IN AVG CAR CYCLE
240          LOOP        1PB,BLK49                      LOOP THROUGH REST OF ROADS
      *      CALCULATE COLUMN 1 OF THE DATA MATRIX
241          ASSIGN      2,5,PR                         STORE NUMBER OF LMILE MATRIX
242          ASSIGN      1,10,PR                        STORE ROAD NUMBER
243    BLK50 MSAVEVALUE  DATA+,PR1,1,V7,MX              ADD FIRST COMPONENT OF PROFIT
244          LOOP        1PR,BLK50                      LOOP THROUGH REST OF ROADS
245          ASSIGN      2,6,PH                         STORE NUMBER OF EMILE MATRIX
246          ASSIGN      1,10,PR                        STORE ROAD NUMBER
247    BLK51 MSAVEVALUE  DATA-,PR1,1,V8,MX              SUBTRACT SECOND COMPONENT OF PROFIT
248          LOOP        1PR,BLK51                      LOOP THROUGH REST OF ROADS
249          ASSIGN      2,11,PR                        STORE NUMBER OF DATA MATRIX
250          ASSIGN      1,1,PR                         STORE COLUMN OF DATA MATRIX
251          MSAVEVALUE  DATA,11,1,V13,MX               FILL IN AGGREGATE RAILROAD PROFIT
      *      CALCULATE COLUMN 17 OF THE ADATA MATRIX
252          ASSIGN      1,11,PR                        STORE ROAD NUMBER
253    BLK56 MSAVEVALUE  ADATA,PR1,17,QC*PR1,MX         FILL IN NUMBER OF CAR SHORTAGES
254          LOOP        1PB,BLK56                      LOOP THROUGH REST OF ROADS
      *      CALCULATE COLUMN 17 OF THE DATA MATRIX
255          ASSIGN      1,11,PR                        STORE ROAD NUMBER
256    BLK57 MSAVEVALUE  DATA,PR1,17,V32,MX             FILL IN % OF CAR SHORTAGES
257          LOOP        1PB,BLK57                      LOOP THROUGH REST OF ROADS
258          TERMINATE   1                              STOP THE MODEL
      *
      *      EIGHTH MODEL SEGMENT:  RUN THE MODEL FOR A MONTH TO NORMALIZE ITS STATE
      *
259          GENERATE    ,,30,1                         CREATE TIMING TRANSACTION
260          MSAVEVALUE  DESTW,1-10,1-10,0,MH           RESET STATISTICS
261          MSAVEVALUE  DESTO,1-10,1-10,0,MH           RESET STATISTICS
262          MSAVEVALUE  1-6,1-10,1-10,0,MX             RESET STATISTICS
263          MSAVEVALUE  7,1-11,1-16,0,MX               RESET STATISTICS
264          MSAVEVALUE  8-10,1-10,1-10,0,MX            RESET STATISTICS
265          MSAVEVALUE  11,1-11,1-16,0,MX              RESET STATISTICS
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266          MSAVEVALUE DATA,11,14,100,MX        RESET STATISTICS                              802
267          TERMINATE  1                        STOP THE MODEL AFTER THE FIRST                803
       *                                         30 DAYS SO STATISTICS CAN BE RESET            804
       *                                                                                       805
       *     SECOND GROUP OF CONTROL CARDS                                                     806
       *                                                                                       807
             START      1                        START THE MODEL FOR THE 30 DAY                808
       *                                         NORMALIZATION PERIOD                          809
             RESET                                                                             810
             START      1                        START MODEL FOR THE ONE YEAR RUN              811
             END                                                                               812
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RELATIVE CLOCK 364 ABSOLUTE CLOCK 394

BLOCK COUNTS

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
1	0	0	11	0	1	21	0	45700	31	0	3229	41	0	0
2	0	0	12	0	364	22	0	45700	32	0	45190	42	0	0
3	0	0	13	0	364	23	0	68936	33	0	45190	43	0	0
4	0	0	14	0	364	24	0	79889	34	0	45190	44	0	0
5	0	0	15	0	3640	25	0	79889	35	241	45190	45	0	3746
6	0	0	16	0	36400	26	0	45190	36	0	45143	46	0	3739
7	0	2	17	0	82100	27	0	45190	37	0	45143	47	0	3739
8	0	2	18	0	36400	28	0	45190	38	0	3746	48	0	3739
9	0	2	19	0	3640	29	0	45190	39	0	3746	49	0	504
10	1	2	20	0	364	30	0	3229	40	0	0	50	0	504

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
51	0	504	61	0	50850	71	0	45190	81	0	909	91	0	0
52	0	504	62	0	50850	72	0	45190	82	0	6608	92	0	2731
53	20	3242	63	0	50850	73	0	45190	83	0	6608	93	0	144
54	0	3236	64	0	50850	74	0	45190	84	0	6715	94	0	2722
55	0	34699	65	0	50850	75	0	5685	85	0	5881	95	0	727
56	0	3746	66	0	50850	76	0	5685	86	0	5881	96	0	727
57	0	50828	67	0	50850	77	0	364	87	0	5881	97	0	727
58	0	50828	68	0	50850	78	0	364	88	0	5881	98	0	220
59	335	50828	69	0	45165	79	0	3640	89	0	5881	99	0	2829
60	0	50850	70	207	45165	80	0	909	90	0	182	100	0	2829

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
101	0	2829	111	0	2818	121	0	36400	131	0	10	141	0	8
102	0	2829	112	0	2818	122	0	3640	132	0	10	142	0	8
103	14	2829	113	0	2818	123	0	364	133	0	1	143	0	1
104	0	2818	114	0	2818	124	0	1	134	0	10	144	0	11
105	0	2818	115	0	2818	125	0	1	135	0	10	145	0	11
106	0	2818	116	0	364	126	0	4	136	0	1	146	0	1
107	0	2818	117	0	364	127	0	40	137	0	10	147	0	11
108	0	2818	118	0	3640	128	0	40	138	0	10	148	0	11
109	0	2818	119	0	36400	129	0	4	139	0	1	149	0	11
110	0	2818	120	0	36400	130	0	1	140	0	1	150	0	11

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
151	0	1	161	0	44	171	0	1	181	0	11	191	0	1
152	0	1	162	0	4	172	0	1	182	0	11	192	0	1
153	0	1	163	0	3	173	0	10	183	0	1	193	0	10
154	0	1	164	0	4	174	0	10	184	0	10	194	0	10
155	0	1	165	0	4	175	0	1	185	0	100	195	0	1
156	0	4	166	0	4	176	0	1	186	0	100	196	0	1
157	0	44	167	0	1	177	0	1	187	0	10	197	0	1
158	0	44	168	0	1	178	0	1	188	0	1	198	0	1
159	0	4	169	0	10	179	0	1	189	0	1	199	0	1
160	0	44	170	0	10	180	0	1	190	0	1	200	0	1

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
201	0	11	211	0	40	221	0	1	231	0	1	241	0	1
202	0	11	212	0	10	222	0	10	232	0	1	242	0	1
203	0	1	213	0	1	223	0	10	233	0	11	243	0	10
204	0	10	214	0	10	224	0	1	234	0	11	244	0	10
205	0	40	215	0	10	225	0	1	235	0	1	245	0	1
206	0	40	216	0	1	226	0	1	236	0	1	246	0	1
207	0	10	217	0	1	227	0	4	237	0	1	247	0	10
208	0	1	218	0	10	228	0	4	238	0	1	248	0	10
209	0	10	219	0	10	229	0	4	239	0	11	249	0	1

210	0	48	220	0	1	230	0	1	240	0	11	250	0	1
BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
251	0	1	261	0	0									
252	0	1	262	0	0									
253	0	11	263	0	0									
254	0	11	264	0	0									
255	0	1	265	0	0									
256	0	11	266	0	0									
257	0	11	267	0	0									
258	0	1												
259	0	0												
260	0	0												

FULLWORD MATRICES

FULLWORD MATRIX DLW

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	2934	2395	912	402	0	0	234	0	0	0
2	2210	12101	4735	484	0	22	267	0	0	20
3	995	2700	8833	1429	0	715	3418	0	0	1147
4	514	4409	795	15830	1455	15	105	0	0	0
5	0	0	0	411	2136	139	0	0	0	0
6	0	56	147	2713	0	7523	278	0	0	405
7	13	73	136	0	0	1025	7962	1392	0	167
8	1	9	29	0	0	228	962	2565	125	131
9	0	0	0	0	0	0	490	0	3339	1321
10	21	521	1048	0	0	597	3112	104	275	9155

FULLWORD MATRIX DLUL

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	4526	67	769	405	0	0	341	0	0	0
2	3369	17913	6505	477	0	55	344	0	0	9
3	1608	958	13448	1102	0	1147	1446	0	0	603
4	768	1717	1190	21511	1410	22	169	0	0	0
5	0	0	0	218	3132	141	0	0	0	0
6	0	101	115	2754	0	11579	77	0	0	233
7	21	75	72	0	0	1605	12167	2150	0	91
8	2	9	26	0	0	333	737	3929	32	98
9	0	0	0	0	0	0	346	0	4505	1049
10	40	680	479	0	0	919	1399	110	264	8515

FULLWORD MATRIX DEM

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	0	23	159	7	0	0	146	0	0	0
2	592	642	178	16	0	7	186	0	0	0
3	160	162	212	64	0	220	475	0	0	120
4	57	51	0	462	184	0	94	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	348	0	148	0	0	0	0
7	3	5	0	0	0	72	79	11	0	0
8	1	1	0	0	0	201	283	56	12	0
9	0	0	0	0	0	0	472	0	693	12
10	27	25	0	0	0	16	230	6	10	401

FULLWORD MATRIX DES

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	2931	0	13	9	0	0	109	0	0	0
2	6172	1850	1590	22	0	5	289	0	0	0
3	43	0	2996	674	0	418	9452	0	0	1123
4	26	1146	316	8468	2287	0	2220	0	0	0
5	0	0	0	1	2728	966	0	0	0	0
6	0	112	4	7464	0	3382	4	0	0	10
7	0	17	23	0	0	7628	3649	1266	0	1
8	0	32	142	0	0	6988	49	3324	83	47
9	0	0	0	0	0	0	2172	0	5743	232
10	9	3836	27	0	0	250	2337	153	0	4763

FULLWORD MATRIX FMILE

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	295100	606622	180310	86775	0	0	63332	0	0	0
2	436600	2072810	410830	163566	0	9110	80532	0	0	8340
3	206200	646182	1298830	349368	0	352109	1007822	0	0	923190
4	101900	1994282	190900	3392065	334124	4780	10600	0	0	0
5	0	0	0	91795	349808	38325	0	0	0	0
6	0	20680	27710	597603	0	1716880	68532	0	0	191490
7	2200	18450	29020	0	0	416000	2121179	185930	0	77800
8	200	1650	4570	0	0	96790	376389	426220	55596	44680
9	0	0	0	0	0	0	205270	0	1020228	414030
10	9990	193750	193560	0	0	277970	1090058	31750	114450	3332209

FULLWORD MATRIX FMILE

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	0	6612	24820	2275	0	0	41466	0	0	0
2	118400	10[illegible]56	29920	5200	0	3250	51804	0	0	0
3	32000	24000	36660	19600	0	99000	136192	0	0	99600
4	11900	8550	0	112928	67344	0	9500	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	78940	0	62790	0	0	0	0
7	600	450	0	0	0	32400	23615	1430	0	0
8	200	150	0	0	0	90450	68725	8890	6330	0
9	0	0	0	0	0	0	212400	0	303708	3750
10	9900	4050	0	0	0	7520	81650	2090	4215	181325

FULLWORD MATRIX ADATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16382	6877	6108	335	62	7460	1232139	2931	74971	0
2	60040	19839	28652	1621	9928	30014	4421788	2492	311930	154
3	55668	19237	20312	1413	14706	22281	4363692	32[illegible]8	399092	88
4	65181	23[illegible]83	26787	848	14463	37341	5447651	8930	209222	28
5	9462	2656	3511	0	3295	5268	479928	2728	0	0
6	37529	11202	14859	492	10976	19102	2622885	3530	141728	0
7	39699	10768	1618[illegible]	178	12580	20129	2846519	3724	58495	0
8	20365	4036	5166	508	10661	6494	1004055	3374	174745	46
9	28374	5110	5900	1177	8147	7844	1639528	6436	519858	31
10	39337	14833	12406	715	11383	17670	5139143	5164	286200	155
11	363997	117635	139882	7279	99201	173603	29197328	42517	2176261	504

ROW/COLUMN	11	12	13	14	15	16	17
1	2922	5991	16652	840	2922	1983	0
2	7514	27534	19180	0	7358	9264	1048
3	7787	34179	19370	0	7619	6591	840
4	8682	18910	18996	227	8574	8654	867
5	1395	1466	5336	184	1395	1148	0
6	4913	14897	25584	516	4915	4764	58
7	5259	15846	32139	982	5256	5200	170
8	2062	10497	5192	14	2015	1672	187
9	1698	6054	809	9	1667	1924	116
10	3628	16503	6899	46	3475	3990	467
11	45780	147877	147877	2818	45190	[illegible]5190	3753

FULLWORD MATRIX OMAND

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	974	785	610	364	0	0	189	0	0	0
2	1395	2544	2426	728	0	57	307	0	0	57
3	974	2188	2426	728	0	553	482	0	0	364
4	421	667	667	5755	610	364	118	0	0	0
5	0	0	0	364	974	57	0	0	0	0
6	0	57	246	671	0	3211	364	0	0	364
7	57	57	478	0	0	482	2467	974	0	364
8	0	0	0	0	0	246	785	974	0	57
9	0	0	0	0	0	0	246	0	1031	421
10	57	246	246	0	0	364	421	57	921	1816

FULLWORD MATRIX SENT

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	0	592	160	57	0	0	3	1	0	27
ROWS 2-3, COLUMNS 1-10 ARE ZERO										
4	7	16	32	0	0	172	0	0	0	0
5	0	0	0	184	0	0	0	0	0	0
6	0	7	220	0	0	0	72	201	0	16
7	146	176	178	94	0	0	0	57	236	115
8	0	0	0	0	0	0	11	0	0	3
9	0	0	0	0	0	0	0	6	0	3
10	0	0	40	0	0	0	0	0	6	0

FULLWORD MATRIX LOADS

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	974	785	610	364	0	0	189	0	0	0
2	1341	2544	2418	678	0	48	282	0	0	47
3	960	2180	2426	713	0	533	464	0	0	343
4	912	659	665	5757	602	363	118	0	0	0
5	0	0	0	364	974	97	0	0	0	0
6	0	57	246	671	0	3211	364	0	0	364
7	57	57	478	0	0	481	2447	972	0	364
8	0	0	0	0	0	230	767	972	0	44
9	0	0	0	0	0	0	234	0	1025	408
10	28	208	220	0	0	347	420	25	408	1017

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	734265	79	21	45	34	41	38	17	4	2
2	4315081	80	20	49	31	33	47	4	16	2
3	2237443	71	29	40	31	34	37	5	24	2
4	3340156	76	24	57	19	35	41	13	11	1
5	469146	65	35	55	10	28	37	28	7	0
6	2[illegible]34387	69	31	58	19	29	40	9	22	1
7	3455346	67	33	50	17	27	40	9	24	0
8	925296	45	55	31	14	19	26	16	39	2
9	862627	54	46	38	16	25	29	31	15	5
10	3381755	69	31	44	25	37	32	13	18	1
11	91552982	70	30	47	23	32	38	11	19	1

ROW/COLUMN	11	12	13	14	15	16	17
1	19	94	0	35	28	8	0
2	18	92	2	143	0	6	13
3	27	96	1	155	0	8	10
4	23	96	0	99	2	7	10
5	35	100	0	27	13	8	0
6	38	94	0	63	10	7	1
7	33	96	0	49	18	7	3
8	53	84	2	202	0	12	9
9	41	74	1	748	0	10	6
10	30	94	4	239	1	9	12
11	29	92	1	100	6	8	8

HALFWORD MATRICES

HALFWORD MATRIX 1

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16	10	0	0	0	0	0	0	0	0
2	0	7	0	0	0	0	0	0	0	12
3	0	2	6	2	0	0	0	2	0	0
4	0	0	0	0	0	27	0	0	0	0
5	0	0	0	7	5	0	0	0	0	0
6	0	0	1	0	0	0	24	24	0	2
7	0	0	22	14	0	0	0	0	4	14
8	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	2	0
10	0	0	0	0	0	0	0	0	0	0

ROW/COLUMN	11
1	26
2	19
3	12
4	27
5	12
6	51
7	54
8	0
9	2
10	0

HALFWORD MATRIX MESTW

ALL MSAVEVALUES IN THIS MATRIX CONTAIN ZEROES

HALFWORD MATRIX 2

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	50	200	0	0	0	0	0	0	0	0
2	150	200	300	916	0	0	0	0	0	0
3	0	200	110	200	0	0	170	170	0	0
4	0	325	490	240	350	459	512	0	0	0
5	0	0	0	366	158	0	0	0	0	0
6	0	0	0	365	0	200	450	0	0	470
7	0	0	284	100	0	260	225	445	900	710
8	0	0	400	0	0	0	130	175	680	0
9	0	0	0	0	0	3	1278	1055	250	350
10	0	0	0	0	0	1225	1390	0	625	250

HALFWORD MATRIX CESTO

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	0	0	0	0	0	0	0	0	0	0
2	54	[illegible]	0	50	0	9	25	0	0	10
3	14	0	0	19	0	20	18	0	0	21
4	0	7	1	0	0	4	1	0	0	0
ROWS 5-7, COLUMNS 1-10 ARE ZERO										
8	0	0	0	0	0	16	16	1	0	13
9	0	0	0	0	0	0	12	0	6	13
10	28	37	25	0	0	[illegible]	2	32	14	0

BYTE SAVEVALUES

NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS
1	4	2	10	3	10	4	12	5	2	6	6
7	7	8	1	9	3	10	4	11	12	12	15
NROAD	2	TTIME	2								

HALFWORD SAVEVALUES

NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS
1	26	2	82	3	79	4	85	5	15	6	55
7	58	8	27	9	23	10	44	11	79	RPLCM	100
CPLCM	25	CPECM	20	PDCPD	500	PDCPM	5	17	5		

QUEUES

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS	$AVERAGE TIME/TRANS	TABLE NUMBER	CURRENT CONTENTS
2	11	2.450	1048	156	14.8	.851	1.000	2	
3	11	2.074	890	88	10.4	.898	1.003	3	
4	13	2.277	867	28	3.2	.956	.988	4	10
6	3	.159	58		.0	1.000	1.000	6	
7	6	.458	170		.0	.982	.982	7	5
8	4	.381	187	46	24.5	.743	.985	8	3
9	4	.291	116	31	26.7	.758	1.035	9	
10	5	.846	467	155	33.1	.659	.987	10	4
WAITN	34	8.890	3753	504	13.4	.862	.995	11	20

$AVERAGE TIME/TRANS = AVERAGE TIME/TRANS EXCLUDING ZERO ENTRIES

TABLES

TABLE WAIT2

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
1048	.851	.355	892.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	156	14.88	14.8	85.1	-.000	-2.391
1	892	85.11	100.0	.0	1.174	.418

REMAINING FREQUENCIES ARE ALL ZERO

TABLE WAIT3

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
840	.898	.313	755.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	88	10.47	10.4	89.5	-.000	-2.869
1	749	89.16	99.6	.3	1.112	.323
2	3	.35	100.0	.0	2.225	3.515

REMAINING FREQUENCIES ARE ALL ZERO

TABLE WAIT4

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
857	.967	.177	829.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	28	3.26	3.2	96.7	-.000	-5.442
1	829	96.73	100.0	.0	1.033	.183

REMAINING FREQUENCIES ARE ALL ZERO

TABLE WAIT6

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
58	1.000	.000	58.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-.000
1	58	100.00	100.0	.0	1.000	-.000

REMAINING FREQUENCIES ARE ALL ZERO

TABLE WAIT7

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
167	1.000	.000	167.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-.000
1	167	100.00	100.0	.0	1.000	-.000

REMAINING FREQUENCIES ARE ALL ZERO

TABLE WAIT8

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
184	.755	.443	139.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	46	25.00	25.0	75.0	-.000	-1.703
1	137	74.45	99.5	.5	1.323	.551
2	1	.54	100.0	.0	2.647	2.807

REMAINING FREQUENCIES ARE ALL ZERO

TABLE WAIT8

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
3733	.866	.345	3236.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	504	13.50	13.5	86.4	-.000	-2.511
1	3222	86.31	99.8	.1	1.153	.385
2	7	.18	100.0	.0	2.307	3.282

REMAINING FREQUENCIES ARE ALL ZERO

TABLE WAIT9

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
116	.758	.484	88.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	31	26.72	26.7	73.2	-.000	-1.559
1	82	70.68	97.4	2.5	1.318	.496
2	3	2.58	100.0	.0	2.636	2.551

REMAINING FREQUENCIES ARE ALL ZERO

TABLE WAIT10

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
463	.665	.472	308.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	155	33.47	33.4	66.5	-.000	-1.408
1	308	66.52	100.0	.0	1.503	.708

REMAINING FREQUENCIES ARE ALL ZERO

K. SUMMARY OUTPUT

This appendix contains the summary output for Runs 1 through 18, which are described in Section 5 and Appendix D. (The output for Run 19 is not included since it is identical to the output of Run 12 except for the profit figures given in Table 5-6.)

The summary output consists of the DATA and the ADATA matrices. Each of the matrices contains 17 columns of output; each column has 11 rows; the first 10 rows refer to the 10 railroads and the last row refers to the nation as a whole. In order to understand these matrices, one must refer to the explanation in Sections B.2 and B.3.

The summary output for each run appears on a single page. The title gives the run number and a brief description of how the run differs from the Base Case Run.

Run 1: Official Base Case (with the Standard Random Number Stream)

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	734265	79	21	45	34	41	38	17	4	2
2	4315481	84	20	49	31	35	47	4	16	2
3	2237443	71	29	48	31	34	37	5	24	2
4	3344196	76	24	57	19	35	41	13	11	1
5	469146	65	35	55	18	28	37	28	7	6
6	2[illegible]34387	[illegible]	31	58	19	29	40	9	22	1
7	3455346	[illegible]	33	50	17	27	30	9	24	0
8	528296	45	49	31	14	19	26	14	39	2
9	862427	54	46	38	16	25	24	31	15	5
10	3381795	69	31	44	25	57	12	13	18	1
11	21352982	70	38	47	23	42	18	11	19	1

ROW/COLUMN	11	12	13	14	15	16	17
1	19	94	0	35	28	8	0
2	18	92	2	143	8	6	13
3	27	94	1	135	0	8	10
4	23	96	8	99	2	7	10
5	35	100	0	27	13	8	0
6	30	94	8	63	10	7	1
7	33	96	8	49	18	7	3
8	53	84	2	282	0	12	9
9	41	74	1	748	0	10	6
10	38	94	4	239	1	9	12
11	29	92	1	108	6	8	8

FULLWORD MATRIX ADATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16882	8877	6108	355	3462	7460	1232139	2931	74971	0
2	60090	19839	20652	1621	9928	50014	4421788	2492	311930	156
3	59668	19237	20512	1513	14708	22281	4563492	32[illegible]8	399092	88
4	65181	23483	26787	848	14463	37341	5447451	8936	289222	28
5	9962	2656	3511	0	3295	5268	479928	2728	0	0
6	37529	11282	18859	[illegible]	18976	19102	2622805	3530	181728	0
7	39699	10768	16181	178	12580	20129	2846519	3724	58495	0
8	20365	4836	5166	588	10661	6494	1004055	3374	174745	46
9	20334	5118	5988	1177	8147	7844	1639528	6836	319858	31
10	39337	14833	12486	715	11383	17678	5139143	5164	286208	155
11	363997	117435	139882	7279	99201	173603	29197328	62517	2176241	504

ROW/COLUMN	11	12	13	14	15	16	17
1	2922	5991	16492	848	2922	1983	0
2	7514	[illegible]	19180	0	7398	9264	1408
3	7707	30179	19370	0	7619	6591	880
4	8682	18918	18996	227	8576	8454	867
5	1395	1466	5536	184	1395	1148	0
6	4913	14897	23384	516	4913	4768	58
7	5259	15846	32139	982	5256	5288	170
8	2062	10497	9192	14	2013	1672	187
9	1690	6454	409	9	1667	1924	116
10	3628	16563	6893	46	3473	3990	467
11	49700	147877	147877	2810	45190	45190	3753

Run 2: Base Case with the Non-Standard Random Number Stream Generated by RMULT 31,,743

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	737817	88	28	45	55	42	38	16	6	1
2	4318005	88	28	50	50	33	47	4	16	2
3	2262084	71	29	48	41	35	36	4	25	2
4	3137993	75	25	57	18	38	41	18	11	1
5	468891	64	36	55	4	27	57	28	6	8
6	2838869	78	30	51	19	30	40	16	26	1
7	3489477	66	39	56	16	26	40	9	25	8
8	526344	47	43	32	15	20	27	17	36	2
9	857878	53	47	37	16	24	24	31	14	5
10	3171288	67	53	44	23	37	30	15	21	2
11	21139358	70	30	47	25	32	38	11	15	2

ROW/COLUMN	11	12	13	14	15	16	17
1	19	94	0	36	9	8	[illegible]
2	18	92	1	141	1	6	12
3	27	90	1	141	0	8	14
4	24	96	0	98	2	7	4
5	34	100	[illegible]	28	13	8	[illegible]
6	29	94	6	63	10	7	1
7	34	94	1	49	18	7	
8	51	84	1	242	6	11	8
9	42	76	2	621	6	10	8
10	31	92	4	231	1	10	12
11	28	92	1	140	6	8	[illegible]

FULLWORD MATRIX ADATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16362	7818	6188	516	2868	7699	1293621	2697	75751	0
2	68058	14975	28627	1588	9868	30208	4410730	2556	311705	135
3	59657	14925	28528	1419	14198	22679	3022190	2554	406494	109
4	65178	22788	26795	888	14787	37345	5359085	9660	220614	15
5	9454	5579	3525	0	3550	5284	477456	2660	[illegible]	0
6	37529	11358	15016	448	16618	19218	2727643	3773	146715	0
7	39654	10517	15917	196	14026	15911	2792136	3939	65264	0
8	28371	4168	5411	531	10265	6655	1136655	3558	186411	35
9	28353	9871	5851	1127	8324	7760	1615626	6666	491316	49
10	39342	14650	12094	815	11793	17348	5043157	5413	523785	159
11	463967	117531	139924	7415	94077	173593	29180724	43264	222354	502

ROW/COLUMN	11	12	13	14	15	16	17
1	2922	6166	16926	855	2522	2016	1
2	7514	27904	19367	6	7379	5277	460
3	7787	31624	18915	0	7598	6648	1127
4	8682	16165	18460	235	8543	8628	655
5	1395	1944	545	191	1395	1147	
6	4913	14967	22822	527	4912	4833	55
7	5259	15006	32006	985	5259	5121	121
8	2662	11150	5015	20	2025	1751	76
9	1698	6189	996	18	1667	1951	44
10	3628	16991	7155	49	3465	3693	441
11	45708	167890	167090	2872	45185	45185	3679

Run 3: Base Case with the Non-Standard Random Number Stream Generated by RMULT 77,,189

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	733969	79	21	45	34	41	38	17	4	2
2	4316709	81	19	50	31	35	48	4	15	2
3	2236787	78	38	39	31	34	34	4	26	2
4	3335694	76	24	57	19	35	41	14	10	1
5	468399	65	35	56	9	27	38	27	8	0
6	2036409	69	31	50	19	29	40	9	22	1
7	3041745	67	33	50	17	26	41	9	24	0
8	526972	47	53	33	14	28	27	17	36	2
9	864909	55	45	30	17	25	30	30	15	5
10	3362697	66	34	43	25	34	30	12	22	1
11	21324370	70	30	47	23	32	30	11	19	1

ROW/COLUMN	11	12	13	14	15	16	17
1	19	94	0	36	29	0	0
2	17	92	1	133	0	6	13
3	20	92	1	163	0	0	15
4	23	96	0	90	2	7	9
5	35	100	0	20	13	0	0
6	30	94	0	64	10	7	0
7	33	96	0	49	10	7	1
8	51	84	2	208	0	11	8
9	40	76	2	660	0	10	7
10	33	94	4	231	1	10	13
11	29	92	1	100	6	8	8

FULLWORD MATRIX ADATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16374	6831	6132	331	5088	7371	1220987	2946	77987	0
2	68037	28871	28714	1584	9664	30021	4417975	2829	389745	146
3	55679	19879	28341	1321	14938	22138	4349530	2567	366134	145
4	65193	22938	26064	926	14473	37348	5432588	9214	216514	15
5	9452	2613	3538	0	3301	5296	475448	2577	0	0
6	37532	11187	14053	519	18973	19137	2647752	3626	147496	0
7	39677	19704	15931	182	19868	28196	2819128	3019	59725	0
8	28350	4203	5587	517	10131	6753	1075912	3632	179095	43
9	28329	5159	6078	1157	7935	7897	1659238	6128	505815	35
10	39357	14458	11918	738	12251	17183	5022592	4850	297485	165
11	363900	117235	139068	7275	99610	173290	29149542	42188	2159916	549

ROW/COLUMN	11	12	13	14	15	16	17
1	2922	6857	16773	854	2922	1979	0
2	7514	27107	20294	0	7368	9283	1036
3	7707	30974	18964	0	7562	6559	1183
4	8492	18411	18934	222	8509	8659	838
5	1395	1579	5523	186	1395	1145	0
6	4913	14769	22834	515	4913	4789	26
7	5259	14732	32017	958	5259	5129	62
8	2062	9973	4706	13	2016	1784	183
9	1690	4304	916	7	1668	1954	125
10	3628	17324	7969	41	3463	3866	485
11	45700	148518	148518	2796	45147	45147	5938

Run 4: Base Case with the Non-Standard Random Number Stream Generated by RMULT 1235,,6789

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	737812	82	18	46	36	43	39	14	4	1
2	4305266	80	20	49	31	32	40	4	16	2
3	8235713	71	29	40	31	34	37	5	24	2
4	1326407	75	25	56	19	34	41	14	11	1
5	460219	63	37	55	0	26	37	20	9	0
6	2020613	69	31	50	19	29	40	9	22	1
7	3449414	66	34	58	16	26	40	8	26	0
8	529469	47	53	32	15	21	24	17	36	2
9	860126	57	43	39	18	26	31	27	16	5
10	8379907	67	33	45	24	36	31	12	21	1
11	21516106	70	30	47	23	32	30	11	19	2

ROW/COLUMN	11	12	13	14	15	16	17
1	17	94	0	37	20	6	8
2	18	92	1	135	0	6	12
3	27	98	1	160	0	0	13
4	24	96	0	99	2	7	10
5	37	100	0	29	13	0	8
6	30	94	0	63	10	7	0
7	34	96	0	50	10	7	2
8	51	84	2	209	0	11	9
9	30	76	1	998	0	10	4
10	32	94	4	220	1	10	12
11	20	92	1	100	6	0	8

FULLWORD MATRIX ADATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16377	7196	6324	312	2545	7657	1325437	2380	71914	0
2	60020	19762	20294	1667	18305	29791	4376415	2943	322313	147
3	55602	19311	20575	1379	14917	22538	4306779	2894	389544	116
4	65152	27706	26562	871	15013	36969	5330743	9419	210404	53
5	9461	2516	3497	0	3448	5211	465736	2677	0	0
6	37405	11159	15015	551	10764	19059	2601031	3462	152446	0
7	39604	10504	15039	109	13072	19965	2779470	3401	60460	0
8	20359	4278	5435	511	10135	6673	1087125	3605	101996	0
9	20344	5382	6232	1149	7581	8820	1717419	5661	500404	51
10	39336	14509	12064	771	11992	17271	5070609	4999	510740	30
11	363900	117399	139937	7400	99272	173154	29149644	41441	2200409	155
										532

ROW/COLUMN	11	12	13	14	15	16	17
1	2982	6340	17044	042	2922	2039	0
2	7514	27294	20169	0	7362	9161	952
3	7707	30250	10077	0	7591	6630	1026
4	8482	10764	10007	235	6565	8509	899
5	1395	1573	5377	103	1395	1127	0
6	4915	14964	23542	519	4912	4029	43
7	5259	16310	32602	981	5258	5086	129
8	2062	10001	4415	12	2000	1770	197
9	1690	4663	667	10	1666	2009	160
10	3620	17066	7415	49	3470	3901	467
11	45700	149313	149313	2031	45149	45149	3001

Run 5: Base Case with the Non-Standard Random Number Stream Generated by RMULT 743,1,31

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	746181	82	18	46	36	43	39	14	4	1
2	4303215	80	20	49	31	53	47	5	19	2
3	2204604	75	25	41	34	36	39	4	21	2
4	3302096	79	25	56	19	34	41	13	12	1
5	477902	66	34	56	18	28	38	25	9	0
6	2059541	69	31	50	19	29	40	7	24	1
7	3495004	67	33	50	17	26	41	10	23	0
8	537216	51	49	34	17	22	29	15	36	2
9	862606	55	45	38	17	25	30	25	20	5
10	3360312	67	33	44	23	36	31	12	21	1
11	21599577	71	29	47	24	52	39	18	19	1

ROW/COLUMN	11	12	13	14	15	16	17
1	17	94	8	46	29	8	0
2	18	92	1	120	0	6	11
3	23	92	2	164	0	7	16
4	24	96	8	96	2	7	11
5	34	100	0	29	12	8	0
6	30	94	8	65	9	7	0
7	33	90	8	49	15	7	2
8	47	86	3	268	8	10	13
9	40	78	5	920	0	10	18
10	32	94	6	223	0	19	16
11	20	92	1	160	5	[illegible]	9

FULLWORD MATRIX ADSIA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16378	7188	6300	311	2587	7643	1298642	2379	69281	0
2	59990	19827	28918	1555	10098	29865	4384397	3150	307075	124
3	55673	20438	21448	1176	17611	23161	4708276	2502	319654	157
4	65214	22443	26519	879	15173	36771	5560305	8606	209584	37
5	9452	2686	3635	0	3131	5385	497132	2366	0	0
6	37443	11058	15104	472	10829	18776	2965304	2980	128544	0
7	39681	10616	16079	134	12852	19974	2824170	4340	47429	0
8	20382	4512	5088	484	9498	6994	1165734	2776	167285	73
9	20394	5217	6069	1056	8052	7945	1643939	5300	459330	89
10	39312	14345	12965	640	12262	17394	5007170	4934	253340	244
11	363947	118442	141705	6707	97093	173908	29455069	39335	1961318	724

ROW/COLUMN	11	12	13	14	15	16	17
1	2967	6356	17459	863	2967	2093	0
2	7628	24983	21077	0	7499	9213	874
3	7794	34818	18260	0	7637	6977	1296
4	8749	19837	20548	198	8705	8517	989
5	1419	1701	5013	143	1419	1166	0
6	4985	15707	24018	467	4565	4896	39
7	5352	19367	31064	843	5345	5181	122
8	2118	10612	4879	4	2034	1876	283
9	1746	7149	777	5	1656	1948	316
10	3727	16984	7611	32	3479	3919	623
11	46477	150706	150706	2587	45726	45726	4542

Run 6: Base Case with the Non-Standard Random Number Stream Generated by RMULT 229,83,111

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	732090	78	22	45	33	40	38	19		1
2	9201916	81	19	50	31	33	49	5	14	2
3	2230301	71	29	39	32	14	37	3	26	2
4	3324951	75	25	57	18	35	40	15	10	1
5	460610	65	35	56	9	27	38	27	8	0
6	2026764	67	33	50	17	20	39	10	23	1
7	3434560	65	35	50	15	26	39	11	24	0
8	527294	49	51	33	16	21	28	14	37	2
9	859309	57	43	39	18	26	31	28	15	6
10	3339670	66	34	43	23	36	30	12	22	1
11	21253513	70	30	47	23	32	38	11	19	2

ROW/COLUMN	11	12	13	14	15	16	17
1	21	94	0	35	27	8	0
2	17	92	2	140	0	6	13
3	27	90	1	165	0	8	16
4	29	96	0	91	2	7	9
5	35	100	0	26	13	8	0
6	32	94	0	64	10	7	0
7	35	90	0	40	18	7	1
8	49	84	2	231	0	11	9
9	37	76	1	869	0	10	6
10	33	94	4	200	1	10	14
11	20	92	1	100	6	8	8

FULLWORD MATRIX ADATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16390	4682	6092	274	3302	7374	1219234	3137	66375	0
2	68061	19996	29089	1590	9466	30168	4481579	3206	308077	171
3	95670	19316	20275	1394	14685	22238	4405522	1980	406352	125
4	65164	22811	26565	876	14912	37181	5368758	10340	217224	1
5	9460	2602	3573	0	3285	5367	474632	2635	0	0
6	37471	10822	14641	549	11459	18916	2541472	3766	150792	0
7	39679	10531	15622	159	13367	19849	2775491	4718	54945	0
8	20100	4305	9652	557	970	6896	1107108	2892	188620	42
9	20354	9412	6251	1278	7413	8093	1728724	5777	543588	20
10	39343	14335	11877	696	12435	17105	4968822	4806	285345	169
11	363932	116092	139557	7373	100110	173167	29071342	43257	2221318	528

ROW/COLUMN	11	12	13	14	15	16	17
1	2934	5039	16413	814	2934	1982	0
2	7500	26607	18972	0	7329	9360	1096
3	7700	31452	19299	0	7583	6529	1264
4	8502	17643	19270	220	8578	8603	788
5	1399	1450	5971	192	1394	1146	0
6	4910	14789	22945	522	4910	4724	19
7	5232	15092	31137	994	5232	5058	99
8	2060	10592	4575	17	2015	1830	196
9	1696	6524	750	14	1676	2023	106
10	3610	17432	8700	56	3437	3833	531
11	65626	167508	167508	2629	65088	65088	6049

Run 7: Base Case with the Non-Standard Random Number Stream Generated by RMULT 1,889,27

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	794522	80	20	46	34	42	38	16	4	1
2	4873940	81	19	50	31	33	48	4	15	2
3	2269363	71	29	48	31	34	37	3	26	2
4	3371735	76	24	56	20	35	41	13	11	1
5	475300	65	35	56	9	28	37	26	9	0
6	2030079	70	30	50	20	29	41	6	24	1
7	3515825	66	34	49	17	27	39	8	26	0
8	543010	53	47	35	18	23	30	15	32	2
9	803062	55	45	38	17	25	30	27	18	5
10	8406049	70	30	44	26	37	33	9	21	1
11	21642113	71	29	47	24	32	39	10	19	1

ROW/COLUMN	11	12	13	14	15	16	17
1	19	94	0	35	28	8	0
2	17	92	2	133	0	6	14
3	27	92	1	150	0	8	16
4	23	96	0	99	2	7	12
5	35	98	0	28	14	8	0
6	29	94	0	65	10	7	0
7	34	98	0	50	16	7	3
8	45	86	2	238	0	10	10
9	48	78	4	893	0	10	14
10	29	94	5	238	0	9	15
11	28	92	1	100	5	7	10

FULLWORD MATRIX ADATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16367	6960	6212	320	2875	7571	1253380	2664	75062	0
2	60076	20009	28725	1513	9829	30070	4372101	2535	287278	166
3	55655	19334	20533	1115	14673	22385	4453425	2119	286548	145
4	65192	23278	26767	932	14215	36815	5511533	8582	222170	28
5	9464	2659	3515	9	3281	5328	478248	2526	2472	0
6	37507	11171	15272	495	10569	16790	2530766	2587	137608	0
7	39699	10754	15763	121	13061	19809	2797973	3394	38810	2
8	20805	4787	6031	540	9027	7234	1224343	3099	186525	55
9	20370	5278	6080	1074	7946	7859	1694337	5591	468270	74
10	39365	14948	12648	699	11070	17672	5204040	3738	290960	190
11	364080	119178	141546	6818	96546	173553	29520146	36795	1997703	660

ROW/COLUMN	11	12	13	14	15	16	17
1	2976	6132	17149	862	2976	2031	0
2	7590	27471	20552	0	7435	9299	1090
3	7785	31151	20669	0	7640	6650	1292
4	8700	19795	19913	107	8603	8634	1109
5	1915	1610	5604	200	1415	1151	0
6	4973	16130	24600	499	4971	4913	39
7	5309	16536	32457	842	5305	5098	208
8	2102	18052	4223	17	2044	1953	216
9	1738	6970	775	0	1661	1979	258
10	3694	17955	7538	14	3503	4835	566
11	46290	158760	153760	2649	45633	45653	4778

Run 8: Per Diem Rate Per Day Equals $6

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	738061	76	24	44	42	40	36	20	4	1
2	4341789	80	20	50	40	32	48	5	15	2
3	2209067	70	30	41	29	34	36	8	15	3
4	3368915	77	23	58	19	36	41	15	8	1
5	478696	65	39	56	9	27	38	25	10	0
6	2054927	70	30	51	19	30	40	12	18	1
7	3509756	67	33	50	17	27	40	26	13	0
8	541546	49	51	34	15	21	28	19	32	2
9	685360	54	46	38	16	25	29	34	12	6
10	3451433	69	31	45	24	38	31	16	15	2
11	21547350	71	29	48	23	32	39	15	14	2

ROW/COLUMN	11	12	13	14	15	16	17
1	23	94	0	38	40	8	6
2	18	92	1	137	0	6	11
3	27	66	[illegible]	167	0	8	0
4	22	96	1	147	5	7	8
5	35	98	0	37	13	8	0
6	29	94	0	74	11	7	0
7	35	96	[illegible]	47	20	7	0
8	49	84	1	253	[illegible]	11	6
9	40	74	1	646	0	10	4
10	29	42	3	241	1	10	9
11	27	92	0	100	6	8	4

FULLWORD MATRIX ADATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16371	6698	5846	318	3509	7255	1226059	3414	74571	0
2	60055	15509	28753	1561	10232	30466	4358157	3267	305543	109
3	55682	16992	20415	1777	14498	22835	4167789	8837	48546[illegible]	0
4	65160	23569	27235	892	13444	38089	5560765	9815	224202	20
5	9451	2626	3548	18	3259	5329	479456	2379	5768	0
6	37528	11571	15030	498	10329	19513	2815479	4635	169885	0
7	39687	10838	15965	266	12678	20237	2910436	8157	63850	0
8	26382	4332	5703	560	9747	7058	1098709	3932	191380	33
9	28364	5122	5977	1267	7998	7881	1647745	7065	543360	21
10	39326	15270	12026	510	11120	17834	5245152	6328	342619	116
11	364606	116547	140498	8127	96834	176497	29510725	57809	2407040	299

ROW/COLUMN	11	12	13	14	15	16	17
1	2922	5702	14632	878	2922	1969	0
2	7514	26322	19196	[illegible]	[illegible]	9252	868
3	7707	[illegible]	22341	21	7707	6562	9
4	8602	17256	16107	274	8579	8855	729
5	1395	1743	[illegible]	[illegible]	1395	1153	0
6	4913	13380	[illegible]	585	4912	4840	34
7	5259	11313	[illegible]	1056	5259	5140	5
8	2062	4392	3712	12	2026	1846	162
9	1698	5618	[illegible]	13	1677	1927	72
10	3628	15164	[illegible]	47	3512	3910	138
11	45700	124700	[illegible]	3154	45394	45394	2177

Run 9: Per Diem Rate Per Day Equals $7

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	744529	75	25	44	31	39	36	21	4	2
2	4329919	82	18	51	31	44	48	10	4	3
3	2195129	72	28	41	31	34	38	23	4	4
4	3341340	77	23	58	19	35	42	18	4	1
5	471377	64	36	56	8	27	37	23	13	0
6	2071992	69	31	52	17	30	39	18	13	2
7	3[illegible]4082	66	34	58	16	27	39	29	4	0
8	548572	56	44	38	18	24	32	27	17	3
9	879182	93	47	38	15	24	29	39	8	6
10	1442584	64	34	44	22	37	29	16	18	3
11	21521906	71	29	48	23	32	39	21	8	2

ROW/COLUMN	11	12	13	14	15	16	17
1	23	92	0	44	31	8	0
2	15	98	0	114	1	6	2
3	24	86	0	103	3	8	0
4	22	94	0	103	4	7	4
5	34	96	0	47	14	8	0
6	29	92	0	98	13	7	0
7	34	96	0	42	24	7	0
8	41	84	0	264	1	9	5
9	41	74	0	455	2	10	2
10	31	98	3	237	3	10	11
11	27	98	0	108	8	7	2

FULLWORD MATRIX ADATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16374	4542	5847	333	3652	7232	1164994	3587	77534	0
2	68832	20461	29136	2165	8270	31165	4611078	6414	457737	4
3	95787	19462	28793	2278	13182	23294	4285798	13088	625402	0
4	65180	23146	27138	1117	13787	38321	5428438	12215	278110	3
5	9458	2597	3528	41	3292	5712	475528	2227	11104	0
6	37515	11394	14711	779	18631	[illegible]	[illegible]	6908	221501	0
7	[illegible]	10846	15665	272	12954	[illegible]	2911371	11843	91046	0
8	20388	4963	6999	615	8211	7827	1278982	5565	220450	19
9	20891	4995	5871	1298	8227	7788	1609748	8128	562341	7
10	39321	14561	11729	1324	11707	17522	5047184	6502	472898	121
11	364843	118967	148949	10214	93913	178363	29612519	76477	3018123	154

ROW/COLUMN	11	12	13	14	15	16	17
1	2922	5555	12601	929	2922	1892	0
2	7514	22453	19615	147	7510	9428	206
3	7787	19325	18674	278	7707	6716	0
4	8602	14644	19178	356	8590	8765	426
5	1395	1919	4082	198	1395	1152	0
6	4913	10915	12182	649	4913	4771	2
7	5259	7624	17972	1290	5259	5021	0
8	2862	6996	2644	23	2040	2121	107
9	1698	4475	983	34	1691	1880	57
10	3628	15297	6432	107	3507	3788	400
11	45788	109205	109203	4883	45534	45534	1178

Run 10: Per Diem Rate Per Day Equals $8

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	750000	78	22	45	33	41	37	19	3	2
2	4339923	80	20	50	30	33	47	15	4	4
3	3191375	72	28	42	30	34	38	23	5	4
4	3327763	75	25	58	17	34	41	22	3	2
5	475350	68	32	58	10	29	39	24	8	1
6	2007654	73	27	54	19	32	41	20	7	2
7	3512418	65	35	50	15	27	38	32	3	1
8	556305	60	40	40	20	25	35	31	9	3
9	893257	49	51	36	13	23	26	47	4	6
10	3499909	69	31	46	23	38	31	27	8	5
11	21628694	71	29	49	22	32	39	24	9	5

ROW/COLUMN	11	12	13	14	15	16	17
1	20	92	0	49	32	8	0
2	16	88	0	126	4	6	1
3	24	86	0	108	6	8	0
4	23	94	0	102	5	7	2
5	31	94	0	93	13	7	0
6	25	90	0	115	14	7	0
7	34	94	0	38	27	8	0
8	37	62	0	245	2	8	1
9	45	72	0	242	3	11	0
10	26	86	0	191	3	10	2
11	26	88	0	100	10	7	1

FULLWORD MATRIX ACATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16378	6722	6083	370	3203	7499	1206804	3194	87564	0
2	60080	20189	28325	2500	9066	30492	4415214	9299	542831	12
3	55680	19366	21194	2327	12773	25640	4373393	13053	625890	0
4	65170	22515	26885	1325	14445	38179	5284497	14416	332414	0
5	9450	2795	5696	107	2852	5574	1140800	2317	27084	0
6	37493	12126	15330	965	3072	20592	3101558	7605	275997	0
7	39669	10851	15262	429	13123	20886	2864672	13019	133026	0
8	20362	5225	7031	775	7351	4249	1364269	6483	274570	3
9	20365	4714	5351	1319	8983	4492	1511938	9582	564063	0
10	39331	15135	12107	2247	9842	10146	5235590	9414	781149	31
11	363970	119658	141264	12364	90692	179963	29891815	88382	3644590	46

ROW/COLUMN	11	12	13	14	15	16	17
1	2922	9625	11456	545	2922	1971	0
2	7514	20269	16102	362	7502	9157	150
3	7707	18987	17473	490	7707	6893	0
4	8602	12575	12252	434	8602	8680	193
5	1395	1559	3205	193	1395	1204	0
6	4913	9296	8078	719	4913	4953	3
7	5259	6564	17267	1454	5259	4928	0
8	2062	5616	2286	53	2059	2270	22
9	1698	3291	1359	53	1698	1753	0
10	3628	11771	6159	123	3597	3885	100
11	45700	95633	99633	4766	45654	45654	468

Run 11: Per Diem Rate Per Day Equals $9

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	753562	[illegible]	20	46	54	42	38	17	3	2
2	4345236	61	19	51	30	34	47	15	4	4
3	2197130	74	26	43	31	35	39	22	4	4
4	3317218	74	26	58	16	33	41	24	2	2
5	476479	71	29	60	11	31	40	26	3	1
6	2083940	73	27	55	18	32	41	24	3	3
7	3401640	62	38	49	13	26	36	36	2	1
8	549660	62	38	41	21	26	36	34	4	4
9	687668	49	51	36	13	22	27	48	3	6
10	3510375	69	31	46	23	39	36	25	6	6
11	21622508	71	25	49	22	32	39	25	4	3

ROW/COLUMN	11	12	13	14	15	16	17
1	18	42	0	54	32	8	0
2	15	68	0	133	4	6	0
3	22	66	0	111	6	7	0
4	24	42	0	101	5	7	0
5	28	42	0	45	14	7	0
6	24	68	0	126	16	7	0
7	37	54	0	32	28	8	0
8	34	62	0	255	2	8	0
9	45	72	0	206	4	11	0
10	25	66	0	166	3	10	1
11	26	68	0	160	11	7	0

FULLWORD MATRIX ADATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16398	6897	6267	384	2850	7645	1240965	2850	92623	0
2	66025	26545	28338	2657	8485	30699	4694845	9463	579967	0
3	55662	19551	21755	2258	12058	24073	4244244	12505	609170	0
4	65145	22059	26374	1407	15310	37860	5138203	15988	362079	0
5	9459	2933	3858	160	2508	5756	554700	2509	48184	0
6	37490	17163	15556	1161	8818	20803	3128610	9005	348982	0
7	39694	16324	14600	463	14307	19490	2748285	14496	145616	0
8	28395	5362	7298	859	6856	8404	1409680	6989	306020	0
9	26388	4621	5371	1316	9060	7501	1493210	9832	567444	0
10	39284	15348	12115	2466	9535	18306	5294956	10050	859127	12
11	363948	115816	141332	13191	89607	180557	29947677	93687	3919212	12

ROW/COLUMN	11	12	13	14	15	16	17
1	2922	4903	10797	940	2922	2020	1
2	7514	19863	14856	345	7514	5172	37
3	7707	15064	17055	526	7707	7004	0
4	8602	11297	11150	496	8602	8556	14
5	1395	1194	2589	197	1395	1256	1
6	4913	7650	6081	794	4913	4989	0
7	5259	5708	17700	1479	5259	4697	0
8	2062	5862	2127	61	2062	2340	0
9	1698	3055	1522	81	1698	1792	0
10	3628	10928	5847	134	3616	3922	52
11	45700	84724	89724	5053	45688	45688	105

Run 12: Per Diem Rate Per Day Equals $10

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	754345	81	19	47	34	42	39	15	4	2
2	4358870	81	19	50	31	54	47	15	4	4
3	2190497	78	27	42	31	54	39	23	4	4
4	3318900	74	26	50	16	54	40	24	2	2
5	473485	71	29	61	10	50	41	26	5	1
6	2085505	73	27	55	18	32	41	24	3	3
7	3483231	61	39	48	13	25	36	37	2	1
8	326827	61	39	40	21	26	35	35	4	4
9	890434	48	52	36	12	22	26	48	4	6
10	3913304	71	29	47	24	40	31	24	4	6
11	21620356	71	29	49	22	52	39	25	4	3

ROW/COLUMN	11	12	13	14	15	16	17
1	17	92	0	56	32	7	0
2	15	88	0	135	4	6	1
3	23	86	0	110	6	8	0
4	24	92	0	103	5	7	0
5	28	92	0	44	14	7	0
6	24	90	0	127	15	7	0
7	38	94	0	30	28	8	0
8	35	82	0	210	2	8	0
9	46	70	0	191	4	11	0
10	23	86	0	199	4	9	2
11	26	88	0	140	11	7	0

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16303	6975	6448	398	2573	7835	1247965	2570	98040	0
2	60098	28532	28324	2767	8445	30578	4766219	9602	598018	0
3	55720	19336	21525	2293	12566	23821	4165795	13030	618998	0
4	65146	22155	26504	1406	15081	38004	5146731	15825	363992	0
5	9966	2914	3801	183	2488	5795	552312	2503	47860	0
6	37495	12173	15485	1148	8609	20875	3128144	9045	335595	0
7	39670	10188	14440	421	14709	19232	2674475	14889	138272	0
8	28898	5324	7134	620	7112	8299	1169095	7258	290830	0
9	20379	4583	5263	1383	9150	7473	1468963	9951	583272	0
10	39277	15746	12335	2434	8762	18633	5436423	9651	831332	15
11	363982	119826	141339	13245	89572	180545	29955720	94324	3906209	15

ROW/COLUMN	11	12	13	14	15	16	17
1	2922	5978	10517	941	2922	2081	2
2	7514	19468	14785	366	7514	9115	83
3	7707	18869	17136	539	7707	6957	0
4	8602	11317	10951	496	8602	8573	6
5	1395	1168	2604	197	1395	1257	6
6	4913	7575	5955	771	4913	5013	0
7	5259	5557	17976	1403	5259	4644	0
8	2062	4833	2212	59	2062	2305	0
9	1690	2955	1547	83	1698	1710	0
10	3620	10993	5510	148	3611	4008	81
11	45700	84113	89113	9083	45603	45683	180

Run 13: Car Service Rules Changed So that a Unit of Demand Can Only be Loaded into Cars Belonging to the Origin or Destination Roads

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	687157	83	17	47	56	44	39	13	4	1
2	3956103	73	27	47	26	29	44	0	27	0
3	2081808	66	34	39	27	32	36	1	33	1
4	3160307	76	24	59	17	34	42	12	12	0
5	421065	52	48	48	4	21	31	13	45	0
6	1024407	65	35	51	14	28	37	1	34	0
7	3061779	62	38	48	14	26	36	3	35	0
8	532120	64	36	42	22	27	37	4	27	2
9	821402	53	47	38	15	24	29	27	20	5
10	2090337	39	61	31	8	30	19	1	60	8
11	19552693	65	35	46	19	29	36	6	29	1

ROW/COLUMN	11	12	13	14	15	16	17
1	16	94	0	46	9	7	2
2	27	96	13	86	0	7	42
3	35	94	7	118	0	4	40
4	24	56	2	95	1	7	15
5	48	94	10	53	11	10	24
6	35	56	8	72	11	8	56
7	38	98	2	59	12	8	22
8	34	68	4	360	0	8	17
9	42	76	4	1303	0	10	16
10	61	98	16	285	0	15	41
11	34	94	7	160	4	8	30

FULLWORD MATRIX ADATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16370	7295	6396	110	2409	7698	1456322	3171	75637	6
2	68037	17650	26427	493	15467	28257	5530665	470	101040	1011
3	55722	18280	19117	792	17609	21744	4003512	1848	223530	574
4	65215	22770	27311	644	14490	38907	5357435	8095	166810	242
5	9470	2881	2895	78	4456	4635	344628	1307	21424	142
6	37524	10804	13446	349	12525	19288	2721412	645	96408	430
7	39784	10510	14252	44	14898	19247	3052211	1243	13570	142
8	20336	5570	7488	520	6758	8669	1456605	1935	173040	89
9	20342	5033	5809	1047	8413	7827	1585618	5653	476096	82
10	39427	7897	7762	70	23690	12252	2537297	486	25808	688
11	364247	107792	131303	4395	120707	160524	26344545	23053	1373355	3318

ROW/COLUMN	11	12	13	14	15	16	17
1	2922	6901	14010	270	2916	2068	64
2	7314	31310	36016	6	6493	8526	3921
3	7707	32930	27849	0	7124	6143	3134
4	8682	14213	19121	126	8359	8867	1375
5	1395	3528	6539	142	1251	921	355
6	4915	17591	24929	449	6477	4443	1401
7	5259	14194	32197	653	5116	4573	1170
8	2062	4732	2699	4	1978	2462	371
9	1698	6862	496	4	1616	1880	284
10	3628	26719	9594	0	3028	2485	1521
11	45788	172570	172570	1764	42344	42344	13476

Run 14: Decrease in Loading and Unloading Times

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	788938	69	31	39	30	41	29	27	4	2
2	4352605	72	28	45	27	52	40	5	23	2
3	2223378	63	17	35	26	44	29	14	23	3
4	3350037	70	36	52	18	36	34	19	11	1
5	4731033	55	45	48	7	26	39	28	17	0
6	2049589	60	40	45	15	29	31	14	26	1
7	3535578	60	40	45	15	27	33	21	14	0
8	558472	44	56	30	14	21	23	21	35	2
9	898544	53	47	36	17	27	26	35	12	6
10	3483739	62	38	40	22	38	24	13	25	2
11	21659905	63	37	43	26	32	31	17	20	2

ROW/COLUMN	11	12	13	14	15	16	17
1	29	92	0	37	31	8	0
2	26	92	0	130	0	6	8
3	34	88	0	112	0	8	0
4	29	96	0	100	3	7	4
5	45	90	0	41	13	8	0
6	39	92	0	72	12	8	0
7	40	94	0	48	21	7	0
8	54	84	1	264	0	11	4
9	41	74	0	842	0	9	0
10	36	92	2	250	1	10	8
11	35	92	0	148	7	7	3

FULLWORD MATRIX ADATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16378	6653	476[illegible]	341	4626	6468	119353[illegible]	4528	79936	0
2	60638	15414	23486	1423	15125	27290	4468129	3361	316367	49
3	55677	15167	14242	1786	18482	20031	4204384	7987	490972	0
4	65158	23819	2244[illegible]	432	17967	36487	5646737	12843	226824	0
5	9453	2482	2763	22	4149	4576	459456	2676	6592	0
6	37519	11165	11552	633	14149	17123	2439503	5494	176269	0
7	39674	11841	12921	174	15538	17955	2932544	8363	61465	0
8	20378	4392	4587	544	10854	6174	1127458	4586	189215	31
9	20367	5659	5138	1317	8253	7363	1802218	7223	572558	0
10	39322	14955	9624	255	13888	15901	5208443	5576	337367	86
11	363964	114138	113510	8227	123089	157368	29674396	62236	2456965	166

ROW/COLUMN	11	12	13	14	15	16	17
1	2922	5382	10344	523	2922	1922	0
2	7514	24388	22440	17	7462	9424	458
3	7787	27659	24485	26	7787	6445	5
4	8602	17828	17653	265	8644	4010	370
5	1395	2201	5516	152	1395	1128	0
6	4918	14902	20589	610	4912	4443	16
7	5259	11356	27399	1122	5259	5144	4
8	2462	5818	3715	11	2028	1867	144
9	1698	4781	686	11	1698	2871	2
10	3628	10045	7711	50	3510	3859	225
11	45788	144840	144860	3215	45525	45525	1536

Run 15: Demand is at the Slack Season Level for the Entire Year

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	672232	79	21	44	35	42	47	17	4	2
2	3860787	81	19	49	32	34	47	2	17	2
3	1977982	62	38	55	27	30	52	3	35	4
4	2989154	62	30	50	12	28	34	38	4	1
5	417558	51	49	49	2	20	31	45	4	0
6	1865421	61	39	40	13	26	35	27	12	2
7	2944130	62	38	47	15	25	37	18	20	1
8	423735	42	58	31	11	17	25	43	15	2
9	651675	42	50	32	10	19	23	52	6	4
10	2975738	59	41	39	20	31	28	35	6	1
11	18802252	63	37	43	20	28	35	23	14	2

ROW/COLUMN	11	12	13	14	15	16	17
1	19	92	0	41	24	8	0
2	17	92	4	265	0	6	35
3	34	82	1	108	0	9	20
4	37	94	0	54	6	8	0
5	49	100	0	12	13	10	0
6	37	88	0	56	15	8	0
7	37	94	0	98	30	8	0
8	56	82	0	138	2	12	0
9	54	74	0	391	1	13	0
10	40	92	0	165	4	11	0
11	35	90	0	188	9	8	4

FULLWORD MATRIX ADATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16365	6887	6101	444	2933	7246	1300269	2353	101879	0
2	68815	20493	28516	1752	9254	24719	4486303	1316	361262	291
3	55694	17855	17919	2633	18087	19603	3899068	1985	769326	104
4	65287	16353	22687	957	23258	32863	4170374	22317	251488	0
5	9478	1967	2918	0	4593	4686	320840	4349	0	0
6	37516	18851	13135	1068	13264	18121	2438067	10381	299394	0
7	39699	18893	14739	456	14411	18739	2828511	7354	158830	0
8	26275	3568	5044	479	11264	6407	853276	8843	164360	0
9	20377	3988	4716	999	18674	6525	1255079	10783	431142	0
10	39365	12355	11860	757	15193	15688	4209916	13845	309910	0
11	364123	184810	126845	9545	122923	159593	25961705	84034	2642591	395

ROW/COLUMN	11	12	13	14	15	16	17
1	2688	6256	14968	655	2688	1977	0
2	6868	28984	18936	0	6559	9214	2321
3	7284	34108	18873	0	7110	5780	1466
4	7756	16867	18599	543	7746	7338	20
5	1268	435	3608	171	1260	944	0
6	4588	9814	15896	781	4588	4211	8
7	4784	13606	27884	1431	4784	4711	12
8	1792	5125	3930	51	1792	1632	0
9	1428	3869	784	23	1428	1516	0
10	3852	9832	5938	138	3056	3548	4
11	41272	120496	120496	3785	40871	40871	3631

Run 16: Demand is at the Peak Season Level for the Entire Year

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	797263	85	15	48	47	45	40	11	4	1
2	4713934	80	20	51	29	33	47	4	16	2
3	2424464	85	18	46	39	41	44	8	7	3
4	3457614	73	27	50	25	34	39		27	1
5	412984	78	22	61	17	34	44	16	6	0
6	2221297	92	8	50	42	38	54	[illegible]	8	0
7	4894647	76	24	49	27	31	49	[illegible]	24	0
8	178760	34	66	22	12	15	19	[illegible]	66	1
9	998014	55	45	39	16	25	30	8	37	5
10	3487612	75	25	44	31	39	36	6	25	0
11	23294439	76	24	47	29	34	42	5	21	1

ROW/COLUMN	11	12	13	14	15	16	17
1	14	96	0	33	32	7	0
2	18	92	0	129	0	6	5
3	14	96	0	79	0	7	0
4	26	96	1	155	0	8	32
5	22	100	0	31	11	7	0
6	8	100	0	66	5	5	3
7	24	98	0	93	7	6	17
8	65	88	8	232	0	16	27
9	48	76	8	832	0	10	24
10	25	98	12	366	0	8	34
11	23	94	2	100	3	7	14

FULLWORD MATRIX ADATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	14373	7484	6584	224	2081	7951	1372341	1926	44032	0
2	64861	19881	28684	1539	9957	30888	4408382	2095	284882	11
3	54653	22983	24344	838	7448	26156	5289756	4929	203910	0
4	69206	22726	29092	658	14770	33209	5519720	308	147700	178
5	9960	4261	4184	0	2015	5848	639400	1577	0	0
6	37487	14340	20202	0	2945	18861	3296761	338	0	0
7	39706	12082	18891	5	9168	19620	3159559	308	700	1
8	20369	5904	3809	287	13069	4902	868498	86	96560	186
9	26336	4159	6091	1175	7911	8044	1632994	1654	309296	173
10	39303	14691	13861	106	9645	17039	5280244	184	30050	513
11	463954	127211	150862	4832	81049	172434	31457675	13863	1318530	1064

ROW/COLUMN	11	12	13	14	15	16	17
1	8150	6496	19118	1011	3150	2138	0
2	8118	24760	20663	0	8107	4275	445
3	8161	24568	31081	0	8161	7457	4
4	9802	31653	28344	0	9204	8048	5118
5	1521	2035	6468	175	1521	1349	0
6	5291	14288	27678	349	5291	6513	165
7	5761	19778	37216	452	4794	5031	1405
8	2314	15781	6777	0	2125	1238	467
9	1950	11638	1278	0	1777	1372	582
10	4156	21680	7074	0	3443	1480	1422
11	49884	177677	177677	1947	48733	48733	7289

Run 17: Demand is at the Slack Season Level for the Entire Year and the Per Diem Rate Per Day Equals $10

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	699815	81	19	45	36	42	39	15	4	2
2	3927919	77	23	48	29	32	45	19	4	4
3	1965219	71	29	48	31	33	38	23	6	6
4	3001239	63	37	51	12	20	39	36	1	1
5	413944	59	41	53	6	24	39	40	1	0
6	1920087	67	33	50	17	29	38	30	3	3
7	2969941	57	43	44	13	23	34	42	1	1
8	436587	49	51	34	15	20	29	46	3	2
9	657343	39	61	30	9	18	21	58	4	4
10	2990077	56	44	39	17	30	26	41	3	3
11	10985376	64	36	44	20	29	45	35	3	3

ROW/COLUMN	11	12	13	14	15	16	17
1	17	90	0	70	27	8	0
2	19	86	0	169	2	6	0
3	23	88	0	142	5	8	0
4	36	92	0	66	9	8	0
5	41	90	0	22	13	8	0
6	30	88	0	127	16	8	0
7	42	92	0	33	36	9	0
8	49	86	0	165	2	10	0
9	57	74	0	242	2	14	0
10	41	90	0	131	6	11	0
11	33	86	0	100	12	8	0

FULLWORD MATRIX ACATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16377	7024	6273	487	2593	7527	1292532	2593	122483	0
2	60019	19700	26713	2931	10667	29093	4602319	11928	680907	0
3	55663	18017	28925	3504	12417	22720	4144934	13259	958694	0
4	65234	18372	22779	1045	23038	33286	4162009	23603	272635	0
5	9967	2305	3309	19	3834	5078	408060	3840	4620	0
6	37519	11871	14107	1246	11095	18991	2857844	11502	560573	0
7	39694	9244	13384	564	16462	17679	2576157	16767	202964	0
8	20413	4170	5901	474	9868	7107	1021285	9931	157615	0
9	20392	3700	4409	986	11294	6211	1177085	11060	412869	0
10	39374	11953	10210	1295	15908	15609	4134798	16385	449219	0
11	364152	104372	128013	12571	117196	163301	26377023	121668	3622579	0

ROW/COLUMN	11	12	13	14	15	16	17
1	2688	6257	8861	738	2688	2039	7
2	6868	18998	11240	193	6860	8602	0
3	7224	19604	13799	412	7224	6747	0
4	7756	8345	12556	740	7756	7333	0
5	1260	549	2485	169	1260	1069	0
6	4508	7026	5750	764	4508	4539	0
7	4704	5248	15895	1705	4704	4293	0
8	1792	3375	2040	52	1792	1909	0
9	1920	2321	959	42	1420	1435	0
10	3052	7380	5600	186	3052	3308	0
11	41272	79183	79183	5001	41272	41272	7

Run 18: Demand is at the Peak Season Level for the Entire Year and the Per Diem Rate Per Day Equals $10

FULLWORD MATRIX DATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	884671	81	19	40	33	42	39	16	[illegible]	1
2	4764437	85	15	53	32	36	43	11	4	4
3	2301535	73	27	43	30	34	39	25	2	2
4	3626865	67	13	66	21	40	47	10	1	3
5	520977	61	19	67	14	45	44	15	4	[illegible]
6	2242574	88	20	60	20	35	45	17	3	2
7	3961155	66	34	52	14	27	39	33	1	1
8	662985	75	25	47	28	33	42	19	6	6
9	1090473	56	44	42	14	26	30	40	4	8
10	3982938	84	16	53	30	48	35	9	7	9
11	24854610	78	22	54	24	36	42	18	4	4

ROW/COLUMN	11	12	13	14	15	16	17
1	18	92	0	47	36	7	0
2	11	90	0	116	7	6	0
3	25	92	0	82	8	7	0
4	18	92	0	167	3	6	0
5	16	88	0	57	14	6	0
6	18	90	0	131	14	6	0
7	33	94	0	20	23	7	0
8	19	78	0	382	3	7	0
9	36	68	0	144	7	10	0
10	7	82	1	254	[illegible]	8	4
11	18	80	0	100	10	7	0

FULLWORD MATRIX ADATA

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	16381	7886	6419	321	2635	7975	1227568	2635	78366	0
2	60847	21620	29897	2484	6038	32083	4910558	6986	437068	0
3	55729	19935	21467	1222	13805	24448	4012030	13946	319044	0
4	65135	26443	30641	1985	6066	43182	6232470	7092	514598	0
5	9455	3345	4321	328	1469	6335	659140	1477	86912	1
6	37501	13282	16835	1182	6282	22787	3405488	6601	325810	0
7	39691	10794	15448	422	13015	20848	2497421	13179	113759	0
8	20373	6756	8619	1207	3711	9771	1804184	3986	464730	0
9	20377	5376	6046	1765	7190	8559	1752216	8213	751497	0
10	39278	18959	14221	3674	2416	21392	6619182	3696	1278200	46
11	363959	139824	158926	14582	62627	197380	35320227	67811	4467784	47

ROW/COLUMN	11	12	13	14	15	16	17
1	3150	5771	12190	1137	3150	2087	3
2	8110	20970	17977	570	8110	4660	29
3	8161	17335	21081	731	8161	6969	0
4	9382	14861	8893	304	9382	9912	49
5	1521	1643	2857	222	1520	1391	11
6	5291	8113	6177	790	5291	5110	0
7	5761	5664	19660	1344	5761	5080	0
8	2319	6616	7189	88	2319	2763	0
9	1950	3605	2166	140	1950	1967	0
10	4156	14182	5578	119	4106	4594	199
11	49004	98768	98768	5445	49753	49753	241

BIBLIOGRAPHY

Association of American Railroads, "Circular No. OT-10-D," Washington, D.C., January 1, 1974.

____________________________, Yearbook of Railroad Facts, Washington, D.C., 1975a.

____________________________, "Operating and Traffic Statistics," O.S. Series No. 216, Washington, D.C., April 1975b.

Baker, Laura, "Review of Computer-Based Models Applicable to Freight Car Utilization," Transportation Systems Center, Report No. FRA-OPPD-77-12, Cambridge, Mass, October 1977.

Baumol, William J. and Wallace E. Oates, The Theory of Environmental Policy: Externalities, Public Outlays, and the Quality of Life, Prentice-Hall, 1975.

Buchanan, James M. and W. Craig Stubblebine, "Externality," Economica, N.S., Vol. 29, 1962, pp.371-84.

Fair, Ray C., A Model of Macroeconomic Activity, Volume 1: The Theoretical Model, Ballinger Publishing Co., 1974.

Gordon, Geoffrey, System Simulation, Prentice-Hall, 1969.

International Business Machines Corporation (Federal Systems Division), Federal Railroad Administration Network Model: User's Manual, May 1975.

Kalman, R.E., P.L. Falb, and M.A. Arbib, Topics in Mathematical System Theory, McGraw-Hill, 1969.

Keeney, Ralph L. and Howard Raiffa, Decisions with Multiple Objectives: Preferences and Value Tradeoffs, Wiley, 1976.

Midwest Research Institute, "The AAR Network Simulation System: A Tool for the Analysis of Railroad Operations," 1971, processed, 525 pages.

Mosbaek, E.J., "Economic Analysis of Per Diem Rates on Freight Cars," prepared by Jack Faucett Associates for the Office of the Secretary, Department of Transportation, D.O.T. report no. OS-00068, National Technical Information Service report no. PB 199 805, January 1971.

Oiesen, James F., "A Freight Car Investment Model," Transportation Systems Center, on file, Cambridge, Mass., March 1975.

________________, "A Framework for Organizing Transportation Research," Transportation Systems Center, on file, Cambridge, Mass., April 1976a.

________________, "What is a Model?" Transportation Systems Center, on file, May 1976b.

Petersen, E.R. and H.V. Fullerton, "A Network Model of the Mainline Operation of a Railway," Chapter 1 in Petersen and Fullerton, eds., The Railcar Network Model, Canadian Institute of Guided Ground Transport, Queen;s University, CIGGT report no. 75-11, Kingston, Ontario, June 1975.

Rand McNally Handy Railroad Atlas of the United States, Rand McNally, 1971.

Rastatter, Edward H. and John W. Snow, "Car Hire Charges and Railroad Car Shortages," in Papers-Eleventh Annual Meeting, 1970, Transportation Research Forum, Richard B. Cross, Co., Oxford Indiana.

Reebie Associated, Toward An Effective Demurrage System, Prepared for U.S. Department of Transportation, Federal Railroad Administration, Report No. FRA-OR-73-1, July 1972.

Schriber, Thomas J., Simulation Using GPSS, Wiley, 1974.

Traffic World, "ICC Prescribes New Regulations Governing Freight Car Movements," November 3, 1975, pp. 46-7.

U.S. Department of Transportation, 1974 Carload Waybill Statistics, Federal Railroad Administration, Statement TD-1 December 1975.

U.S. Senate, Freight Car Shortages, Hearings Before the Special Subcommittee on Freight Car Shortages of the Committee on Commerce, Ninety-second Congress, first session, 1971.

Winter Sidney G., Jr., "Economic 'Natural Selection' and the Theory of the Firm," Yale Economic Essays, vol. 4, 1964, pp. 225-72.

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