RESTRUCTURING A RAILROAD ENGINEERING ECONOMICS MODEL:
Responding to Management Needs

by

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ABSTRACT

The high cost of designing, implementing, and maintaining a complex engineering economics model should be recouped by using the model to help managers make better decisions. Therefore, to fully exploit the value of the model, it should be used as an input to as many problems as possible. There are railroad planning models which have had some measure of success at being used in different kinds of analyses by different levels of managers. However, the fundamental problem with most complex railroad planning tools is the large quantity of data required to structure an analysis. In addition, many tools lack quality reports, tailored to specific needs. This creates a user hostile atmosphere which discourages managers from using the tools to analyze problems.

There are software designs and programming techniques which can be used to minimize these problems. Some have been used in other railroad planning models and some are standard to the software design industry. The Total Right-of-way Analysis and Costing System, TRACS, employs a knowledge engineering process, as well as the standard methodologies, in order to achieve a level of versatility unprecedented by other railroad planning models.

Tens of millions of dollars have been spent on railroad track research over the last fifteen years. There has never been a computer planning model which satisfactorily organized the information gained from this research into a framework which made it useful to a large number of railroad managers. The close cooperation of an industry task force played an important role in giving TRACS the potential to be the primary interface between real managerial problems and complex scientific knowledge.

Acknowledgements

Table of Contents

List of Exhibits

Glossary

Activity Menu - by pressing <Esc> at any time inside of TRACS, a red menu will pop up
which contains options or activities available to a user at that point.
Some of the activities include: exit to DOS, Save the File, Quit without
saving, and moving to other levels of detail.

Control Program - a program that ties together all of the modules and sub-modules. The
control program includes the introductory screens, the selection menus,
and analysis data input screen.

Cost Report - these reports combine the output from the deterioration model with the data
from the cost file. The reports are designed to aid budgeting, economic
planning, accounting and other financial analyses.

Deterioration Model - a program that simulates the life a track or right of way
component, predicts what actions will be taken to maintain or replace it,
and produces inputs to the Reports module.

Downward Assertion - term applied to the various functions that input some detailed
values to files based on less detailed inputs. The term is also applied to
the process of interpreting qualitative inputs into quantitative data.

Engineering Report - a report which does not show any information about costs. These
include information on project schedules, material requirements as well
as data about component life and deterioration rates.

Help Screen - by pressing <F1> at any time inside of TRACS, a menu will pop up which

contains information about the format and definition of the input at the

current cursor position. Sometimes the help screen will list acceptable

choices, or offer an option for additional help in this area.

Higher Level of Detail - a screen in the Traffic, Rout/Track, or Cost input module which

prompts the user for exact information. The numbers at the top of the

screen designate what level of detail is currently being displayed i.e. the

higher the number, the higher the level of detail.

Install Supplements - a set of three booklets which serve as a User's Guide and Technical

Manual for each of the three Install Sub-Modules. When giving access to

any of the Install Sub-Modules, the respective supplements should also be

distributed along with the program.

Knowledge Engineering - term used to refer to the idea of using a limited amount of

information from a user, and intelligently inferring all of the inputs

needed to run TRACS.

Level of Detail - in the Traffic, Route/Track, and Cost input modules, a user can choose

to input different volumes of information. The program prompts the user

for the most important information first. As the user progresses through

the screens, he increases the volume of inputs within that module. Each

screen represents a "level of detail".

Lower Level of Detail - a screen in the Traffic, Rout/Track, or Cost input module which

prompts the user for qualitative information and or summary data. The

numbers at the top of the screen designate what level of detail is currently being displayed i.e. the lower the number on the screen, the lower the level of detail.

Module - a stand alone program or group of programs that combine together to make the TRACS system. The Modules are: Install, Traffic, Route/Track, Deterioration, Reports.

PESOS - acronym for Post Economic Sensitivity Options. These are batch programs that will perform common analyses with simplified user inputs. The batch program does the file creation, bookkeeping, and report generation automatically. These are considered as part of the Control Program, but they are run from within the Reports Module.

Range Checks - each input has a set of limits associated with it. These limits define the range of values that could be considered reasonable inputs. In addition, the Checks should also check for format and allowed choices.

Sub-Module - a stand alone program that is a part of a larger Module. The sub-modules are: Maintenance Policy, Component & Condition, Reference, RAILWEAR.

Technical Manual - The documentation which contains the detailed descriptions of all of the data files in TRACS, descriptions of each compiled program, and technical information about the theory of the various deterioration sub-modules.

TRACS - acronym for Total Right-of-way Analysis & Costing System. This is an acronym. It is redundant to say the TRACS package, the TRACS system,

the TRACS program, or the TRACS model. These should be viewed as incorrect. It is, however, acceptable to refer to TRACS's programs, TRACS's modules, the reports from TRACS, or inputs to TRACS.

Upward Distillation - if the input modules are used to edit existing files, this is the term applied to interpreting detailed information in existing files so that summary values can be displayed in the input screens. The data is distilled and averaged into summary data and qualitative measurements.

User's Guide - The documentation which will describe to a user of TRACS how to set up the disks, and run example analyses. This documentation contains descriptions of the example files, and exhibits of each screen a user may see.

TRACS Conventions

Red Screens - Generally mean the User is in part of the Control Program

Green Screens - Associated with the Maintnenance Policy Sub-Module

Brown Screens - Associated with the Component and Condition Sub-Module

Dark Blue Screens - Used in the Reference Sub-Module, RAILWEAR, some Reports

Light Blue Screens - Indicate that user is in the Traffic Input Module

Gray Screens - Background Color of the Route/Track Input Module

Purple Screens - Used in the Cost Input Module

Multi Colored Screens, with changing borders - Associate with Reports Module

Designated File Suffixes in TRACS

*.COM - stand alone programs compiled files

*.CST - files produced by the Cost Input Module

*.??D - Default files which are developed in the Reference Sub-Module

*.DAT - data files from the component and condition module, also some inputs to
RAILWEAR which are not edited

*.EXE - stand alone programs compiled files

*.FIL - the PASCAL prcedures for RAILWEAR

*.MNT - files that were built by the Maintenance Policy Sub-Module

*.MSG - files containing help messages

*.OUT - also known as the bridge file, this is the connection between the simulation models and the reports module

*.PES - files that are use by the PESOS program

*.RPC - file that are produced if the user saves a Cost Report

*.RPE - files that are produced if the user saves an Engineering Report

*.RTP - files that were built using the Route/Track Percentage approach

*.RTS - files that were built using the Route/Track Segment approach

*.SCR - Compiled files which contain the screens used in the user interface

*.TRF - files that were built using the Traffic Input Module

1 Introduction

The costs associated with the design, implementation and maintenance of a complex computer model are quite high. In order to recover this cost, and exploit a model to its fullest potential, it would be very desirable to have a model that could be used by many different types of people in many different types of analyses. Over the past fifteen years, there has been a trend in the railroad industry to include in models more features that would increase the user friendliness, simplify the data input process, and promote the use of the models by diverse users in diverse applications. The Total Right of Way Analysis and Costing System, TRACS, was recently developed at M.I.T. to be used as a planning tool in decisions related to the management of railroad track. The object of this thesis is to show that existing models do have various levels of versatility, that the railroad industry needs models that are much more versatile than any presently available, that the approach used to structure TRACS achieves a level of versatility that has never before been obtained in a railroad engineering economics model, and that the techniques used in TRACS may be useful in other applications.

1.1 Background to the Development of TRACS

As part of the development of a rail deterioration model, the M.I.T. research staff added several features to the Track Maintenance Cost model, TMCost, that were intended to make the model easier to use. However, after reviewing comments from a group of model users, it became clear that the complexity of TMCost would have to be packaged within a software superstructure that would drastically reduce the time required to learn the model, significantly increase the applicability of the model to different kinds of analyses, and enable the model to be used by different levels of management. In addition to a friendly user interface and a more elegant computer structure, the superstructure had to maintain the ability of TMCost to do highly detailed analyses.

18

The M.I.T. Railgroup research team added additional goals of making the new package usable during intermediate stages of development and increasing the potential use of other AAR computer tools within the package.

The structure that was designed for TMCost succeeded in meeting all of the above requirements. Implementing the TMCost package within this new superstructure made such marked improvements that a new name was given to the package. It is now known as the Total Right-of-Way Analysis and Costing System or TRACS.

This thesis will describe the features that should be in a versatile computer model. After a discussion regarding facets of the railroad industry that dictate a need for versatile models, the paper will outline potential benefits that the industry could gain by structuring other railroad computer models in order to make them more versatile. Before annotating the methods that were employed to implement a versatile version of TMCost, i.e. TRACS, a review of the structure of the TRACS software and the structure of the TRACS user interface will be helpful. In Chapter 6 examples are often cited from the TRACS implementation to help explain the general methodology that was used to achieve a high level of versatility. Finally, some hypothetical problems of the type that are common to the railroad industry will be analyzed to demonstrate the versatility of TRACS.

1.2 Goals in Restructuring TMCost

The primary motivation for restructuring TMCost was to encourage more people to use the model. An engineering economics planning model such as TMCost has the potential to be used as an input to many decisions throughout a corporation, but the complexity of the original model had limited its use. In October 1987, only five people were identified who considered TMCost as a tool that could contribute to an analysis.

That is reinforced by the number of times TMCost was used as an input to a decision (Exhibit 1 - 1). However, many managers from various railroad planning groups agreed that they needed a model which could contribute to decision-making in the area of track maintenance.

The research at M.I.T., aimed at improving the TMCost model, was performed in cooperation with the M.I.T. Track Advisory Committee. This committee was originally composed of seven members. The areas of expertise and level of decision making responsibility may be expressed in terms of their respective titles (Exhibit 1 - 2). However, as word spread in the industry regarding the nature of the research at M.I.T., the group became much larger and included people from different departments within one company and different levels of decision making responsibility (Exhibit 1 - 3). The growth and diversity of the Advisory Group indicated to the research staff that there existed a broad interest in a model that could be used as an aid in track management decision-making. During the meeting of this Advisory Group, it quickly became apparent that each of the members had different ideas regarding the area of research priority. This disparity helped to precipitate the concept of designing one computer model that could be structured to meet all of the needs of the different members of the Advisory Group. In order to accomplish this goal, the model would have to be flexible so that it would improve its success in the following areas:

1) Useful to many levels of management
2) Useful to different departments in a company
3) Useful in decisions and analyses of varying importance
4) Easily updated to reflect new data or research

Throughout this paper computer models will be referred to as having certain qualities that make them "versatile". The word "versatile" is used as a shorthand representation of the four goals outlined above. There are many things that can be done to improve the flexibility and decrease the user hostility of a computer model. This thesis describes the

approach that was developed and implemented in TRACS. It remains to be seen if TRACS will ever gain the widespread popularity that the versatile approach was meant to achieve, but preliminary feedback from the industry is very positive.

Applications of TMCost

Exhibit 1 - 1

Technology Assesment of Covered Hoppers
Double Track to Single Track Study
System Average Costs for All Traffic
Incremental Costs for a Traffic Class
Technology Assesment of Heavy Axle Loads [1]

Original M.I.T. Track Advisory Committee

Exhibit 1 - 2

Name	Title
J. Eshelby	Senior Engineering Analyst
M.B. Hargrove	Manager Engineering Economics
S.T. Lamson	Research Associate, CIGGT
A.J. Reinschmidt	Manager Track Research
M.D. Roney	Manager Engineering Systems
D.E. Staplin	Director Planning, Engineering Department
R.F. Tuve	Manager Quality Control, Engineering Research

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1 Interview with Dr. Michael Hargrove and Carl D. Martland

Current M.I.T. Track Advisory Committee

Exhibit 1 - 3

Name	Title
A.R. Auzmendi	Engineering Economist
T.J. Berry	Quality Control Engineer
C.J. Dunham	Industrial Engineering Analyst
J. Eshelby	Manager, Rail Scheduling
M.B. Hargrove	Director, Engineering Economist
T.B. Hutcheson	Track Research Consultant
H.M. Lees	Manager, Track & Structural R & D
P. Madsen	Manager, Industrial Engineering
D.B. Mesnick	Asst. Manager, Technical Studies
T.E. Pulkrabek	Manager Special Projects
N.B. Rao	Director, Cost & Economic Analysis
H.S. Rawert	Director, Cost & Economic Planning
A.J. Reinschmidt	Manager, Track Research
G. Rinehart	Manager, M&W Budget
D. Robertson	Manager, Product Assessment
M.D. Roney	Manager, Track Technology
C.N. Smith	Cost Analysis
M. Smith	Manager, Technical Analysis
D.E. Staplin	Director, Quality Control
R.K. Steele	Director, Metallurgy
R.G. Thomas, Jr.	Manager, Quality Control Engineering

2 What is a Versatile Computer Model?

The degree of versatility of a computer model can be observed by looking at the number of different applications for which it is used and the number of different kinds of users within a company and the railroad industry as a whole. This chapter describes a method for rating model versatility and proceeds to analyze the important planning models that are currently used or are available to railroad managers.

All of the large rail companies are utilizing computers and automated systems in their daily work. Most of the reporting for quality control, billing, and regulatory requirements is now on-line. Managers ranging from the president of a company down to the field officers and clerks have ready access to personal computers or main frame terminals. Many software tools exist which were designed for specific purposes or for specific people. In addition, some tools exist which were meant to have a broader application. The software tools that are related to the TRACS development process are the planning models that are used by or available to railroad managers.

In a discussion about the effects of deregulation on the railroads' data systems departments, William Dempsey, President of the AAR, predicted in an interview with "Progressive Railroading":

> Analysis of abandonments and mergers will all require use of computer technology. Marketing people will likewise have to work with the data systems when developing a price and service package custom-tailored for a particular customer. "Indeed, deregulation will require that all departments of the railroad work more closely together since each may have access to only a part of the information needed before a customer can be sold on railroad service. Data systems must be horizontally as well as vertically integrated within your corporate structures." [1]

For the purposes of this thesis the measure of versatility of planning models is based on its successful application to different types of problems and its successful application by

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1 Progressive Railroading, "New Twist to Computer Technology", December 1981.(p.46)

different types of users. The pool of users should be larger, both horizontally (different departments) and vertically (different levels of management), for more versatile models. Although Mr. Dempsey only described two dimensions, versatility is marked by a third which can be thought of as depth. The term, depth, will refer to the ability of the model to analyze problems at different levels of complexity.

The models that will be analyzed will be limited to planning models, that is, tools that are used to give inputs to decisions. This does not include such things as real time dispatching systems, automated waybilling systems, real time equipment distribution models, and car tracing tools. The number of times that a model has been used is a gauge of its success rate. In addition, one needs to asses the potential for applying a model in a certain scenario as some models do not benefit from wide publicity.

The objective measure of a model's versatility will no doubt be influenced by the publicity associated with that model. This publicity is sometimes the result of active support from various types of groups. Some models, such as the Service Planning Model, are aggressively marketed by consulting firms. Other models, such as RECAP, are demonstrated to different people in the rail companies by the AAR in order to encourage a wider use of the model. A third type of backing for a model may come from users' groups, who meet on a regular basis to discuss problems, future research, and software maintenance. A good example of a successful users' group is the Rail Subcommittee of the AAR Track Research Committee which supports the Rail Performance Model.

When one tries to assess the versatility of a model based on the number of times it has been used, it is necessary to look at the support the model receives. The popularity of the model may be due in part to the visibility of the model, not to its inherent versatility. On the other hand, a co-variance does exist between models which are supported and those models' versatility. The support groups have an interest in keeping their respective models up to date; consequently, they often incorporate new features which make the models more

versatile. The Service Planning Model (SPM) and Rail Performance Model (RPM) are good examples of models which have been upgraded with features that encourage a broader base of users and analyses to be performed with the models. Both models now utilize data input screens, file building routines, and reports that were requested by the rail companies in order to increase the models' flexibility.[23] This thesis will not try to discern whether a model has been used many times because of its versatility or because it was promoted by an organization.

At the opposite end of the spectrum are computer models which are purposely not promoted outside of a company. Some rail companies are very interested in maintaining their own models in-house. By not sharing the technology with the other companies, they feel that they may potentially gain a competitive advantage. One company spent two years developing a network model for equipment distribution which has many features that make it more versatile than other comparable products on the market. The model achieves its flexibility by defining general categories of equipment, by using management expertise instead of model forecasts, and by combining heuristic rules and optimization techniques. Although the model is the most versatile of its kind in existence, it has a limited use due to the company's desire to keep the actual formulation and implementation a secret.[4]

A series of charts at the end of this chapter will review many of the planning models that are available to the rail industry by summarizing any evidence that was found supporting the use of each model by different users for different purposes. This exercise will identify some features of TRACS that have been used before in railroad planning models. Each model is assessed in the three degrees of versatility:

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2 Interview with Carl Van Dyke

3 Interview with Al Reinschmidt

4 Demonstration of the CSL Intermodal IEDS at the AAR Intermodal Steering
Committee meeting at Atlanta, 1989

1) The complexity of analyses that the model design can reasonably handle

2) The benefit of the model to different functional areas in a company

3) The types of users who actually use the model for input to a decision

In order to identify all of the important models that have been developed and are currently available to the industry, a group of people from the AAR and officials from several railroads were interviewed. The models that are displayed in the charts represent a composite of responses from these people. Each person was asked to identify models that are available today which are designed for railroad managers and discuss the kinds of analysis that can be done with the model and the potential for using the model in the various categories discussed above. Summaries of the interviews with the experts can be found in Appendix 1.

In order to decrease the subjectivity of the entries, an attempt was made to contact the designer of the model. In most cases, the person who was responsible for the concept and/or implementation of a model had maintained contact with users of the model. This person was able to recommend other people to contact in the rail companies and in consulting firms who were able to discuss specific applications and analyses utilizing the model. Exhibit 2 - 2 lists the names and titles of the people who were interviewed.

Each degree of versatility will be explained before an examination of specific models.

2.1 Complexity of Analyses

The problems faced by managers in the rail industry are much like those faced by managers in other industries. Some decisions are made quickly by individuals while others take much longer. The important decisions are reached only after research, debate, and analysis of the subject. The results of computer models - including spread sheet models, simple regression models, simple operations research models, simulation models, complex OR models, and very complex engineering economics packages -

provide information for most of these decisions. The routine day-to-day decisions are often made easier with computer tools. Software is now available to help guide a manager in project control, scheduling of appointments, and ordering supplies. This thesis deals with more specialized models which are meant to be used in the non-routine decisions that require specific kinds of analysis within the rail industry.

In terms of categorizing the versatility of a model, the manager may depend on the same model for decisions of different importance. To simplify the discussion and categorization of different models, the types of decisions have been broken into four groups. Each group is defined by the amount of data and degree of obscurity of the data that is readily or potentially available to a manager. The second aspect of a group is marked by the amount of data manipulation that must take place before the manager has a useful result. A model serves the purpose of organizing the data collection and transformation as well as automating the data manipulation process for the manager.

A paragraph describing each group of decisions follows. Examples of the type of decision were purposely designed to demonstrate how a model, such as TRACS, could help a manager to make a more informed decision. It will be shown in detail in Chapter 6 how TRACS can be used as a decision-making aid for representative scenarios from some of the categories.

2.1.1 Simple Inputs, Simple Analysis

Apart from the routine decisions mentioned above, a manager is often faced with problems which need quick answers. The problems in this category are not difficult to solve and do not have a major impact on the operating policies of a company. A person who is familiar with the subject area can often make an expert judgment. Some problems, however, require that the expert defend his decision to others. In other cases the manager may have limited exposure to an area.

A decision in the railroad industry exemplifying this group is pricing for small accounts. While the level of revenue does not merit in depth cost analysis, a manager would still like to have a "floor" from which to work when negotiating with the customer. The simplest cost model would be similar to that used in the days of regulation: some function of system average costs. [5] Under deregulation, however, the railroads are free to negotiate contract prices on each individual shipment. Simple cost models with a few inputs are used by the Kansas City Southern to increase the precision of the system average approach. [6]

One could imagine a situation where a manager would be called upon by the labor unions to give a report which showed the expected level of employment for the coming year. In the area of track section gangs, the analysis is simple enough: the number of gangs needed multiplied by the size of each gang. The inputs required would include: 1) the length of track to be serviced with high, medium, and low quality of maintenance and 2) the number of gangs required per mile for each level of maintenance. TRACS has the ability to create such a report from the detailed data base.

2.1.2 Simple Inputs, Complex Analysis

Some decisions that are to be made may have an important, long term effect on the company. The problems in this category should be analyzed in detail, but due to budget constraints or time constraints, the manager must make a recommendation based on limited knowledge.

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5 U.S. DOT, <u>A Prospectus for Change in the Freight Railroad Industry. A Preliminary Report by the Secretary of Transportation</u>, October, 1978.(pp.113-124)

6 L.A. Shughart, Minutes of the Meeting with Kansas City Southern to Discuss TMCost2, January 27, 1988.

Recent changes in the ICC regulations regarding accounting policies made it worthwhile for rail companies to perform depreciation studies. One of the inputs to these depreciation studies was the expected remaining life of the different track components. On one hand, the purpose of doing the depreciation study was to adjust the accounts to reflect the true state of the track in different locations on the railroad; therefore, using system average lives was unacceptable. However, the cost associated with collecting and analyzing detailed data on track geometry and traffic would have far outweighed any benefit of doing the study. The solution was to use models which had simple inputs, such as "heavy traffic", "high density", and "low curves" to classify a subdivision. Typical component lives for each class of subdivisions were then calculated. Calculating the expected component lives was complex, but the task was simplified by limiting the number of analyses to a few typical cases and using data from one subdivision to represent similar situations. [7]

2.1.3 Complex Inputs, Simple Analysis

The types of problems that can present the greatest challenge to managers are the problems that have seemingly obvious answers, but the decision maker must convince others that the choice is valid. Mike Smith from the BN noted that, "Experts will always have an opinion on something; the problem comes in trying to validate it." This approach is often used to validate or criticize decisions that were made previously.

Having models which require extensive inputs, most of which change the basic answer very little, can waste the time of a user and confuse the situation. Moving outside the realm of railroads for an example, it was found that other infrastructure models had some of the same drawbacks as the original TMCost. The PAVER model is a complex

7 Interview with Bill Stout, Consultant with Gannett Fleming for the BN, at the 1989 AREA Technical Conference, Chicago, IL.

tool which predicts crack growth and other defects in a road surface. This model has only been used in a few studies because of the time required to collect all of the data necessary to perform one run, even in cases where the analysis was straightforward and did not require all of the data. [8] Only a few of the inputs have a major impact on the results. The complexity of the model makes it difficult to help predict pavement life to defend optimal replacement strategies. Instead, the problem is solved based on budgetary constraints, public perception of the pavement performance, and political pressures. The PAVER model did not find wide success because it was not structured in a way that would make it easy for a user to ignore the less important inputs. In fact, it is not even obvious to a user of the model which inputs are the most sensitive. [9]

In contrast, the ability to incorporate many details may be a feature that is needed by a model, even for straightforward analysis. In the rail industry there are at least two reasons that can force a manager to make a more detailed analysis of a situation necessary: 1) Tenacious management and 2) Regulatory Proceedings.

There are usually a few important parameters that determine the deterioration rate of a track component. However, other parameters also have a small effect. There are so many other variables, such as traffic growth and decline and changing maintenance policies, that the parameters with small effect can be ignored for the purposes of simulation and predicting component life.

In the case of a wooden tie in a swampy territory, the primary deterioration mode is rotting. The other important parameter in predicting life is the annual Million Gross Tons (MGT). However, the rate is also slightly affected by operating speed, the quality

8 Sue McNeil, 1.22 Infrastructure Management, Lecture 15, Class Notes

9 M.Y. Shashin and S.D. Kohn, Overview of the Paver Pavement Management System, Paper Presented to the 61st Annual Meeting of the Transportation Research Board, Washington, D.C., January, 1982.

of metallurgy of the rail, the load spectra of the traffic, and many other parameters. In order for a study supporting a major decision, such as determining a policy for concrete ties, to have enough credibility with the highest levels of management, the analysis may have to include some of the less important parameters, such as speed.

One of the problems associated with designing a model that contains input slots for large amounts of data arises when the model must make use of the detailed data. It can be very difficult to calibrate the mathematical relationships for these detailed inputs. The matter is further complicated with the issue of co-variance. Changing groups of the less sensitive inputs is different than changing just one of the factors. In the fourth group of decision types, cases will be examined where it is necessary to have the ability to enter complex inputs before the analysis can be performed because the results of the analysis are sensitive to many inputs.

2.1.4 Complex Inputs, Complex Analysis

Some decisions have a large impact on a company's long term profitability, market strategy, or ability to adapt to a changing environment. The larger problems faced by a manager usually require much time to arrive at a decision. The issues that must be considered are very broad and lie outside the scope of expertise of any one person in a company. A model is a useful tool in structuring all of the different types of data. After data is collected, very detailed analysis must be performed to weigh the differences between two options.

A benefit to one department of a company may be a detriment to another department. Although it would be easier for the operating department to have high-speed track throughout a system, the cost of maintaining that performance level would be excessive. The cost of upgrading a mainline from FRA Class 3 track to FRA Class 6 track

for intermodal traffic may result in lower track maintenance costs and a savings on fuel consumption for other freight. In the 1970's the cost of rail equipment was not taken into account in decisions about terminal operations and other operating policies. After models were built demonstrating the importance of this cost, drastic changes were made in the operating policies of the industry. [10] There are some managers today who feel that the trade offs in operating costs, service levels, and maintenance are not being analyzed in sufficient detail. [11] Consequently, very important decisions are often made without evidence of the pros and cons of each alternative.

2.2 Applications to Different Functional Areas

Some analyses in the rail industry are important to more than one department of a company. The traditional functional areas that existed in a rail company are beginning to break down. The Boston and Maine Case study at M.I.T. concluded that a company could benefit from interdepartmental task forces. [12] The influence of Japanese style management techniques also contributed to some railroads restructuring their management hierarchy. The most extensive restructuring occurred at the Union Pacific Railroad in 1987. At the UP a matrix structure was introduced which was centered on creating a high quality of service company. At CSX Transportation a group was formed within the company called the Management Science Steering Committee.

10 Steven Rothberg, Et.Al., "The Design of a Management Control System for Railroad Freight Terminals", Studies in Railroad Operations & Economics, Volume 27, Center for Transportation Studies, M.I.T., Cambridge, MA, 1980.

11 Bill Romig, "Providers of Transportation: Railroads Over the Next 20 Years", Perspectives of Freight Transportation and Freight Service Beyond 2000, Unpublished Paper Edited by R.K. Whitford, Spring 1989.

12 Carl D. Martland, Et.Al.,"Implementing an Operating/Service Plan: A Case Study of the Boston and Maine", Studies in Railroad Operations and Economics, Volume 29, Center for Transportation Studies, M.I.T., Cambridge, MA, 1980.

The sharing of duties and responsibilities by different departments has created a need for tools that can be used by people from different backgrounds. If one tool can serve more than one type of user, that is one degree of versatility. In addition, the most versatile software models should be capable of presenting the results in a form that is responsive to the unique perspective each user will have of the larger problem. Applying a model to problems in different functional areas of a company is referred to as horizontally expanding the base of users.

Following is a discussion that gives examples of some of the responsibilities that are usually given to each department area. The models are used by the managers in each department to help solve the problems described. By introducing versatile models, different departments will be able to share the expense of data collection, model maintenance, and calibration. Each problem will still require the model to be run and the results cast into a format that is useful to the managers.

2.2.1 Engineering / Mechanical

Engineering departments are typically staffed with people who worked their way up the management ladder from field positions. Consequently, the managers have an extensive knowledge of practical limitations and potential problems in carrying out different tasks in the field. However, the managers often find it difficult to communicate these problems to the financial planners in terms of R.O.I., economic benefit, and hidden costs. Models can play an important role in bridging this gap. Versatile models are especially helpful because the same tool will be used by the different parties involved. That fact alone will offer a common ground from which the discussions can be launched.

Project planning is an important task in every railroad engineering department. Each year road masters on a railroad must submit a proposal that outlines the work that should be done on their respective territories. Each middle level manager combines these reports and submits an expenditure request to upper level management. In these various requests the managers from the engineering departments sketch project plans which estimate the materials, machinery, and labor required for each activity. The people responsible for deciding which activities are in the following year's program often check the availability of the different resources. When possible, projects are scheduled earlier or delayed so that more work can be done in one geographic location at one time. This takes advantage of the economies of scale in track rehabilitation. Projects that take place in high traffic density territories are usually coordinated with the traffic department far in advance of the actual work in order to minimize the effect on the service. Planning for these activities, therefore, requires tools that can predict projects four or five years in the future. [13]

After planning for a series of projects, the engineering department must insure that each project is finished in a timely manner and within the budget constraints. Models can help a manager with project control by aiding in materials requisition planning, checking on gang productivity, and accounting for different costs that are incurred. The manager could use different models for each of these problems, but one versatile model should be able to produce reports tailored for each analysis.

When new inventions are introduced to the industry, managers must decide if they should incorporate them at all and, provided they are used, to what extent. Innovations are normally accompanied by a higher price. Consequently, high quality rail steel may

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13 Carl D. Martland, Et.Al., "Scheduling Rail Relays with the Assistance of an Expert System", Paper Presented at the Hermes Community Expert Systems Colloquium, Vienna, Austria, March 1989.

only make economic sense in high degrees of curvature and high tonnage areas. A technology assessment must be performed to define the exact thresholds where the costs of one approach equal the costs of a different approach.

Computer models can play a role in helping engineers understand physical properties of their railroad. An understanding of lateral and vertical forces is necessary to explain phenomena such as rail roll-over, which would most likely result in a derailment. Very detailed curving models and engine performance models are available for these purposes.

The mechanical departments are responsible for the locomotives and cars on the rail-road. The problems those managers face are much the same as the engineering department. They must make decisions about spending large amounts of money. They analyze new technologies in regard to the life cycle costs of maintenance and fuel savings.

2.2.2 Operations / Transportation

The operations department must schedule trains to service the customers. They must determine what level of service each train will offer. They can use models to analyze the costs of heavier equipment and longer trains on the right of way and determine if the saving will cover the difference. The level of service is also a function of the number and the size of the terminals, the quality of the track, and the density of traffic. In the past, operating departments have been criticized for ignoring the cost of equipment rental, the cost of track maintenance, and the value of dependable service. Versatile computer models can play a role both in allowing the operating departments to defend their policies and in allowing the other functional areas to educate the operations people.

Mergers of two or more railroads have often created many areas with multiple tracks serving the same city pairs. Also, new technologies in signalling systems enable railroads to run more trains on a single track for a given time period. These facts resulted in many line abandonments, plan rationalization programs, and short line sales in the early 1980's. One of the considerations of an operating department in these situations is the cost savings of track maintenance on the abandoned line and the cost increases of higher density traffic on the remaining lines. One of the issues raised by high density lines is the cost to the operating departments of track time for maintenance activity. Although it is hard to value the cost of delay and loss of good will, it is equally difficult to justify spending formidable amounts of money for high productivity track machinery and high quality materials that have a longer life.

2.2.3 Marketing

Before deregulation, prices had to be submitted to the ICC for approval. The traffic departments often spent their time trying to justify the rates they were proposing, rather than analyzing the market and trying to price at a competitive level. As mentioned before, the original TMCost model was implemented to study a rate that was in question. In the current environment the railroad marketing departments must compete not only among themselves, but also with increasing pressure from steamship lines, pipelines, trucking companies, and barge lines. The marketing departments are sensitive to the need to understand the real costs of providing a service and often seek advice from other departments of the railroad in helping to identify the marginal cost of

different types of traffic on specific lines. CSX Transportation has a model that will calculate the incremental cost of different traffic. This is then used as a floor by the Marketing department in rate negotiation. [14]

The marketing departments have influenced the configuration of plant and equipment in recent years. The freedom allowed under deregulation has encouraged private firms to speculate on new innovations such as double stack container cars and combination highway/rail vehicles. Models have served the marketing department in helping to defend the benefits of the new ideas to upper level management, resulting in investment in some of these new technologies. One of the initiatives from the past that has re-surfaced is the increased use of heavier axle loads. There has been pressure from the marketing departments to load more freight in each individual car. This would reduce the relative tare weight of the vehicle, decrease the cost of crew per ton of freight, and decrease the number of cars required in a fleet. It is not clear what the costs of the heavier axle loads will be, but models are being run to analyze the impacts on track maintenance and investment.

The costs of different levels of service that the railroad provides to customers vary. In order to maintain the high reliability and low trip times that the merchandise freight market demands, intermodal freight requires specialized terminals, cars, and dedicated trains. In contrast, electrical power plants, which are the major consumers of coal and coal transportation, typically keep a large reserve of coal stockpiled at the plant. Frequency of service and reliability are not relevant issues with coal. The cost of operating priority trains includes the cost of operating the service in times of low demand, the cost associated with low productivity of track gangs because of the small

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14 Interview with Bill Cosgrove, AVP Cost & Economic Analysis, CSX Transportation, April 1989.

work windows they are allowed, and the cost of maintaining a very good track structure so the trains can operate safely at high speeds. The SPM, RECAP, and TRACS, along with route capacity models, should be used to clarify the cost of different service levels.

The marketing departments must perform competitor assessments in order to gain a better understanding of the market place. Under deregulation the railroads are not required to publish the rates that are in the contracts that they negotiate with each customer. However, the models can be used to make guesses about a competitor's cost structure. The AAR developed a spread sheet model for estimating the cost of carrying freight by truck in a given corridor. The models could also be used to assess other rail companies. For example, if Railroad One has a shorter route between two cities than Railroad Two, they most likely would have no problem in obtaining the time sensitive freight because of their implicit service advantage. However, Railroad Two could still price its service at a competitive level for the bulk commodities, which are normally time-insensitive. Before entering a negotiating session, they would like to know what price Railroad One was likely to offer the coal company. Since that data would not be available on Railroad One, they could synthesize it using models. By approximating inputs to the models such as typical trains for Railroad One, typical track geometry and quality, and typical traffic density, Railroad Two could estimate the costs of Railroad One and then infer what their price would probably be.

2.2.4 Economic/Financial

Partly because of the move toward interdepartmental cooperation that was discussed before and partly due to the recent ICC willingness to look at economic costs as well as accounting costs, the roles of the accounting departments and the economic analysts are blending together. An example of the overlap in roles was discussed at the AREA

Technical Conference. The responsibilities of the AREA Committee 11, Engineering Accounting and Record Keeping, were not clearly defined as separate from the AREA Committee Engineering Economics. [15] Therefore, the functions of both will be grouped together for the purpose of categorizing a model's use. Worthy of note is the fact that these departments have been playing an increasingly important role in the decision making process of the railroads. Hays T. Watkins, the CEO of the CSX Corporation, gained his experience in a railroad finance department, achieving the level of Vice President of Finance. Many roads now require that every project request be accompanied by a justification in terms of its financial impacts on the company as opposed to the previous method of automatically replacing equipment and track when it was old.

Some of the functions that are performed by the economic and financial branches of the railroad and that would benefit from the use of planning models include tax planning, capital expenditure planning, economic assessments of different technologies, and profitability analysis.

2.2.5 Strategic Planning

The most important group or department that uses planning models is the planning department. This group sometimes exists as a formal department led by a Vice President of Planning. However, it is not uncommon to find that another department has the responsibility of strategic planning for the company. Which persons are actually doing the planning depends on the politics of the organization. Manheim asserts that "planning is not just the activity of a single organization called the 'Planning Department';

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15 L.A. Shughart, Minutes of the AREA Committee 11 meeting, March 1989.

but it is a part of the responsibility of each manager". [16] The railroad planning functions can be separated into three basic areas: 1) Service Planning, 2) Equipment Planning, 3) Infrastructure Planning. Exhibit 2 - 1, which is taken from Manheim, summarizes the activities that occur in each area.

Recent trends in route rationalization include the abandonment and sale of many low density lines. This is done in order to eliminate the cost of maintaining the lines, to eliminate low margin services, and to eliminate labor costs. The decision to keep, abandon, or sell must take into account the competitor's position, the demand forecasts, the labor environment, and many other issues.

Changes in the federal tax system of accounting have allowed railroads to capitalize large investments in track and right-of-way improvements. These investments are then depreciated over time rather that incurred as an expense all in one year. The pros and cons of short term expenditures for track, such as maintenance and slow orders, versus the large capital investments which can be annualized over time are studied using financial models along with service and engineering planning tools. It may be desirable to delay a capital expenditure due to financial consideration but not feasible because of engineering safety parameters. The deferred maintenance that accumulated in the 1970's helped cut the costs of railroad operations but had a devastating effect on the service levels.

Exhibit 2 - 1

General Objectives are Translated into Specific Objectives
Through Three Interrelated, Interdepartmental Planning Processes

OPERATIONS/SERVICE
PLANNING

- train schedules and

  blocking

- trip time standards

- operating costs

- pricing and sales

INFRASTRUCTURE
PLANNING

- investments

- maintenance

- abandonments

EQUIPMENT
PLANNING

- acquisitions

- retirements

- maintenance

- allocation to regions and ser-

vices
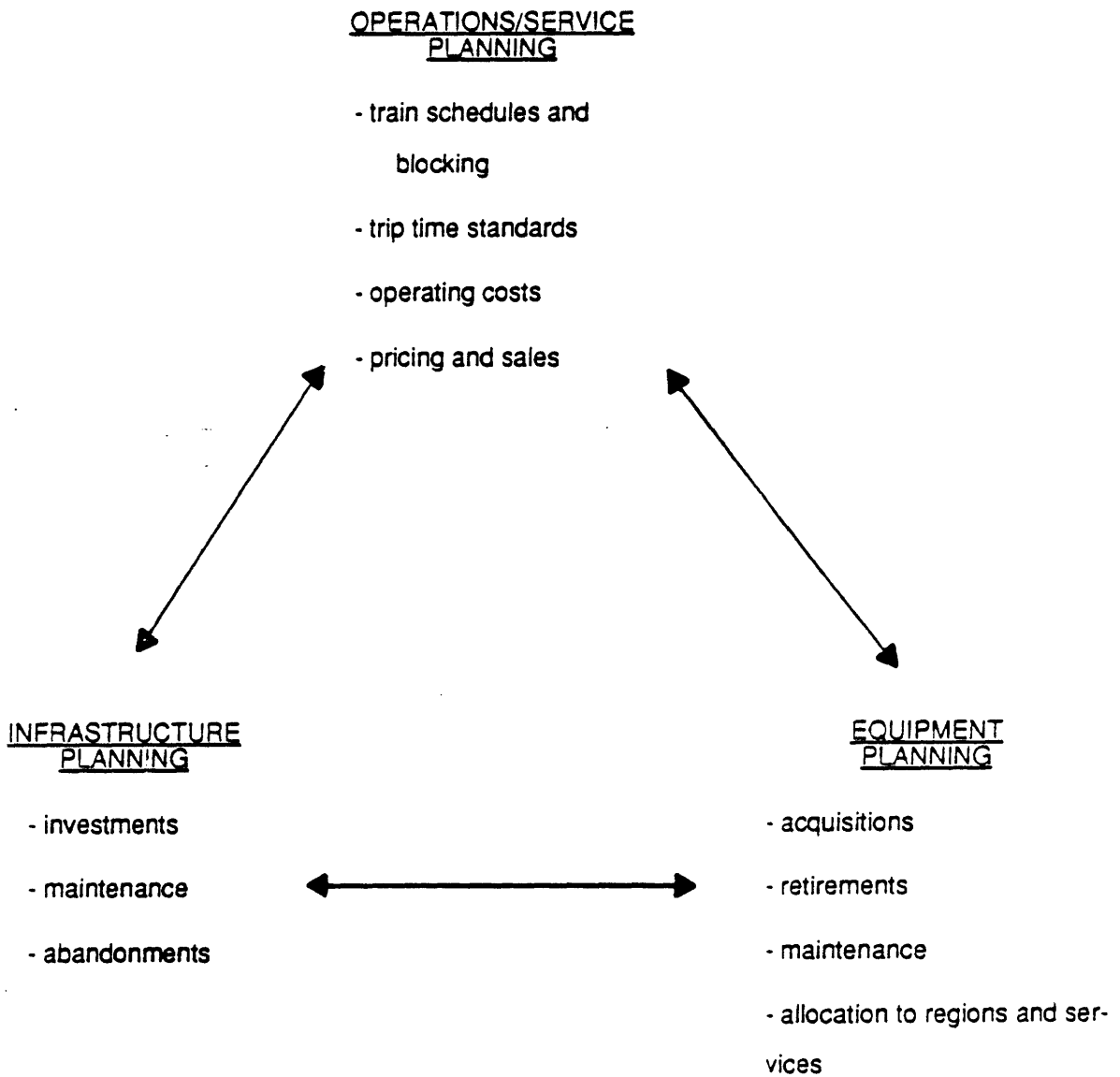
2.3 Different Users of Models

Within each department or functional area described above, there exists management strata. Each level of management has different resources available to it, different levels of responsibility, and different kinds of decisions that need to be made. Building versatile models that serve the needs of managers from all levels is referred to as vertical expansion of the user base within a company. It is not always true that higher levels of management on the chart of corporate structure have the most power or make the most important decisions. Some railroads are actively pushing decision-making responsibility to the lower levels, encouraging the analysts, road masters, and managers to structure opinions. Mr. Jim Eshelby, Director of Rail Scheduling at the Burlington Northern, wants to distribute computer models to all of the middle and low level mangers. He feels that it will increase the level of analysis in the decision making process. In addition, the practical field knowledge that would be added to the models would help sharpen the software into a more useful product.

> It's like the people in the field are building a house. They are pounding nails in with rocks. We have to give them tools so that they can do a better job. So we give them a hammer. Some of them will continue to use rocks, some of them will use the hammer, a few will come back to me and say, 'Why don't you put a claw on the back of this hammer, so when we bend a nail, we can pull it out faster?' [17]

Other roads are aggressively centralizing the decision making process and releasing rules and company policies to be used as guidelines by the lower levels of management. The middle and lower level managers in the engineering department of the Santa Fe have no input to the strategic policy decisions that are made. For example, the person

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[17] Minutes of the M.I.T. Track Advisory Committee, November 1988.

in charge of scheduling rail relays was told that the minimum length of track that should be relaid in one site is three miles. He had no idea what consideration went into that decision. [18]

The different levels of management generally have different experience with computers and computer models. While it is difficult to draw definite conclusions, many of the senior level decision makers are of an older generation and do not feel comfortable using complex computer packages. A paradox exists in that these same senior level people are often the only ones in the department who have the experience to interpret the output of models and identify nuances, weak assumptions, and unfeasible answers.

In terms of this thesis, using a computer model means that the manager will develop a case and run the model. For middle and upper level managers, there is often a support staff which will build a base case. The building of the base case requires a larger effort than structuring alternative cases that need to be tested, which also qualifies as using the model. If a manager is simply aware of a model and requests that the model be used to improve an analysis, that does not necessitate that manager's running the model. Like TRACS, the SPM included reports that were designed for use by senior executives. However, the reports are generated by others within the company. This thesis focuses on trying to structure the models so more managers will consider building scenarios and running the model, as well as using the model's inputs.

The following subsections will elaborate on types of positions that are included in each grouping of management strata that is used to categorize model versatility. Also, a general description is given which describes the background that would be typical for persons in such a position.

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18 Interview with Santa Fe Engineering Department Staff, March 1988.

2.3.1 Analysts, Operations Research Groups, R&D Groups

The people in this group are the traditional users of computer models. They are typically the ones responsible for running the models, calibrating the relationships, and even building new models if the need arises. In the rail industry, these people usually enter the company at this level with a B.S. degree or an advanced degree. In recent years, it has become more likely to find personnel with Ph.D.'s in these groups.

Examples of job titles in the rail companies that would fall under this heading include: manager of economic analysis, manager equipment purchasing, manager of technology assessment, and manager of operations research. These people perform the development and implementation work for analyses.

Outside of the rail companies themselves, one can find scientists, researchers, and analysts at both the AAR labs and specialized consulting firms who would also fall into this category. In these groups the titles may reflect a higher position in the organization chart because of the technical nature of the group in question. Examples of job titles from the AAR and consulting firms include: Director of Metallurgy, Vice President of Development, managers of a specific package, engineering economists, or managers of quality control.

2.3.2 Low Level Management

The people in this group are the field personnel who come in contact with the day to day operation of the company. If these people have used models at all in the past, they were of the simple-inputs, simple-analysis type described above. The models with which they are familiar include spreadsheet type models and online reports that are available on most mainframes. In the rail industry, these people usually enter the company several levels below this position as laborers, administrative assistants, etc. Some may

have transferred into the rail company at this level from a comparable position in another industry. It is not uncommon to find people with Bachelor degrees at this level, but in some jobs it is not necessary.

Examples of job titles in rail companies that would fall under this category include: road masters, field salesmen, terminal managers, yard masters, and shop foremen.

2.3.3 Middle Level Management

The people in this group make many decisions that benefit from analysis using software tools. Depending on the background of the person involved and the staff resources available in each company, a middle level manager may set up analyses and run the models, may outline the problem and have another group perform the runs, or may possibly have a base case scenario prepared and then test parameter sensitivities himself. This level of managers will be called upon to evaluate a model, to criticize new models, and to interpret the output from sets of models. In the rail industry these people can be promoted from low level management positions or enter the company through a management trainee program. People at this level usually have a college education, an MBA is not uncommon.

Examples of job titles in rail companies that would fall under this category include: directors of corporate budgeting, directors of marketing for commodity groups, division superintendents, directors of project scheduling, directors of service planning, and directors of equipment acquisition.

2.3.4 High Level Management

Higher level managers in the rail industry are usually promoted from the most experienced middle managers. Due to companies downsizing and offering management buy-outs, more and more high level managers are coming into these jobs with experience in computer tools. [19] In the past, considerable effort was often spent convincing high level managers to use the output of computer models, to validate decisions from middle level managers, and to finance the development of new models. Although the new school of high level managers supports software aids in decision-making, they do not have the time to actually utilize the complex engineering economics models in their own work. Unlike the middle level managers, a high level manager seldom sets up analyses and runs the models. He usually reviews the results of analyses performed by others and may suggest alternatives that should be modeled in other iterations. [20]

This level of managers will be called upon to determine the benefit of different models to the company as well as reinforce their judgment with funding for model development and maintenance. Because of the time constraint on these people and the importance of their endorsement of a model, it is important to include a facet of versatility in complex models that is tailored to them. The models should enable high level managers to perform simple analyses, review results at an aggregate level, and validating the decisions made by subordinates; decisions which may have been partially based on model output. People at this level usually have a college education, coupled with a deep knowledge of the railroad industry which was gained from past work experience in different departments of the company.

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19 Interview with John Orrison, Special Assistant to the Executive Vice President, CSX Transportation, April 1989.

20 Interview with Peter French, AAR, April 1989.

Examples of job titles in rail companies that would fall under this category include: Chief Engineer, Chief Mechanical Officer, regional superintendents, assistant vice presidents, and vice presidents.

2.3.5 Inter-Departmental Task Force

As discussed in the section on different departments of the rail company, special task forces are sometimes used to study very important and complex issues. Although representatives from all of the different levels of management described above can be on any of these committees, there are sometimes outside experts who are employed to offer additional insight into the issues. These outside experts include lawyers, consultants who are not necessarily railroad specialists, and government representatives. The most versatile of computer models should adapt to the needs of this audience as well.

Finally, the results of these endeavors often end in presentations to the corporation's board of directors. The directors may come from industries other than transportation or railroads. During presentations to the board, the middle and upper level managers must present the most important decisions that have been made since the last meeting and explain what issues were considered. Using the results of complex models can be overwhelming in a short period of time. This creates a need for some reports that sum up the models' results in a simple fashion. When these reports do not exist, the presenters are forced to build their own reports manually, transferring the key data to slides that are less cluttered and more professional looking.

2.4 Overview of Some Planning Models for the Rail Industry

The following set of charts lists and describes models that experts from the industry feel are the most important planning tools currently available to railroad managers. The list

of experts that were interviewed is summarized in Exhibit 2 - 2. The chart summarizes the versatility of each model based on its successful application or potential success in each of the categories.

Each model can be found in four charts. Chart 1 gives a short description of the model, the date it was originally released to the industry, and the name of the developer(s). Chart 2 rates the model's versatility in the area of analysis complexity. Chart 3 rates the model's versatility in the area of applicability to different subjects. Chart 4 rates the model's versatility based on the type of users. One method of measuring versatility is to count the number of cells that have an entry under each model. The greater the number of entries, the more versatile the model. The models are listed in chronological order by date of release to the industry. It is interesting to note that, in general, the later models are more versatile than earlier models.

In each entry of the table, several codes may appear. These codes are as follows:

D - The designer of the model supports the use of the model in the application. This is based on the references cited in Chart 1 and, in some cases, interviews with the designer.

- There is documented evidence of the model being used in this application. The number is a reference to an interview with an expert. Each interview is summarized in Appendix 1.

P - The model has the potential to be used in this application. The P is accompanied by a reference if an expert clearly discerned a potential use and there was no specific example cited. A 'P' without a reference indicates that the author discerns a potential.

Sometimes it was not possible to locate an example of a model being used in a particular category. If the designer did not suggest that the model could be used in that capacity, a subjective opinion had to be formed. In order to determine if a model could potentially be used in a situation, the railroad personnel who had experience with the model were asked if they had considered or might ever consider the model as useful in that situation. For some models, this information was combined with this writer's experience. If the model could reasonably be used by the type of user in question or for the type of analysis, then a "P" was entered in the chart.

2.4.1 Chart 1: Description of the Models

Name of the Model	Description of the Models
TPS	Train Performance Simulators have been around for 25 years. They calculate the speed and fuel consumption for a train over a certain segment of track. Many railroads have their own version of the TPS.
SPM	The Service Planning Model was first released to the industry at large in 1982. It simulates individual flows through a rail network, modeling train connections, yard times, and transit times using PMAKE functions. The model was developed at M.I.T., and is now supported by ALK Associates.
TMCost	A series of models that was collected by the AAR in 1982 was labeled TMCost for Track Maintenance Cost. Later in 1987 the tie and surfacing models were replaced with models that were developed at the Canadian Institute for Guided Ground Transport. The rail wear model was replaced by the M.I.T. RAILWEAR model. The TUCost model, short for Track Unit Costs, was an accompanying program to the package.
Line capacity models including: C-Model, BN LCM, PMM, and RCM.	A set of models developed by various people. No one model ever became very popular, partly due to the immense data requirements. The intent was to study line capacity, double/single track, abandonments, and mergers. C-model was developed by Chip Kraft at CSX.
VPI Empty Car Distribution Model	Developed at Virginia Polytechnic Institute in 1984 in order to improve car utilization.
Conrail Budgeting Model	The Budgeting Model is a spread sheet model which was developed internally and used since 1985. It produces draft P&L statements, Balance sheets, and Capital Plans for the upcoming year.
PTNM	The Princeton Transportation Network Model is maintained and sold by ALK Associates. The model features very good graphics capabilities. It is distributed with a data base that describes the U.S. road and highway networks in detail.
AAR IEDM	The AAR had the Intermodal Equipment Distribution Model developed around 1986 as a result of the recommendations of the Intermodal Productivity Task Force.
YCM	The Yard Connection Model was developed at Conrail several years ago. It determines the best time to dispatch outbound trains, based on inbound train schedules and inbound flows.
RPM	The Rail Performance Model predicts the optimal time to replace rail based on fatigue failures. Output from the PHOENIX model is combined with field data to predict fatigue life. An economic post processor analyzes the used rail market, and produces many reports. The model is supported by the AAR Track Maintenance Research Committee.

LFRAM	The Locomotive Fleet Requirement Analysis Model is a spread sheet model developed at the AAR that is used as an input in decisions regarding locomotive purchasing, rehabilitation, and leasing.
ABM	The Automatic Blocking Model was developed in 1987 by ALK as a tool to be used with the SPM. It sets up a feasible blocking scheme, given a set of flows, and yard descriptions.
RECAP / TEM	The Rail Energy Costing Analysis Package simulates one train traveling over a very specific route. The package uses a matrix of output from TMCost to calculate maintenance costs. The package runs the Train Energy Model to gain data about fuel consumption, speed, and power requirements. RECAP has been updated continually by the AAR since it was first brought out in 1986. The TEM is a product of the AAR Chicago Technical Center and was included in RECAP in 1988.
TSS	The Train Scheduling System was developed in 1988 by ALK as a tool to be used with the SPM and the ABM. It sets up a feasible train schedule to carry the blocks over the network.
SCAN	The Schedule Analyzer was developed in 1988 at the Wharton School of Business and is used to study main line management.
AAR Tie Model	A spread sheet model that was developed in 1988 by the Tie Subcommittee of the AAR Track Research Committee. The model analyzes the replacement strategy for a subdivision in steady state.
AAR Ballast Model	A spread sheet model that was developed in 1988 by the Ballast Subcommittee of the AAR Track Research Committee. The model analyzes ballast degradation and predicts life.
CSL Intermodal IEDS	The Intermodal Equipment Distribution System developed by CSL Intermodal combines expert forecasts with heuristics and optimization routines to study empty trailer distribution. The model has been used since 1988.
Software A&E Car Distribution Model	A consulting firm, Software Architecture and Engineering, is currently working closely with the NS on a very user friendly model to improve car utilization.
TRACS	The Total Right of Way Analysis and Costing System was released by M.I.T. and the AAR on March 1, 1989. It is a framework for studying track maintenance and investment planning. Currently only the rail component can be modeled.

2.4.2 Chart 2: Versatility of the Models by Analysis Type

Name of Model	Simple Inputs, Simple Analysis	Simple Inputs, Complex Analysis	Complex Inputs, Simple Analysis	Complex Inputs, Complex Analysis
TPS		9		8, 9
SPM	D - 9	D - 9	D - 9	D - 9 8
TMCost				D - 4
Line capacity models including: C-Model, BN LCM, PMM, and RCM.				9
VPI Empty Car Distribution Model				D - 2
Conrail Budgeting Model		D - 1		
PTNM	9	5, 9	9	5, 9
AAR IEDM	D - 2		D - 2	
YCM				P - 7
RPM		D - 5		D - 5
LFRAM	D - 2			
ABM	D - 9	D - 9	D - 9	D - 9 8
RECAP / TEM		6		D - 4 5, 6, 8
TSS	D - 9	D - 9	D - 9	D - 9 8
SCAN		D - 3		D - 3 8
AAR Tie Model	D - 5			
AAR Ballast Model	D - 5	D - 5		
CSL Intermodal IEDS			P	P
Software A&E Car Distribution Model		2		2
TRACS	P - 5	P - 5	P - 5	P - 5

2.4.3 Chart 3: Versatility of the Models by Functional Area

Name of Model	Engineering Mechanical	Operations	Marketing	Economic/ Financial	Strategic Planning
TPS	9	8	P - 9		
SPM	Footnote [21]	D - 9 8	P - 9 Footnote [23]	Footnote [22]	D - 9 8
TMCost	D - 4		D - 4	D - 4	
Line capacity models including: C-Model, BN LCM, PMM, and RCM.	Footnote [24]	9			
VPI Empty Car Distribution Model		P			D - 2
Conrail Budgeting Model				1	
PTNM	P - 5, 9	5, 9	9	9	5, 9
AAR IEDM		D - 2			D - 2
YCM		P - 7			
RPM	D - 5			D - 5	
LFRAM	D - 2	D - 2	D - 2		D - 2
ABM		D - 9 8	P - 9		D - 9 8
RECAP / TEM	D - 4 5	D - 4	6	D - 4 6	D - 4 8
TSS		D - 9 8	P - 9		D - 9 8
SCAN	P - 3	P - 3			D - 3 8
AAR Tie Model	D - 5				

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21 Interview with Carl Martland, B&M Case Study

22 Ibid.

23 Ibid.

24 Interview with Carl Martland - B&M used ICC Model

AAR Ballast Model	D - 5				
CSL Inter-modal IEDS		9		P	9
Software A&E Car Distribution Model		P - 2			P - 2
TRACS	P - 5	P - 5	P - 5	P - 5	P - 5

2.4.4 Chart 4: Versatility of the Models by User Group

Name of Model	Analyst	Low Level Management	Middle Level Management	High Level Management	Inter- Department Task Force
TPS	8, 9				
SPM	D - 9 8	D - 9 8	D - 9		D - 9
TMCost	D - 4				
Line capacity models including:	9				
VPI Empty Car	D - 2				
Conrail Budgeting Model		1	1	1	
PTNM	5, 9	P - 5, P - 9	P - 9	P - 9	P - 9
AAR IEDM	D - 2	D - 2			D - 2
YCM	P - 7				
RPM	D - 5	D - 5	D - 5		
LFRAM	D - 2	D - 2	D - 2		D - 2
ABM	D - 9 8	D - 9 8	D - 9		D - 9 P - 6
RECAP / TEM	D - 3 5, 6, 8				

TSS	8	8			D - 9 P - 6
SCAN	D - 4	P - 4			D - 4
AAR Tie Model	D - 5				
AAR Ballast Model	D - 5				
CSL Intermodal IEDS	P				
Software A&E Car	P - 2	P - 2			P - 2
TRACS	P - 5	P - 5	P - 5		P

2.4.5 Results of the Review of Current Planning Models

Recalling that the method of measuring versatility is a function of the number of different ways a model can be used, then each model can be rated by using the number of cells with entries in the charts. Some interesting statistics follow.

Out of a possible 14 cells, only the Princeton Transportation Network Model had "perfect" versatility.

It may be that a bias exists since many of the PTNM cells were filled in by Carl Van Dyke, whose company supports the model. However, three other experts cited the model as important. Therefore, the frequency of references to Van Dyke should be attributed to the fact that he works more closely with the model than the other experts, thus being knowledgeable about specific applications. This logic applies to the other models and developers as well.

Excluding TRACS for a moment, there were 19 other models reviewed. Only four of them had ratings of 10 or greater. In addition to the PTNM, these four included the SPM, ABM, and TSS. All of the experts who cited these models referred to them as the "family" of SPM models. It is logical to expect that if one of the models is used in an

56

application, the others will also be considered as part of the analysis. However, the three models are distinct in purpose, can be operated independently of the others, and were developed at different times. The models are used separately as well as in a group. Therefore, the rating process maintained that they were unique.

Eight of the 19 models had ratings of '5' through '9' inclusive. These could be broadly grouped as having a medium level of versatility. Both RECAP and RPM, which have a reputation in the industry as being "good" models and "useful" tools, fell in this group. RECAP received an '8', which was largely a function of its horizontal versatility. It has been used, or has the potential to be used, for analyses in all of the departments. The RPM's rating of '6' was broadly based, having a medium level of versatility in all three degrees. It is interesting to note that TMCost received enough points (5) to qualify it as having marginally medium versatility. This fact seems to suggest that the railroad managers' appeal to add versatility to TMCost was not founded solely on its user hostility. That is reaffirmed by the fact that the strength of TMCost was, like RECAP, in the horizontal degree. Thus, the importance of the subject matter and the immediate need for extensive work in the area of track maintenance planning likely contributed to the decision to design and implement TRACS. This topic will be covered in detail in the next chapter.

Five of the set of 19 models explored had ratings of '4' or less, using the same approach. Three of the models were developed "in-house" by the railroad companies who use them. As predicted earlier, this would considerably reduce the number of potential users. The other two models that received very low ratings were the AAR Tie and Ballast models. They both had shallow depth versatility in that they were limited to doing tests with simple inputs and simple analysis.

The fact that TRACS was just released to the industry at large on March 1, 1989, contributed to the fact that all of the rating of TRACS was done based on its potential. All of the railroads are laying the groundwork to use TRACS for various kinds of analysis. The members of the M.I.T. Track Advisory Committee have all run the model with example cases. Inspection of the proposed applications of the model suggests that the '13' rating is not wishful thinking. The only category for which TRACS did not receive a mark was the use of the model by high level managers. The fact that PTNM did receive the mark was based on a rare case of the model actually being run by a president. Although the occasion was only for demonstration purposes, it did verify the fact that a high level manager could potentially use the model.

The next chapter will discuss the environment of the rail industry, specifically identifying facets that dictate a need for more versatility in planning models. It will conclude with a review of the specific things that the members of the M.I.T. Track Advisory Committee disliked about TMCost and their reaction to the TRACS proposal.

Experts Interviewed About Planning Models

EXHIBIT 2 - 2

NAME	TITLE	COMPANY
Joe Folk	Vice President Financial Analysis	Conrail
Peter French	Director	AAR
Pat Harker	Professor	University of Pennsylvania
Michael Hargrove	Director Engineering Economics	AAR
Al Reinschmidt	Director of Track Research	AAR
Rich Sauder	Director Operations Research	Norfolk Southern
Bill Sheppard	General Supt. Service Control & Transport Analysis	Conrail
Mike Smith	Manager Technology Assessment	Burlington Northern
Carl Van Dyke	Vice President	ALK Associates

3 Responding to Management Needs

The railroad industry has been criticized in the past for being as deficient in its management as other heavy industries in the U.S. The then Secretary of Transportation Brock Adams specifically identified the failure of railroads to adapt to new technologies as one of the main causes of their dismal financial status in 1978. [1] The rail companies were not alone in their plight of the 1960's and 1970's. The steel industry and the auto industry lost much of their business to foreign competition. The U.S. Government's formation and subsequent operation of Conrail proved to many policy makers that the secret to railroad profitability lie in route rationalization, better service, and better control of equipment. Improvement in these area started with research conducted by the FRA in the 1970's. Deregulation by the Staggers act of 1980 continued to give rail companies more freedom in their management. Many things have happened that have restored some financial stability and future viability to the industry.

On one hand, some aspects of railroad companies are quite different from corporations in other industries. These characteristics are partially a result of the large geographic area covered by each company, the historical policies of government regulation, and the traditional, but often ineffective, management structure. On the other hand, many of the benefits of versatile planning models exist because of the bureaucratic structure of large corporations. These same benefits could be gained by any large company. The representatives from the railroads on the M.I.T. Track Advisory Committee were supportive of the idea of restructuring TMCost2 into a more versatile tool. Since the restructuring process was meant to overcome the problems of having a very specialized software package, all the members of the group were in favor of proceeding with the development effort.

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1 U.S. Department of Transportation, A Prospectus for Change in the Freight Railroad Industry: A Preliminary Report by the Secretary of Transportation, October 1978.(p.3)

In order to understand what motivated the committee members to delay the development of new component deterioration models in favor of making the model more useful, it is necessary to analyze the circumstances that these managers must deal with on a day to day basis. In the following sections the mangers' environment is divided as follows:

1) The Industry Environment
2) The Management Environment
3) The Hardware and Software Environment

It is not sufficient to use the environment to explain the need for versatility. The railroad managers would never have selected the versatile approach if they did not expect to achieve results. The benefits and costs of the models must be analyzed as well. The second half of the chapter looks specifically at the TMCost model. Many of the problems that the M.I.T. Advisory Committee had with TMCost2 are annotated. Thus, there are two additional, more precise, reasons that can be identified as explaining why the industry supported the development of TRACS as a versatile alternative to TMCost.

4) The Response to TMCost2
5) The Expected Benefits and Costs of Adding Versatility

3.1 The Industry Environment

Railroad companies are in the business of transportation. In the 1980's, the transportation business expanded the use of intermodalism, purchased customs and freight brokerages, and started companies that offered for sale a total logistics management system. The railroads have bought truck companies, air lines, and shipping lines. In addition to the multi-modal trends, the railroads have been merged into seven major companies. After each merger, the routes were rationalized, resulting in the creation of regional and shortline railroads. In short, the competitive pressures on the rail

companies are very high. Revenue per ton mile has been decreasing while total ton miles has been increasing over the last 8 years. [2] The management is aware that they must exploit every available method to increase their profitability.

Although the Reagan administration helped to fight re-regulation efforts, the railroads will continue to face pressure in this area. The last decade saw many new technologies being introduced into the marketplace. Such things as premium rail steel, double stack container trains, and fiber optics were readily accepted. Other innovations such as the concrete tie and the 125 ton car did not receive such a warm reception. The railroad managers have had different degrees of success in using planning models in fighting regulation, choosing new technologies, and planning the shape of the company.

3.1.1 Government Regulation/Deregulation

The AAR emphasizes in all of its literature dealing with regulation that the Staggers Act of 1980 only partially deregulated the rail industry. Some railroads must still price some of their services below a certain ceiling, which is calculated by the regulators on the basis of the variable cost of the service. Apart from rate regulation, the railroads must meet certain safety standards. Other areas in which the ICC has played an important role include the approval of mergers, the setting of rates for joint facility operation, and the institution of mandatory traffic rights over some lines.

Although the original TMCost package was put together in response to a need that arose from a rate hearing, the current TRACS package is not promoted by the AAR Research and Test Group as having any benefits in this area. Part of the reason lies in the fact that TMCost did not significantly contribute to the rate case, and the case was in fact settled against the railroad. Dr. Michael Hargrove was emphatic in saying that using the tool

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2 William J. Rennicke and Anthony A. Davis, "New Cars: Boom or Blip?", Railway Age, April 1989.(p.35)

for defending prices was the least important reason that a rail company should support the model. However, it was the opinion of some of the members of the M.I.T. Track Advisory Group that models do serve as a tool in rate-making and ultimately in rate hearings. If a railroad or group of railroads were to find itself in a court case involving regulatory proceedings, using a model that was supported by the whole industry and represented the most current technology would be the best alternative. [3]

One of the forms of regulation which still exists is the mandatory trackage rights. The State of West Virginia passed a law in March of 1986 which embodied what some futurists predict is the inevitable configuration in American Railroads. The State Legislature attempted to force all rail companies in the state to allow third parties or consumers of rail service to operate trains over company tracks at a rate that would be set by the West Virginia Public Service Commission. [4] Although that law was struck down by the federal district court, a trend is emerging on some lines that might indicate a voluntary move by companies to market their right of way as a separate profit center. Such a move would have to be preceded by a company study to determine what the costs for each kind of traffic would be relative to the present traffic base and track quality. This creates a need for a TRACS type model.

The ICC has historically given trackage rights to rail companies as a solution for decreasing the monopoly power that often results in company mergers. With the creation of Amtrak in the U.S. and the subsequent purchase of the N.E. Corridor by Amtrak, a complete set of charges had to be agreed upon by the member railroads for trackage rights to Amtrak trains and for trackage rights to freight trains on the N.E. Corridor. The trackage rights insured continued freight service in parts of the northeast and passenger service in the rest of the continental U.S. A similar problem exists in

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3 Minutes of the M.I.T. Track Advisory Committee, November 1988.
4 Traffic World, "State Transportation News", July 28, 1986.(p.56)

Canada. The conservative politicians view the high costs of operating VIA passenger trains on the freight companies' tracks as a hidden subsidy to the private rail companies. The Canadian Transportation Commission, which is responsible for setting the prices, is very interested in analyzing the appropriate level of transfer price.

3.1.2 AAR Research

The Association of American Railroads was formed to serve the interest of its member companies. Some of its activities include government relations, setting industry standards, and acting as a clearing house for interline payments. The AAR also introduces highly scientific research into the industry environment. The Chicago Technical Center specializes in detailed engineering research. The Engineering/Economics division of the AAR Research and Test Department specializes in applying economic principles to engineering decision making. One of the problems faced by the rail managers is that the planning models that are produced by the AAR are very complex and can only be used by people who are experts in the field. The experts knowledgeable in each model are so specialized that it is not uncommon to find only one or two, the ones who developed the models.

The AAR also operates the Facility for Accelerated Service Testing (FAST track). This loop of track in the Colorado desert has been producing experimental data for many projects. It was felt by the AAR representatives on the Committee that some of the data could be combined with industry data to 1) help determine what the relevant inputs were to TRACS and 2) calibrate the deterioration relationships.

Finally the AAR's role as a forum to share information encourages the railroad companies to commit to a project as large as TRACS. The railroads depend on the AAR scientists to validate the models' outputs. The AAR provides the funding to the

project, which is in turn shared by each of the member roads through annual dues. In the dialogue at the committee meetings, the managers discuss their most recent work. The research benefits from having access to a cross section of data from different kinds of traffic and track combinations.

3.1.3 New Technologies

Better track materials, high productivity track machinery, and different maintenance techniques, such as rail lubrication, tie adzing, and no-tamping, have confused the track maintenance planners' jobs. These products have been introduced to the market, often without a lot of experimental evidence validating their performance. Models can be used to help assess the costs and benefits of these new technologies without investing in the technology. The decision to purchase the traditional or new technology is usually a major one because the new technology is priced at a premium above the standard technology. The models also have an advantage in that they can give immediate answers, while field tests of the technologies take years.

3.2 The Management Environment

The railroad management has been going through a period of transition. The common theme among the major companies is "Change". The railroads recognize that they must adapt to the higher demands placed on them by the customers. The attempt to offer better service renews the problem of conflicting goals that all transportation managers must reconcile. The conflict is to provide a high quality of service to the customer while maintaining low costs. [5] In the past, the second of the two goals was emphasized.

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5 Chi-Kuo Mao, "Integrating Technological and Organizational Perspectives - An Approach to Improve Rail Motive Power Management", M.I.T. Doctoral Dissertation, October, 1982.

Railroad managers were considered successful if they were able to keep costs down. Now the rail companies are building a new strategy of offering a quality service that is intended to rebuild their customer base. Because of a company's reorganization, management tasks are redefined, some jobs are eliminated due to automation, and new jobs are created to serve special needs.

3.2.1 Historical Structure

The railroad companies in the 1800's were among the first to separate the management of their system into a hierarchy. The control of the operations, pricing, and mainte-nance of the railroad was transferred to a set of general superintendents. The board of directors dealt with the strategic issues of expansion and competition. The new hierarchical structure required levels of authority and communication between the field managers and the centralized managers. In order to make the system work as a system, a constant flow of detailed, daily, weekly, and monthly reports had to be passed up through the hierarchy. Frequent inspections and critiques had to be performed on the lower levels of managers by the higher levels. [6] The flow of paper work in a bureau-cracy and the shuttling of problems from one manager to another has the potential for slowing the response time of the companies. On the other hand, automation and communications made great inroads into these problems.

It may be that the organizational structure is less at fault for the demise of the railroads in the 1970's than the managers who occupied each block of the chart. The three levels of control systems described by Mao result in an organization that is necessarily struc-tured in a hierarchy. The three major levels of that hierarchy are identified by Manheim et.al. as:

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6 Alfred D. Chandler, Jr., Strategy and Structure Chapters in the History of the Industrial Enterprise, The M.I.T. Press, Cambridge, MA, 1962.

a) Strategy formulation, which includes establishing general goals, monitoring progress toward achieving those goals, and taking action to achieve the goals.

b) Planning, which includes the transformation of the general goals into specific operational goals.

c) Implementation, which includes supervision of the daily activities of the system being controlled. [7]

Problems arise with the management structure when the historical military structure dictates either formally or informally that the lower levels in the hierarchy must only respond to specific commands from the upper levels. This attitude will squelch innovation and experimentation with new ideas. Assuming that each level of the hierarchy is encouraged to make decisions about *how* to best carry out their assigned tasks, the upper levels need only define *what* the tasks are. Manheim suggests that each decision process is made up of a series of sub-tasks. The specific sub-task that is of interest to this thesis is "Predictive Procedures". The sub-task is outlined as follows:

Prediction Procedures - how impacts of alternatives are predicted using formal and/or informal components including:

decision variables incorporated explicitly

impacts predicted explicitly

exogenous variables considered explicitly

-events external to the organization

-events internal to the organization
but external to the decision maker

formal theories embodied in prediction procedures

degrees of empirical verification in procedures [8]

TRACS aids the decision maker by structuring the alternatives in terms of the inputs to the model; structuring the formal scientific knowledge such as deterioration rates in terms of the simulation part of the system; including exogenous information such as

7 Marvin L. Manheim et.al., A General Planning Framework for Railroad Management, M.I.T. Rail Group Working Paper 88-2, Originally Published October 31, 1982, Abridged January 1988.(pp.5-6)

8 Ibid.

discount rates, tax rates, and maintenance policies; and presenting the results in a format that can be reviewed easily by different parties. The review process can be looked at as one facet of empirical verification. The TRACS model does not make decisions, it is a tool that aids decision makers.

3.2.2 Geographic Diffusion

Railroad companies, like all transportation companies, must operate their systems over a very large geographical area. There are manufacturing companies that are classified as "global multinational", but their operations are different from the transportation company's. The railroads must coordinate the activities in one part of the system with the plans of another. There are classic cases that illustrate the necessity to communicate between geographical locations.

A manager at the local level may be tempted to reserve empty cars in his yard, in order to have the ability to respond quickly to a customer's request for empty cars. Although that manager is doing what he thinks best from his perspective, there may very well be a customer in another part of the system which has already placed an order for a car. It is not uncommon that the best revenue comes from supplying cars to customers who happen to be in areas of the country with car shortages. Therefore, the manager who is reserving the empties is impeding the larger rail system from making a better profit.

The different parts of the rail network are connected by physical infrastructure. The connection between different manufacturing facilities is often non existent, if two plants are producing unrelated products. A railroad cannot effectively serve its customers if it does not maintain the links in the network. In addition, the operation should be planned so that the interchange of traffic gives the best possible service to the greatest number of customers possible. Sometimes this means sacrificing a little better

service for one part of the traffic, in order to accommodate the needs of other parts. The SPM model is used to demonstrate how perturbations in one part of the system can create problems in other parts.

Finally, the network of the railroad and its geographical spread are a dynamic system. In the Midwestern and Western parts of the U.S., there are companies who specialize in the harvesting of wheat. They too must service customers over a large geographical area, but their system is not very stochastic. Every spring the companies will harvest wheat in the South. As the season progresses, they move their machinery northward, harvesting the wheat as they go. By the end of the fall season, they are in Canada, planning for the following season when the process will start again. The railroads are often called upon to ship the grain from the Midwest to the seaports for export or to factories for processing. It is much more difficult to predict the demand for grain transportation than it is for grain harvesting. The sale of the grain depends on the yield in foreign countries, the political treaties, and the outlook for the next season. At times, railroads have been asked to ship a large amount of grain as quickly as possible, only to be followed by a period of several months without any grain shipment.

Railroads respond to the changing demand throughout their systems by moving the locomotives and cars to the areas with the greatest needs them the most. Manufacturing firms, on the other hand, do not have the luxury of transporting a plant or a warehouse from one location to another if there is suddenly a larger need for the facility elsewhere.

3.2.3 Strong Departmental Power

One of the problems that may be associated with regulation was the rigid rules that were developed for many of the functions within the rail companies. Decision-making in the various departments was constrained more by the government regulators than by the

needs of the company. The result was that the operating departments had a very strong influence on the railroads policies. They had some flexibility to change variables in the business plan that were not controlled by regulation. The engineering departments were relegated to the status of a support group that was responsible for keeping the track maintained. The operations department was impressed with good performance, which led to a corporate culture wherein the engineering managers tried to maintain the track at a very high standard, which was often in excess of the performance required.

In the 1970's the railroad managers began to cut costs as a means of maintaining their financial viability. Many of the engineering departments lost their excessive budgets. The absence of the engineering departments in the decision making process, led to deferred maintenance and tracks which were maintained at a standard that was often *less* than the performance required.

Interdepartmental task forces have been used and are still being formed to increase the communication between departments. The fact remains that each department is very specialized in its own area and often has specialized knowledge that is not easily understood by other departments. The communication process is hindered even when there is voluntary cooperation. A versatile planning model can act as a basis for discussion in such a situation by using terminology that is understood by everyone and by presenting the results in different formats, each tailored to fit the needs of a specific group.

3.2.4 Limited Resources

Even though many of the computer systems on the railroads have evolved to the point that they maintain large data bases of information, there is a limited number of people with the background to interpret the data that is available. This is due to a recent trend

of the rail companies. They are offering early retirement packages as part of a general downsizing of the managerial work force. Decision makers in the Engineering department often do not have access to financial data, are not trained in Economic Analysis, or do not have the time to assemble the information required to make an informed decision. As mentioned before, the AAR has a relatively small staff that is very specialized, but it cannot support the decisions at every company.

When the company is fortunate enough to have people who excel in their respective jobs, those employees are promoted to other positions. When they are promoted, one of two things happens. Either they continue to do their old job as well as the duties associated with the new position, or a less qualified person takes over the old job. Jim Eshelby voiced his frustration on the matter: "...any time I want to know something at the BN, there are ten people I call. Their titles keep changing, but they keep doing the same job!" [9] As part of the solution to the problem of limited resources, the BN is developing an expert system to aid in the scheduling of rail replacements. This system manipulates data bases, interprets the data, uses outputs from planning models, and produces recommendations. [10] TRACS can play a similar role. The INSTALL files can be developed by a few people who have a very specialized knowledge and then distributed to all users of the model in the form of a data base.

The future railroad managers, as envisioned by an expert in the field, will come from other modes, such as trucking, barge, or air freight companies. They will bring with them a desire to operate a much more automated business, depending on computer models to plan how the network should be operated and what level of service should be

9 Jim Eshelby, Interview at Kansas City, January 1988.

10 Carl D. Martland, et.al., "Scheduling Rail Replacement with the Assistance of an Expert System", Hermes Community Expert Systems Colloquium, Vienna, Austria, March 8, 1989.

offered. [11] If this is true, there is little possibility that the railroad management staffs will ever return to the size they once were. The future need for faster, informed decisions will be as great or greater than the present need.

3.3 The Hardware and Software Environment

The demand for versatile computer models was influenced by the introduction of user friendly software into the market place. Managers were exposed to packages that contained simple user interfaces and pleasant graphics.

In the next sections, other aspects of the computer technology environment that influenced the development of TRACS will be examined.

3.3.1 Existing Models Complement Each Other

At the time that TMCost2 was rejected as being user hostile, some railroad planning models were gaining popularity. The SPM family of models had just been released in its new format, the RECAP model was being demonstrated throughout the country to different kinds and different levels of railroad managers, and various profitability analyses were being performed. The operations plan, the service plan, the equipment plan, and the financial plan all had computer models that could be used as inputs to the analyses. A need for a comprehensive tool that analyzed the track and the other right of way components was apparent.

One of the reasons that the RPM has a large user base is that it fills a void in a manager's tool box.[12] In the same way, a track maintenance cost model was needed to fill a void.

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11 Bill Romig, "Railroads Over the Next 20 Years", Perspectives on Freight Transportation and Freight Service Beyond 2000, Unpublished Paper, Edited by R.K. Whitford, Spring 1989.

12 Al Reinschmidt, Interview April 17, 1989.

The RECAP model utilizes a matrix of results from TMCost, which is outdated. The SPM family of models requires inputs about track costs. The financial analysts were studying issues about transfer pricing and fully allocated costs. They needed a better handle on the right of way costs. The output from the TMCost package was not versatile enough to act as an input to the different needs of these models.

3.3.2 Large Data Sets

The mainframe computers that the railroads use contain very detailed records on some aspects of the railroad. The data associated with other activities has not been kept current, or does not exist at all. In terms of collecting the data that is needed as inputs to a planning model, the process can be quite time consuming. CSX, for example, was willing to contribute some calibration information to the M.I.T. Track Advisory Committee. The data base was able to quickly produce detailed information about every car that traveled over a territory. However, it took six months to get the data aggregated by wheel load.

The TRACS model had to be set up in such a way that if the real data for an input was available, it could be incorporated into the model. Otherwise, an alternative approach of estimating the input was needed. The best data bases do not have all of the information that is needed. The Burlington Northern, like most railroads, does not have the capability to discern which track of a double track mainline a particular train used. Some estimation will have to be made here.

3.4 Management Response to the TMCost Model: What are the Needs?

The preceding discussion is a general overview of the rail industry. The subjects discussed were chosen to demonstrate that the managers work in an environment which requires them to deal with a large bureaucratic organization. They must be able to communicate effectively with the other members of that organization. They must be able to make good decisions faster in order to compete in a deregulated environment. The managers have been given a greater number of duties since the trends toward reorganization, mergers, and downsizing. The software technology, large data capabilities, and available research create the possibility for building very complex computer models that will help solve some of the problems in the rail industry.

However, in the case of TMCost, the managers could not use the model to address many of the problems they had to confront in the corporate culture. The next part of the chapter looks at the specific reasons the M.I.T. Track Advisory Committee supported the restructuring of TMCost into TRACS.

3.4.1 Background on the TMCost Model

Before continuing with the discussion of Management Response to TMCost, it may be helpful to the reader to review the structure of that model, some of the problems associated with it, and the M.I.T. Railgroup's first effort at improving the model.

TRACS builds upon TMCost, an earlier set of models for estimating track maintenance costs. TMCost was originally assembled by the AAR's engineering economics group in 1979 in order to model high cube covered hopper cars. It was offered in 1981 as an alternative to the Speed Factor, Gross Ton Mile methodology of costing in regulatory

proceedings. [13] Almost from the outset it was apparent that the original TMCost needed to be upgraded if it was to be useful to the industry. Part of the problem was that the model was assembled quickly to be used by research staff in order to meet various regulatory deadlines. Although TMCost was subsequently used successfully for some analyses, it remained a cumbersome, data hungry, user hostile model. From a theoretical standpoint, TMCost also suffered from serious deficiencies because it was based upon research conducted prior to the mid-1970's. After that time, the problems associated with the introduction of the 100-ton car led to more than $10 million of research conducted at the Facility for Accelerated in Service Testing (FAST) and in rail research laboratories around the world. TMCost was not structured to take advantage of this research, and it dealt poorly with some issues, such as rail lubrication and grinding, that became critical to railroad engineering departments in the mid-1980's.

Since the committee members represent their respective companies, the decision was partially motivated by the people in their companies. In June of 1988 the TMCost effort had been progressing for six years without producing a high profile deliverable. Many of the committee members expressed a need for a model that could be demonstrated to high level management, as well as be used for some analyses. [14] It was supposed that a demonstration could be used to help maintain the funding level for track modeling. The next sections review the first half of the industry response to the idea of versatility. The committee's positive and negative comments regarding the success of TMCost2 and the TRACS proposal will be traced.

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13 Iowa Public Services vs. Burlington Northern Railroad, ICC Proceedings, Docket 37021 and Docket 37029.

14 Minutes of the M.I.T. Track Advisory Committee, June 7, 1988.

3.4.1.1 New Features of TMCost2

When M.I.T. began working with TMCost in 1986, the railroad personnel made it clear that there were many problems with the tool. Auzmendi grouped these problems into three areas:

1 - Built on Old Research
2 - User Hostile
3 - Complexity and Amount of Input Data [15]

An attempt was made in TMCost2 to address each of these areas. The PHOENIX and M.I.T. RAILWEAR model were added to the package. These models utilized the most recent research in rail, incorporated new technologies such as grinding and lubrication, and addressed different kinds of rail metallurgy.

The user hostility of the model was improved by dividing much of the technical information into files. Thus, it was intended that a user would only edit the files that contained the information which defined a new analysis. Example files were included with the model that represented generic situations that a railroad might encounter. A file called "HILLY AND CURVY" would represent a typical route with those characteristics. The matrix of Unit Costs that was included with the package were streamlined by eliminating many of the options. This was done so that the user would have an easier time choosing a cost file pointer. The costs of maintaining bolted rail was not considered. And, where the old TMCost used ten classes of traffic density, there were now four, more aggregate representations. The Track file was streamlined in a similar fashion.

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15 Alvaro Auzmendi, "Implementing a Model for Investigating the Economics of Railwear", M.I.T. MST Thesis, May 1989.(p.16)

The new wear model did eliminate many inputs as Auzmendi purports. [16] However, it also introduced many new inputs. These were needed to define the forces at the rail wheel interface, quantify the effectiveness of lubrication, and quantify the level of grinding.

On October 20, 1987, the AAR Affiliated Lab at M.I.T. distributed a prototype version of TMCost2 to the Track Maintenance Advisory Committee. The members of the committee were asked to experiment with the model, suggest changes to the structure, note what improvements were especially helpful, and contribute data for the purpose of calibration. In order to monitor the feedback from the railroad companies and observe the model in use, the M.I.T. staff visited several companies to discuss the above issues. These visits were part of a larger Beta Testing procedure which was supposed to identify problems with the model, improve its usefulness, and broaden its applications. One of the railroads was especially helpful since they had much experience with the old TMCost model. Below is a summary of some of the comments that were made during those meetings and later at the M.I.T. Track Advisory Committee meeting in the Spring of 1988.

3.4.1.1.1 Positive Remarks

Many of the positive comments received were related to the RAILWEAR formulation. For the purpose of this work, only those comments that were related to the increased versatility will be examined.

The simplified format of the track file was thought to be more useful to some of the users. The track file had been reduced to general kinds of track. A user needed to choose a track record based on the metallurgy of the rail and the level of maintenance.

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16 Ibid.(p.41)

Although the new format was easier to use, it had a limited number of combinations. One of the companies wanted to be able to model combinations of maintenance quality; for example, good ties, bad subgrade, and premium rail. The file did not contain those options. [17]

One of the improvements in TMCost2 that M.I.T. supported as being very important was the ability to model lubrication and grinding. The functional aspects of this addition met with unanimous support. However, only a few people supported the idea that a qualitative judgement of lubrication effectiveness could be accurately converted into a quantitative measure of the coefficients of friction. [18]

The idea of using generic route and traffic files was well received by some members of the task force. However, the functionality of editing the files that were included with the model was not acceptable. One person suggested that a base case file could be developed for each subdivision in detail. Then all of the alternative cases could be sketched out in terms of the percentages. A better estimate of predicted traffic distribution and proposed route geometry could be made by looking at the base case. [19]

Although TMCost2 did not meet with success in terms of many people using the model for real applications, it did make an impression in various industry circles. In March of 1988, the AREA Research Steering Committee gave the TMCost2 research an "A++" rating in its annual review of ongoing research. [20] By the June meeting of 1988, the M.I.T. Track Advisory Committee had 21 active members. This was a good indication to the research team that the work was moving in the right direction.

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17 Minutes from the Meeting with Kansas City Southern to Discuss TMCost 2, January 27, 1988.

18 For more information: Auzmendi, "Implementing a Model for Investigating the Economics of Rail Wear", M.I.T. MST Thesis, May 1988.(p.91)

19 Interview with Mike Roney by Carl Martland, September 9, 1987.

20 Interview with Herb Webb, AREA Technical Conference, March 1988.

3.4.1.1.2 Negative Remarks

Like the positive comments, many of the criticisms were not related to the model's versatility. Of particular importance is the fact that the tie and surfacing models that were included with the package had some programming errors in them. The other major criticism surrounded the matrix of SSC outputs that was used in the M.I.T. RAILWEAR model.

Much of the increased versatility in TMCost2 was introduced by using qualitative descriptions for various items. The development team found that the railroad people were willing to talk in terms of these descriptions but were not comfortable inputting them into a model. The managers feared that their perception of "bad" may be significantly different than that programmed into the model. One suggestion was to include photographs of actual track in the manual. Each photograph would match one definition of track modulus or track quality. [21]

As part of the attempt to make the model easier to use, example scenarios were presented in the TMCost2 User's Guide. These scenarios were written with a hypothetical story, thinking that a manager would be more at ease dealing with a problem in those terms rather than being stifled by a lot of computer jargon and scientific data. No positive comments were received about the examples. No one admitted to actually attempting to run one of the scenarios as was intended by the M.I.T. staff. One manager commented that he thought the tone of the examples was unprofessional and tiresome.

The operation of TMCost2 required that a series of files be edited using a text editor. These files would then be saved to a different name so the file template would not be destroyed. The CALFIL.INP was updated with all of the new file names using the same

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21 Ibid. KCS Meeting.

method. Typing the command TMCost at the DOS prompt simply ran a batch file that called all of the deterioration modules in order. The reports were saved to the same files each time. The M.I.T. research staff had developed a skill in manipulating the various TMCost2 files. It took approximately 10 minutes for one of them to set up and run an analysis. This was done during all of the demonstrations of the model. However, it was soon discovered that the railroad managers, who were supposed to be running TMCost2 and criticizing it, often did not have a proficiency in microcomputers. A knowledge of DOS and the ability to run a text editor was central to the operation of TMCost2. Many managers were not able to install and run the model. Those who could, felt that there were too many files to be edited, and they often forgot to change parameters in different files. There were no error checks in the model that would preclude a user from entering data into two or more files that were incompatible. There were some error checks built into RAILWEAR in the case that files were being called which did not exist, but only two managers ever got to that point in the program.

The reports generated by TMCost2 were found to be virtually useless. The cluttered reports were missing data labels, date of the analysis, and names of the input files. The railroad managers asked for reports that could be presented to senior level managers. [22] The reports did not show in which year future rail relays were to take place. The supporting data was very sparse as well. [23]

During the demonstrations of TMCost2, many comments were made regarding the excessive run time of PHOENIX. This comment is included in a discussion of versatility since several interviews revealed that middle and upper level managers are very pressed for time. [24]

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22 Ibid. KCS Meeting.

23 Interview with Gene Reinhart, March 1988.

24 Interview with Al Reinschmidt, April 1989.

3.4.1.2 Proposed Structure of TRACS

After the first release of TMCost2, the AAR asked M.I.T. to propose changes to the tie model that would eliminate the bugs and make the simulation more rigorous. In June of 1988 the research staff outlined a proposed structure of a tie model to the M.I.T. Track Advisory Committee. The structure included provisions for inputting the current condition of the ties, for modeling maintenance policies, and for calculating life cycle costs using a discount rate. In addition to the increased rigor in the formulations, a series of proposed features was presented that would make the tie model much easier to use than RAILWEAR. The ideas were well received by the committee members, but they decided that these formulations were needed in the rail model. The directive was given to M.I.T. to restructure TMCost2 using the proposed features for the tie model. [25]

3.4.1.2.1 Proposed Features of the New Tie Model

Many of the features that were suggested were designed to solve the same problems as TMCost2. The criticisms received from the TMCost2 beta testing exercise influenced the design of the various techniques. For example, the concept of file building programs was presented in response to suggestions regarding the excessive number of inputs required by TMCost. The inputs that were not directly entered by the user would be asserted by the program. Other features were designed to respond to the need to model different maintenance policies. Finally, the idea of a control program was introduced. This feature would guide the user through all of the necessary steps in setting up an analysis. The users would no longer have to have a knowledge of DOS, text editors, or microcomputers.

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25 Minutes of the Meeting of the M.I.T. Track Advisory Committee, June 1988.

Some of the proposed features were ideas initiated by the M.I.T. research staff. The industry criticism regarding the TMCost2 reports precipitated the idea of offering both engineering planning reports and financial reports. The staff realized that a lot of intermediate information was calculated in TMCost between the raw data inputs and the life cycle costs. The engineering reports would structure the intermediate data for users who were interested in project scheduling, materials acquisition, and labor requirements. Example reports were presented that displayed how the information could be presented at different levels of aggregation. A manager may need the ability to study specific segments or to look at an entire subdivision at once.

3.4.1.2.2 Perceived Advantages by the Industry

In general, the proposed user interface on both the inputs and outputs of the model was well received. The notion that a framework could be developed that would be easily adaptable to any deterioration model was also accepted. The AAR committee members advocated the idea of building the framework and the improved tie deterioration model at the same time. Then, at a later date, the RAILWEAR model would be updated to fit into the more versatile framework. However, the railroad representatives indicated that the framework would be very useful to them. The task of organizing the inputs and manipulating the outputs was given the highest priority. Some of the committee's reasons for wanting the rail model cast into a more useful structure before developing a tie model included:

1) The RAILWEAR model had two years of time and money invested into it

2) The model could be used for some analyses without the other deterioration models being in place

3) It would narrow the problem so it would be easier to handle from a development standpoint [26]

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26 Minutes of the M.I.T. Track Advisory Committee meeting, June 1988.

3.4.1.2.3 Perceived Disadvantages by the Industry

The presentation in June emphasized the fact that the proposed framework would be very versatile. Examples were given that demonstrated howthe model could be run by managers without computer expertise, managers without much time, and managers without an expert knowledge about every facet of the inputs. Up to this point, the development team had been working under the assumption that the model should be designed so a greater number of people would use it. The committee clarified that assumption. Some of the committee members cited some potential disadvantages related to a wide distribution of a flexible computer model. These included:

1) Low level managers misapplying the model
2) Viewing model results as "gospel" without developing rigorous inputs
3) Research initiatives into scientific models being delayed or stopped

The first criticism was based on the following hypothetical scenario. A low level manager or a road master might change a few of the more technical inputs without understanding the sensitivity of the model to those inputs. The reports would then indicate that a certain action should be taken, and the decision would be made based on model output that is incorrect. In the case that the analysis would have to be checked by a knowledgeable user, i.e. someone from the planning department, it might be difficult to locate the bad inputs among the thousands of potential candidates.

The second criticism involved the ability to enter different levels of detail. The managers felt that this feature might be abused in the following fashion. An analysis would be run using only a few inputs. The upper level managers would make important decisions based on the results of the model. The M.I.T. staff suggested that the people who were in charge of the model should emphasize that the low level analyses can be

used as a screening method to identify the best of many alternatives, but that important decisions should only be made after time and money are invested to further define some of the more detailed inputs.

Finally, the AAR representatives agreed that work on a tie deterioration module could be delayed until the Rail deterioration model was basically complete. Some of the railroad managers questioned if the RAILWEAR model was sufficiently calibrated for doing analyses. Dr. Roger Steele, Directory of Metallurgy, AAR, said that the calibration effort had sufficiently exploited all of the available wear data, and any further work would be pedantic until more wear data was collected. Furthermore, he noted that, in his expert opinion, any new wear data would simply verify the wear parameters that had been developed or have a marginal affect on them.

3.4.1.2.4 The Cost Model and Financial Reports

Recall that the M.I.T. staff had suggested additions to the model that included different financial reports. The financial reports were designed to present the results in formats that were consistent with either the economic analysts' or accountants' perspectives. These ideas were fostered by a paper entitled "Life-Cycle Costing for Railroad Rights-of-Way" by Carl Martland. This paper had been sent to all of the members of the M.I.T. Track Advisory Committee for review prior to the June meeting. As an aside, most of the members representing railroads on the committee were from the engineering departments. The work of the committee up to this point had dealt with the deterioration models. Some of these members were intrigued by the paper but did not feel qualified to comment on the proposed financial reports. Therefore, they concluded that the M.I.T. Track Advisory Committee should be expanded to include people from the railroads with expertise in economics and finance.

In his paper, Martland defended the use of life-cycle costing. He pointed out the impact of a discount rate, a planning horizon, and the current condition of the track structure. The fact that the current track will most likely be partially deteriorated, means that the life cycle of any new track components will not begin until some point in the future when the current track is replaced. [27] The committee did confirm that the next version of the cost model should contain provisions for a discount rate and a planning horizon. In addition, it wanted the RAILWEAR model to be upgraded to include the current condition of the rail. With these improvements to the deterioration model, the structure would be in place to do all of the types of analyses demonstrated in Martland's paper within the framework of TMCost.

3.4.1.3 Interpreting the Criticism

The support and criticisms that were received from the M.I.T. Track Advisory Committee were a valuable source of information. The feedback gave the development team a first-hand indication of the needs and wants of the railroad managers. Most of the time the comments pertained to very specific formulations in the model, incorrect terminology, or suggestions for other reports. Sometimes, however, the criticisms were more broad. The comment may have been initiated by a visible aspect of the program, but the improvement needed to be made at a more fundamental level in the approach. Sometimes the comments were interpreted and the large pieces of the model were redesigned. This resulted in a new iteration of the package that not only addressed the manager's one criticism but also extended one of the dimensions of versatility.

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27 Carl D. Martland, "Life-Cycle Costing for Railroad Rights-of-Way", Center for Transportation Studies, M.I.T., Dec. 10, 1987, Unpublished Paper.

An example of the latter kind of comment and response follows. Throughout the TMCost overhaul, the managers and the AAR scientists impressed upon M.I.T. the need for track models that included the ability to deal with the current technology. With new technologies being utilized and introduced into the market base on a continuing basis, M.I.T. aimed not only to make the design deal with the current technologies but also to preclude the same criticism in the future by making the design easy to update. One of the aspects of the TRACS design is that it is a framework that can organize the inputs and manipulate the outputs of many different deterioration models. The TRACS framework acts as a foundation for the development of new deterioration models and the improvement of old ones. However, each deterioration model is independent of the others. The incorporation of a tie model may increase the validity of the rail module, but the rail module is not dependent on the output of a tie module to run. This structure was developed in response to a collection of comments and was suggested by the M.I.T. staff rather than the committee.

In the last chapter, the discussion of management response to TRACS will conclude by giving a summary of the feedback received after the release of Version 1.1. of TRACS.

3.4.2 The Benefits and Costs of Versatile Computer Models

As stated before, the primary motivation for restructuring TMCost was a desired increase in the number of users. Increasing the number of users of a computer model is not an end in itself. Rather, from the perspective of the AAR, the benefits derived from a model that has a large number of users are very important. Examples include future money to support the model and money to perform related research. The AAR was formed to serve its member roads. The maximum benefits of a model are not realized by the individual railroad companies until a model is used within each organization.

Although the benefits of versatile models are often difficult to quantify, it is understood that benefits do exist. The costs of adding versatility to an existing models are relatively low compared to other development costs. For example, the cost of collecting data for calibrating the deterioration models requires personnel to travel to field sites around the country on a periodic basis. Two measures of costs in software design and development can be used: programmer days or time elapsed.

In the next section, examples of potential benefits of versatile computer models are discussed. Following that is an estimation of the costs of adding versatility to TMCost in terms of programmer days and time elapsed.

3.4.2.1 Benefits to the Railroad Companies

Each railroad company will see tangible and intangible benefits from the increased use of computer planning models.

Examples of material cost savings include:

> 1) The elimination of duplicate development and maintenance costs for a group of similar models
> 2) The elimination of costs for the preparation of data used as inputs

The potential value in restructuring any tool to make it more useful to a larger group of managers would have to be assessed on a case by case basis, but the sort of savings mentioned above would be a starting point for trying to quantify the benefits of more versatile models.

There are secondary benefits that may very well have more long term cost savings. Following is a list of some of the less palpable benefits gained by a company if a model would be used more frequently:

> 1) Increased use of analysis at all levels of the decision making process, resulting in better decisions

87

2) Standardized tool for all departments which gives a consistent frame of comparison

3) Greater flow of information for model calibration

4) Identification of weak points in the model

3.4.2.2 The Cost of Versatility

Millions of dollars have been spent on track research. The TMCost model and now TRACS are frameworks that can be used to organize some of the results of that research into a form that is useful to managers in the rail industry. The M.I.T. Railgroup's past successes in creating models that disseminated information about railroad operations and service levels were cited by Dr. Hargrove at the first meeting of the M.I.T. Track Advisory Committee as one of the reasons for its selection to build this framework. As shown below, the initial cost of building the TMCost model and implementing it at a level that was useful by analysts is very small, compared to the millions of dollars mentioned above. Furthermore, if the cost of adding versatility is only an additional 20% of the model's cost, as demonstrated below, then the cost of transforming a model so that it will be used by managers is far from exorbitant and certainly not prohibitive.

The purpose of this Chapter is to identify why the M.I.T. Track Advisory Committee supported the TRACS design. The discussion about the different management environments seeks to reveal some of the basic causes that create a void in a manager's tool box. The benefits and costs of versatility are analyzed in order to demonstrate that the decision was not a large fiscal commitment. The committee members made the commitment, based only on the development team's estimate of that cost.

Using TMCost as the base case model, the time spent in adding versatility for TMCost2 was the equivalent of one month of a programmer's time and one half a month of a staff member's time. That included the addition of a file editor, the creation of a control

program that tied all of the modules together, and the development of example files that could be used as approximations in an analysis. The remaining time was spent implementing the M.I.T. RAILWEAR model.

The directive to design and develop a more versatile version of RAILWEAR was approved by the M.I.T. Track Advisory Committee in March of 1988. TRACS Version 1.0 was a test version of the model that was released to a limited number of people in November 1988. During that seven months, RAILWEAR was restructured to include current conditions, traffic predictions, a planning horizon, and maintenance policy variables. Those changes should be thought of as improving the formulation of RAILWEAR, not adding versatility. The work done during that period which improved the versatility included:

    20 Reports
    11 File Editors
    2 File Input Modules: Traffic, Route/Track
    1 Control Program

Those features were designed and implemented with 4 months of staff time and 10 months of programmer time.

After the release of Version 1.0, work continued to improve the versatility of TRACS. Version 1.1 was released to the industry in March 1989. During that time period approximately 8 months of programmer time was invested on the versatility aspects of the project. The staff time was spent preparing documentation and manuals for the programs. The additional features that were included in that release were as follows:

    10 Reports
    3 File Editors
    1 File Input Module: Cost
    Over 100 Activity Menus
    Over 100 Help Screens

1 Control Program - Including a Protected Install Feature

The following Exhibit summarizes both the elapsed time in calendar years before various parts of the models were made available and the time spent programming the features. The unit of "equivalent programmer weeks" is used because at times there were multiple programmers working congruently. One of the important things to note from this chart is that the process of designing, implementing, upgrading, and calibrating a planning model is not especially programmer intensive. The differences that exist between the time elapsed, and the programming effort is accounted for by work in other areas. Such work included literature studies, collecting field data, running sample cases of the model, meeting with experts, and documenting the work. Adding versatility, however, is largely a programming effort. In terms of the cost of adding versatility, the potential users had already waited over six years for the model to become a reality. The time required to make the model more useful was minimal, especially when one considers the fact that it was being done parallel with the upgrading of the deterioration models. The conclusion is that versatility is not a relatively expensive part of the model, that it requires programming experts, not technical or management experts, and that it can be implemented at the same time other work is being done on the model.

**Cost of Versatility in TMCost2 and TRACS Tasks
with the Cost of Other Tasks**

Exhibit 3 - 1

Task	Time Elapsed	Equivalent Programmer Weeks
Collecting Models Together for Initial TMCost	1 month	1 week
Improving Tie and Ballast Models for TMCost2 .	1 years	no data
Designing RAILWEAR	1 year	2 weeks
Implementing RAILWEAR	1 year	12 weeks
Adding Phoenix and RAILWEAR to TMCost2	1/2 year	2 weeks
Preliminary Calibration of RAILWEAR	1 year	4 weeks
Building the SSC Input Matrix	1/2 year	4 weeks
Automated Calibration of RAILWEAR	1 year	6 weeks
Improving RAILWEAR with Current Conditions, Planning Horizon	1/2 year	6 weeks
Adding Versatility to TMCost2 - TRACS Design & Implementation	2 years	72 weeks

3.4.3 Summary of the Management Needs

The M.I.T. Rail Group has been responding to management needs since its start in the 1970's. The Service Planning Model was the first complex simulation model that encompassed the modeling of railroad practices and railroad costs, and presented reports that were designed to serve specific management needs. The first SPM was identified as a very useful tool in two case studies conducted with the Boston and Maine and the Santa Fe railroads. However, it lacked a comprehensive set of reports and the ability to transfer the model easily, and it had a data input process that was very abstract. In 1981, the Railgroup restructured the SPM to make it more useful. It

increased the number of disk based files and split the program into different modules. [28]

As part of that effort, many of the inputs were changed to include the names of the nodes, reports were added and improved, and the transferability was improved using a microcomputer environment. The restructuring resulted in successful applications of the model on most of the major U.S. railroads, continuing through to the present. [29] As discussed above, when the M.I.T. Railgroup used the same methods to improve TMCost, the result was not considered useful. TMCost2 went an additional step by including sample files that could be used as templates in setting up an analysis; the managers were bewildered by the large number of files and the computer operating system. Auzmendi's last attempt before leaving M.I.T. at making TMCost2 a more useful product was the implementation of a full screen file editor. [30] The managers still resisted the model due to the amount of effort required.

At this point, the responses to TMCost, TMCost2, and the proposal to develop TRACS have been discussed. The committee supported the next step in the evolution of a versatile planning model by directing M.I.T. to launch an effort to design and implement programs that would create files. The evolution may not stop here. One AAR expert predicted that TRACS in its current form would be a short lived product. He indicated that railroad managers are already hankering to have a system that runs all of the important planning models in one context, surrounded by an expert system. [31] However, like Van Dyke with the SPM, the TRACS development team strongly supports the theory that the programs must be developed iteratively. The adage, "You have to walk before you can run", applies to software design and implementation as

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28 Carl Van Dyke, "Microcomputers and the Service Planning Model: Designing a More Useful Tool for the Rail Industry", M.I.T. Master's Thesis, June 1981.

29 Interview with Carl Van Dyke, April 1989.

30 Alvaro Auzmendi, "Implementing a Model for Investigating the Economics of Rail-wear", M.I.T. MST Thesis, 1988.(p.47)

31 Interview with Al Reinschmidt, April 1988.

well. In the next Chapter, an overview of the TRACS model will be discussed at length. If the reader is already familiar with the model, he may want to simply scan the information that is found there.

4 The TMCost Evolution: Overview of the Structure of TRACS

The Total Right of Way Analysis and Costing System (TRACS) estimates the life cycle costs of installing and maintaining track components. The basic structure of the model is given in Exhibit 4 - 1. The Install Module allows the user to edit the defaults that represent a company's management policies and existing track conditions. Once the Install Module has been run, the first step in most analyses will be to build or choose a collection of input files that represent the traffic, track, and cost combination that is being analyzed. Next, engineering models for the major track components are used to calculate rates of deterioration, which are translated into expected lives for rail and ties and expected surfacing cycles for ballast. Based on a company's maintenance policy and unit costs for replacement and maintenance, the model then produces a series of reports that give resource requirements and a variety of costs. The analysis is done for each segment in a subdivision, then summarized for the complete subdivision.

MODULAR STRUCTURE OF TRACS

```
┌──────────────┐                ┌──────────────┐
│   INSTALL    │ ──────────────▶│   TRAFFIC    │
│    MODULE    │                │    INPUT     │
│              │                │    MODULE    │
└──────────────┘                └──────────────┘
                                        │
                                        │
                                        ▼
                                ┌──────────────┐
                                │ ROUTE/TRACK  │
                                │    INPUT     │
                                │    MODULE    │
                                └──────────────┘
                                        │
                                        │
                                        ▼
                                ┌──────────────┐
                                │     COST     │
                                │    INPUT     │
                                │    MODULE    │
                                └──────────────┘
                                        │
                                        │
                                        ▼
┌──────────────┐                ┌──────────────┐
│   REPORTS    │ ◀──────────────│DETERIORATION │
│    MODULE    │                │    MODELS     │
│              │                │    MODULE     │
└──────────────┘                └──────────────┘
```
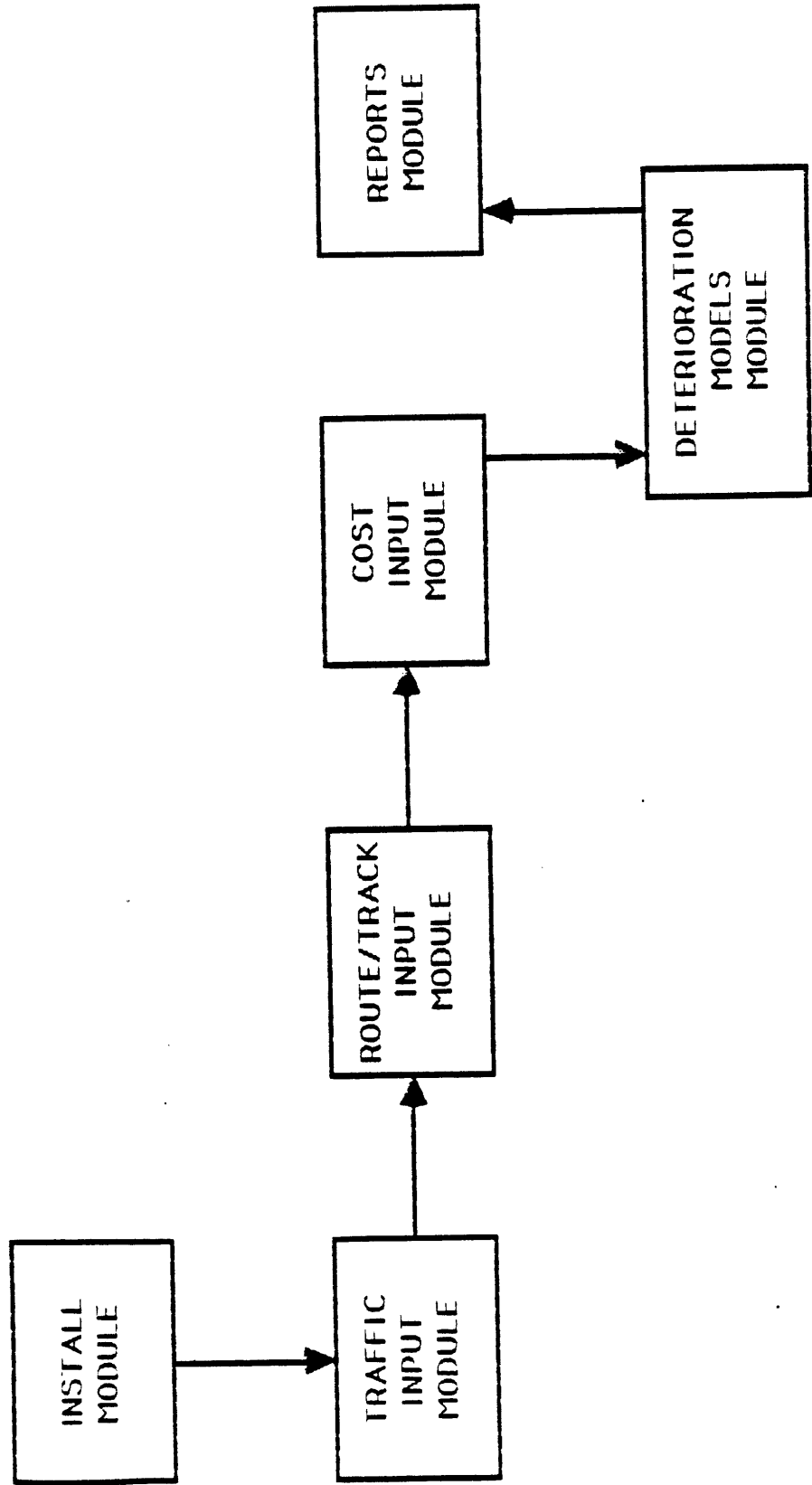
During the design stages for TRACS, the development team set up self imposed ground rules that would guide the course the new package would take. For example:

a) No input values would be blank; the user would always be given a number or an entry to edit, which could be accepted.

b) Whenever possible, the technical data, which should not be edited more than several times a year, would be separated from the actual analysis inputs in order to decrease user effort.

c) The architecture of the software files and programs would not dictate in what order or in what format the user would input the data. Rather, the input modules would be designed separately based on comments from the TMCost2 experience, this author's own experience, and the sensitivity of the various deterioration models to certain parameters. The program would take care of the bookkeeping by assigning all of the inputs to the proper file in the proper format.

d) Rather than trying to standardize the various terminologies and policies that sometimes exist between companies, TRACS would have enough flexibility to allow a user to choose the approach with which they felt most comfortable. The program would have the capability of inferring an actual, reasonable set of numeric inputs based on the lesser number of inputs.

e) The user would be able to input information in terms of qualitative assessments and/or in terms of typical values for a subdivision or region, as opposed to entering every value on a case-by-case, segment by segment basis. Here again the program would use these values to create the "fleshed out" version of the input files.

f) The greater the number of reports that could be offered to the users, the better the package.

g) The package should be given a structure that could be expanded. Updates of the package could be released to the industry on a periodic basis. Each new version would be a tool that could be used in a real analysis. [1]

These rules clarified goals for the new TMCost package and clearly organized the design process.

The idea of releasing unfinished versions of the model that could be used by the industry was not a new concept in the area of track maintenance modelling. The US Army Corps of Engineers produced a simple version of a sophisticated track maintenance planning tool

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[1] Minutes of a Series of Meetings of the the TMCost Programming Staff, April and May, 1988.

while the more sophisticated software was under development. In addition to its timeliness, the simpler model was to serve a long term function as a tool which was useful to personnel not familiar with track maintenance. The model would most likely fall in the Simple-Simple category of the last chapter. The Army press release put it this way:

> A track inspection and evaluation system that is tied to rail maintenance standards and can be used by inexperienced personnel is essential. USA-CERL is developing the RAMSEY system to meet that requirement. RAMSEY will lack the sophistication planned for RRM2S because of time constraints, but will meet FORSCOM's basic requirement to provide a quick determination of whether existing track meets or does not meet established standards. RAMSEY will be a simplified system with a yes/no type decision process that is designed to indicate which track sections are currently satisfactory and which require immediate rehabilitation work.
>
> Until RRM2S can be complete, RAMSEY will serve as a quick and simple substitute. The knowledge gained in the development of this simplified system will also serve to enhance the development of the more extensive and sophisticated RRM2S system. [2]

The model that resulted from the effort described above is known as RAILER. It does have the ability to work at two different levels of detail, a simple and a more complex. The model does not simulate deterioration rates but relies on expert knowledge about the life remaining in a track component based on its current condition and other inputs. The ability to model different policies does not exist in RAILER. The U.S. Army regulations specify a single set of policies which is are hardwired into the model. [3] Although the formulations in the model are fundamentally different from TRACS, the attempt to use the same model for different kinds of users in different applications, and the release of an unfinished version of the model parallels some of the goals of the TRACS development team.

2 U.S. Army Corps of Engineers, Construction Engineering Research Laboratory, Public Affairs Office, FACT SHEET, "Development of a Simplified Railroad Track Inspection and Evaluation System (RAMSEY) for Field Use", Published Champaign, IL, July 1985.

3 D.R. Uzarski, D.E. Plotkin, and D.G. Brown, "Maintenance Management of U.S. Army Railroad Networks The RAILER System: RAILER I Description and Use", Draft Report, 1988.

At the beginning, many of the boxes in the TRACS flow charts were connected by arrows that represented rather vague ideas. How the programs were going to accomplish the magic required by points (c), (d), and (e) above was rather nebulous. The solution consisted of developing an expert system-like approach that would be built around data bases that contained typical values for each railroad, conversion matrices for qualitative to quantitative values, and separating the programs that developed the input files from the programs that actually used the input files. Although TRACS probably is not an "expert system" in the purest sense of the phrase; i.e., it does not use a traditional expert system programming language, it does not do backward and forward chaining, and it simulates its results rather than deducing them; TRACS does logically manipulate data in a structured context. The set of methodologies used in TRACS has been dubbed "knowledge engineering" by the TRACS development team. This is consistent with Sriram's definition from his work. [4] Chapter 5 will discuss the methodologies in the knowledge engineering approach.

4.1 Data Files in TRACS

Some of the files in TRACS were designed as a result of the new framework. Many of the data files in TRACS were adapted from the TMCost file structures. Since TRACS only had one deterioration model, RAILWEAR, and the intention of the committee is to upgrade each of the deterioration models before including them in TRACS, the files were given a new format. The new format for the files eliminated commas between every entry, which were needed for the FORTRAN programs in TMCost. The new formats also allowed room at the top of each file for data labels and column headings. In most cases, the TMCost files were expanded to include more pointers, or information

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4 D. Sriram, editor, <u>Computer-Aided Engineering: The Knowledge Frontier</u>, Intelligen-tEngineering Systems Laboratory, Department of Civil Engineering, M.I.T., Unpublished Text, Draft Copy, Cambridge, MA, 1988.

for the knowledge engineering process. A user can change the selection of input files, edit file contents, and expand or combine files. In the following discussions of the important TRACS files, the TMCost approach will be reviewed, the current TRACS implementation will be highlighted, and each discussion will conclude by noting potential improvements.

4.1.1 Output from Other Models

The M.I.T. RAILWEAR model uses a matrix of forces at the rail - wheel interface as an input. The current matrix was produced by the AAR Steady State Curving Model. [5] Because the matrix is stored in a file, a user can easily increase the precision of the model by expanding the matrix to include more sample cars. Some analyses may use an expert in vehicle dynamics to predict how the forces will be affected in an alternative strategy. The RAILWEAR model will then transform the sensitivity of the forces to a sensitivity on the wear rates.

TMCost: In RAILWEAR the matrix of forces is an input to the calculation of wear rates. This structure is a compromise between two extreme approaches. In the RMCM, the rail wear model from TMCost, the forces were calculated by the model. Including the model for forces required many more inputs and a longer run time. In RECAP, the program uses a matrix of outputs from TMCost to determine incremental track maintenance costs for a particular train. This matrix contains the final answer to the question, not an intermediate parameter. Therefore, the matrix is much larger. Updating the costs in the matrix is very time-consuming, since there are over 10,000 combinations of route, track, and traffic that need to be input. Calibrating the cost matrix for a particular company is also an equivalent effort.

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5 Carl D. Martland, et.al., "User's Guide to TMCost2", October 1987.

TRACS: The TRACS package is not dependent on deterioration models being structured in this way. The package will call any deterioration model. The system does require that the model use inputs that are in the TRACS data files and structure the outputs in a given format.

The matrix of outputs from the complex engineering models is an item in TRACS that should only be dealt with on an expert level. These models are not available to the railroads of the AAR. It is the AAR policy that only AAR Personnel run the models. The M.I.T. staff is also allowed to run the models under a special agreement wherein AAR personnel must review the output of the models and any conclusions that were drawn from a study before the study is published. In reality, the matrices of outputs should not be considered a part of TRACS, but rather parts of the deterioration modules contained in TRACS. Therefore, TRACS does not give a user access to the complex engineering models' outputs. They must be edited using a text editor.

Potential Improvements: Recognizing that there are advantages to this approach, the RAILWEAR case can be used to develop a general methodology that could be applied in other deterioration models. Outputs from the physical model are stored in a matrix, so the actual model does not need to be run during the simulation. The dimensions of the matrix and the variables that are used to select the output for a given scenario are chosen from the inputs to the complex model. Not every input to the physical model is a dimension of the output matrix. Rather, the variables to which the output of the model is most sensitive and important non-linear variables are used. If there are other inputs that vary linearly with the result or can be approximated by a linear relationship, then a series of multipliers is applied after the output is selected from the matrix. The value of the coefficients is stored in another file, called the Other Factors File.

If the proposed design of the TRACS Rail Fatigue Module is implemented, it will be the second M.I.T. track deterioration model that uses the above approach. This module will have two data files that contain outputs from the AAR PHOENIX model. The matrix will contain parameters or fatigue rates for generic situations. Another file will contain multipliers that will adjust the output from the matrix for other factors. The sensitivity of the output to the other factors can be derived by running the PHOENIX model. [6]

The output from the physical models is not sufficient for predicting deterioration rates. The fundamental forces, or parameters, must be interpreted and converted to wear rates. The file that contains the information for that process is outlined in the next section.

4.1.2 Calibration Parameters for the Deterioration Models

Each component deterioration model will have a corresponding file that contains the calibration parameters for that model. These parameters will be calculated one of three ways: 1) by aggregating actual field data and combining the information using a statistical technique like regression, 2) from laboratory tests, or 3) from expert opinion.

Each set of outputs from the physical models discussed in the last section, will have a set of calibration parameters associated with it. RAILWEAR has recently been cali-brated to a set of outputs from the SSC that modeled used wheel and used rail profiles. [7]

6 Minutes of the M.I.T. Track Advisory Sub-Committee on Rail Fatigue, February 1989.

7 Michael P. McGovern, "Using Railroad Curving Models to Produce Parameters for Modeling Rail Wear", Department of Mechanical Engineering, M.I.T., Bachelor Thesis, May 1989.

Ongoing research at the AAR and other organizations will produce more field data that reflects the impact of better management techniques and new materials. When these are made available, it is much easier to update a few calibration parameters than it is to update all of the contents of a matrix.

4.1.2.1 Field vs. Laboratory Data

There were two attempts at calibrating the RAILWEAR model based only on field data. Both attempts used a data set that was compiled by Roger Steel from experiments that were carried out in the past. The first attempt approximated the traffic using an average wheel load and ignored the low rail sites. [8] The calibration parameters were distributed to the members of the M.I.T. Track Advisory Committee in June 1988. Dr. Steel noted at that time that it would be better, given the limited data set, to aggregate the seven different kinds of metallurgies into three general categories. An updated set of calibration parameters was released to the committee in the Fall of 1988. [9] The second calibration attempt included the low rail sites from the data set and approximated a wheel load spectrum rather than using the average wheel load. The results from this calibration were released to the committee in March, 1989.

The fact that the calibration parameters were in a file allowed the updated results to be easily distributed each time. The effort required by a user was simply to copy the new file over the old one, and the most current version of the model was on his computer.

Calibrating the deterioration relationships is a challenging task. Originally, the M.I.T. RAILWEAR model was to be calibrated using a combined data set from the field and

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8 Larry A. Shughart, "Preliminary Calibration of the Railwear Model", Memo to TMCost2 Project Staff, May 1988.

9 Minutes of the Meeting of the M.I.T. Track Advisory Group, October 1988.

from laboratory tests. [10] However, some tribological tests produced results that showed wear rates as a function of pressure. [11] These results were converted to the same units as the M.I.T. RAILWEAR model and were used to verify trends. [12] The laboratory tests could also be used to approximate calibration parameters for situations that are not well represented by the field data. For example, the data set that was used to calibrate RAILWEAR did not contain any metallurgies that were of the "Super Premium" variety. A laboratory test could be used to show that in the laboratory Super Premium steels performed better than Premium steels. In the calibration file, a user could input calibration parameters for Super Premium that were the same percentage increase over the Premium rail field sites.

4.1.2.2 Automated RAILWEAR Calibration

Because the calibration task was very labor intensive, an automated RAILWEAR Calibration routine was developed. This program determined the best statistical calibration parameters based on a set of wear measurements. The output was then printed to a file that had the same format as the TRACS metallurgy calibration file. [13] The time required to develop a set of calibration parameters was reduced from one week to about 20 minutes. As stated before, the data set that was used for the RAILWEAR calibration exercise was collected for other purposes, thus it did not have all of the information that was needed to run the Calibration Program. The missing data was approximated by the M.I.T. staff. The quick turn-around time allowed several alternative calibration files to

10 Carl Martland, "Preliminary Results of the New Rail Wear Model", M.I.T., Unpublished Paper, Cambridge, MA, February, 1987.

11 P.J. Bolton and P. Clayton, "Rolling/Sliding Wear Damage in Rail and Tyre Steels", Wear, Vol. 93, Elsevier Seguoia S.A., Lausane, Netherlands, 1984.

12 Carl D. Martland, Letter to Roger Steele, May 9, 1988.

13 Larry A. Shughart, "Calibrating RAILWEAR: Explanation of a Pair of Programs", Unpublished Paper, M.I.T., Cambridge, MA, January, 1989.

be produced. The differences in the calibration files resulted from making different assumptions about the data missing from the data set. For example, the traffic mix was reconstructed from expert opinions. These were then reviewed by experts who identified the most realistic file.

4.1.3 TRACS Management Policy Files

TMCost: The TMCost model did not have the structure necessary to model an actual situation. The program did not have inputs for current condition, and considered replacement as the only alternative for a deteriorated component.

TRACS: As discussed in the last chapter, the second version of the M.I.T. RAIL-WEAR model addresses this problem. This simulation starts with the actual track materials, the current condition of each component, and the current traffic. As the model simulates the track deteriorating through time, the component condition is updated to reflect the cumulative deterioration. When the condition reaches a physical condemning limit, the program resets the current condition to "New" and starts the deterioration process again.

The type of component that is used in a rehabilitation is determined by rules that are usually set by the regional or system level policy makers. Ideally, the components selected will be the ones which minimize the life cycle costs of the track. There are several reasons that bring about a situation wherein the replacement component is of a different material, a different brand name, or a different design than the condemned component that is being removed from the track. Among them are the following:

Changing traffic patterns
New technologies in maintenance or materials
Change in management due to a merger
Change in financial status of the company; i.e., low capital, changes in the tax code.

In order to realistically simulate this process in TRACS, the rules that dictate the management policy had to be included in the program. This was done by developing a new file. An example Rail Management Policy File is shown in Exhibit 4 - 2. In each year of the simulation, the updated current condition is compared to the wear and fatigue limits that are found in this file. If the condition falls within any of the limits, then the prescribed activity is carried out. If the rail is to be replaced, the file is checked to see what kind of rail should be used in the replacement, based on the track geometry and the level of traffic.

Example Rail Management Policy File

Exhibit 4 - 2

Insert Exhibit 4 - 2 an example Rail Maintenance Policy file here

```
TRANSP    HIGH MGT                     MED MGT                      LOW MGT
          min gf  max gf  max hh  min gf  max gf  max hh  min gf  max gf  max hh
CURVE     ------- ------- ------- ------- ------- ------- ------- ------- -------
           9.000   0.000   0.000   0.360   0.470   0.570   0.370   0.480   0.580
           9.000   0.000   0.000   0.370   0.480   0.580   0.380   0.490   0.590
           9.000   0.000   0.000   0.380   0.490   0.590   0.390   0.500   0.600

HILO      HIGH MGT                     MED MGT                      LOW MGT
          min gf  min hh  max hh  min gf  min hh  max hh  min gf  min hh  max hh
CURVE     ------- ------- ------- ------- ------- ------- ------- ------- -------
           9.000   9.000   0.000   0.460   0.410   0.570   0.470   0.420   0.590
           9.000   9.000   0.000   0.470   0.420   0.580   0.480   0.430   0.600
           9.000   9.000   0.000   0.460   0.430   0.590   0.490   0.440   0.610

RELAY     HIGH MGT             MED MGT             LOW MGT
          max gf  max hh  max gf  max hh  max gf  max hh
CURVE     ------- ------- ------- ------- ------- -------
           0.610   0.700   0.615   0.710   0.625   0.750
           0.610   0.700   0.615   0.710   0.625   0.750
           0.610   0.700   0.615   0.710   0.625   0.750

          plates   spikes  anchors m/dhigh  m/dmed  m/dlow  weight
TRANSP.    90.00    50.00    95.00     1.0     1.0     3.0    40.0
HIGH-LOW   80.00    25.00    95.00     1.0     1.0     2.0    50.0
RELAY      50.00     0.00    50.00     1.0     1.0     1.0    30.0
DEFECT     95.00    20.00   100.00     5.0     7.0    10.0    12.0
TURNOUT REPLACEMENT
TURNOUT MAINTENANCE

LBS LUB   excell      good      poor   APPLI   excell      good      poor
HIGH       50  55   60  55   50  45             38  33   15  14   10   9
MEDIUM     45  50   55  50   45  40             33  28   12  11    9   8
LOW        40  45   50  45   40  35             28  23    7   6    4   3
BRANCH     35  40   45  40   35  30             23  18    2   1    1   1   25  20

GRINDING PRE MED COR
HIGH      2.0 1.0 1.0
MED       3.0 2.0 2.0
LOW/BR    4.0 3.0 2.0

                                 OTM PLATES     SPIKES        ANCHORS
RAIL    tangent    low    medium high <132 >132 TA LO ME HI  FLAT GENT STEE
HIGH      1  2    2  3    2  3   3  3   8    4   2  2  4  4   2 2  2 3  4 4
MEDIUM    1  2    2  2    2  3   3  3   8    4   2  2  4  4   2 2  2 3  4 4
LOW       1  2    2  2    2  2   2  3   8    4   2  2  4  4   2 2  2 2  4 3
BRANCH    1  2    1  2    2  2   2  3   8    4   2  2  4  4   2 2  2 2  4 3
```

Potential Improvements: The rules for tie and surfacing management, as well as other right of way components, have not yet been structured in a file. One alternative would be to put each component's policies into a separate file. A user could then model a situation that has high maintenance standards for rail and low maintenance standards for ties. The potential ability to combine different maintenance policies is another example of the flexibility offered by the TRACS framework.

4.1.3.1 Defining Engineering Practices in a File

TMCost: The old TMCost model only simulated a rail replacement. The model was not able to account for activities that extended the life of the rail. Furthermore, the condemning limits for the rail had to be specified for each general type of track. A user specified limits for each combination of track type, which numbered over 300.

TRACS: In the time simulation of the TRACS model, the program simulates different activities based on the limits found in the Management Policy File. The limits are found in look-up tables that are contained in the management policy file. The dimensions of each look up table are aggregated into categories. A user now defines the limits for all sites with "Medium Curvature and Low Annual MGT". In contrast to TMCost, a TRACS user must specify limits for at most 27 general cases, including rail transposition and rail high-low.

Simulating a rail relay is straightforward. At the end of each simulated year the current conditions are compared to the limits in the look up-table. If the current conditions exceed the limits found in the look-up table, the rail is "replaced" with the type specified in the Material Selection Look-up Table for rail. That table is also found in the Management Policy File. The rail materials selection table is divided into 16 general cases, defined by four types of curvature and four levels of traffic. A user specifies the weight and the metallurgy of the rail separately.

Transposition of rail occurs on curves. The gage face of the rail wears out faster than the head loss. Since the rail is symmetrical, the two rails can be swapped when the gage face gets worn away too much. The side of the rail that was originally exposed to the "field" side of the track becomes the new gage face. This policy extends the life of the rail. Modelling transposition is more involved than modelling rail relay. A manager will not choose to transpose two rails if the gage face of the rail is not sufficiently worn. Some low and medium degree curves may have accumulated a lot of head loss along with the gage loss. In this case, a transposition would be bad as well, since the rail will soon be replaced due to head loss. Therefore, the management policy file lists three limits for a transposition: the minimum gage wear required, the maximum gage wear allowed, and the maximum head height loss allowed. A rail condition must lie within that range in order for a transposition to take place. Sometimes managers do not consider transposition as a viable strategy because of the limited amount of track time allocated for maintenance work. On high density lines, the disruption of train service and the delay of trains must be avoided. In those cases, the rail is always replaced. The old rail, which still has some life in it, can be transposed and cascaded to another line.

A High-Low rail relay is done by some engineers in situations where the low rail is experiencing excessive crushing, due to plastic flow or fatigue failures. The activity includes replacing the low rail in the curve with the high rail, and replacing the high rail with new rail. High-Low relays are not a standard practice but are used as a corrective measure in extreme situations. The ideal situation would include determining what caused the low rail to crush and correcting the problem. However, correcting the problem is not always possible. The most frequent example occurs on curves that are super-elevated for high speed passenger service. However, slower freight trains share the line, and low rail crushing results from the unbalanced speeds. The freight trains cannot go faster because of their weight. The track cannot be re-configured because of the passenger trains. In terms of the management policy file, a high low should only be

done if the following limits are true: the gage face of the high rail is sufficiently worn, meaning the low rail would simply be replaced with a new rail; the head of the high rail is not worn too much, meaning both rails would be replaced; and the head of the low rail is worn past some limit.

Track Jewelry and Other Track Materials (OTM) are both terms used to refer to a group of items that connect the different track components. OTM includes rail anchors, spikes, tie plates, tie pads, and elastic fasteners. These items deteriorate along with the major track components but are managed in the same way. OTM is replaced during tie renewals, rail renewals, or rail transposition. The management policy file has a series of look up tables that structure information about OTM. One table contains the kind of plate used in eight generic segments as defined by four levels of traffic and two weights of the rail. The number of spikes used per plate is determined by a look-up table that defines 16 generic segments. Finally, the number of anchors in a segment can be calculated by knowing the number of anchors used on each tie and the number of ties anchored. The RAILWEAR model does not use this information. The OTM look up tables are used by the Cost Input Module and the Reports module to calculate the number of pieces of OTM that are replaced during each project.

Potential Improvements: The rail deterioration model could be upgraded to include plastic flow and fatigue. Provisions need to be made in the Rail Management Policy File look-up table that would allow the program to consider the flow and defect limits of the rails as well as the wear.

Track jewelry affects the modulus, sometimes referred to as the stiffness, of the track structure. The type of OTM may be included as an "Other Factors" input variable for the rail fatigue, the tie, or the surfacing deterioration modules.

The Management Policy File could be improved by adding look-up tables that define the level of annual maintenance for generic segments. Currently in TRACS the level of rail grinding and the quality of lubrication are defined for each segment in the Route/Track file. The simulation does not change the levels of maintenance, but rather expends the prescribed amount of maintenance regardless of changes in traffic, changes in the materials used, or changes in the component condition. This structure is a carry-over from the TMCost model that should be changed. Most important is the fact that maintenance levels are highly sensitive to traffic, material type, and component condition. Therefore, the program should be changed to capture the "saw tooth" shaped cost curve that is often associated with infrastructure management. [14] See Exhibit 4 - 3 for a comparison of actual costs over time and the current representation in TRACS. Although a discussion of the Route/Track file follows, it should be pointed out in this context that a Route/Track file record is quite large. It would be very cluttered to add all of the other routine maintenance policies such as tie treatment, brush control, spot tie renewal, local tamping, etc., to this file.

14 Sue McNeil, Transportation Infrastructure Management, M.I.T. Class Notes, Course 1.22, Fall, 1987.

Comparison of Typical Infrastructure Cost Pattern

with TRACS Cost Pattern

Exhibit 4 - 3

Dollars per Year

Time (Years)
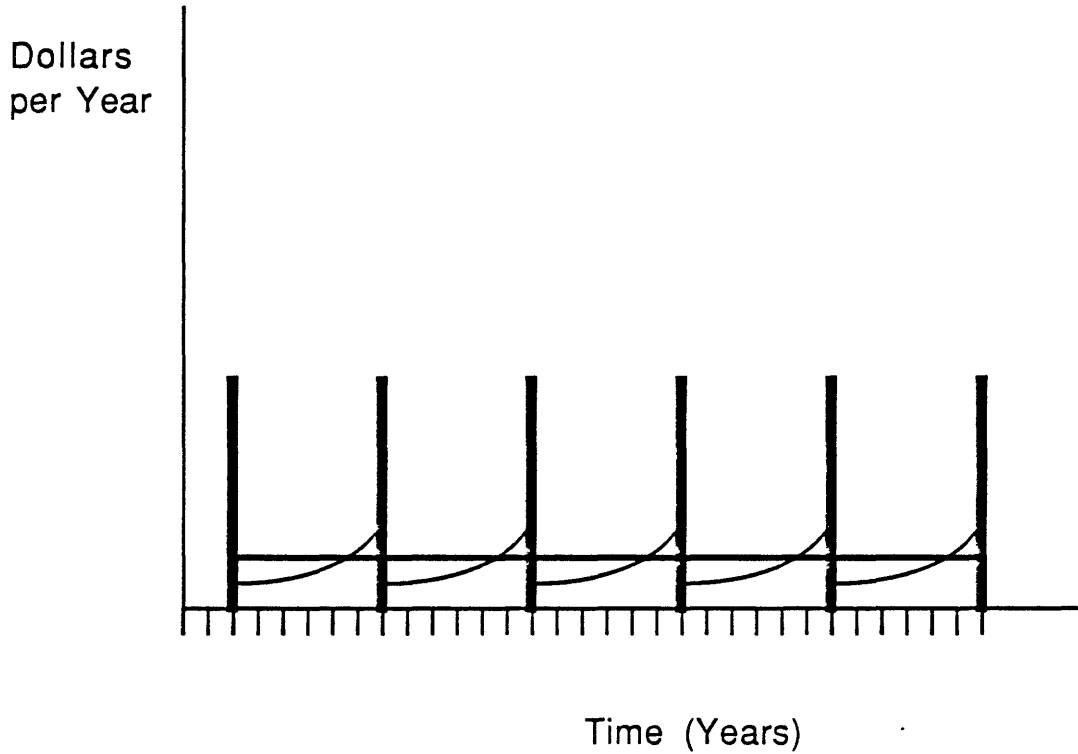
——— Actual Maintenance Costs

——— TRACS Modeled Maintenance Costs

███ Actual & TRACS Rehabilitation Costs

4.1.3.2 Defining Costs and Productivity Measures in a File

TMCost: TUCost was a separate program that was used to calculate unit costs. These were used as an input to the TMCost program.

TRACS: Many of the same calculations used in TUCost are found in TRACS. It was decided that the calculations should be done within the framework of TRACS. This allows more detailed cost studies. The data in TUCost that was not directly related to the cost of an activity were partitioned from the financial data and placed in the Management Policy file. Some of the non-cost items were retained in the Cost Input Module because the information is readily available from accounting records. For example, the gang size is included in the TRACS Cost Input Module.

For each type of rail project (relay, transpose, and high - low) the Management Policy File includes data on the gang productivity for generic territories. The territories are divided by their traffic densities. This reflects the ability of the work crews to get track time. Other data included with the productivity measures deal with the amount of OTM replaced for each type of project and the weight of the OTM scrapped per mile. These numbers are used by the Cost Input Module to calculate Low Level Unit Costs and by the Reports Module to calculate detailed costs for each activity.

There is information about routine maintenance activities as well. The productivity of a grinder is used to calculate the total cost of grinding for 9 generic types of segments. The segments are defined by the traffic density, reflecting the ability to get track time, and by the type of grinding being performed. To do corrective grinding, a gang may have to make several passes over the same rails.

Rail lubrication data is stored in the Management Policy File. There are two types of productivity information related to rail lubrication. First, the technical information

regarding the mechanical features of track side applicators can be found in tables. The amount of grease and the number of applicators required to achieve a given lubrication effectiveness are listed by generic segments. Here a segment is defined by the curvature, traffic density, and level of lubrication.

Potential Improvements: The maintenance activity of rail inspection is not yet considered in TRACS. The Rail Management Policy file needs to be updated to reflect the productivity of a rail inspector and of automated inspection devices.

The representation of productivity in the Management Policy File should be improved by making the production rates a function of gang size and the amount of money spent on equipment. These two parameters are input in the Cost Input Module by a user but do not affect the speed with which an activity takes place. There are economies of scale in track maintenance gang size. If a larger gang is selected, the productivity should be greater. In addition, there are now highly automated track machines on the market which are very expensive, but reduce costs through their high output rate and reduced labor requirements. The problem could be fixed in one of two ways. The productivities that are currently listed should be associated with a typical gang size and machinery cost. A multiplier could be used to adjust the productivity of a gang based on its size and the cost of the equipment. The drawback to this approach is that the relationship between productivity and gang size is probably not linear; thus the multiplier would have to be calibrated and structured to reflect this. Alternatively, several tables of productivity data could be listed for each type of activity. Each table would represent a generic gang defined as "large", "medium", "small". This approach has a disadvantage in that the thresholds would be deterministic. A user could change gang size within the limits defined by "Large" and the productivity would not change.

4.1.3.3 Summary Management Policy File

The idea of structuring management policies in a model was first introduced to M.I.T. by the Burlington Northern Rail Relay Project staff. They used an expert system shell to format the policies in terms of "rules". [15] TRACS checks a series of tables that summarize the various policies. These tables are stored in the Management Policy File. This offers a simple way of capturing information that is necessary to properly simulate an actual situation. The policies are described for different generic segments in different generic territories, where each generic category is defined by the variables that are most important to that policy. The contents of the TRACS Management Policy File are presented later in the discussion of TRACS file editors. There the exhibits demonstrate the meaning of the file contents in a much better fashion than simply looking at the flat file in Exhibit 4 - 3.

4.1.4 Defining Current Conditions in Files

Simulating an actual track segment requires that the program be given the initial conditions of the track components. Since most analyses are intended to study what is going to happen in the immediate future, the current condition of the track components is the starting point. An exception is when an analysis is done on historical data in order to validate the program. In those cases, the initial conditions should be the level of deterioration at the starting year of the simulation. Another exception is the calculation of the life cycle costs of a component over the course of its life. In those cases, the simulation should start with new conditions.

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15 Carl D. Martland, Et.Al, "Scheduling Rail Relays with the Assistance of an Expert System", Paper Presented to the Hemes Community Expert Systems Colloquium, Vienna, Austria, March 8, 1989.

The structure of using pointers was expanded by Auzmendi in TMCost2 in order to increase the flexibility of the program. [16] The pointer implementation for conditions was an extension of this approach. The actual conditions of the components could have been added to the Route/Track Record, but that was not feasible. A condition is not defined by one number, but rather by a set of numbers. In the case of rail, the simulation program needs to know the gage face wear on the high rail, the head height loss on both rails, the cumulative defects per mile, and the defect rate for the last several years; which is five numbers. In the case of ties, there are four different modes of deterioration, and not all ties in a track segment have the same condition. Not only must different conditions be defined, but a distribution of those conditions must be defined for all of the ties in a segment; in the proposed M.I.T. Tie Model structure that is 14 numbers. The same idea applies to ballast, subgrade, switches, and the other track components. In other work at M.I.T. the concept of rail wear patterns is emerging. [17] If these condition patterns are accepted by a company, they could be easily incorporated into TRACS, with each condition pointer representing a condition pattern.

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16 Alvaro Auzmendi, "Implementing a Model for Investigating the Economics of Rail Wear", M.I.T. Master Thesis, May 1988.

17 Interview with Luiz Vieira, Research Assistant, M.I.T.

Example Rail Condition File

Exhibit 4 - 4

```
RAIL CONDITION FILE
C
O           WEAR IN INCHES      DEFECTS/ CUMULATIVE
D           HIGH  LOW   GAGE  MILE/    DEFECTS/
E DESCRIPT  RAIL  RAIL  FACE  YEAR     MILE
----------  ----- ----- ----- -----   -----
1  >50%DET  0.600 0.600 0.400     1      9
2  <50%DET  0.400 0.400 0.200     1      7
3  <25%DET  0.200 0.200 0.100     1      5
4     NEW   0.000 0.000 0.000     0      0
5HI GAGEWR  0.200 0.200 0.400     1      3
6LO GAGEWR  0.400 0.400 0.100     1      3
7HI HEADWR  0.600 0.600 0.100     1      3
8LO HEADWR  0.200 0.200 0.200     1      3
```

4.1.5 Defining Component Assortment in a File

TRACS: A track component is defined by its brand name, price, size, and quality. The quality of a component is defined in TRACS by the calibration parameters discussed above. There are currently Component files for ties, rail, ballast, subgrade, and OTM. Each record in a Material file describes one version of that component. In some cases, there are two files used to describe a component. In those cases the total number of available combinations is the product of the number of records in both files. This drastically decreases the file space needed to define all of the different components. In the future, other Component files will have to be added to define bridges, turn-outs, signals, etc., along with the other changes to the framework.

In the case of rail, there are two modes of deterioration, wear and fatigue. There are five calibration parameters needed for each type of metallurgy in the M.I.T. RAILWEAR model. There will be at least that many needed for a fatigue calculation. Since the wear rates and the price of rail can be easily identified with the metallurgy of the rail and the fatigue rates are more closely associated with the size of the rail, there were two files created to define a rail: the metallurgy file, and the rail parameters file. Example files appear in Exhibit 4 - 4.

Example Rail Component Files

Metallurgy File and Rail Parameters File

Exhibit 4 - 4

METALURGY FILE:

CODE DESCRIPT	Threshhold	Mild Lube	Wear Dry	Friction Coef Lube	Severe Wear Dry	slope	y-interc	Grams per High Rail	inch Gage Face	Cost $ per ton
1 STANDARD	45	7.75	4.80	0.15	0.50	0.00295	-0.2046	12000.0	8000.0	400
2 PREMIUM	45	4.50	2.50	0.15	0.50	0.00246	-0.2823	12000.0	8000.0	450
3 SUPERP	45	4.00	2.25	0.15	0.50	0.00210	-0.3000	12000.0	8000.0	500

RAIL PARAMETERS FILE

CODE	RAIL CROSS SECT.	TYPE OF JOINT (B or W)	CROSS SECTIONAL INERTIA	DEFECTS P. YEAR LIMIT	POISSON'S RATIO	YOUNG'S MODULUS	WEIBULL SLOPE PARAMETER
1	115	W	65.6	2	0.300000	30000000	3.60
2	132	W	65.6	2	0.300000	30000000	3.60
3	136	W	65.6	2	0.300000	30000000	3.60

The TRACS Fastener file lists all of the different kinds of OTM available to a user when describing a track segment in the Route/Track file. Since all of the different kinds of OTM appear in one file, not all of the measurements used to describe the OTM may apply to every record. For example, the "Thickness" for a pad is an important input for determining the forces exerted on the tie, but is not used to describe a spike. The length of a spring clip is rather meaningless as well. The price of each piece of OTM is included in the file. Although OTM is not usually bought by the piece, this method is still employed because all other methods can be easily converted to a unit price. For example, spikes are bought by the keg, but an average keg holds a certain number of spikes.

Potential Improvements: The Tie and Ballast Component files currently in TRACS could be used as inputs to tie and ballast deterioration models. The contents of the files were intended to capture all of the possible information a deterioration model may need. There will have to be additional calibration parameters added, however, based on those specific models.

The right-of-way components that are not currently included in TRACS are different from the track components. The former are made up of many different parts. For example, a bridge has timbers, stringers, trusses, and beams. A switch has guard rails, a frog, slide plates, and heel blocks. A signal has bulbs, lenses, wires, and a tower. At first, these items could be modeled as a unit. In that case, a bridge component file may contain records named, "steel bridge", "wooden bridge", "concrete bridge". The next iteration of the model could improve the simulation by analyzing the deterioration rates of each part. In that case, each bridge would be defined as being made up of smaller components, with pointers in the Bridge Component File to a Beam Component File, a Stringer Component File, a Pier Component File, etc.

4.1.6 Files Containing Default Values

TMCost: In TMCost2 there were example files that could be edited to fit a user's needs. In a Route File with 100 segments, for example, there were over 1500 inputs. The user only needed to change the most important inputs, such as the length of each type of segment or the pointer to the Track File. The criticism that the users had for such a system was based on the fact that it was possible to edit one input and not change another relevant input. For example, a user could edit the Track pointer from a record containing standard metallurgy to a record containing super premium metallurgy. If he did not also change the pointer to the Cost File (the Cost record contained the price of rail), then the program would calculate the costs based on the wrong metallurgy.

TRACS: In the first section of this chapter, the first general guideline for TRACS development indicated that the user would always have a recommended input to edit. If a user creates a new file, the inputs must come from somewhere. The values displayed in the input screens are read from Reference files. The Reference files contain information that describes the typical case for that railroad.

In one sense, the default files in TRACS are like the TMCost2 example files, but there are important differences. The first is that the TRACS default files should be edited and saved by experts in the company. A user is always guaranteed that the default inputs that he sees in an input screen closely represent his problem. Second, the default files can only be edited by qualified users of TRACS. If a field manager or a senior level manager prepares an analysis, anyone called upon to validate the findings will be comfortable with most of the inputs. It is improbable that managers in those categories would change more than 10% of the inputs. Finally, multiple Reference files can be developed that reflect the typical scenarios on each region of a railroad or each division.

The Reference file is used to fill in missing data whenever a user edits a file. The values that he does not edit are asserted by the program. The files represent the initial conditions of the traffic, route, and track. Therefore, when building a Reference file, the user should try to reflect the current typical situation of a railroad. The current policies may be inconsistent with past policies. The Reference files can be thought of as capturing what used to be the typical policies, and the Management Policy files capture what the situation should be. In cases where there has been little change in policy, the maintenance activity should be in steady state, and the two files would contain similar information in different formats.

The TRACS Management Reference File is structured exactly like a Management Policy File. The TRACS Cost Reference File is structured exactly like a Cost File. The full screen editors for these files do not make use of data distillation and downward assertion which are explained in the next chapter, so no additional information is needed. When a user creates a new Management Policy File or a new Cost File, the file is initially a copy of the default file. This is not different from the old TMCost approach.

The criticism regarding the potential for inputting inconsistent data still applies, but the chance of that happening is greatly reduced. If a user intentionally inputs an inconsistent policy, the program will not reject it. For example, if the user claims that High MGT territories are maintained at a much worse level than branch lines, or that Super Premium Rail costs less than Standard Rail, the program will accept the input. However, as the reader will note in the discussion of the full screen editors, the complete look-up table is displayed on the screen at any given time. In addition, all of the input boxes are clearly labeled and there are help screens available. Finally, no one except qualified users can edit the Reference Files.

Potential Improvements: In the future, a Reference file could be developed that would allow a user to redefine many of the qualitative descriptions used in TRACS. For example, the limits of a "Medium MGT" line are currently 40 to 70 annual MGT. Different railroads have different concepts of what limits should define "Medium". At least the following qualitative measures should be defined in a Reference file, rather than be hard-wired: Traffic Density, Curvature, and Gradient.

4.1.7 TRACS Traffic File

TMCost: The traffic file contains the information about the various cars and locomotives that comprise a traffic mix. The simulation models do not differentiate between cars in different trains that are of the same car type and travel at equal speeds. The TMCost Traffic file was structured so a user could rearrange the records of the file and create different traffic mixes within the same file.

TRACS: Each traffic mix is assigned to its own file. This keeps each file at a reasonable size, reduces the probability of error, and makes the Traffic Input Program easier to use. In order to reduce the computation, the Traffic File Input Program takes the information as input by the user and reduces it to the minimum amount required by the deterioration models. The information is stored in a similar format as a TMCost file. The total annual MGT is found in the Route/Track file. This allows a user to specify the same proportionate mix of traffic while adjusting the total volume.

An additional item in each of the car records is an annual growth or decline rate. As the time simulation progresses, the traffic mix will change based on these rates. The rates that are found in the file are for each car. The reader will note in the discussion of input

screens that the user inputs the growth rates for train types. The Traffic File Input program converts the train growth and decline rates to car type rates using a weighted average of the growth rates for all train types that contain the same kind of car.

At the bottom of the TRACS traffic file are three additional tables that store information about the traffic. The first set of records lists the name of each train type in the mix, the number of trains weekly, and the growth rate for that train type. The second set of records describes the typical consist for each train and its speed category. The third set of records contains detailed data for each type of car. These tables are currently only used by the Traffic Input Program as a means by which a TRACS user can structure less detailed inputs. However, the data could be used in a future deterioration model.

Example Traffic File

Exhibit 4 - 5

```
NORMAL        14   14    1    28        630100

1 3    26666    5500      40    2.361  4       90      0    0.00
2 2    12500    1600      33    8.927  4       55      0    0.00
2 2     7500    1600      33    5.356  4       55      0    0.00
1 3    26666    5500      40    0.533  2       90      0    0.00
2 2    20000    2000      36    7.110  2       55      0    0.00
1 3    23333    3500      40    0.267  4       90      0    0.00
2 2    20000    2000      36    8.443  4       55      0    0.00
1 3    33333    5500      40    0.508  7       90      0    0.00
2 2    25000    2000      36    5.713  7       90      0    0.00
1 3    30007    5500      40    0.971  4       90      0    0.00
1 3    26666    5500      40    1.295  4       90      0    0.00
2 2    25000    2000      36    6.745  4       90      0    0.00
2 2    20000    2000      36    5.396  4       55      0    0.00
2 2    12500    1600      33    3.372  4       55      0    0.00
1 3    26666    5500      40    1.828  4       90      0    0.00
2 2    12500    1600      33    6.149  4       55      0    0.00
2 2     7500    1600      33    3.689  4       55      0    0.00
1 3    26666    5500      40    0.533  2       90      0    0.00
2 2    20000    2000      36    7.110  2       55      0    0.00
1 3    23333    3500      40    0.622  4       90      0    0.00
2 2    20000    2000      36   12.506  4       55      0    0.00
1 3    33333    5500      40    0.889  7       90      0    0.00
2 2    25000    2000      36    9.998  7       90      0    0.00
1 3    30007    5500      40    0.971  4       90      0    0.00
1 3    26666    5500      40    1.295  4       90      0    0.00
2 2    25000    2000      36    6.745  4       90      0    0.00
2 2    20000    2000      36    5.396  4       55      0    0.00
2 2    12500    1600      33    3.372  4       55      0    0.00
```

Exhibit 4 - 5 Continued

```
NUMBER_OF_TRAINS
EMPTY         14   7   0
INTERMODAL     7   7   0
LIGHT_UNIT     3   7   0
HEAVY_UNIT     4   7   0
MIXED         17  17   0
PASSENGER      7   7   0




TRAIN_CARS
EMPTY         0   0   3   0   0   0    0    0  50  50   4
INTERMODAL    0   0   3   0   0   0    0   80   0   0   2
LIGHT_UNIT    0   0   0   4   0   0    0   80   0   0   4
HEAVY_UNIT    4   0   0   0   0   0   90    0   0   0   7
MIXED         0   2   3   0   0   0   25   25  25  25   4
PASSENGER     0   0   2   0   0   0    0    0  10   3   1




CAR_DATA
LOC200  3  33333.0  5500  40  90
LOC180  3  30007.0  5500  40  90
LOC160  3  26666.0  5500  40  90
LOC140  3  23333.0  3500  40  90
CAR100  2  25000.0  2000  36  90
CAR80   2  20000.0  2000  36  55
CAR50   2  12500.0  1600  33  55
CAR30   2   7500.0  1600  33  55
```

4.1.8 TRACS Route/Track File

TMCost: In TMCost there was a pointer in the Route File to a record in the Track File. This Track record contained descriptions of each of the track components. Because of the many different variables in each record, this approach required an excessive number of records to be built in the Track File. It was not uncommon in very detailed analyses for each Route File record to have a unique Track File record.

TRACS: The TRACS Route/Track File replaced the two TMCost files and combined the information. A series of pointers was added to the new file. Each pointed to a record in a component material file and a component condition file.

The pointers to the OTM file never existed in the TMCost Track file. There are three pointers that combine to define the complete fastening system. The first pointer is used to select a spike if wooden ties are used in the segment or a tie pad for concrete ties. Only one pointer place is needed in each record since pads are not used with wood ties and spikes are not used in concrete. The second OTM pointer always defines the tie plate that is used. The third OTM pointer is used to specify an anchor for wood tie track or a clip, if elastic fasteners are used. Anchors are seldom used with elastic fasteners because the clips will hold the rail in place better than spikes.

The file was upgraded to contain the beginning mile post. The various reports now identify a segment by name and beginning and ending mile posts. Another improvement involved the elimination of the pointer to the grinding file for the high rail gage face. The gage face of the rail is never ground. Finally, an indicator was added to each record to summarize the climate for that segment. A climate is defined by the number of freeze thaw cycles in a year (many, few, none) and by the moisture in the air or in the subgrade (dry, temperate, wet). The indicator will be used by the tie and surfacing deterioration models.

Potential Improvements: In the future, the information on rail lubrication and grinding could be removed from this file and put in the Management Policy file. This would make the treatment of all policies consistent. Other pointers will have to be added to the Route/Track records if other right of way component deterioration models are added to TRACS.

Exhibit 4 - 6

Label																															
FT0	25.00	0.0	25	0.0	0.0	40.0	1	2	2	2	3	1	5	9	3	3	7	5	5	5	0.0	15	85	77	72	64	60	55	51	47	-688	TF
FT1	25.00	0.0	25	0.0	1.0	40.0	1	2	2	2	3	1	5	9	3	3	7	5	5	5	5.0	15	85	77	72	64	60	55	51	47	-688	TF
FL2	5.00	0.0	5	0.0	2.0	40.0	1	3	2	2	3	1	5	9	3	3	5	5	5	5	2.8	15	45	41	38	36	34	31	29	27	-688	TF
FL3	5.00	0.0	5	0.0	3.0	40.0	1	2	2	1	3	1	5	9	3	3	5	5	5	5	4.2	15	45	41	38	36	34	31	29	27	-688	TF
FL4	5.00	0.0	5	0.0	4.0	40.0	2	2	2	2	3	1	5	9	3	3	5	5	5	5	5.5	15	45	41	38	36	34	31	29	27	-688	TF
FM5	1.67	0.0	1	0.0	5.0	40.0	2	2	2	2	2	1	5	9	3	3	4	5	5	5	3.1	13	30	27	26	24	23	21	20	18	-688	TF
FM6	1.66	0.0	1	0.0	6.0	40.0	2	3	2	2	3	1	5	9	3	3	4	5	5	5	3.7	13	30	27	26	24	23	21	20	18	-688	TF
FM7	1.67	0.0	1	0.0	7.0	40.0	3	2	2	1	3	1	5	9	3	3	4	5	5	5	4.4	14	30	27	26	24	23	21	20	18	-688	TF
FH8	0.83	0.0	1	0.0	8.0	40.0	3	2	2	2	3	1	5	9	3	3	2	8	8	8	3.5	13	25	23	21	20	19	18	16	15	-688	TF
FH9	0.83	0.0	1	0.0	9.0	40.0	1	2	2	2	2	1	5	9	3	3	2	8	8	8	3.9	13	25	23	21	20	19	18	16	15	-688	TF
FH10	0.83	0.0	1	0.0	10.0	40.0	1	3	2	2	3	1	5	9	3	3	2	8	8	8	4.4	14	25	23	21	20	19	18	16	15	-688	TF
GT0	5.00	0.0	5	1.5	0.0	40.0	1	2	2	2	3	1	5	9	3	3	7	5	5	5	0.0	15	80	72	68	64	60	56	52	48	-688	TF
GT1	5.00	0.0	5	1.5	1.0	40.0	1	2	2	2	2	1	5	9	3	3	7	5	5	5	4.5	13	80	72	68	64	60	56	52	48	-688	TF
GL2	1.67	0.0	1	1.5	2.0	40.0	2	2	2	1	3	1	5	9	3	3	5	5	5	5	2.2	12	40	36	34	32	30	28	26	24	-688	TF
GL3	1.66	0.0	1	1.5	3.0	40.0	2	3	2	2	3	1	5	9	3	3	5	5	5	5	3.4	13	40	35	34	32	30	28	26	24	-688	TF
GL4	1.67	0.0	1	1.5	4.0	40.0	2	2	2	2	3	1	5	9	3	3	5	5	5	5	4.5	14	40	36	34	32	30	28	26	24	-688	TF
GM5	0.84	0.0	1	1.5	5.0	40.0	1	2	2	2	2	1	5	9	3	3	4	5	5	5	2.2	12	25	23	21	20	19	18	16	15	-688	TF
GM6	0.83	0.0	1	1.5	6.0	40.0	1	3	2	1	3	1	5	9	3	3	4	5	5	5	2.6	12	25	23	21	20	19	18	16	15	-688	TF
GM7	0.83	0.0	1	3.0	7.0	40.0	1	2	2	2	3	1	5	9	3	3	4	5	5	5	3.1	13	25	23	21	20	19	18	16	15	-688	TF
ST0	2.50	0.0	2	3.0	0.0	40.0	2	2	2	2	3	1	5	9	3	3	7	5	5	5	0.0	15	70	63	59	56	53	49	46	42	-688	TF
ST1	2.50	0.0	2	3.0	1.0	40.0	2	3	2	2	2	1	5	9	3	3	7	5	5	5	3.4	13	70	63	59	56	53	49	46	42	-688	TF
SL2	0.83	0.0	1	3.0	2.0	40.0	2	2	2	1	3	1	5	9	3	3	5	5	5	5	1.7	11	35	32	30	28	26	24	23	21	-688	TF
SL3	0.84	0.0	1	3.0	3.0	40.0	1	3	2	2	3	1	5	9	3	3	5	5	5	5	2.6	12	35	32	30	28	26	24	23	21	-688	TF
SL4	0.83	0.0	1	3.0	4.0	40.0	1	2	2	2	3	1	5	9	3	3	5	5	5	5	3.4	13	35	32	30	28	26	24	23	21	-688	TF
SM5	0.83	0.0	0	3.0	5.0	40.0	2	2	2	2	2	1	5	9	3	3	4	5	5	5	1.4	11	20	18	17	16	15	14	13	12	-688	TF
SM6	0.84	0.0	0	3.0	6.0	40.0	2	3	2	2	3	1	5	9	3	3	4	5	5	5	1.7	11	20	18	17	16	15	14	13	12	-688	TF
SM7	0.83	0.0	0	3.0	7.0	40.0	2	2	2	1	3	1	5	9	3	3	4	5	5	5	2.0	12	20	18	17	16	15	14	13	12	-688	TF

4.1.9 TRACS Cost File

TMCost: The TUCost model was a support program to TMCost that calculated the unit costs for different kinds of rehabilitation activity as well as annual maintenance costs. These unit costs were stored in generic records that were identified by the level of traffic, the type of traffic, the kind of rail, the calendar year the record was produced, and the level of maintenance: excellent, good, poor. Each segment was assigned a pointer to a cost record.

As an aside, one may find it puzzling that the post processor, cost portion of the TMCost model was of the Simple-Simple category, while the engineering portions of the model were of the Complex-Complex category. The exquisite level of detail necessary to run an analysis was suddenly glossed over by the simple method of assigning cost pointers. One user did develop segment specific cost records using TUCost in order to overcome that problem. [18]

The TUCost model included financial inputs as well as data about the various labor gangs. Both types of inputs were needed to calculate the unit costs. However, it is unusual to find one manager who has detailed information about all of the prices and the operating policies of different kinds of gangs. The financial data that was required included items like the price of rail, the price of a tie, the cost of labor, and the cost of a work train. The gang data included things like the size of the gang, the productivity of the gang, the amount of OTM used for each type of activity, and the number of hours worked per day. It was mentioned in the explanation of the Management Policy file that some of the TUCost inputs are now found in that file.

---

18 Interview with Tom Pulkrabek, Kansas City, January 1988.

TRACS: The TUCost structure was improved by including the unit cost calculation within the framework of TRACS. The total costs are now calculated based on the detailed inputs found in the cost file.

The cost file contains two kinds of costs: Low Level and High Level. The low level costs are an aggregation of the high level costs. The high level costs are the most detailed values in the cost file. A Low Level Cost Item is similar to the unit costs calculated in TUCost. The low level costs for each project activity are in units of dollars per mile; for routine maintenance, they are in units of dollars per mile per year. There are two sets of Low Level costs. The first set is derived by combining the information from the detailed or high level costs in that cost file with the prices for typical components found in the component materials files and with the productivity parameters for a typical segment found in the Management Policy File. These are called the Derived Low Level Costs. The second set of low level costs are initially equal to the Derived set. If a user wishes, he can edit the low level costs. This is useful for performing analyses that are more global in nature. For example, in order to study the consequences of a new technology that halves the cost of tie renewal, an analyst should start by editing the low level costs, rather than by editing all of the detailed costs and productivities that affect that number.

Whenever a user edits the cost file, it may be useful to know if the values were previously edited or if the costs are equivalent to those found in the Cost Reference File. A system of flags was included in this file. The first flag is the "High" asterisk. If this flag appears in the file, it indicates that at least one of the High Level costs has been previously edited. The second flag is the "Low" asterisk. If this flag appears in the file, it indicates that the user has edited at least one of the Low Level unit costs. Finally, each Low Level cost item has a flag associated with it. If the flag is a dash, that indicates that all of the inputs used to calculate that cost were the same as the default values

in the Cost Reference File. Otherwise, an asterisk appears, indicating that at least one of the High Level Costs that is used to calculate this Low Level Cost Item has been edited.

Potential Improvements: Low Level Cost Reports could be made available through the Reports Module. The option to view Low Level Cost Reports will appear only if the "Low" flag exists.

The cost of rail inspection is not included in the file. There should be a cost for a person doing the inspection and a cost for each of several types of automated inspection cars. Examples include track geometry cars, Sperry rail cars, and Lite-Slice vehicles.

The TRACS development team tried to anticipate the different costs that would be needed for the tie and surfacing cost models. These costs are in the cost data base but are not currently used. Pending the completion of the Tie Management Policy File and the Surface Management Policy File, the detailed costs could be used to calculate unit costs. The unit cost calculator does not depend on the existence of the deterioration models. If it is determined that unit costs would be of immediate use to some managers, they could be implemented before the related deterioration model. After the deterioration models are implemented, low level cost reports would be available immediately. These could serve as a temporary measure until the full set of detailed cost reports are implemented.

The large spaces in the Cost file are reserved for future placement of unit costs, material costs, and labor costs for the right of way components.

Example Cost File

Exhibit 4 - 7

```
Cost file mitdef.CST
High * Low *      (See bottom of page for notes)

Discount rate   Inflation rate   Income tax rate  Depreciation rate
---------------  ---------------  ---------------- -------------------
   10.00   %        3.00     %      20.00      %      S    25 years (See notes)

? Derived/Low-level costs    Derived    Low-level   (See bottom for notes)
- -------------------------   --------   ----------
* Rail relay                  234567      234567    $/mile
* Rail transposition          33465.0     44567.0   $/mile
* Rail high-low               198736      197545    $/mile
* Annual rail grinding        300.00      350.00    $/mile/yr
* Annual rail lubrication     301.00      351.00    $/mile/yr
- Annual rail defect rep.     456.00      567.00    $/mile/yr
- Tie program                 789.01      890.12    $/mile
* Tie out-of-face  renewal    1234.56     2345.67   $/mile
* Tie treatment               300.00      300.00    $/mile
* Annual spot tie renewal     400.00      400.00    $/mile/yr
* Raise, line, and surface    1000.00     1000.01   $/mile
* Annual surfacing            300.00      250.00    $/mile/yr
- Ballast renewal             400.00      300.00    $/mile
- Undercutting and renewal    400.00      500.00    $/mile
* Ditching                    600.00      700.00    $/mile
* Subgrade stabilization      400.00      400.00    $/mile
- Annual subgrade washout     200.00      168.90    $/mile/yr
```

Gang type	Hours /day	Size	Wages $/hr	WorkTrain $/mile	Transport $/job	Machinery $/day
RELAY GANG	8.0	30	14.50	500.00	999.00	999.00
TRANSPOSE GANG	8.0	20	15.00	500.00	999.00	999.00
HIGH-LOW GANG	8.0	20	14.50	500.00	999.00	999.00
DEFECT REPAIR	8.0	2	15.00	300.00	0.30	100.00
OILER GANG	8.0	10	20.00	0.00	0.00	1000.00
TURNOUT REPAIR	7.0	5	15.00	0.00	0.00	500.00
TURNOUT MAINT	6.0	4	16.00	0.00	0.00	500.00

```
Other material costs
-----------------------------
LUBRICATION    50.00 $/lb
APPLICATOR     50.00 $/each
GRINDER       500.00 $/hr
```

Exhibit 4 - 7 Continued

```
SCRAP VALUE OF RAIL      :  100.00 $/ton
DISPOSAL COST FOR RAIL :   10.00 $/ton
SCRAP VALUE OF OTM       :  100.00 $/ton
DISPOSAL COST FOR OTM  :   50.00 $/ton
```

NOTES:

High * Low * : An asterisk after the word "High" means that the user has inputted at least one cost at the high level of detail, otherwise all detailed costs are defaults. The asterisk after "Low" indicates that the user has given low-level costs to be used for non-specific cost reports if desired. No asterisk signals TRACS that low-level analyses are not available.

Depreciation rate : Letter choices are (E)ngineering life, (P)lanning horizon, (S)traight line, (A)ccelerated. Only options S & A will have a number in addition -- how many years to figure into the depreciation. The first two choices are analysis-specific, and will be figured during the analysis.

Derived/Low-level costs : The first column indicates whether the Derived cost was calculated from detailed costs (with an asterisk), or was taken from default values (dash).

4.1.10 TRACS Bridge File

The TRACS Bridge file does not contain information about railroad bridges. Rather, it is a file that passes information from the Deterioration Module to the Reports Module. The TRACS program is unique in that in creates a data base of information that is used to generate reports. The calculations for the reports are not performed until the user specifies that he wants to see a certain report. Furthermore, the reports are not saved unless the user determines that they should be kept. In this way the CPU time and the number of files are considerably reduced. A report can be generated at any time from a Bridge file.

Each analysis creates a Bridge file that is saved under the analysis name. The bridge file contains the important information about each track segment, such as name, length, beginning mile post, and degree of curvature. In addition, all of the projects that occur on that segment during the next 10 years are listed by year and by the type of project. Finally, each segment has certain statistical information that is used by the Reports module. This set of information includes such things as average wear rates, the life of the rail, and the annual MGT after five years of simulation. There is other information that is related to the analysis which is stored in the Bridge File as well. This includes things like the name of the user, the date and time of the analysis, and a list of the files that were used in the calculations.

Potential Improvements: The Bridge file could be produced by other programs in addition to the TRACS deterioration modules. The Reports module would then format the reports for those programs in a similar fashion. The bridge file could also be used as an input to other programs that may treat the information in a more or less rigorous manner than the TRACS Reports module.

134

Exhibit 4 - 8

```
FT0           0.00    20.00 0.00 2 1 35.00     6   9.9R 1 1.
 0.01547 0.01547 0.00000        48.5R 37.86
FT1           0.00    20.00 1.00 2 1 35.00     6   9.4R 1 1.
 0.01547 0.01547 0.02441        25.6R 37.86
FL2           0.00     6.67 2.00 2 1 35.00     6   OT 8.2R 2 2.
 0.01143 0.01143 0.02126 18.3T 32.0R 37.86
FL3           0.00     6.67 3.00 2 1 35.00     6   OT 8.2R 2 2.
 0.01143 0.01143 0.02126 18.3T 32.0R 37.86
FL4           0.00     6.67 4.00 2 1 35.00     6   OT 8.2R 2 2.
 0.01143 0.01143 0.02126 18.3T 32.0R 37.86
FM5           0.00     5.00 5.00 2 1 35.00     6   6.3R 2 2.
 0.01143 0.01143 0.02126 17.9T 32.0R 37.86
FM6           0.00     5.00 6.00 2 1 35.00     6   6.3R 2 2.
 0.01143 0.01143 0.02126 17.9T 32.0R 37.86
FM7           0.00     5.00 7.00 2 1 35.00     6   6.3R 2 2.
 0.01143 0.01143 0.02126 17.9T 32.0R 37.86
FH8           0.00     3.33 8.00 2 1 35.00     6   6.3R 2 2.
 0.01462 0.01462 0.02126 17.4T 32.0R 37.86
FH9           0.00     3.33 9.00 2 1 35.00     6   6.3R 2 2.
 0.01462 0.01462 0.02126 17.4T 32.0R 37.86
FH10          0.00     3.3310.00 2 1 35.00     6   6.3R 2 2.
 0.01462 0.01462 0.02126 17.4T 32.0R 37.86
GT0           0.00     5.00 0.00 2 1 35.00     6   9.9R 1 1.
 0.01547 0.01547 0.00000        48.5R 37.86
GT1           0.00     5.00 1.00 2 1 35.00     6   9.4R 1 1.
 0.01547 0.01547 0.02441        25.6R 37.86
GL2           0.00     1.67 2.00 2 1 35.00     6   OT 8.2R 2 2.
 0.01143 0.01143 0.02126 18.3T 32.0R 37.86
GL3           0.00     1.67 3.00 2 1 35.00     6   OT 8.2R 2 2.
 0.01143 0.01143 0.02126 18.3T 32.0R 37.86
GL4           0.00     1.67 4.00 2 1 35.00     6   OT 8.2R 2 2.
 0.01143 0.01143 0.02126 18.3T 32.0R 37.86
```

```
C:\TRACS\DATA\LANDMART.RTP
C:\TRACS\DATA\CASE.TRF
C:\TRACS\DATA\WEAR.DAT
C:\TRACS\DATA\FACTORS.DAT
C:\TRACS\DATA\GRINDING.DAT
C:\TRACS\DATA\LUB.DAT
C:\TRACS\DATA\METAL.DAT
C:\TRACS\DATA\PARAM.DAT
C:\TRACS\DATA\RAILCOND.DAT
C:\TRACS\DATA\TIEMAT.DAT
C:\TRACS\DATA\FASTENER.DAT
C:\TRACS\DATA\TIECOND.DAT
C:\TRACS\DATA\BALLAST.DAT
C:\TRACS\DATA\SURFACE.DAT
C:\TRACS\DATA\G.MNT
C:\TRACS\DATA\STANDARD.CST
USERNAME              lar
DATE AND TIME         02-25-89  22:34
PLANNING HORIZON      100
```

4.2 TRACS Program Modules: Structure of the User Interface

Now that the reader has reviewed some of the important files that are necessary to do an analysis with TRACS, two questions must be addressed. How are new files developed? How are old files edited? A glance at the example files shows that a lot of information is needed to properly edit or add a record.

TRACS offers the capability to perform a complete range of analyses. A user may still want to model the engineering aspects in a detailed manner, while approximating the costs. Unlike RAILER, TRACS does not limit the user to either the simple or the complex approach. An analysis can be formulated in a myriad of different ways. The inputs are divided into four areas: the technical information stored in the INSTALL programs, the traffic data, the route and track data, and the cost data. A new analysis is formulated any time one of the four areas of input is changed. Within each category, a user can specify as much or as little information as he chooses. The different kinds of analyses, or depth versatility as labeled in Chapter 2, vary in a seemingly continuous spectrum from the very simple through the very complex. Each area of input will now be examined.

4.2.1 TRACS Install Module

There are many inputs used by TRACS that will seldom be changed, including the following:

    1) Calibration parameters
    2) Inputs related to management policies
    3) Defaults used by the input screens (which may be different for various companies).

These inputs are of little interest to most users because they refer to scientific details or to policies that are not dependent on review by all levels of management. For these

reasons TRACS has an "INSTALL" module, which is partitioned off from the main body of the input screens. It contains the files and input screens related to these inputs. Separating the Install Module program from the rest of TRACS has two main benefits. First, the ordinary user cannot incorrectly specify key control parameters by accident. Second, the Install program simplifies the user interface by removing large amounts of technical information from the routine editing screens.

The access to TRACS by different departments and different levels of managers is obviously a decision that should be made by each company. TRACS was designed to be an acceptable management tool for a very diverse group of individuals. Potential users include people with little background in either the scientific or the managerial issues surrounding track maintenance. There was some discussion by the M.I.T. Track Advisory Committee regarding the wisdom of releasing the total package to such a diverse group of people. Therefore, the INSTALL program was added to give companies more flexibility in assigning responsibility and access to the TRACS package.

A person will be given a copy of TRACS package with access to none, some, or all of the sub-modules of INSTALL. The following things should be considered in deciding if a person will need any of the sub-modules of INSTALL:

1) Does this person have information that could validate or invalidate the current entries used as inputs in these files?

2) Does this person have decision-making responsibility in the company which would affect the values used as inputs in these files?

3) Does this person belong to a professional group which shares information and research about the inputs?

4) Does this person have responsibility for maintaining the programming updates and enhancements associated with computer models?

If the answer to any of the above questions is "yes", then that party should probably be allowed access to particular sub-modules of the INSTALL program. Nevertheless, the

137

fact that an extensive amount of valuable research and analysis can be carried out using the TRACS package without accessing the INSTALL files or associated software needs to be emphasized. The last section of this chapter describes the Control Program. The method for protecting the INSTALL modules will be outlined there in detail. The next section explains when the INSTALL program should be used.

Each version of TRACS contains sample INSTALL files prepared by M.I.T. The values in these files represent typical scenarios and operating policies that may or may not be used on an actual railroad. For this reason, each company will want to review INSTALL as soon as possible. Reviewing and revising these values will be the most tedious task in working with TRACS. For broad-brush analysis or experimentation with the new models, the files provided will certainly suffice.

For a more important analysis, INSTALL files should be developed that represent the operating policies, materials, and management practices used by the company. It is recommended that a set of files representing the whole system be developed first. However, some users will identify distinct differences between regions of their railroad. For example, one region may lubricate all curves greater than 5 degrees, while another may lubricate all curves greater than 3 degrees. In this case, separate INSTALL files for each region should be made. Consequently, when the model is distributed to various managers, one may choose to include only the INSTALL files specific to that manager's region.

Other analyses can be done using the INSTALL program. For example, running a scenario with different INSTALL files can give some insight into which set of policies is best for a particular set of circumstances.

In order to evaluate different policies for maintenance management, the user will need to develop two INSTALL files which depict the choices to be made. The need may

often arise to study combinatorial effects, for example increasing the lubrication while lowering the quality of replacement rail on curves. The INSTAL program is the easiest way to simulate this type of problem. On a given subdivision, the manager has to plan a strategy. Regardless of the type of rail present on the track, he can choose to replace it with another type. Even though the current level of lubrication may be optimal for that steel, TRACS can help the decision-maker look at different levels of lubrication. Does better lubrication allow a company to save money by using less expensive rail? The two Install files will include:

    1) Replace with current metallurgy and keep the same lubrication
    2) Replace with lower quality steel and increase the level of lubrication

TRACS is now run twice. The first time, the user must use the first Install file and either choose existing files that represent his traffic and route/track parameters or build new files. The second time, however, only the choice of the INSTALL file will change. The most interesting reports in this case are the Subdivision Statistics Cost Reports.

INSTALL is made up of three sub-modules. Each is a program containing file editors that include definition and help screens. There are also range checks for each input. Exhibit 4 - 9 summarizes the structure of the INSTALL input screens.

Structure of the INSTALL Input Screens

Exhibit 4 - 9

```
┌─────────────┐      ┌─────────────┐      ┌─────────────┐
│ Management  │      │ Component   │      │ Reference   │
│ Policy      │      │ and         │      │ Sub-Module  │
│ Sub-Module  │      │ Condition   │      │             │
│             │      │ Sub-Module  │      │             │
└─────────────┘      └─────────────┘      └─────────────┘

┌─────────────┐      ┌─────────────┐      ┌─────────────┐
│ Input       │      │ Define      │      │ Define      │
│ Engineering │      │ Condition   │      │ Typical     │
│ Limits      │      │ Classes     │      │ Traffic     │
│             │      │             │      │             │
└─────────────┘      └─────────────┘      └─────────────┘

┌─────────────┐      ┌─────────────┐      ┌─────────────┐
│ Input       │      │ Define      │      │ Define      │
│ Productivity│      │ Component   │      │ Typical     │
│ Measures    │      │ Options     │      │ Route/Track │
│             │      │             │      │ Data, Segment│
│             │      │             │      │ Approach    │
└─────────────┘      └─────────────┘      └─────────────┘

┌─────────────┐      ┌─────────────┐      ┌─────────────┐
│ Input       │      │ Input       │      │ Define      │
│ Material    │      │ Deterioration│     │ Typical     │
│ Selection   │      │ Parameters  │      │ Route/Track │
│ and         │      │             │      │ Data, Percent│
│ Requirements│      │             │      │ Approach    │
└─────────────┘      └─────────────┘      └─────────────┘
```

4.2.1.1 TRACS File Editors for Management Policy Files

The Management Policy module includes information about track engineering management and business management. For example, the user can choose rules about the track replacement procedure, including such things as condemning limits, maximum allowed plate cut, and type of rail used on a seven degree curve in high MGT territory. Other inputs relate to varied topics such as the productivity of work gangs, the minimum number of ties that merit a program, and routine maintenance procedures.

The Management Policy Sub-Module is used during the simulation. The other two INSTALL Sub-Modules are used to construct inputs for files. Of the three, the first one is most useful for different kinds of analysis. The information in this file only affects the future course of action, while the information in the other two files is needed to define the current situation. Of the three, it may be the least dangerous to distribute to the users who do not have access to the complete INSTALL program.

Management Policy File Editor

Main Menu

Exhibit 4 - 10

Maintenance Policy Areas, Main Menu

The Main Menu lists the 18 areas of maintenance policy. To edit data in one of these areas, type the number of the area. Since some of the areas are not yet implemented, a message will appear to that effect, if you choose an irrelevant number.

1. RAIL RELAY	10. 100% TIE REPLACEMENT
2. TRANSPOSITION	11. SPOT TIE REPLACEMENT
3. HIGH-LOW	12. TIE TREATMENT
4. DEFECT REPAIR	13. TIE MATERIALS
5. GRINDING PRODUCTIVITY	14. RAISE, LINE & SURF.
6. MATERIALS-RAIL	15. BALLAST RENEWAL
7. MATERIALS-OTM	16. SUBGRADE MAINTENANCE
8. MATERIALS-LUBRICATION	17. SURFACE MATERIALS
9. PROJECT TIE RENEWAL	18. TURNOUTS
TO EDIT THE POLICY PARAMETERS, ENTER THE NUMBER OF THE MAINTENANCE ACTIVITY FROM THE ABOVE LIST. TO QUIT TYPE 0 1	

Management Policy File Editor

Example of Engineering Limits and Productivity Screens

Exhibit 4 - 11

RELAY LIMITS	RAIL WEIGHT	MAX GAGE WEAR ALLOWED	MAX HH WEAR ALLOWED
HIGH MGT	> 132 lbs.	0.610	0.700
	< 132 lbs.	0.610	0.700
	< 110 lbs.	0.610	0.700
MEDIUM MGT	> 132 lbs.	0.615	0.710
	< 132 lbs.	0.615	0.710
	< 110 lbs.	0.615	0.710
LOW MGT	> 132 lbs.	0.625	0.750
	< 132 lbs.	0.625	0.750
	< 110 lbs.	0.625	0.750

1. RELAY PRODUCTIVITY: SCREEN 2 OF 2

MAINTENANCE POLICY FILE: GOOD.MNT

RELAY PRODUCTIVITY
Percentage of materials replaced with new material:
plates 90.00   spikes 50.00   anchors 95.00
Track miles relayed per gang per day:
high MGT 1.0 med MGT 1.0 low MGT and branch 3.0
Weight of OTM scrapped per mile: 40.0

Management Policy File Editor

Example Materials Selection Screen

Exhibit 4 - 12

6. MATERIALS - RAIL: SCREEN 1 OF 1

MAINTENANCE POLICY FILE: GOOD.MNT

RAIL TYPES REQUIRED by MGT and CURVE								
	TAN		LOW		MED		HIGH	
HIGH MGT	1	1	2	2	2	2	3	3
MED MGT	1	1	2	2	2	2	3	3
LOW MGT	1	1	2	2	2	2	2	2
BRANCH	1	1	1	1	2	2	2	2

RAILTYPE

Format:integer
The first number indicates
the weight (see railpara-
meters file, the second
number indicates the
metallurgy (see metallurgy
file).

4.2.1.2 TRACS File Editors for Component and Condition Files

In this sub-module, the user will review all of the current components defined in the files. The files contain the names, measurements, wear parameters, definitions, and physical data about ties, rail, ballast, turnouts, and other components that can be used on the company's track. A company can redefine the parameters for specific components if they believe that their track is not well represented by the calibration parameters that are currently in the file. The prices of each of the components can be edited in this module and again in the Cost Input Module. Therefore, a user without access to this file editor can still edit the prices.

The other major purpose of this sub-module is to categorize the different right-of-way components into condition categories. These condition categories are used by the deterioration models to predict the life remaining in a particular element of the track. The rail section includes inputs that describe its condition in terms of cumulative wear and cumulative defects. This area is still in development for ties and ballast, but recent work indicates that surface indices will be used for the surface condition. In the INSTALL program, all possible conditions that may be encountered on a given railroad should be included. A user of TRACS who is not interested in detail can review a selection table at one of the intermediate screens in the Route/Track module and choose a condition such as "Half Old, Half New" to represent the age of ties in a sub-division or in a route segment. The INSTALL file then relates this general description to a statistical distribution of ties by the life remaining with respect to each mode of tie deterioration. Since a user cannot expand the choice set of conditions without access to the INSTALL module, a large spectrum of choices should be provided with each copy of TRACS. This permits more flexibility in choosing descriptions for condition.

After choosing a file from the main menu, the user will next see a screen that summarizes all of the records that are currently in the file that he chose. He can look at one of the existing records or create a new record. Either way, the next screen will be a record editing screen. Each entry in a record is marked with a label. If the user needs more information, on-line help screens are available. From this screen a user may choose to edit another record, return to the main menu, or leave the Component and Condition file editing program.

Component and Condition File Editor

Main Menu

Exhibit 4 - 13

The ROUTE/TRACK file contains pointers to records in 10 other input files, called the component and condition files:

1. METALLURGY FILE	C:\TRACS\DATA\METAL.DAT
2. RAIL PARAMETERS FILE	C:\TRACS\DATA\PARAM.DAT
3. RAIL CONDITION FILE	C:\TRACS\DATA\RAILCOND.DAT
4. TIE MATERIAL FILE	C:\TRACS\DATA\TIEMAT.DAT
5. FASTENER FILE	C:\TRACS\DATA\FASTENER.DAT
6. TIE CONDITION FILE	C:\TRACS\DATA\TIECOND.DAT
7. BALLAST FILE	C:\TRACS\DATA\BALLAST.DAT
8. SURFACE FILE	C:\TRACS\DATA\SURFACE.DAT
9. GRINDING FILE	C:\TRACS\DATA\GRINDING.DAT
10. FRICTION FILE	C:\TRACS\DATA\LUB.DAT
TO ADD A RECORD TO A FILE,	OR EDIT A RECORD IN A FILE,
TYPE FILE NUMBER.	TO QUIT TYPE 0 1

Component and Condition File Editor

Example Records Overview Screen

and

Example Record Editing Screen

Exhibit 4 - 14

```
┌─────────────────────────────────────────┐      ┌──────────────────────┐
│        RECORDS OVERVIEW SCREEN.          │      │ COMPONENT & CONDITION│
├─────────────────────────────────────────┤      │    METALLURGY FILE   │
│ THIS FILE C:\TRACS\DATA\METAL.DAT        │      │     SCREEN 2 OF 3    │
│ CONTAINS THE FOLLOWING RECORDS:          │      └──────────────────────┘
├─────────────────────────────────────────┤
│                                          │
│    1 STANDARD                            │
│    2  PREMIUM                            │
│    3   SUPERP                            │
│                                          │
│                                          │
│                                          │
│                                          │
│                                          │
├─────────────────────────────────────────┤
│ TO EDIT A RECORD TYPE ITS NUMBER         │
│    TO ADD A NEW RECORD TYPE   4          │
│    TYPE 0 TO CHOOSE ANOTHER FILE      1  │
└─────────────────────────────────────────┘
```

```
         COMPONENT & CONDITION: SCREEN 3 OF 3

METALLURGY FILE:

┌──────────────────────────┐   ┌──────────────────────────────────────────┐
│ Code : 1                 │   │ MILD WEAR IN GRAMS/METER/MGT               │
│ Description:STANDARD      │   │  - lubricated conditions :  7.75           │
│ Threshhold :45           │   │  - dry conditions         :  4.80          │
└──────────────────────────┘   │                                            │
                               │ COEFFICIENTS OF FRICTION                   │
                               │  - lubricant : 0.15                        │
                               │  - steel     : 0.50                        │
                               │                                            │
                               │ Coeffic. for severe wear :0.00295          │
                               │ Y-intercept : -0.2046                      │
                               ├────────────────────────────────────────────┤
                               │ High Rail   grams/in:   12000              │
                               │ Gage face   grams/in:    8000              │
                               ├────────────────────────────────────────────┤
                               │ Cost :   400.00 $/ton                      │
                               └────────────────────────────────────────────┘
```

4.2.1.3 TRACS File Editors for Reference Files

There are five Reference files in TRACS: Management Policy, Traffic, Route/Track Percentage, and Route/Track Segment. The Management Policy Reference File and the Cost Reference file have the exact format of a standard Management Policy File and a standard Cost file. Therefore, if a qualified user wishes to edit either of these maintenance policy files, he can temporarily rename the Reference file name into a file name ending with the standard suffix. For Example, *.MND becomes *.MNT. The Reference file is then edited using the standard editing programs for those files.

The Reference Sub-Module of the TRACS INSTALL program gives a user the ability to edit any or all of the other three reference files; Traffic, Route/Track Percentage, or Route/Track Segment. In addition to editing existing files, new files can be created.

Example Reference File Editor

Route/Track Percentage

Exhibit 4 - 15

```
ROUTE/TRACK REFERENCE EDITOR   SCREEN 2
INPUT VALUES THAT ARE DERIVED FROM FRA - CLASS
```

FRA CLASS	surface condition	rail condition	tie condition	speed limit
1	1	1	1	15
2	2	1	1	30
3	3	2	2	60
4	4	3	3	80
5	5	3	4	90
6	6	4	5	110

4.2.2 TRACS Input Modules

Unlike a file editor, which prompts the user for the exact entries in a file, the input modules are designed to interface with the user in an environment that is easier for the user to understand. There are three input modules in TRACS: the Traffic Input Module, the Route/Track Input Module, and the Cost Input Module. These three areas were developed as input modules, as opposed to file editors, for the following reasons:

1) They are the files that are most often edited in analyses

2) Although each module only edits one file, they are the most complicated files in TRACS

3) The structure that was used in order to increase the efficiency and elegance of the software was not the best structure to use in the user interface

In an input module, a user can choose to input different volumes of information. The program prompts the user for the most important information first. As the user progresses through the screens, he increases the volume of inputs within that module. Each screen in the module represents a level of detail. The numbers at the top of each screen designate which level of detail is currently being displayed; the higher the number, the higher the level of detail, hence the higher the volume of information that needs to be edited by the user. A lower level of detail screen will prompt the user for qualitative information and summary data that applies to the whole file. Lower Level screens ask for such information as traffic descriptions by trains, the FRA class of the subdivision, and system average unit costs. A higher level of detail screen prompts the user for information about specific records within a file. At the highest level, the input module becomes a file editor for the inputs that were not covered in the previous levels. A user does not necessarily have to visit all of the levels of detail. Managers' time constraints, a lack of user expertise in technical details, or analyses for less important decisions are examples of situations that would not necessitate visiting the higher levels of detail.

In each of the next sections, the Input Modules are examined more closely. A flow chart at the beginning of the section will summarize each level of detail within that Module. Example screens from each level of detail and further discussion of each Input module can be found in Appendix 2. Appendix 2 includes the sixth, seventh, and eighth chapters of the TRACS Manual.

4.2.2.1 TRACS Traffic Input Module

TMCost: The Traffic Input Module was first introduced to the M.I.T. Track Advisory Committee in the form of a Lotus Spreadsheet. The spreadsheet was distributed along with the TMCost2 package. A user could edit tables in a spreadsheet, which then calculated the percent of the total MGT represented by each car. These numbers had to be manually copied into a traffic file template.

TRACS: The Traffic Module is similar in structure to the spreadsheet model. The inputs for traffic growth and decline were included in the TRACS version. More information about the Traffic Input Module, as well as examples of the screens, can be found in Appendix 2, section 7.2 .

Potential Improvements: A future version of the program could develop a structure wherein a user can input the growth and decline rates for each kind of train by the direction of travel. The user must now input the total growth and decline rate for each train type. If one train type has 10 weekly trains going East with an expected growth rate of 5%, and 5 weekly trains going West with an expected decline rate of 5%, the user must stop and manually compute that the net effect for cars in that train type is a growth rate of 2.5% . That formulation could be done by the Input Module.

Another potential upgrade would consist of changing the third screen, where the train consists are edited, so that the gross weight of a car or locomotive is not hard-wired.

Originally, these were meant to be labels that described categories of cars, but some users became confused on this point. To solve that problem, a user would enter the approximate gross weight as well as the number of cars in each category for a train type.

Exhibit 4 - 16

TRAFFIC INPUT MODULE SCREENS

```
┌─────────────────┐
│     TRAFFIC     │
│      INPUT      │
│     MODULE      │
└─────────────────┘
         │
         ▼
┌─────────────────┐
│      INPUT      │
│      TYPE &     │
│   NUMBER OF     │
│     TRAINS      │
└─────────────────┘
         │
         ▼
┌─────────────────┐
│      INPUT      │
│     CONSIST     │
│   OF CARS IN    │
│   EACH TRAIN    │
└─────────────────┘
         │
         ▼
┌─────────────────┐
│      INPUT      │
│     DETAILS     │
│      ABOUT      │
│    EACH CAR     │
└─────────────────┘
```
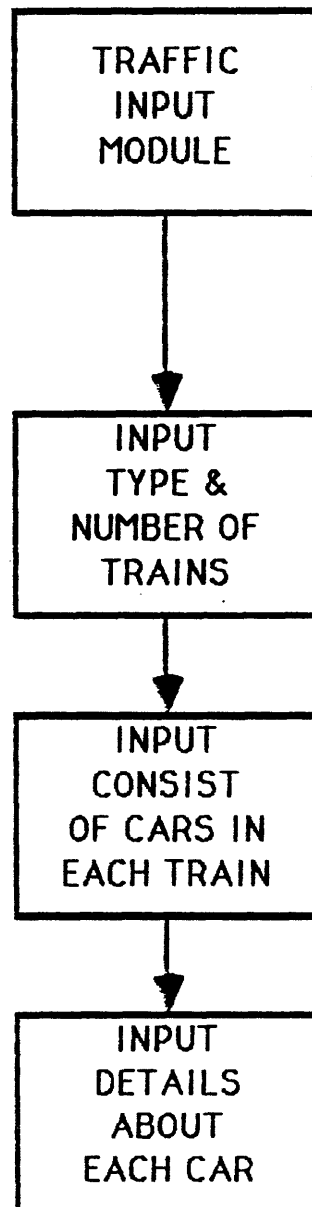
4.2.2.2 TRACS Route/Track Input Module

The Route/Track Input Module gives the user the option to develop Route/Track files using a general approach or a specific approach. Regardless of which way he chooses, the file formats are exactly the same. Many of the inputs in this module are in the form of pointers to other files. A frequent user of TRACS will become familiar with the pointers that are in his files and be able to edit them. However, new users and infrequent users are accommodated through the help screens. For the inputs that require a pointer, the on-line help screen will read the file in question and display the pointer and a description for all of the valid options.

The Route/Track file has the most complex relationships between levels of detail of the three TRACS Input Modules. Changing a value in a high level of detail will automatically change all of the values in the lower levels of detail that are related to that input. For example, if a user inputs FRA Class 2, the Input Module Program will change the surface condition to "Poor". All of the relationships that are currently coded into the system are listed in Appendix 2, section 7.3 .

Exhibit 4 - 17

ROUTE/TRACK INPUT MODULE SCREENS

```
                    ┌─────────────┐
                    │ ROUTE/TRACK │
                    │    INPUT    │
                    │   MODULE    │
                    └─────────────┘
                           │
          ┌────────────────┴────────────────┐
          ▼                                 ▼
  ┌───────────────┐                 ┌───────────────┐
  │     INPUT     │                 │     INPUT     │
  │  SUBDIVISION  │                 │  SUBDIVISION  │
  │     DATA      │                 │     DATA      │
  │  PERCENTAGE   │                 │    SEGMENT    │
  └───────────────┘                 └───────────────┘
          │                                 │
          │        ┌───────────────┐        │
          └───────▶│    CHOOSE     │◀───────┘
                   │   A SEGMENT   │
                   │    TO EDIT    │
                   └───────────────┘
                           │
                           ▼
                   ┌───────────────┐
                   │     INPUT     │
                   │   GEOMETRY    │
                   │  & MATERIALS  │
                   └───────────────┘
                           │
                           ▼
                   ┌───────────────┐
                   │     INPUT     │
                   │  MAINTENANCE  │
                   │ & OPERATING   │
                   │    SPEEDS     │
                   └───────────────┘
```

156
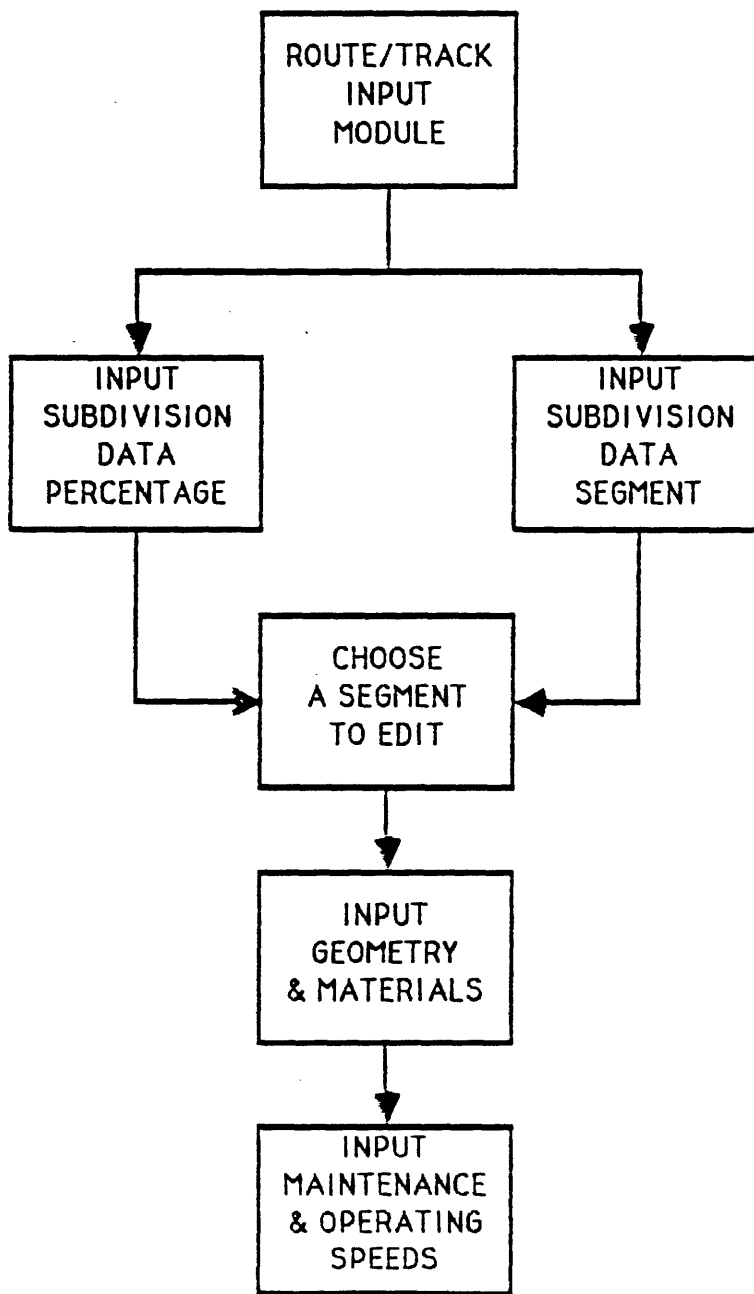
4.2.2.2.1 Percentage Approach

TMCost: TMCost2 included Route file templates for different kinds of routes. A file called "Flat, Straight" would contain only a few segments with straight track and low degrees of curvature. The intention was to have a user edit the lengths of each type of segment to reflect his approximate situation.

TRACS: In the Percentage Approach, there are twelve general categories of route geometry described in a table. A user must input the percentage of the track in the subdivision that is described by that category. For each cell with a non-zero value, the program will create several Route/Track records. For example, a user inputs that the total length of a subdivision is 100 miles, 10% of which can be described as having flat grade, low degrees of curvature. The program checks the Route/Track Percentage Reference File and finds that the M.I.T. Defaults indicate that three segments should be created with curvature of 2, 3, and 4 degrees respectively. Each segment will be 3.33 miles long with zero gradient. If another Reference file had been used, perhaps the segments would have been created with slightly different characteristics.

4.2.2.2.2 Segment Approach

The specific approach to building a Route/Track file allows a user to create a record in the file for each actual segment of track. This is a very tedious process using the Route/Track Input Module. The base case Route/Track file would most likely be created outside of the TRACS program. Information on the Railroad's main-frame computer systems would be dumped to a properly formatted flat file. In this approach, missing data is simply assigned a default by the analyst who is creating the program.

The power of the Route/Track Input Module should be exploited during the editing process. Rather than changing numbers in the flat file, the file can be called up in the Input Module Program. In this way, alternative cases can be quickly structured by changing a few important values.

The benefits of structuring the Route/Track file with the real segment descriptions become evident in the reports. The activities for each location on the railroad are very clearly presented, which is helpful in presentations to personnel at the local level.

4.2.2.2.3 Down-load Approach

The Segment Approach has an additional feature that should be very useful to some companies with incomplete information about their systems. If a file is called by the Route/Track Segment Approach, the program will check to see if any of the fields in any of the records are blank. If they are blank, then a value will be put into that field by the Input Module. The value is chosen using the same methodology employed by the program to change low level of detail inputs, whenever a high level of detail input is changed. The value is a default in that it is not based on fact. However, it is a value that reflects the typical case for this company. This is better than hard-wiring the value, as was suggested in the last approach.

The program will only fill in blank fields if the field is classified as a low level of detail. There is a minimum amount of information that must be in a file for this system to work. An example Route/Track file, with the abbreviated format, is shown in Exhibit 4 - 18. After this file is called by the Route/Track Input Module, it will contain all of the information that is found in a standard Route/Track File.

158

Exhibit 4 - 18

```
SEG1     10.00  100.0   5  0.0  0.0   40.0
SEG2      0.30  105.0   5  3.0  0.0   40.0
SEG3      5.00  110.0   5  0.0  0.0   40.0
SEG4      1.00  115.0   5  1.0  0.0   40.0
SEG5      5.00  120.0   5  0.0  0.0   40.0
SEG6      5.00  125.0   5  0.0-1.0   40.0
SEG7      5.00  130.0   5  0.0  0.0   40.0
SEG8      1.00  135.0   5  2.0  0.0   40.0
SEG9      5.00  140.0   5  0.0  0.0   40.0
SEG10     5.00  145.0   5  0.0  1.0   40.0
SEG11     5.00  150.0   5  0.0  0.0   40.0
SEG12     0.20  155.0   510.0  0.0   40.0
SEG13     5.00  160.0   5  0.0  0.0   40.0
SEG14     0.30  165.0   5  2.0  0.0   40.0
SEG15     1.00  170.0   5  1.0  0.0   40.0
SEG16     5.00  175.0   5  0.0  0.0   40.0
SEG17     0.50  180.0   5  2.0  0.0   40.0
SEG18     9.00  185.0   5  0.0  0.0   40.0
SEG19     0.50  190.0   5  3.0  0.0   40.0
SEG20    10.00  195.0   5  0.0  0.0   40.0
```

4.2.2.3 TRACS Cost Input Module

The Cost Input Module is divided into two basic levels of detail. The Low Level of Detail Cost Inputs includes the Unit Costs for different activities and Average Cost Inputs for project and maintenance gangs. The High Level of Detail Cost Inputs asks the user for data about specific gangs and about material prices.

A user can develop several cost files to reflect the differences in work gangs in different divisions, the difference in prices for material, or the cost of transporting the gangs to remote areas.

More information about the Cost Input Module can be found in Appendix 2, section 7.4 .

4.2.2.3.1 Low Level Cost Inputs

TRACS: The first type of data that can be found in the Low Level Cost Inputs is the Unit Costs that were described in the Cost File discussion. The TRACS cost file supports problems that deal with changing detailed costs or varying unit costs. The TRACS Report Module calculates the costs of each activity based on the most detailed costs. The Cost Input Module contains a simplified version of the very sophisticated cost model that is found in the TRACS Reports Module. The Reports module calculates the exact costs for a specific segment based on the materials in that segment, the traffic density, the track geometry, and the management standards. In contrast, the Cost Input Module calculates the costs on a typical one mile segment. The typical segment uses standard rail, has medium traffic density, and uses the information in the Management Policy File that is in the CALFIL.INP.

The second kind of Low Level Cost Inputs are typical descriptions of project gangs and maintenance gangs. The Cost Input Module Program displays a value in the Derived column that represents the average of all of the values currently in the detailed cost data base. For example, if a user enters a new average value for "Gang Size" in the Production Gang Low Level Unit Costs screen, that new value will be copied to Gang Size for a Rail Relay Gang, Transposition Gang, and High Low Gang. This feature can save a user time if the same variable changes in a majority of the gangs. By changing the variable in the Low Level first, only the cases that are exceptions need to be edited in the High Level Input Screens.

Potential Improvements: The Cost file contains inputs for income tax rate and depreciation rates. These are not currently used by the cost model. The design plan calls for the use of the tax rate in calculating a tax credit for capital expenditures. In addition, the plan indicates that the depreciation rate should be used to calculate various accounting reports, such as annual expense, book value, and property taxes. The sophistication of these inputs is subject to change depending on the final design of the cost model. It has not been decided if they should be used in the calculation of the Low Level Unit Costs in the Cost Input Module.

The typical gang descriptions in the Low Level Input Screen may also be copied to all Tie Production Gangs and Surfacing Production Gangs.

4.2.2.3.2 High Level Cost Inputs

The costs in this section are the most detailed costs for specific gangs. Although the material prices are stored in the Component files, the user can edit them through this module. This is a clear example that the computer file structure and the structure of the user interface are very different.

Exhibit 4 - 19

COST INPUT MODULE SCREENS

```
                    ┌──────────────┐
                    │  FINANCIAL   │
                    │     DATA     │
                    │    INPUT     │
                    └──────────────┘

   ┌──────────────┐              ┌──────────────┐
   │  LOW LEVEL   │              │   DETAILED   │
   │    COST      │              │    COST      │
   │   INPUTS     │              │   INPUTS     │
   └──────────────┘              └──────────────┘

        ┌──────────────┐         ┌──────────────┐
  ╭───╮ │   AVERAGE    │◄───────►│  LABOR COST  │
  │UNIT│ │  LABOR COST  │         │   INPUTS     │
  │COSTS││    INPUTS    │         │   BY GANG    │
  │BY   │ └──────────────┘        └──────────────┘
  │ACTIVITY
  ╰───╯  ┌──────────────┐         ┌──────────────┐
         │   AVERAGE    │◄───────►│  MACHINERY   │
         │  MACHINERY   │         │ COST INPUT   │
         │  COST INPUT  │         │   BY GANG    │
         └──────────────┘        └──────────────┘

         ┌──────────────┐         ┌──────────────┐
         │   AVERAGE    │◄───────►│   MATERIAL   │
         │   MATERIAL   │         │ COST INPUTS  │
         │    COST      │         │   BY GANG    │
         │    INPUT     │         └──────────────┘
         └──────────────┘
```

162
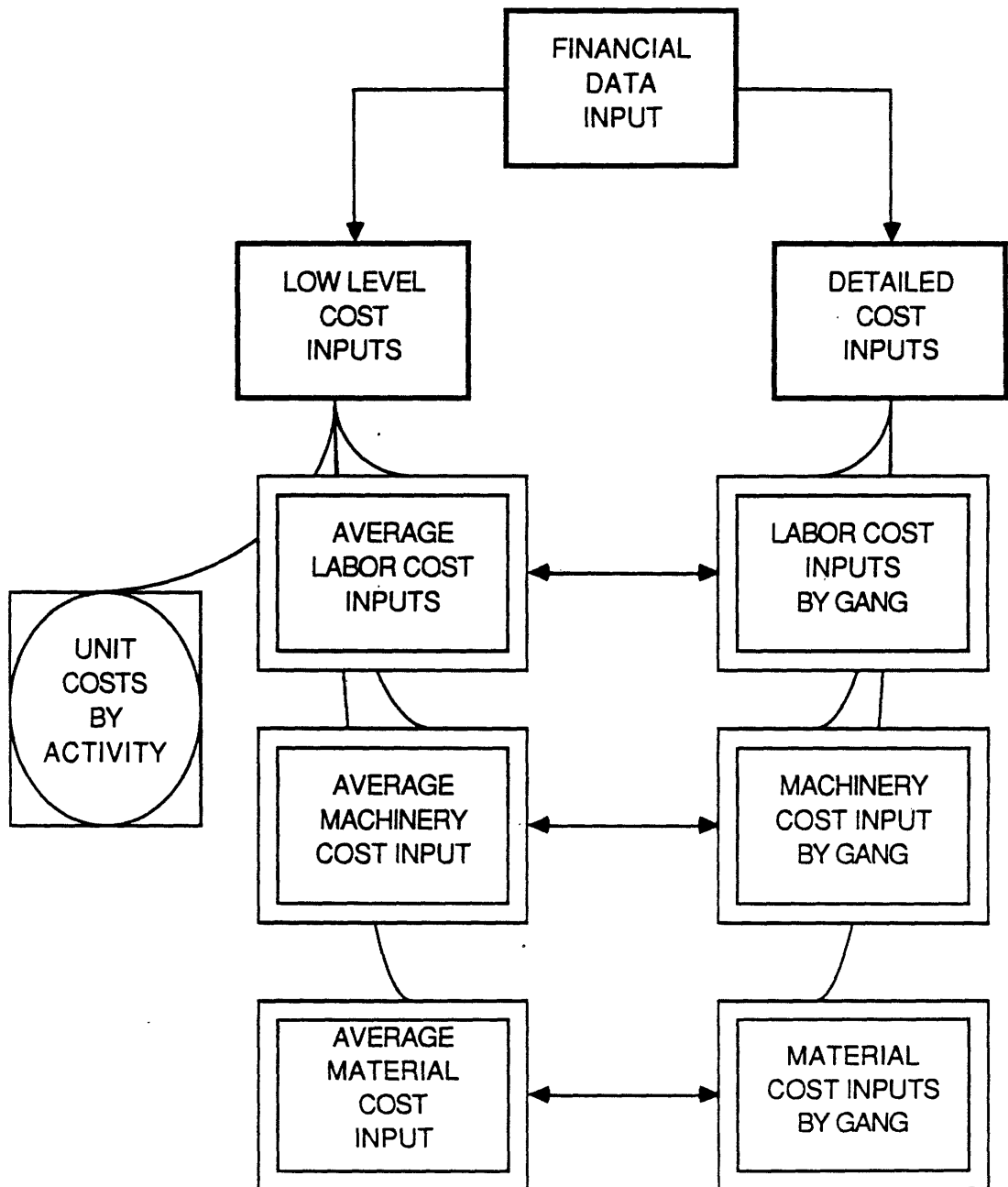
4.2.3 TRACS Report Generation Module

TRACS: The reports in TRACS are designed to meet specific needs. A user will not look at every available report at the end of an analysis. Rather, there will be a few reports that structure the output in a format that is useful for the problem at hand. The reports that are currently available look at engineering statistics and costs associated with rail projects and rail maintenance.

The appearance of the reports was designed for use in presentations to senior level managers. There are several levels of detail available to a user. Depending on the audience and the importance of the analysis, a user should choose reports with more or less supporting details.

Finally, each report can be saved in a file for later use. If this option is chosen, the report will be printed as it appears on the screen to a file. The file header will contain additional information that does not appear on the screen version of the report. That information includes the time and date the analysis was run, the name of the user, and the name of the important input files that were used. More information and example reports can be found in Appendix 2, section 8.

Potential Improvements: The same reports can be made available for tie activities and surfacing activities as well. After these are implemented, summary reports that describe the cash flows and economic statistics for the total track structure should follow.

A future version of the Reports Module could contain reports that are tailored for use by accountants. In addition, the design calls for graphic representations of the tables. If this were to be added, a user could choose to view a graph or a table for each report, as well as move from one to the other.

Exhibit 4 - 20

REPORT MODULE SCREENS

```
                    ┌─────────────┐
                    │   REPORT    │
                    │   MODULE    │
                    └──────┬──────┘
                           │
                    ┌──────┴──────┐
                    │    MAIN     │
                    │    MENU     │
                    └──────┬──────┘
                           │
              ┌────────────┴────────────┐
              │                         │
       ┌──────▼──────┐          ┌───────▼──────┐
       │   PROJECT   │          │   CAPITAL    │
       │ ENGINEERING │          │    COST      │
       │   REPORTS   │          │   REPORTS    │
       └──────┬──────┘          └───────┬──────┘
              │                         │
       ┌──────▼──────┐          ┌───────▼──────┐
       │ MAINTENANCE │          │   EXPENSE    │
       │ ENGINEERING │          │    COST      │
       │   REPORTS   │          │   REPORTS    │
       └──────┬──────┘          └───────┬──────┘
              │                         │
       ┌──────▼──────┐          ┌───────▼──────┐
       │   TOTALS    │          │    TOTALS    │
       └─────────────┘          └──────────────┘
```
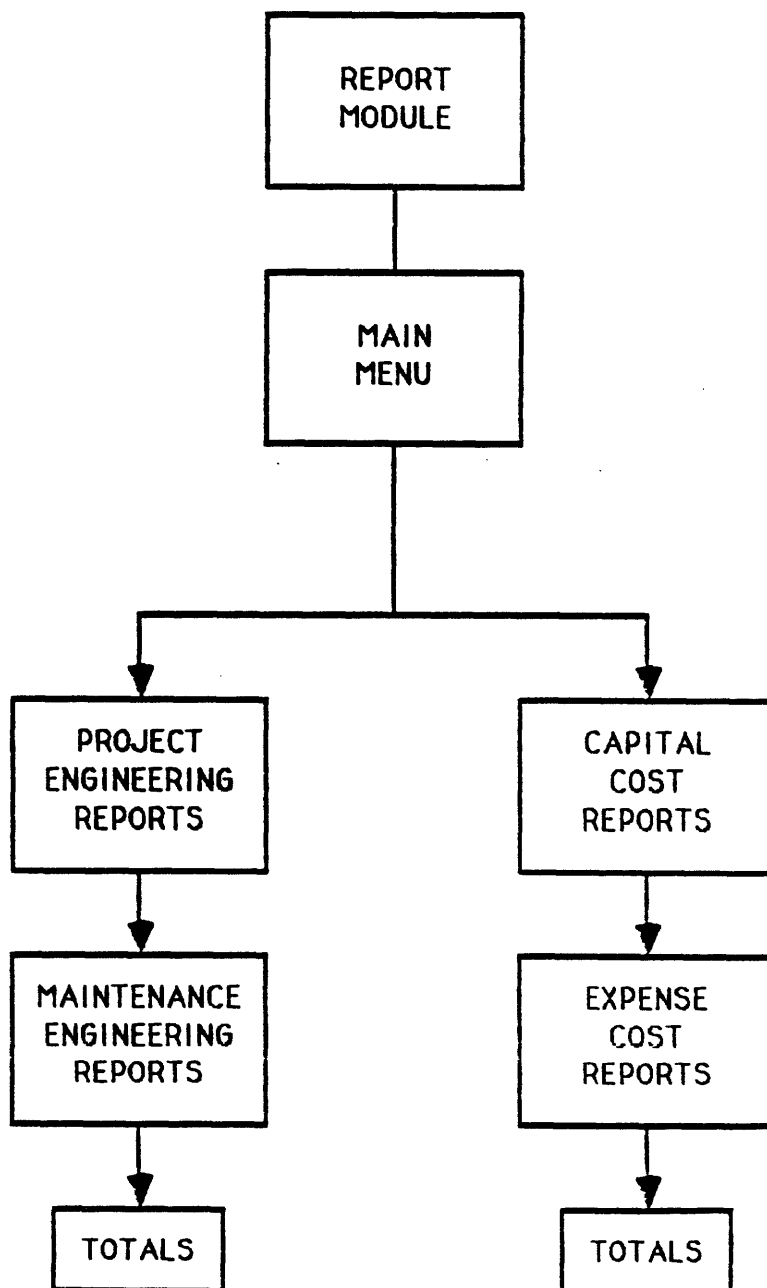
4.2.4 TRACS Control Program

The Control Program acts as a calling program to the other TRACS modules. The user running TRACS must first pass over two introductory screens that are contained in the Control Program. The third screen is the Main Menu of the Control Program. The modules that are available to that user appear on this menu. The user selects a module and edits the inputs to satisfy his needs. When he exits the module, TRACS will send him back to the Main Menu of the Control Program. The selection box on the main menu will automatically be set at the next module. This is a feature that helps to insure that in a given analysis a user will pass through all of the modules.

Some users who have become comfortable with the TRACS structure find that they prefer to edit a set of traffic files, then a set of route/track files. This is especially advantageous when similar files are being prepared. The user can easily recall the last file while working on the new one.

4.2.4.1 Controlling the Access to Install

The Main Menu of the Control Program will display the option to run the INSTALL file editors only if the file editing programs exist in the TRACS directory. In order to protect one of the three INSTALL sub-modules (Management Policy, Component and Condition, and Reference), the file editing programs should not be copied to the directory. Alternately, the file can be copied to the directory but given a different file name. The Control Program will search the file names and display only the Sub Modules that have the name which is hard-wired into the Control Program code.

4.2.4.2 PESOS

There are a few types of problems that a majority of the railroad companies can address using TRACS.

The traditional steps in applying planning models to a problem are as follows:

>   1) A base case scenario is developed in the model.
>   2) If the results are calibrated to field data, the base case can be a very close representation of the current situation in the field.
>   3) The next step is to change the input parameters that would be affected by the proposed change in policy.
>   4) The planning model is run with the alternate set of inputs.
>   5) The base case output is compared to the alternative case.

Rather than trying to calibrate the base case, a user can simply run the model and determine the percentage effect on the base case results. The sensitivity is then applied to the actual data for a prediction of what may happen if the proposed policy is implemented.

For complex analyses or analyses that must be done over and over, much of the analyst's time is spent in structuring the alternative scenarios and running the simulation models. The important parameters may be in several different files, requiring that many alternative files be built. Often many combinations of the variables must be tested.

For example, many problems involve finding the optimal combination of two variables. A case from TRACS is the problem of finding the combination of metallurgy and lubrication that minimizes the cost of RAILWEAR. Each combination must be run to determine the total costs of the system. Assuming that there are three different metallurgies and four different levels of lubrication, the deterioration model would have to be run twelve times.

The Post Economic Sensitivity OptionS, or PESOS, were developed to address this problem. After a user develops a base case, he may choose to run PESOS from the Reports Module. Although PESOS is called from the Reports Module, it is really part of the Control Program.

It is called from the Reports Module for two reasons. 1) The user is forced to enter the Reports Module, where he will likely look at the reports for the base case before choosing to run PESOS. This acts as a screening exercise so PESOS is not run unnecessarily. 2) The Reports Module must generate an input file that is used by the PESOS program.

In general, PESOS will automatically perform the steps outlined above. The user will select the packaged analysis that he wishes to perform. If the PESOS needs additional information about the alternative cases, it will prompt the user to fill out a table of inputs. The PESOS program then creates new files with the alternative data and runs the simulation program as many times as is necessary. The output from the simulation program is collected on one PESOS report. Each bridge file from the alternative scenarios is saved so a user may go back into the TRACS Reports Module and look at all of the available reports for each alternative case as well. More information and sample PESOS screens are in section 6 of Appendix 2.

PESOS

Flow of Program

Exhibit 4 - 21

```
┌─────────────────┐     ┌─────────────────┐     ┌─────────────────┐
│ User Reviews    │     │ User Chooses    │     │ User Inputs     │
│ Reports         │ ──► │ a PESOS         │ ──► │ Alternative     │
│ from the        │     │ from the        │     │ Data            │
│ Base Case       │     │ Menu            │     │                 │
└─────────────────┘     └─────────────────┘     └─────────────────┘
                                                          │
      ┌───────────────────────────────────────────────────┘
      │
      ▼
┌─────────────────┐     ┌─────────────────┐     ┌─────────────────┐
│ PESOS           │     │ PESOS           │     │ Reports         │
│ Creates         │ ──► │ Runs            │ ──► │ Module          │
│ Alternative     │     │ Necessary       │     │ Calculates      │
│ Files           │     │ Analyses        │     │ Important       │
│                 │     │                 │     │ Data            │
└─────────────────┘     └─────────────────┘     └─────────────────┘
                                                          │
      ┌───────────────────────────────────────────────────┘
      │
      ▼
┌─────────────────┐     ┌─────────────────┐     ┌─────────────────┐
│ PESOS           │     │ User            │     │ User may        │
│ Creates         │ ──► │ Reviews         │ ──► │ Review          │
│ Summary         │     │ PESOS           │     │ Standard        │
│ Reports         │     │ Reports         │     │ Reports for     │
│                 │     │                 │     │ Alternatives    │
└─────────────────┘     └─────────────────┘     └─────────────────┘
```
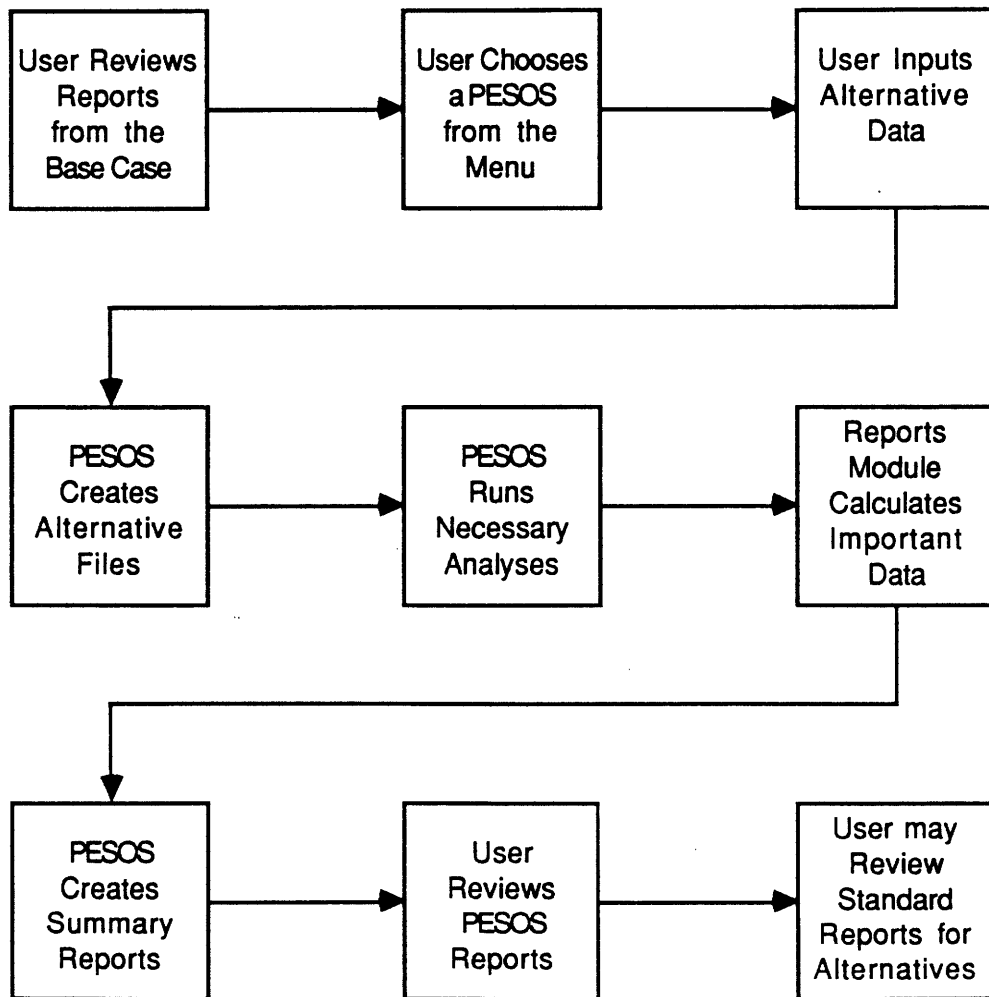
Post Economic Sensitivity OptionS

Areas Under Consideration for PESOS Development

Exhibit 4 - 22

Costing of an Incremental Traffic

Costing of Last MGT of Each Traffic Type

Testing Changing Traffic Patterns

Technology Assesment

Project Scheduling

Capital vs. Maintenance Expenditures

4.3 Summary

This chapter was designed to give the user an overview of the TRACS structure. The first half of the chapter discussed the important TRACS files. The intention was to give the reader a flavor for the complexity of the data required by the TRACS simulation models and the sheer volume of the data. The second half of the chapter briefly explained some aspects of the TRACS user interface. Examples of the Input Screens and Help Screens and further discussion can be found in Appendix 2. The objective of this half of the chapter was to communicate the fact that a user can choose the depth to which he wishes to carry out an analysis.

A typical TRACS analysis simulates a set of trains traveling over a subdivision. As an illustration of the above points, look at the following statistics regarding a typical scenario consisting of a traffic mix with two different kinds of locomotives, five different kinds of cars, and 100 segments of track. Over 4100 different values in 15 files are required to run the rail deterioration model for this scenario. By combining the information from Exhibits 4 - 23, - 24, - 25, and - 26, one finds that by bypassing the INSTALL Program and editing every file at the highest level of detail, including the Segment Approach, requires that 3300 values be input by the user. A medium level of detail in each input module, including the Segment Approach, requires a total of 500 inputs. Finally, this same scenario can be modeled with just 62 inputs using the first level of detail in each of the other input modules and the Percentage Approach to create Route/Track segments.

Although it is difficult to describe the mechanics of the TRACS programs, hopefully the reader has the impression that the TRACS Framework offers a versatile solution to the problem of building and editing the input files and interpreting the outputs of the simulation models. In the next chapter, the important methodologies that were

employed to achieve this versatility will be described. The chapter will end with a discussion of some of the comments and criticisms that have been received from the M.I.T. Track Advisory Group since the release of TRACS to the industry.

**Inputs to a Typical Analysis of Rail
Required by Each Install Sub-Module**

Exhibit 4 - 23

Sub-Module	Inputs Required
Management Policy	242
Component and Condition	243
Reference - Traffic	148
Reference - Percentage	104
Reference - Segment	88
TOTAL	825

**Inputs to a Typical Analysis of Rail
Required by Each Level of the Traffic Input Module**

Exhibit 4 - 24

Level	Description of Level	Inputs Required
1	Mix of Trains	20
2	Train Consists	50
3	Car Details	35
TOTAL		105

Inputs to a Typical Analysis of Rail
Required by Each Level of the Route/Track Input Module

Exhibit 4 - 25

Level	Description of Level	Inputs Required
1 Percentage	Subdivision Statistics	19
1 Segment	Subdivision Statistics	7
2	Segment Geometry	400
3	Segment Materials	1100
4	Segment Maintenance	1700
TOTAL		3226

Inputs to a Typical Analysis of Rail
Required by Each Level of the Cost Input Module

Exhibit 4 - 26

Level	Description of Level	Inputs Required
1	Financial Data	5
2	Unit Costs	18
3	Detailed Costs	43
TOTAL		66

5 Methodologies Used to Achieve Versatility in TRACS

The fact that TRACS has been implemented and is currently in use suggests that the approaches employed in the implementation of the model are credible methodologies. This chapter identifies the programming techniques and discusses each in a broader fashion than the last chapter. Specific examples from the TRACS model are cited.

5.1 Qualitative vs. Quantitative Inputs

One way to eliminate excessive detail is to recognize that there is value in approximating a particular situation. For example, if a train consist includes several different kinds of cars, all weighing between 110 and 115 tons, a general description for a simple analysis might assume that all of the cars weighed 112 tons. It is true that approximations like this will lead to inexact results. However, if the result of an analysis using this approximated train shows that Premium Steel Rail will save 30% in costs a year for the next five years, then further analysis with more refined traffic will add little to the already strong suggestion to "Use Premium Rail". Refining the approximation in the train mix will not change the answer. As a user becomes more familiar with TRACS, he may be quite comfortable with some results, while needing to refine the analysis for situations where the results appear inconclusive.

TRACS has incorporated screens which accommodate approximation, qualitative inputs, and data aggregation. Managers are able to input phenomena using the same terms employed by them in a conversation. For example, rail quality is referred to as being "Standard", "Premium", or "Super Premium". Tie age is "Mostly Old", "Steady State", or "New". The screens also aid the user in communicating the approximate information by offering what is called the "Percentage Approach" to developing a route file.

In the old version of TMCost, a user would have to list each individual segment of track in a subdivision. The reality of the model is that it will calculate the same costs in the following two scenarios: 1) The subdivision is divided into separate segments as they lie in the track or 2) All similar segments are aggregated into one longer segment. With the "Percentage Approach", the user inputs the percentage of track with similar characteristics in a subdivision. The program will then interpret information, such as "10% Low curvature on a Flat Grade", into several route segments which might fit this general description. In this way, a user quickly builds a route file which closely approximates the distribution of different kinds of track geometry in an actual route. If the results of an initial analysis prove interesting and/or controversial enough to merit more work, the user should go back and refine the route segment definitions.

The use of qualitative and quantitative inputs was designed to increase the vertical degree of versatility and the degree of depth. The theory was that different levels of managers thought about problems at different levels of aggregation. The analysts should still have the ability to do very detailed work, and the model should allow one analysis to progress from a very simple first iteration to a series of more complex iterations.

5.1.1 General Approach

What are general inputs to an analysis? In the most polar sense, they may include any data that is not based on actual measurements. However, that definition is rather meaningless in the realm of modelling, where the purpose is not to simulate reality exactly, but to model it in sufficient enough detail that the results can be valuable as an input to a decision making process. In TRACS the general approach includes using

175

approximations for data instead of the actual data, aggregating information into logical categories, and using qualitative descriptions to communicate the meaning of a quantitative concept.

Approximating data is virtually self-explanatory. Using approximations instead of real data does not necessarily occur because the data is unavailable, but because the time it would take to access the data base and reformat the data to a TRACS readable format would be excessive. In some cases the data may be available, but the data set is in error, and in some cases the data was never collected.

Grouping similar data into sets and dealing with the sets, rather than each piece, decreases the number of inputs that a user must give. If the same policies are generally carried out on all curves below three degrees, then it would be redundant to ask the user for a set of inputs three times. The concept of aggregation is not foreign to railroad managers who use aggregation in most of their operating policies and safety rules. For example, the FRA Class system is not a continuous spectrum but aggregates different track qualities into six groups. Operating rules that match the size of a crew with the length of a train do so by aggregating the trains into a few categories. [1]

Qualitative descriptions serve to communicate with users of the model who understand the problem but do not think about it in the same terms as the equations that are used to simulate the different processes. Many of the numbers used by the TRACS deterioration models conceptually mean very little to most railroad managers. For example, most engineers would not know the coefficient of friction on a given curve. However,

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1 Barry Baines, Superintendent Operations, CSL Intermodal, Presentation to the AAR Intermodal Productivity Task Force, Atlanta, 1989.

if asked to rate the effective level of lubrication, they would undoubtedly have a response which was cast in qualitative terms. The TRACS framework simply uses conversion tables to transform qualitative inputs to quantitative information.

One of the merits of the general approach is that it does not require a user who is very familiar with a situation to spend a large amount of time collecting data. Even if the user is not comfortable approximating information, a short telephone conversation with a field officer can often yield helpful information about a subject. [2]

The general approach is useful for screening different alternatives, in order to determine which ones have the most potential for improving the rail company. Those analyses with large savings in cost or large returns on investment are strong candidates for further research. Other alternatives that show marginal benefits to the company or results that suggest the situation might actually worsen, should be cancelled. The cost of structuring all of the alternatives in great detail was precluded.

5.1.2 Specific Approach

TRACS maintained the capability to perform very specific analysis. By using the INSTALL Program, a user can always redefine the qualitative inputs. Additional options may be added to files as well. For example, the Rail Condition File contains records that are qualitatively described as "Less that 50% deteriorated". Very specific records can be created alongside the general ones. A record might be called, "The Wear on Segment 11". The record would contain real wear measurements, rather than typical conditions. The approximations can be eliminated as well. For example, the Traffic File is a description of the number of cars that travel over a subdivision. Using the

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2 Interview with Yen Shan, Director Operations Research, CSL Intermodal, June, 1988.

Traffic input editor, the cars are aggregated into five groups of wheel loads. However, a user may still build a traffic file that contains as many records as there are kinds of cars.

Using the specific approach is sometimes necessary. For example, in a court of law an analysis is likely to have more credibility if its inputs are as rigorous as possible. Very important decisions that involve spending large amounts of capital or embarking on risky ventures merit close scrutiny. Some studies are very scientific in nature. Those analyses often deal with changing the inputs a small bit, in order to measure the sensitivity of the programs. In those cases TRACS should be used with specific inputs. Examples of such analyses include the study of different forces that result from using radial trucks versus standard trucks on the rail cars, and the effect of heavy axle loads on rail wear.

5.2 Knowledge Engineering

TRACS has the ability to take a piece of information from the user and infer another logical piece of data. This process will be referred to as "Knowledge Engineering". By nesting these logical inferences in one another, cross-linking information which is dependent on other information, and referring to a data base in order to assert missing inputs, the superstructure succeeds in "hiding" the horrific detail and allows the user to perform analysis without large investments of time. Also, the program will do all of the bookkeeping. The computer will decide in which computer files each piece of information belongs and place the values in the proper column and line of a file. Furthermore, if the program requires the information to be in a format different than that used by the input screens, the program will perform the necessary conversions.

The following sub-sections summarize the concepts that were used to achieve the ability to perform analysis at different levels and with a variable amount of user interaction.

The use of Knowledge Engineering was aimed primarily at the vertical degree of versatility. The elimination of inputs would decrease the amount of time it would take a user to formulate a problem within the model. However, by using intelligently selected defaults, some credibility is maintained within the results. The theory was that middle and senior level managers will be more comfortable using the model to study problems because of the decreased time commitment. Field level personnel will consider using the model because the inputs are simple.

5.2.1 Multiple Levels of Detail

In the TRACS Knowledge Engineering environment, a level of detail is represented by an input screen within a particular module. Each input screen takes the information given to it by the user and interprets it. The results are then passed to a more detailed input screen. In any given module, these input screens become increasingly more detailed until the final screen is actually asserting raw data directly into the computer file. The user can use some, all, or none of the default values for traffic, route, or cost information.

The inputs that would appear in each level of detail were chosen based on the sensitivity of the deterioration processes to that data. In this way the user is always guaranteed that any additional information is of less importance than what he has already input. Consequently, if an analyst has input all available data and the need arises to do an additional iteration of a particular analysis, the analyst is advised to expend his resources on obtaining the data in the least detailed screens first.

5.2.1.1 Downward Assertion

TRACS obtains values for the intermediate screens and, ultimately, for the input files through processes called "assertion" and "distillation". Assertion is a downward process. It creates details given general information. Distillation works in the opposite direction, interpreting a mass of detail in terms of the general measures used in the more general screens. Examples of each of the processes in action follow.

The only time downward assertion occurs without being accompanied by upward distillation is in the creation of a new file. The user first names the file and then proceeds to the first input screen, which is the screen containing the most important, but least specific, data. This screen displays the default values for the key inputs for this file. In the case of the Route/Track file, these inputs include such things as the Annual MGT, the length of the subdivision, and the name of the traffic file that represents the traffic mix. The default values ideally represent an average or typical subdivision. The analyst then edits the default values as required. When finished, typing <Esc> will accept the inputs currently displayed on the screen and TRACS will begin to downward assert default values. First the program will check which values are dependent on the information contained in this screen. Continuing with the example above, Rail Metallurgy is dependent on the Annual MGT. Since Rail Metallurgy is also dependent on other factors, such as speed and curvature, the computer will downward assert the metallurgy based on an analysis of several factors. In this respect, the asserted value is more than a default. It is an elegant selection of a key parameter that represents the typical case.

5.2.1.2 Upward Distillation

The values that appear in intermediate level input screens of the Route/Track File are not stored in the Route/Track file. The Derived High Level Costs are stored in the file, but they are updated each time the file is saved through the data distillation process. The route file only contains the raw data used by the program to run the different deterioration models. These intermediate values - which often take the form of indices, pointers, abbreviations, or words - are chosen based on the values found in the lowest levels of detail. The reference file contains the information used to "distill" the large volume of abstract data into a series of values that are better understood by a user.

A scenario using Data Distillation will be helpful in understanding the concept. Suppose that the Marketing Department has used TRACS as part of a study promoting the use of heavy axle loadings on a particular route. Let's further suppose that Marketing had neglected to include any medium or sharp curves in the analysis. How much effort would be required to find this error? By simply looking at the introductory route screen, someone reviewing the study would see a chart showing the percentage of the route in tangent track or in each of several categories of curvature. It would not be necessary to sort through the mass of unformatted numbers in the underlying route file. The person reviewing the analysis would immediately see that the entire route consisted of tangent track and mild curves. The percentages displayed on this introductory screen are created by calculating the total mileage in each category of grades and curvature within the route file.

Distillation is more subjective than downward assertion. Since it is always true that FRA Class 6 track is in "Excellent" condition, it is logical to assert values such as "New" for ties, "Excellent" for surface, and "Few" for cumulative rail defects. However, it is not as valid to read "New" ties, "Excellent" surface, and "Few" defects

and infer that the track is FRA Class 6. In fact, excellent track may be found in some stretches of lines with any FRA Classifications. Other information is impossible to distill. For example, the Traffic file must store the intermediate values. There is no way to capture a group of train consists from a list of cars. Some cars may appear on several trains while others are found only on one train.

5.2.2 Default Values

The Reference Module is the data base which contains the default matrices. The computer can sort through a table, match the situation with the closest case in the matrix, and print the value found in the table into the input slot on the screen. If the user never views the intermediate or low level screens, the values are printed directly to the file when the user exits that input module. Tables of operating speeds, traffic densities, and FRA Classes are contained in this section. The values found in the Reference file matrices may come from several sources. Reference files may be developed that contain information from a combination of the sources, or different files can be developed in order to study certain problems.

5.2.2.1 Historical Practices

The most important use of the Reference File is to create files that represent the typical situation. If a user creates a new file and does not edit the higher levels of detail, the information that is downward asserted should reflect what the base case is likely to be. Following that line of reasoning, the values in the Reference files should be based on the historical policies for that region of the railroad.

5.2.2.2 Literature

Some of the values that are asserted are based on acceptable engineering practices. These are found in the American Railway Engineering Association standards. For example, the value for super elevation is calculated using the standard equation. Since curvature and FRA class are both found in the low level of detail, the program can infer speed and calculate the inches of super elevation.

5.2.2.3 Expert Opinion

It may not be useful to look at historical data for some information. For example, the Traffic input editor automatically asserts a typical traffic mix when a user creates a new traffic file. It would be best if this mix reflected the typical mix for a railroad company. In cases where a user was not familiar with the traffic characteristics, the error in the results would be minimized. In situations where a company has had a recent marketing effort or traffic patterns have shifted dramatically, it would be better if an expert outlined what the traffic was expected to be over a railroad, rather than using the historical data.

5.2.2.4 Optimization

Some railroads are trying to find the lowest cost set of policies by using optimization techniques. If a research department produces a mathematical program that suggests a certain policy change, the program can be validated by using its suggested set of policies in a simulation of historical data. In terms of the TRACS program, an Operations Research Department may have found the low cost combination of metallurgy,

grinding, and lubrication. An alternative Reference file could be built which would assert all of the alternative policies as defaults. This would be much easier than editing each segment individually.

5.3 Separating the User Environment and the Programming Environment

The user often thinks about problems in a much different manner than the way that that problem would be best structured for an analysis inside a model. A user is biased in his perception because of his background, his expertise, and his vested interest in the outcome of the problem. A computer is deterministic. It doesn't value one input more than another unless the formulation places more weight on the significance of one input. However, the programs need all of the inputs in order to run.

TRACS attempts to structure the user interface in a framework that is closer to a manager's approach to a problem than to a model's approach. A manager does not start out thinking about a problem in terms of all of the details. Thus, TRACS hides the detail in the INSTALL program. Likewise, a manager does not begin by thinking about the problem in terms of other parts of the company, but rather how the problem affects his department. Thus TRACS separates the inputs and the reports by subject area.

5.3.1 Modular Input Programs

One of the difficulties of TMCost was that the users were not made aware of which inputs were most important to the formulation and which were not. Part of that problem was addressed in TRACS through the levels of detail. Splitting the inputs into different areas of expertise also addressed this problem. The areas of expertise in TRACS are Traffic, Route/Track, and Cost. They may be closely associated with the Marketing

184

Department, the Engineering Department, and the Finance Department, respectively. The input programs can be run as stand-alone programs by each department. Within the TRACS framework a user can skip over the input modules that do not interest him. Before running an analysis, he may choose files that approximate his general situation, without ever having to edit one input within those files.

The clearest example from TRACS which demonstrates that the user interface was not constrained by the computer structure lies in the Cost Input Module. Although the prices for the different materials are input in this module, they are not stored in the Cost File. The prices are stored in the Component files, which also contain very technical information about the various parts of the track. This file structure eliminates the need for listing the components in two different files.

5.3.1.1 Separating Inputs by Area of Expertise

The separation of information by area of expertise encourages users to work at different levels of analysis. A user will input the values with which he is most comfortable. In chapter 2 it was noted that interdepartmental planning groups are frequent users of planning models. This structure provides a simple way for the group to divide the work required in setting up a base case and the alternative cases.

Some users admit their lack of expertise in an area but often have enough knowledge to make reasonable estimations. Therefore, a user from the engineering department may be quite comfortable working in all of the levels of detail in the Route/Track Input Module. He may have a vague notion of the traffic description on a line as well. If his initial analysis shows encouraging results, he can ask someone from the traffic department to fill in the Traffic Input Module. He does not have to be an expert in any other field in order to complete the information about the traffic.

5.3.1.2 Separating Inputs by User Responsibility

The inputs to the program are also partitioned into parts by the responsibility of the user. In simple planning models the input data that is noticeably absent from the user's perspective is often included in the model in the form of assumptions that the developer has hard-wired into the system. Complex models ask the user to identify as much information as is needed by the model. Therefore, a user must be well-versed in all of the complex formulations of the model in order to develop rigorous analyses. The INSTALL concept in TRACS gives users with responsibility for understanding those assumptions the ability to change the assumptions in the model, but the difference between TRACS and other complex models lies in the fact that the detailed information can be concealed from the users who wish to use the model for less complex studies.

In a way, the partitioning of the INSTALL inputs is consistent with separating the inputs by user expertise. There are some people in the company who are experts in details. They have a broad base of knowledge that has been gained through experience. They may be members of industry committees that share information, or they may be very skilled at retrieving information from the company's mainframe computer system.

5.3.2 Modular Computer Structure

The modular structure of the computer program is the primary reason that the TRACS model can be useful at intermediate stages of development. Given the stand alone nature of each of the programs, they can be run without the complete package being in place.

In addition, the modular programming structure enabled many different programmers to work on the package at once. After the file structures were specified, each programmer was responsible for one of the programs that either wrote to a file or read

from a file. The TRACS development effort had four programmers working in parallel. After several months of independent programming effort, it took less than a week to have the eight modules and the control program working together as one package.

The different input programs can be upgraded, without having to worry about conflicts with other programs. For example, Version 1.0 of TRACS contained a temporary Cost Input Module that was only a file editor. Version 1.1 contained an upgraded version of the program. The change did not affect any of the other input programs or the deterioration model. The programs interact through files. If the file structure is changed, each program that reads and writes to that file must be changed.

5.3.2.1 Files

One of the benefits cited by Van Dyke that resulted from reprogramming the SPM unto a microcomputer, was the use of files instead of matrices that were internal to large programs. The file structures provided a way to easily add on new modules. His hypothesis was later proved correct with the advent of the Automatic Blocking Model and the Train Scheduling System which both use the SPM file structures. [3]

The structure of the Route/Track file enabled the TRACS development team to build the Down Load approach, a feature that was not in the original TRACS plan. During the development effort it was suggested that an incomplete file could be built from a mainframe data dump. With a few small changes to the Route/Track Input Module, a communication device was built between TRACS and any railroad mainframe.

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3 Carl Van Dyke, "Microcomputers and the Service Planning Model: Designing a More Useful Tool for the Rail Industry", M.I.T. MST Thesis, June, 1981.

5.3.2.2 Other Models

The modular program structure decreases the problems of introducing other deterioration models into TRACS. The RAILWEAR model is not dependent on the existence of other deterioration models. Therefore, test versions of the tie model can be incorporated into the package without having to worry about the RAILWEAR program.

If another research team within a railroad wants to build other models, it can use the existing TRACS data bases and the TRACS reports modules with its models.

Having a framework that ties all of the models together is an important feature of modular programming. The TRACS framework is a start, but some more thought should be given to problems that arise when the files need to be changed. For example, the introduction of a Signal deterioration module will require variables that were not anticipated in the original TRACS design.

5.4 Control Program

The purpose of the Control Program is to guide the user through the network of modules described above. The Control Program offers the user a chance to select which input modules to run. The Control Program was designed to address the problems of users who were not familiar with microcomputers and DOS commands. A more versatile control program could include menus that allowed the user to erase or rename files.

5.4.1 Avoid DOS

The Control Program allows the user to review the input files that will be used in a run before running an analysis. If any of the files are incorrect, the user may choose a new file from the list. In TMCost, this simple exercise required the use of a text editor and a knowledge of the DOS commands.

5.4.2 Do the Bookkeeping

The control program also prompts the user to enter his name and a name for the analysis. The program marks this information, along with the date and time of the analysis, in the bridge file. This information is then available in any reports that are generated from that bridge file.

5.4.3 PESOS, Prepackaged Analyses

The Post Economic Sensitivity OptionS are designed to allow a user to set up a series of analyses with a minimal amount of effort. Most planning models were designed to be used to address certain kinds of problems. PESOS is a control structure that allows that user to run the analyses in batch. This concept is not new; there are batch features on the RECAP model. However, PESOS takes this idea a step further. After setting up a base case, a user does not have to create the files for alternative cases. Within the PESOS input screens, a user may specify the variable that he would like to test. The PESOS program, which is an extension of the Control Program, will create the files and run the series of analyses.

PESOS also helps to organize the output from the series of analyses. Instead of creating a set of output files and making the user compile the information, the PESOS program

produces reports that summarize the results of the test. Since these are analyses that are done on a frequent basis, the reports are designed to answer the specific question. Only in rare cases should a user have to generate other reports. However, the bridge files for each case are saved so a user could produce any TRACS report he wishes.

5.5 Application Specific Reports

The TRACS Reports Module is a very important aspect of the package's versatility. A planning model development would be fatally flawed if time and effort were spent in designing and implementing a versatile input procedure, only to find that if the reports were nothing more than the raw output from the model. The reports must be tailored to serve the same people that the inputs were meant to capture as users of the models.

5.5.1 Aesthetic Formats

The Reports that are available with TRACS were designed to be versatile and useful. It is not expected that every user will ever want to routinely view every report that is available. However, by including many options, it is probable that at least one report exists which can be relevant to a particular analysis. Each of the reports was designed to be "Board Room Presentable". The clear presentation and specific focus of the reports will enable them to be used as attachments in memos, exhibits for technical papers, and slides for presentations.

Just as the inputs could be aggregated into groups, the outputs also are presented at different levels of aggregation. A user may look at costs for projects, costs for routine maintenance, or the two together. One report shows the costs broken down by materials, labor, and equipment for each year, while another report shows just the totals.

The inputs are separated by user expertise, and the Reports Module follows suit. Reports are available for engineers, budget analysts, and economists. Others are planned for accountants.

5.6 Other Features

There are many features in TRACS which are not in vogue, such as "knowledge engineering", but they contribute to the versatility of the model just the same. If planning models are going to be successfully used by field personnel, there must be features to insure that the model is not abused. The INSTALL protection was implemented for this reason. The other features that address this problem are range checking and on line help. In order to give the package credibility with high level managers and encourage them to continue funding the program, the M.I.T. Track Advisory Committee made it clear that an aesthetically pleasing environment had to be created. These features address that goal as well.

5.6.1 Performing the Same Analysis as TMCost

Version 1.0 of TRACS contained what turned out to be a major flaw in its design. Although there were 20 reports offered by this version, a user could not duplicate the one type of analysis offered by TMCost. During the restructuring of TMCost, the capability to do the exact kind of analysis provided by TMCost was lost in TRACS. There was no reason for not including that report in the initial version of the model. It was simply not a priority. However, the development team now recognizes that a key part of restructuring a planning model is maintaining a link to its predecessor. The members of the committee who had exposure to TMCost wanted to start learning TRACS from a frame of reference with which they were familiar. That oversight was corrected in Version 1.1, and a lesson was learned.

5.6.2 Example Files

A collection of prepared files is included on the disks that were distributed with the model. These files are useful for instructing first-time users, but they may also be useful inputs to analyses where the user lacks the time or expertise to develop his own files. Different combinations of these files can be used to study the sensitivity of some inputs.

The prepared files may be tailored to reflect more accurately a real-life situation. For example, while the traffic file named HEAVY.TRF lists 7 heavy unit trains a week, there may only be 5 in a particular real-life situation. It would be very easy to change the number of trains in each category and run the model. In this way valuable time is saved which would otherwise be required to build completely new files.

5.6.3 Format and Range Checking on Inputs

Every input has a range check and a format check. The program will not allow the user to input data that is not "sane" . If the computer wants a number, it will reject a word. If the value the user tries to input is out of a reasonable range of accepted values, an error message will be displayed. In these cases the user should first look for typing errors, check the help screen for the required units and format, and finally check the manual for a detailed account of what the program needs. The default values will always be the typical case and very reasonable. In general, if the user does not understand an input or does not have data available on it, the best approach is to skip the input and stay with the default.

5.6.4 On line Help

There is an On-Line help facility everywhere in TRACS. When editing an input, the user can look at the required format, the options available, or the definition by pressing <F1>. A pop-up screen which contains the information will then appear. Some of the help screens include conversion tables which help a user transform inputs from qualitative to quantitative format. Other help screens offer information that gives examples of typical policies and the proper way to enter those policies into TRACS. The input may be asking for amount of grinding in terms of "inches per pass". The help screen in this case relates "inches per pass" to the number of grinding wheels and the speed of the grinding machine. Other inputs which require associated parameters from INSTALL will display an index of the available options. At the input slot for ties the program will go to the INSTALL file and copy all of the legitimate options to the help screen.

5.6.5 Graphics

The graphics capabilities of the Princeton Transportation Network Model was the chief reason given for its success at versatility by the experts in chapter 2. Although there are no graphics currently available in the TRACS Reports Module, they have been in the design since the beginning. Graphs are used at all levels of management to summarize the results of analyses. In order to increase the versatility of the model, graphical representations of the reports should be available. This would reduce the time required by a user to produce them outside of the system, help users to understand reports that are outside their area of expertise, and promote the use of the model at higher levels in the organization.

5.7 Summary of Methodologies used to Achieve Versatility in TRACS

This chapter looked at some of the methodologies that were employed by the TRACS development team. Perhaps some of the concepts used in the TRACS effort may be applied in the restructuring or development of other planning models. However, one must consider if the methodologies, or TRACS for that matter, were successful in achieving the level of versatility that was desired. Because the model was only released two months ago to the industry at large, it is difficult to judge if TRACS will ever be used in all of the 14 different categories defined in chapter 2.

Exhibit 5 - 2 summarizes each of the methodologies used and indicates if the technique was employed by TMCost, TMCost2, or TRACS. This exhibit shows the evolution of the versatility. Exhibit 5 - 3 compares TRACS to the most versatile models discussed in Chapter 2. In conclusion, TRACS appears to have a level of versatility commensurate with the most versatile models listed.

Summary of the Methodologies Used to Achieve Versatility in TMCost, TMCost2, and TRACS

Exhibit 5 - 1

Methodology	TMCost	TMCost2	TRACS
Qualitative Inputs		Yes	Yes
Levels of Detail			Yes
Downward Assertion			Yes
Upward Distillation			Yes
Default Values		Yes	Yes
Historical		Yes	Yes
Literature			Yes
Expert Opinion		Yes	Yes
Optimization			
Modular Input Programs			Yes
Inputs Separated by Expertise	Yes	Yes	Yes
Inputs Separated by Responsibility			Yes
Modular Computer Structure	Yes	Yes	Yes
Use of Files		Yes	Yes
Control Program	Yes	Yes	Yes
PESOS, Prepackaged Analyses			Yes
Application Specific Reports			Yes
Aesthetic Report Formats			Yes
Example Files		Yes	Yes
Format and Range Checking on Inputs			Yes
On-Line Help			Yes
Graphics			

**Summary of the Methodologies Used to Achieve Versatility
in TRACS and Other Versatile Models**

Exhibit 5 - 2

Methodology	SPM/ABM	RPM	PTNM	RECAP	TRACS
Qualitative Inputs	Yes		Yes		Yes
Levels of Detail	Yes		Yes		Yes
Downward Assertion	Yes		Yes		Yes
Upward Distillation					Yes
Default Values	Yes	Yes	Yes	Yes	Yes
Historical				Yes	Yes
Literature			Yes	Yes	Yes
Expert Opinion		Yes		Yes	Yes
Optimization	Yes	Yes	Yes		
Modular Input Programs	Yes		Yes		Yes
Inputs Separated by Expertise					Yes
Inputs Separated by Responsibility					Yes
Modular Computer Structure	Yes		Yes		Yes
Use of Files	Yes		Yes	Yes	Yes
Control Program	Yes	Yes	Yes		Yes
PESOS, Prepackaged Analyses		Yes	Yes		Yes
Application Specific Reports	Yes		Yes	Yes	Yes
Aesthetic Report Formats	Yes	Yes	Yes		Yes
Example Files					Yes
Format and Range Checking on Inputs					Yes
On-Line Help			Yes		Yes
Graphics		Yes	Yes		

196

6 Applying TRACS to Different Problems

There are various problems in the rail industry that involve maintenance of way modeling. The extent to which the engineering issues contribute to the problem differs with different classes of problems. Since TRACS has not been available to the industry for a very long period of time, there have been no actual documented studies using the model. The objective of this chapter is to outline how TRACS may be used to address a selected set of problems. The substance of the chapter contains specific problems that were chosen to demonstrate how TRACS can be used in different ways and by different people.

The following discussions are not case studies of specific situations. Instead, they are broad descriptions of problems. Based on the kind of analysis and the importance of the decision, one can presume to know who makes the final decision. It is assumed that the reader will look to these examples as guidelines when addressing real problems within a company. The suggested approaches are based on the plan that the M.I.T. development team had in mind when designing TRACS. Future case studies as well as attempts to use the model in real situations may provoke others to devise better ways of exploiting the power of TRACS.

The following cases make a few basic assumptions about the use of TRACS within the hypothetical company that would be applying the model. The cases assume that TRACS is used as an input to management decision-making on a regular enough basis. Also, some group in the company supports the model. Therefore, there are INSTALL files that represent the typical management policies in the company, typical descriptions for the common types of trains, typical descriptions of the train mix on the average line, and typical route and track data. A TRACS base case would consist of a Traffic file and a Route/Track file that would describe in detail the characteristics of every subdivision. The company does not maintain such a base case since that would require building over 500

files. Instead, it has classified the subdivisions into broad groups and maintains generic files that represent each group. In a similar fashion, it has classified the traffic over the various subdivisions into broad groups as well. There are traffic files that represent each group. The files that are available are shown in Exhibit 6 - 1. If a base case is needed for a specific subdivision, there is data available on the company mainframe. Data which is more than a year old is stored on tapes, resulting in a long turn-around time for data retrieval. This process requires about three weeks of effort.

With those assumptions in mind, the following cases describe how TRACS could be used to address the specified problems.

Exhibit 6 - 1

A: TRAFFIC FILES	DESCRIPTION
Heavy Traffic	More than 50% of the tonnage is either in unit coal trains or in unit grain trains with 100% empty returns. There are also a few merchandise trains.
Mixed Traffic	There is very diverse mix of trains and cars. This is the kind of mix that would be expected on very busy subdivisions which are near cities.
Fast Traffic	This traffic is marked by the presence of priority intermodal trains or passenger trains. The majority of the tonnage is split between freight in mixed trains and in unit trains. The tonnage travels at much slower speeds.
B: ROUTE/TRACK FILES	DESCRIPTION
Mountainous	This route is through the mountains. There are many curves, with a few being the sharpest in the system. There are also a few steep grades.
Rolling Hills	These routes have many curves, but they are not severe. There are a few gentle grades as well.
Flat and Straight	Describes most of the main line track miles. There is still a representative number of curves, but none greater than four degrees.

6.1 Technology Assessment

Railroad managers must analyze the technology that is best for different scenarios. Equipment managers must decide if it is better to buy specialized freight cars or cars that can be applied in several lanes of service. Operations managers must look at the differences that result from running a few long trains or many short trains. Likewise, engineering managers must choose track materials for different situations. The problem for engineers is that there are different qualities of materials available from the same manufacturer and there are different manufacturers. For this example, the problem of choosing the rail metallurgy with the lowest life cycle cost will be

addressed.

Ignoring this problem could cost the company several million dollars a year. In the absence of a company policy, it is likely that the individual road masters would make reasonable decisions about the proper rail to use. However, there are several reasons why a system policy is desirable. Experience has shown that some road masters do not understand life cycle costs and replace the rail with what was there previously. Some road masters think that minimizing capital costs will make them look good, while others try to have the best looking tracks in the system. Company policies will act as guidelines to the road masters. They will also make the allocation of resources to different subdivisions a more objective process.

The decision that dictates the system policy will be made by the Chief Engineer of Rail or a Director of Economic Analysis. The Road masters still have the option of asking for a different metallurgy, but they must defend their reasoning to the Regional Engineer who has the final approval.

The economics of technology assessment are dependent on the technology of the material and on the technology of the maintenance processes. Different maintenance may extend the life of the material. The other major factor in the analysis is the price of the materials. The managers at the system level have several months to perform this analysis, since rail relay can occur only in the summer season. Once the company policy is set, it needs to be reviewed once a year. If there were any major breaks in technology or a significant change in prices, then the analysis should be redone, and a new set of policies released to the field.

6.1.1 Recommended Level of Analysis

The company policy must be applicable to the complete railroad system. The rail metallurgy that a road master should use in a certain segment will be based on the kind of traffic, the annual MGT, and the degree of curvature. This railroad believes that the grinding policy should not be a function of the metallurgy. Furthermore, the lubricators on this road are all mounted on the locomotives. Therefore, on the average, every curve typically gets a medium level of lubrication. This eliminates the consideration of maintenance policies. The intention is to distribute a look-up table to each road master. A simple example is shown in Exhibit 6 - 2.

Example of a Company Policy for Rail Metallurgy

Exhibit 6 - 2

CURVATURE	ANNUAL MGT	TYPE OF TRAFFIC	METALLURGY
0 - 1	> 0	Mixed	Standard
0 - 1	0 - 40	Heavy	Standard
0 - 1	40 - 100	Heavy	Premium
2 - 5	< 10	Mixed	Standard
2 - 5	10 - 40	Mixed	Premium
2 - 5	> 40	Mixed	Super Prem.
2 - 5	< 40	Heavy	Premium
2 - 5	> 40	Heavy	Super Prem.
6 - 10	< 5	Mixed, Heavy	Premium
6 - 10	> 5	Mixed, Heavy	Super Premium

The INSTALL program will be necessary for this analysis. Since it is up-to-date, it contains the most recent calibration parameters from the AAR for each metal. It also contains the current company policy on rail replacement. In order to test alternative strategies, three management policy files should be created. In the first, standard rail should be chosen as the replacement choice for every situation. The second and third files should be similar, using premium and super premium metallurgy respectively.

As stated in the introduction, the traffic module has already been run by the traffic department, and typical files for mixed traffic and heavy traffic have been prepared. A set of Route/Track Files should be developed using the Segment Approach.

The user will need to run a complete spectrum of analyses in order to identify the least case cost for each scenario. Some of the obvious decisions can be made at the start, for example the choice to use standard rail in tangent track. It is not obvious that some of

the options can be ignored along the way. For example, if an analysis shows that premium rail has a higher life cycle cost than standard, it does not follow that super premium also has a lower life cycle cost. The life may be significantly different.

An initial file should be built that contains one segment. The user will not have to set the lubrication and grinding codes because the program will downward assert the typical amounts from the Reference File. The user should set the Condition code to the worst condition. This is reasonable since the decision to be made deals with rail that is to be replaced. By choosing the "Worn Out" condition, the metallurgy in the Route/Track File will not need reset each time. The initial file should be saved, so it can be called back, edited, and saved to a different name. The critical parameters that should be changed in each file are the curve and the MGT. Assuming that there are 10 curves and 4 groups of traffic density, 40 route files should be made. The Chief Engineer of rail, has already filled in some of the blocks in the table using his expertise, so only 30 of the files need to be built.

Alternatively, the same file could be edited at the end of every analysis. Technology assessment will have to be done for ties and surfacing as well, however, so it would be expedient to keep a library of files.

A user will have to run an analysis for each combination of the three Management Policy files, the two traffic files, and the 30 route files, making a total of 180 runs. As an aside, this is the kind of analysis that would exploit the power of PESOS.

6.1.2 Suggested User of Model

This analysis uses the INSTALL program and requires the user to develop 30 Route/Track Files at the third level of detail. In addition, the deterioration models must be run many times. This is clearly a job for an analyst. The Chief Engineer would

likely review the results and base his decision entirely on the TRACS outputs.

6.1.3 Recommended Reports

The report that should be used for this analysis lists the net present value of all cash flows during the planning horizon. Other statistics are calculated as well. However, the metallurgy that produced the lowest NPV is the choice that minimizes the life cycle costs for each scenario.

6.1.4 Improving the Analysis

Suppose that a road master requests a review of several of his five degree curves and makes a good case to his superiors. He feels that the traffic levels on his track merit better rail. The above analysis would be made more rigorous by developing a traffic file that matched the road master's territory. It may be helpful to bring the road master into the office and let him describe the traffic mix at the first level of detail. In this way he feels that he has helped in the review process and better understands how the decisions are made.

This time only three runs of the model must be made, one for each type of rail. The decision should be made using the same report, but in order to help the road master understand life cycle costs, a report showing the difference in project schedules may be useful as well.

6.2 High Productivity Machinery

A few companies have experimented with very expensive machinery that improves by nearly 300 percent the rate at which track rehabilitation can be performed. The problem

that faces a budget officer of the company is whether the higher levels of productivity compensate for the high price of the machine. This question becomes more difficult for companies who already own one or two pieces of the high productivity equipment. There is a downside risk that there will not be enough work to utilize the machine at capacity. The equipment manufacturers have responded by offering to rent the equipment to railroads. This case analyzes how a budget officer could use TRACS as an input to the decision to rent the high productivity equipment or to purchase standard equipment.

The impact of this decision on the company is rather minimal. There is no fear that the standard equipment won't be fully utilized because of its lower productivity rates, and the high productivity equipment can be sent back to the lessor at any time without a penalty.

In this case the budget officer of the company must make the final decision. He will consider the TRACS output along with his availability of capital, the labor agreements that are in place, and input from the traffic department. The budget officer is not pressed for time since he begins preparing the budgets for the company one year prior to their approval by the board of directors.

6.2.1 Recommended Level of Analysis

The TRACS input to this decision is only one issue that will be considered. Therefore, little effort should be expended in the analysis. TRACS can be used as a calculator to compute the cost per mile for a rail relay, given the cost of the machinery, the gang size, and other significant data.

The current INSTALL files contain Rail Relay productivities for the standard equipment. The first analysis will use the prepared maintenance policy file. Therefore, the

user can skip all of the modules before the Cost input module. The High Level cost option should be used to edit the data relevant to rail relays. Data should be entered for gangs using the standard machinery.

The second analysis requires the user to change the Management Policy file. The Relay productivities must be increased for the better machinery. Even if the user is not familiar with the productivities, he can approximate the fact that the new machinery is three times more productive than the standard. After saving the INSTALL file to a different name, the user should change the inputs in the cost file to reflect the different gang size and the different costs.

6.2.2 Suggested User of Model

This is a very simple analysis. It is reasonable to expect that a budget officer could follow these instructions and perform the analysis. The fact that the INSTALL file needs to be edited may require that the officer obtain a copy of the INSTALL editor if he does not already have one.

6.2.3 Recommended Reports

The reports module and the deterioration models do not need to be run for this analysis. By comparing the cost per mile of the two scenarios, which is found in the form of a Derived Low Level Unit Cost in the low level option of the Cost Input Module, the budget officer can determine which solution will have the lowest production costs. This information can be combined with the other inputs of the decision.

206

6.2.4 Improving the Analysis

The TRACS model could be used to address the problem of equipment utilization. For example, if the railroad was going to need three standard relay gangs every year for the next several years, then it may be better to buy the high productivity equipment. This simple analysis is likely to lead to a discussion regarding the purchase of the equipment. The budget officer might donate his work to an interdepartmental productivity task force. This would be combined with the engineering department's TRACS analysis that predicted the project schedule for the next five years.

The latter analysis would not have to be very detailer. As long as it demonstrated that the amount of work would be above the threshold required to purchase the machine, that would be sufficient. In a marginal case, where it was unclear if there would be enough work to fully utilize the new equipment, the marketing department would probably be the deciding factor. They would consider such things as the cost of train delay and slow orders.

6.3 Costing a Service

The marketing department must decide if they should compete in certain markets. If they decide that they can offer a competitive alternative, then a campaign will be launched. One of the inputs to that decision is incremental cost of the infrastructure. A marketing lane often crosses several subdivisions. The initial analysis will determine if the company should enter the market. Later analyses will develop actual costs for profitability analysis and rate negotiations.

The marketing department has limited resources which should be targeted to the highest potential profit areas. This analysis would help measure the approximate costs for the proposed service. By considering some market demand predictions, an analyst could

associate projected profit levels for different lanes. The marketing effort would then be centered in those lanes. The alternative would be to distribute a little effort in all of the lanes. The final profitability of the company would be quite different. In addition to the impact on the bottom line, the analysis will help formulate the strategic plan. In the long run, this will create an image of the company that is well defined from the customer's perspective. Therefore, the analysis is an important input to the decision, along with other cost models and demand models.

The decision to enter certain markets will be made by senior level management. They will probably only consider the total cost of service in each lane. The low level mangers will likely develop the reports that will be presented to the senior level management. The low level managers will be responsible for combining the outputs from the operating cost models, track cost models, and financial cost models.

This is a strategic type of decision, not made in response to an emergency or a pressing matter. Therefore, the lower level managers would have some time to develop a few analyses.

6.3.1 Recommended Level of Analysis

Assuming that there is a set of lanes under study, the lower level managers must develop the incremental costs of adding traffic to each lane. The first step is to identify the nature of the route in each lane and the nature of the current traffic.

As mentioned above, some lanes may have a diverse route. Consider the example of the Chicago to Philadelphia traffic lane. The first two thirds of the route is flat and rather straight, since it travels over the Midwest. The second part of the route goes through

the Appalachian Mountains, terrain that would be best described as rolling hills. The traffic mix along the route is basically the same. It would be described as a mixed traffic. Similar descriptions should be developed for all of the proposed lanes.

To structure a base case the manager should choose the prepared files that match the general description of the lane. In the Chicago to Philadelphia example, the lane would be split into two parts and analyzed separately. For this analysis, the crucial figure is the incremental cost per mile. In the first level of detail, therefore, the length is not an issue. At a minimum, the user should input the current annual MGT.

If the user did not want to use the traffic PESOS to do the analysis, he would then have to develop alternative route files which showed a higher level of traffic, in the form of a higher level of MGT. This number must be edited for each route segment in the second level of detail.

6.3.2 Suggested User of Model

Since the base case will be prepared using the available generic files, it is reasonable to expect a low level manager to build the base case. If the manager decides to use PESOS to build the alternative files and look at the incremental cost, that would be acceptable as well. However, if each alternative route file were developed from the Route/Track Input Module, that would take some time, and an analyst would most likely be called upon to build the files and run the cases.

6.3.3 Recommended Reports

It is recommended that the traffic PESOS be used for this analysis. Since the problem is to cost additional traffic on a line, the traffic PESOS option that allows a user to enter a new mix of traffic should be chosen. This program will build the alternative route

files, including the increase in the annual MGT, and run the cases. The PESOS will also calculate the Equivalent Uniform Annual Cost for the base case and the alternative cases. The Report will show both figures plus the difference. The difference is the incremental cost which can be associated with the additional traffic. If the user did not input the actual length of the routes for each lane, he should normalize these figures to an incremental cost per mile.

If the user wanted other statistics, they would be available in the Subdivision Statistics Cost report in the TRACS Reports Module.

6.3.4 Improving the Analysis

After the above analysis is finished, the senior level managers will decide which lanes they should target. At this point, a marketing campaign will start. The company will publish prices that can be used by any customer. These prices are determined by market experts who try to determine what price the market can bare. Since these lanes were specifically chosen for the potential profitability, it is likely that the prices will be well in excess of the incremental cost that was calculated by the above analysis.

Large customers will approach the company about rates. Before entering the negotiations the company should develop a firm price floor based on the incremental cost. This would require modeling the lane in greater detail. It would still be acceptable to use the percentage approach, but the track charts should be examined closely so the percentage of each type of segments is a better approximation than the typical files used above. In addition, a traffic file should be developed for that lane which represents a closer approximation to the traffic mix. This should be done at the train level, since the typical consists from the system will correspond to the consists in this lane.

6.4 Different Problems, Different Levels of Analysis

In summary, there is a list of different types of problems in Exhibit 6 - 3. These problems are representative of the problems that railroad managers and researchers discuss as potential cases for TRACS analyses. Accompanying each class of problems is a suggested approach that could be used to study the situation. In general, using levels of detail beyond those recommended in the table will serve to validate an answer, but will not have a significant impact on the precision of the results. Each Install Sub Module is marked with a 'Y' if needed. If the Input Module should be used, there is a number indicating the highest level of detail at which the user needs to work. For the Route/Track Input Module, the 'S' and 'P' indicate if the Segment Approach or the Percentage Approach is suggested. Based on the examples in the chart, there are different issues that require different levels of analysis.

General Classes of Problems
& Suggested Level of Detail

Exhibit 6 - 3

Type of Problem	Install Needed?			Detail Required		
	Mgt. Policy	Comp. & Cond.	Ref.	Traf.	Route	Cost
Engineering Planning						
Maintenance Policy	Y		Y	1	P-4	2
Technology Assessment	Y	Y		1	P-1	2
Project Scheduling	Y			2	S-4	
Material Requirements				1	P-4	
Study New Materials	Y	Y		1	S-4	2
Financial Planning						
Short Term Capital Planning				2	S-2	2
Costing of a Specific Traffic/Rate Case	Y			3	S-4	2
Marketing						
Costing of a Typical Traffic				2	P-4	1
Strategic Planning						
Long Term Capital Planning				1	P-1	1
Abandonment Study				2	S-4	1
Cost of Heavy Axle Loads	Y	Y	Y	3	P-3	2

P = Percentage Approach

S = Segment Approach

Level 1 = Least Detailed

Level 4 = Most Detailed

6.5 Summary of Example Cases

In the first example, the required analysis used detailed information about the maintenance policies. The analysis did not look at specific routes but analyzed each degree of curvature. This required a medium level of detail in the Route/Track file. The traffic and cost information was very simple and taken from prepared files. This analysis required someone with policy-making responsibility in the company to interpret the results but was sufficiently difficult that an analyst was used to make the runs of the model.

The second case did not have a big impact on the company. The analysis was straightforward. The user did not have to run the deterioration models or look at the reports. The framework of TRACS was utilized to do a simple analysis with some simple inputs. It was asserted that the budget officer, typically a middle level manager, would be able to perform the analysis. Benefits to the manager of using TRACS as opposed to building a spreadsheet model included the fact that the productivities of the technologies were already in TRACS, the cost model was already in TRACS, and his analysis could be combined with other TRACS analyses in order to address more complex problems.

The third hypothetical problem occurred in the marketing department. Although it was a complex analysis, the strategy of using prepared files and the PESOS programs allowed the model to be run by low level managers. Without the aid of PESOS the same analysis would have been quite involved and would have required analysts to run the model.

In just three hypothetical scenarios, suggested approaches have been given which used TRACS at a very complex level of detail, a very simple level of detail, and a medium level. The model was run by analysts, by low level managers, and by middle level

managers. There were examples of the model aiding the engineering department, the financial department, and the marketing department. In all three cases the analysis may have precipitated interdepartmental communication or laid the foundation for additional work with the TRACS model.

TRACS is a tool that has the potential to help different levels of managers in different departments make better decisions. Although the model is very complex, it can be applied in clever ways which do not require more than a few hours of set up time to prepare the data. TRACS should not be used in a vacuum. Rather, its results should be combined with expert knowledge and other models' outputs in order to give the decision maker the best possible information.

7 Summary and Conclusion

A versatile planning model will be used by different levels of managers, in different kinds of analyses. A company benefits from better decisions, reduced costs of software, and improved internal communication whenever one model can serve many purposes. Few railroad planning tools are considered versatile. However, it is feasible to add versatility to existing models and to models under development. The Total Right of Way Analysis and Costing System, TRACS, combines techniques previously used in other models with methodologies never before used in railroad planning models.

7.1 Summary

In the majority of the cases, the planning models currently used in the railroad industry are run by analysts and low level managers in order to study special projects. Some of the models, which have fewer inputs and better reports, have found applications in more than one department of a company. The Service Planning Model and the Princeton Transportation Network Model stand out as being the most versatile models available to the industry. However, smaller railroad management teams, new corporate structures, new research results, and modern software technology reinforce railroad managers' desires for more versatile tools.

The M.I.T. Rail Group, working closely with a group of railroads and AAR scientists, designed and implemented TRACS. The structure of TRACS is essentially a control program that acts as a framework linking other programs. A package of programs that build input files is combined with matrices of outputs from complex engineering models. These files and matrices are used by a series of track deterioration models to predict component life. Another program interprets the output from the simulations, combines the information with company policies, and calculates maintenance schedules, life cycle costs, and statistical data. This information is presented in many

215

different formats in reports that have been designed to serve specific management needs. TRACS provides the railroad industry with a tool that can be used for analyses of varying complexity, in different areas of the business, and by different levels of managers.

7.2 Results

At this stage in the TRACS development process, it has been proven that a complex engineering economics computer model can be structured within a versatile framework. Many of the concepts used in the TMCost restructuring could be incorporated into new models as well. The M.I.T. Rail Group is considering adding enhancements to a system being developed for the Burlington Northern, which would make that model more versatile. The TRACS Reports Module initiated a discussion at CSX about the feasibility of writing a new Reports module for the SPM, which would be designed to offer the versatility and "Presentation Quality" of TRACS reports. It seems that TRACS will not be the last word on versatile computer models.

The M.I.T. Rail Group set a goal at the beginning of the model restructuring effort to develop a model which would be useful to the railroad companies at different stages of development. The most recent version of TRACS has been released to the industry at large and contains only one deterioration model. Railroad managers are using TRACS to analyze the incremental costs of incremental rail wear for different traffic. Engineering planning departments are using the model as an input to policy decisions about rail metallurgy selection. The Rail Group hypothesized that releasing an unfinished model would benefit the development process as well. TRACS, in its unfinished release version, did launch discussions involving various subjects, such as new inputs, a simulation structure, and the incorporation of new technologies. Had TRACS not been partially implemented prior to these discussions, no reports would have been

available, which clarified the type of outputs needed. No inputs would have been available, which clarified the model's content. Finally, the presence of a versatile model encouraged the participation of a very diverse group of managers and scientists in the M.I.T. Track Advisory Committee.

7.2.1 Importance of Versatility

The decision making process in a railroad will benefit from having versatile computer models that can be used by many people for many different kinds of analyses. A planning model that is versatile enough for many people to use and understand helps to combine the specialized knowledge of experts within a company. A single model focuses the calibration efforts, data collection efforts, and software maintenance activity, resulting in reduced costs. A versatile model acts as a basis of communication between managers at different levels who each have different time constraints, resources for analysis, and understanding of computer modelling. Finally, a versatile model will have the potential to grow, expand, and adapt to new technologies, changes in management policies, and breakthroughs in scientific research. The above advantages lead to a model which is more likely to gain wide acceptance by every facet of the industry. This collective endorsement is in the best interest of the industry, when dealing with government regulators and other legal proceedings.

7.2.2 General Methodology Used to Achieve Versatility

There are probably many ways to achieve versatility in a computer model. The recipe for success in the case of TRACS combined elements of versatility from other models, ideas from the industry, and clever software design. The M.I.T. Rail Group set out to make TRACS a tool that is more than a friendly user interface, more than an intelligible model, and more than relevant reports. Their experience may be helpful to others who

have similar goals. While there may be more elegant ways to implement these ideas, the TRACS experience has at least shown that a versatile computer can be built using the following general premises:

1) Work closely with the industry during model development

2) Utilize many files and separate program modules

3) Incorporate the output from scientific models as inputs to simulation models

4) Do not use the software structure as a pattern for the structure of the user interface

5) Partition the technical inputs from the routine variables that would be changed in most analyses

6) Separate the inputs by management areas

7) Segment the input data into levels of detail so a user can input as much or as little information as he wishes

8) Offer many reports that summarize the results from different perspectives and at different levels of aggregation

9) Utilize a control program and a package of standard analyses to link the model's parts

10) Provide intelligent defaults for all input values.

Not all of these ten points contribute to the versatility of the user interface. Many of the guidelines are driven by the need to build a model which can be easily updated. The development was constrained by time and by money. Therefore, the modular program structure benefitted the initial programming effort. In addition, not all of the ideas were developed as original concepts in the TRACS approach. The SPM was developed in close cooperation with the industry. It uses a file-based structure and contains many different kinds of reports. The TMCost model used a control program to link the parts, incorporated the outputs of more complex models, and was released with example files.

The TRACS model combined these concepts with the knowledge engineering methodology to develop features that do not exist in any of the major planning models in the rail industry. The idea of creating an INSTALL program to hide the complex detail from the users was a new idea in TRACS. The ability to perform analyses at varying levels of detail is also a new concept. Other programs have used defaults or hard wired

218

assumptions to simplify the inputs. For every input, TRACS asserts logical values that are chosen from a default data base. The user can accept the default or edit the input. Furthermore, the set of defaults is defined by experts within a rail company. The flexibility offered to a railroad for developing unique default data bases, resulting in railroad specific defaults, is a feature unique to TRACS.

7.2.3 Success of TRACS

The theme of this thesis has centered around the restructuring of one planning model into a more versatile tool. However, one must consider if the methodologies, or TRACS for that matter, were successful in achieving the desired level of versatility. Because the model was released to the industry at large only two months ago, it is difficult to judge if TRACS will ever be used in all of the 14 different categories of applications defined in chapter 2. It is interesting to study the comments that have been received by the M.I.T. Track Advisory Committee. Appendix 3 contains a memo that describes the response of the committee to Version 1.0 . Note that the same group of people who criticized TMCost with broad comments are now critiquing TRACS at a much more specific level. Where TMCost required too many inputs and was difficult to understand, TRACS is now criticized for using the wrong terminology in some of the input screens. The users progressed from not understanding the model to not understanding a few of the inputs.

Many things were changed in the model between then and Version 1.1 . There are currently three railroads who have successfully run the model and are preparing to do a detailed analysis with it. One other railroad is designing a study that would use TRACS to look at maintenance policies. Many of the users who had trouble getting the model started, or had trouble grasping when higher levels of detail should be visited, admitted that their problems stemmed from spending too little time learning the model. This can

be contrasted with TMCost, when the users were always suspicious of inherent problems in the model. In light of these observations, it seems that the methodologies discussed above have had a positive influence on the use of TRACS.

7.3 Conclusion

The high cost of designing, implementing, and maintaining a complex engineering economics model should be recouped by using the model to help managers make better decisions. Therefore, to fully exploit the value of the model, it should be used as an input to as many problems as possible. TRACS employs a knowledge engineering process, as well as standard methodologies, in order to achieve a level of versatility unprecedented by other railroad planning models.

The TMCost model was not structured in a manner which encouraged many managers to use it as a tool. TRACS, on the other hand, due to its versatility, has the potential to be the primary interface between real managerial problems and complex scientific knowledge.

7.4 Recommendations for Future Activities

The TRACS development experience was marked by a need to produce a prototype model that would demonstrate to the railroad managers what the M.I.T. Rail Group envisioned as a versatile model. Sometimes the most elegant programming approach was bypassed in order to gain time. For example, global variables were often used where arguments to procedures would have been preferred. From the larger perspective, the PASCAL language was chosen, because the M.I.T. RAILWEAR model had

been developed in that language. An unlimited budget and a greater amount of time would allow the software to be streamlined and improved in many ways. Following are some areas that merit special consideration in the future.

7.4.1 Improvements to the Model

There are many features that have been suggested by various people from the railroads that would add to the models' user interface. Graphs could be added for every report, some of the choices in the inputs screen could be transformed to pull down menus, and the control program could be designed to run in a batch file so many miles of track could be analyzed at once. Other necessary changes to TRACS include the elimination of some of the limits currently placed on file size. For example, the Traffic Input Module only allows the user to define seven types of trains and five types of cars; the Component and Condition Sub-Module of Install only allows 20 types of rail metal-lurgies, fasteners, and ties; the Route/Track editor should allow the user to model the individual rails; and the traffic growth rates should be separated by direction of travel. In addition to the functional changes that are needed, the code could be carefully studied with the intent of consolidating similar procedures, eliminating duplication in variables, eliminating global variables, replacing array and matrix structures with linked lists, and improving the management of the memory stack space.

7.4.1.1 Additional PESOS

There are many Post Economic Sensitivity OptionS, PESOS, that could be added to TRACS. These are pre-packaged analyses that decrease the amount of effort required to run the model. The development team attempted to write the first set of PESOS to do analyses that every railroad company considers important and would perform

manually in the absence of a PESO. Version 1.1 of TRACS has three PESOS that deal with incremental traffic costs. Other possibilities for PESOS that would serve most railroad companies include technology assessment and capital vs. maintenance costs.

Given a traffic mix and maintenance policies, a technology assessment PESO could calculate statistics for different rail metallurgies in different curves. After implementing the tie model, this PESO could test the costs and benefits of concrete vs. wood ties.

In all types of infrastructure there exists a basic trade-off between the initial investment costs and the annual maintenance expenditures. Increasing the level of maintenance will extend the life of the asset. In contrast, it may be better to replace the component before high maintenance costs become a necessity due to safety. In terms of TRACS, it may be cheaper to use standard rail and excellent lubrication than to use premium rail. A PESOS could streamline this type of analysis.

PESOS should also be applied to very complex analyses that make many assumptions. Properly structuring the base case and alternative cases requires the user to edit many inputs. An important angle that deserves consideration in the analysis may be overlooked. An example of this type of analysis deals with the problem of adding or subtracting incremental traffic to a subdivision that requires a change in the FRA class. The cost allocated to this traffic should reflect the increased capital investment, etc., but might also contain a credit for decreased maintenance costs.

7.4.1.2 Other Deterioration Models

There is currently an effort underway to include in TRACS a rail fatigue model which uses a matrix of PHOENIX outputs as an input. The intention is to design the matrix so any fatigue model or an expert could supply the values to this matrix, similar to the SSC

222

forces that are used in the RAILWEAR model.

The tie and surfacing models that were included in the TMCost2 package had some limitations. The M.I.T. Rail Group proposed a structure for a tie model that would model modes of tie deterioration as a function of many variables, including tie condition and environment. Successfully implementing this complex model would require a TRACS-like umbrella to control the flow of data into and out of the model.

Other right-of-way models should also be added. Mention has been made in the committee meetings that any of the following components would be potential candidates for TRACS type modelling: bridges, turnouts, signals, culverts, sidings, wayside buildings, crossings, vegetation, yards, and terminals.

7.4.2 Recommendations for Railroad Software Tools

There is a broader set of improvements that could be made to TRACS. The improvements are broader in the sense that most engineering economics models could benefit from these improvements. However, the difference with TRACS lies in its versatility. By investing the effort to make major revisions to TRACS instead of to another existing model, the impact of using the latest technology or improving the efficiency may be greater. Other models are more limited in the scope of their application and much could be gained with a minimal investment by first transforming the model into a package which is more versatile, using a TRACS-type approach. The improvements outlined below would likely be very expensive.

7.4.2.1 Advanced Software Languages

The Advisory Committee requested that, for the initial development and implementation of TRACS, M.I.T. use the PASCAL programming language. The M.I.T.

RAILWEAR model had already been developed and implemented in PASCAL, the CIGGT models in TMCost2 were in FORTRAN, and the TUCost model had been implemented in BASIC. Unifying all of the code with one language was considered a high priority, and most people indicated that PASCAL maintenance was not a problem.

In the future some time and effort should be spent in researching alternate software development languages and packages that are especially suited to creating user interfaces, reading files, and managing the computer memory. These tools would not only help speed up the development process, but would make the model much more efficient in terms of memory requirements and run time. An example of a language which is based on the C programming language, but which has many more resident functions for graphics and screen design, would be MODULA II. The WINDOWS package is also very popular among software engineers who work in the field of producing menu driven programs and friendly user interfaces. [1]

7.4.2.2 Software Maintenance Group

The AAR does not think it is desirable to have several versions of the same model being used simultaneously in the industry. [2] However, for a planning model to grow and adapt to the changing needs of railroad managers, it is necessary to add new program modules, make changes to the existing code, and change existing file structures. It is not clear to this author how these changes should be orchestrated.

The process of designing, developing, implementing, and improving an AAR software package would benefit from a consistent AAR policy that prescribed the roles of the

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1 Interview with Dr. Yosef Sheffi, April 1989.
2 Interview with Al Reinschmidt, April 1989.

various parties involved, including academic institutions, the AAR research labs, rail-road companies, and private consulting firms. In the case of TRACS, a long term plan describing the future directions of the project would be helpful in identifying the present priorities.

7.4.2.3 Consolidating the Important Railroad Computer Models

The discussion in Chapter 3 regarding the specific software and hardware facilities to which most railroad companies have access suggests to the author that the AAR or a group of rail companies should commission a consulting company to design and build communication programs for the more popular railroad models. Especially good candidates for this exercise are RECAP, SPM, and TRACS. A standard data base could be built which would serve as a source of information to all of the models. Initial mainframe dumps would create a fundamental data base, and translation programs could then be used to update the data base from reports generated by the various models. The data base, in turn, would serve as a source of information and build data files in the necessary formats for each model. The result of this reciprocating flow of data would be analysts easily using predicted train speeds from RECAP as inputs to TRACS, track maintenance costs from TRACS as inputs to RECAP and SPM, and alternate operating scenarios as inputs to TRACS and RECAP. Because of the reduced time requirement, the complex trade-offs that typically need to be studied in large scale analyses, such as strategic plans, would increase in accuracy. The reduced time and cost investment would likely increase the number of alternatives tested as well.

7.4.2.4 Expert System Shell

Since TRACS does not recommend optimum policies for track maintenance and investment, but already contains an extensive knowledge base, an expert system shell

could be added to TRACS with less effort than it would take to develop a similar system as a stand alone program. TRACS would then actually recommend answers rather than simulate alternatives. The expert system shell could act as a post processor which would be driven off of a matrix of TRACS results. Alternatively, the expert system could actually determine how many analyses would be required with TRACS and the structure of the inputs, as well as analyze the results. Whereas a user might approach a problem with a "Naive" attitude, (for example, run all possible combinations of metal, lubrication, and grinding and identify the lowest cost option), the expert system would be able to screen out unreasonable combinations. A combination may be unreasonable because of FRA safety regulations, preliminary cost calculations, or expert rules that would eliminate absurdities. After eliminating the unreasonable alternatives, the expert system would run the combinations in an "intelligent" manner.

The expert system would be able to account for other assumptions as well. Rather than take the traffic base of a railroad as a given, the expert system could find the optimal level of traffic and track quality that would yield the highest R.O.I.

Finally, the expert system might contain knowledge about other management tools, which would result in recommendations for more important decisions that could be subject to further analysis. The TRACS model would be combined with other tools, and the system would identify which inputs should be considered as important and which can be ignored.

APPENDIX 1

Summaries of Interviews with Experts:

Versatility in Important Planning Models

1 Joseph Folk

Title: Vice President Financial Analysis

Company: Conrail

1.1 Important Models:

Conrail Budegting Model

1.2 Disscussion of Specific Models

The Conrail Budgeting Model has been in use since 1985. It requires many complex inputs, but is a very straight forward model. Dr. Folk classified it as a "Complex Inputs - Simple Analysis" type. The inputs are marketing forecasts, and purchasing plans from all of the department VPs. The model then takes the information and builds financial reports that represent predicitons for the next year. The Board of Directors reviews the results and suggests actions such as, "Reduce the capital requirements", "Increase revenue", or "Increase service levels to several citites". Managers set up the models and run them. Iterations are sometimes performed by Senior level management in response to the Board's comments.

1.3 General Comments

Conrail has two other models that are used, but aren't important from an industry perspective. The Freight Car Forecasting Model and Locomotive Planning Model help managers plan repairs to cars and locos, as well as lease vs. buy decisions.

The Freight Car Model uses inputs from the Marketing department and run by the Car Management Group, which at Conrail is under the auspices of the Marketing Department. The model has been in use for 10 years.

The Lococmotive Planning Model predicts the number of locomotives that will be needed given the projected GTM, utilization rates, and current availability. The model has simple inputs and simple analysis and is used by the Mechanical Department.

2 Peter French

Title:

Company: Association of American Railroads

Date: April 15, 1989

2.1 Important Models:

SPM / ABM / TSS

RECAP / TEM

TMCost

PTNM

AAR IEDM

LFRAM

VPI Empty Car Distribution Model

Software A&E Car Distribution Model

2.2 Discussion of Specific Models

The AAR IEDM model is a very versatile model. The CN is going to apply it to

covered hopper cars. The program is very modular. It is simple to substitute the

complex definitions of intermodal cars with more simple descriptions for other kinds of cars. The assumptions that are used in the model can be accessed and changed through files.

Depending on who makes decisions on locomotive purchasing, different departments have run the LFRAM model. The model has been used in interdepartmental committees as well. The model is a spread sheet base system that has simple inputs and simple outputs. It may be described as "transparent". The model is structured in three parts which are separated by functional area. The railroad operating policies feed into the engineering calculations. The financial data is then combined with the engineering predictions. The various departments tend to concentrate on their own specialty area when using the model. The model is used by analysts and middle level managers.

The VPI Empty Car Distribution Model was first available in 1984. It is a mainframe based model with very complex inputs and complex outputs. It can be used for short term and long term planning. The AAR has used it to study multi levels and for the Florida GM plant analysis. Once the model is set up, it is easy to run lots of different alternatives. It doesn't have a screening model capacity, which would be a useful attachment.

The Software A&E Car Distribution Model overcomes a lot of the problems of the VPI model. It has a sexy user interface that allows the user to attack the problem at different levels.

2.3 General Comments

In general, PC based models are more versatile than mainframe based models. Simple models do exists, but the assumptions that make them simple are often unrealistic. No managers at the AVP level are running models. In reality, the useful models are complex, complex models require lots of data, that means lots of set up time, and AVPs do not have a lot of time.

3 Pattrick T. Harker

Title: Associate Professor of Decision Sciences

Company: University of Pennsylvania

Date: April 18, 1989

3.1 Important Models:

SCAN

3.2 Discussion of Specific Models

The SCAN model is only run by analysts. The model is used by the Service by Design Group in the Transportation department at the Burlington Northern. There is a real potential use for the model to be used in scheduling of maintenance activities. Although the model requires complex inputs including train schedules, priorities, and track configuration, it includes a feature that allows the user to perform a quick simulation. In comparison, the SPM is a fine model, but it does not allow the user to get a first cut view of the problem. Mr. Harcker was suggesting that the SPM did not adapt well to performing analyses that were approximations of more complex situations.

3.3 General Comments

People do not need models for everything they do. Models are meant to give insight to a problem. The people making the decisions are pretty smart, and sometimes the

only additional insight they need is from a quick and, not dirty but perhaps approximate, analysis. There is no bad side in having the ability to do different levels of analysis with one tool. The people using the tools are smart, and therefore recognize when the model tells them to do something that is out of the ordinary. No decision maker is going to make a radical policy change based on the output from the first cut of an analysis.

4 Dr. Michael B. Hargrove

Title: Director Engineering Economics

Company: Association of American Railroads

Date: April 14, 1989

4.1 Important Models:

TEM / RECAP

TMCost / TRACS

PTNM

RPM

SCAN

SPM / ABM / TSS

4.2 Discussion of Specific Models

The RECAP model is supported by Dr. Hargrove's group. The model is run by analysts and managers. RECAP accesses information from TEM and TMCost. Therefore, sometimes it is used as a surrogate for a more complicated analysis. For example, RECAP has been used to look at operating alternatives, and fuel consumption. Its intended uses were technology assessment and powering strategies. The departments that use RECAP vary from road to road. Some examples include

transportation, industrial engineering, engineering, planning, and mechanical. At the CN, Duncan Robertson is using the package in an interdepartmental group for the expressed purpose of breaking down interdepartmental barriers. It is also being used in interdepartmental applications at CSX/Sea-Land Intermodal. The model depends on detailed specifications, therefore it is only used for complex inputs, complex analysis type situations.

The original TMCost model was very data intensive. It was only ran by analysts at the AAR. It did find wide application in cost studies that covered unit trains, heavy axle loads, technology assessments, and coal litigation cases. The coal cases were driven by an interdepartmental group including lawyers, while the HAL study was driven by the marketing department. TMCost2 was an attempt at upgrading the model to include better deterioration models, and to make it simpler to use. It was not successful, because it was quickly upstaged by TRACS. The TMCost / TRACS models are difficult to rate because they change so often due to the ongoing development process, that no one in the railroads have made extensive use of them.

5 Al Reinschmidt

Title: Director of Track Research

Company: Association of American Railroads

Date: April 17, 1989

5.1 Important Planning Models:

PTNM

RECAP

RPM

AAR Tie Model

AAR Ballast Model

TRACS

5.2 Discussion of Specific Models

The PTNM is used by the AAR in testing changes to the Car Service Orders. The AAR committee simulates potential changes to the Car Service Orders and analyzes the effect on the industry. This helps eliminate company optimal solutions, and instead helps the industry as a whole. Although the Engineering Departments of the railroads don't use the model, they do refer to it and help develop inputs for it in studies involving the upgrading and downgrading of lines. The model is run by

analysts, however, managers can use it. It is straightforward to use.

The RECAP model is used by people from the mechanical and transportation departments. This model requires analysts and is very difficult to set up. The fact that the AAR spends so much time going around to the railroads helping them to use the model, indicates that it is complex.

The Rail Performance Model is a product of Dr. Reinschmidt's group. Originally the model was only used by engineering departments. However, since Dave Staplin, who is chairman of the Rail Subcommittee, got his MBA, the model has been expanded to include features that have encouraged people that do cost analysis to use the model. The model is very successful not because it is spectacular, but because it fills a real void. The model has a slow, but steady increase in the number of people using it. Many of the recent improvements to the RPM are reports that were designed to serve specific user needs. It is structurally very easy to add the reports, since the calculations are already performed. The model is driven off of other models and off of field data. The outputs from PHOENIX are combined with field data using baeysian techniques. The RPM then calculates rail life. RPM has the ability to do analysis with different levels of detail input. CSX uses the model at several levels of complexity. Dave Staplin is a Director and uses the model. Most people are analysts who use the model.

The AAR Tie Model is a Lotus Spread Sheet model that automates the forest products curve given a set of track characteristics. The model is strictly a steady state model, and predicts what tie programs will be like in the future. The model cannot simulate,

and does not do economic analysis. The model deals effectively with tie clusters. This is a real strong point of the model. The model is simple to use, and is limited in that it cannot do complex analysis.

The AAR Ballast Model predicts the life of ballast material based on the depth, gradation, and type. It calculates the voids that are present and determines how long it will take for the ballast to break apart and fill those voids. It does not look at the ability of the ballast to hold surface. For the number of surfacing cycles needed and other surface maintenance, it uses input from the user. However, the intention is to add a module to do this. The model does a good job. It is not transparent, but the inputs are simple.

It is difficult to say if the TRACS model will be successful in doing what it was designed to do. That is, be used by different departments at different levels of analysis to study the effect of their various decisions on the track maintenance process. It certainly has the potential to do that, the question is if it will be accepted. One of the big drawbacks is that it may be short lived in its current form. The technology and need exists to go beyond what TRACS is trying to do. Someone needs to make the commitment to design an integrated system of planning models that combines elements of TRACS, such as the deterioration models, with elements of other models such as SPM and RECAP. The whole thing needs to be shrouded in an expert system, and the question that it answers is, "How do I run my railroad?". Ever since the days of passenger trains, railroads have grappled with the idea of allocating costs. TRACS has the ability to structure an analysis that looks at incremental costs. The user needs to recognize subtleties such as the cost of maintaining a class 6 track instead of a class 3 track for one intermodal train, includes increased low rail crushing on the curves when slower trains operate, the savings in maintenance and the cost of more capital.

TRACS will not be able to deal with fully allocating costs until the theoretical, economical issues are solved. Solving that problem is basically infeasible, due to the very poor records that are kept on parts inventories, daily maintenance work, and traffic flows on double and single track.

5.3 General Comments

The directors and AVPs do not have any time to run the models.

Models that were built in the past that reflect the use of out dated technology should not be used for planning and should not be considered planning tools. The Rail Tie Association tie model doesn't incorporate new technology in surfacing equipment, rail metallurgy, and rail maintenance. It cannot look at different fastening systems effectively.

Analytical tools that are used by scientists should not be considered planning models. PHOENIX is an example of a model that has found no application outside of the AAR. It is extremely complex to run and requires a metallurgy expert to interpret the results.

Dr. Reinschmidt was not familiar with many models that were developed internally at the railroads. The OR type models that do rail inspection scheduling, ballast logistics, and equipment allocation do exist.

Regarding the role of the AAR, consultants, academe, and the railroads in software development and maintenance; the AAR does not have a policy. The railroads should not be allowed to have the code to AAR models because of the potential for the model going to a court case as an AAR model, although the internal formulations have been

changed. If the railroads insist on this approach, then the AAR will be forced to stop supporting the models after the initial development work. Upon transferring the maintenance of the model to a railroad, it would no longer be known as an "AAR Model" but as "Railroad X" model. Then the railroad would lose all the benefits of having an industry supported tool. Given the right consultant, the AAR is not averse to having consultants develop new upgrades, and maintain models. Experience has shown that the consultants will not speculate on improvements to the models. There is definitely going to be a problem maintaining TRACS whenever M.I.T. gives up that facet of the work.

6 Rich Sauder

Title: Director, Operations Research

Company: Norfolk Southern

Date: April 17, 1989

6.1 Important Models:

SPM / ABM / TSS

RECAP

Software A&E Car Distribution Model

6.2 Discussion of Specific Models

RECAP had very limited use at the NS. The Cost and Finance people got involved because it does do costing. The model was only run at the analysts level. There was some degree of simplicity in the inputs in one analysis where the marketing department use very rough estimates of traffic projections as inputs.

The SPM family of models is just starting to get some use. The SPM will not be used at all because there is not a need for it once you run the ABM and TSS. There isn't enough experience with these models to discuss them in detail. There are problems with the TSS model which will have to be fixed before it is useful for us.

The SPM family of models can benefit all of the departments, but having each department run them is too much effort. Instead, they should be run in interdepartmental task groups that includes representatives from MIS, service planning, stations & terminals and the marketing departments.

6.3 General Comments

Maintaining very large models is staff intensive. One can simplify the models to make them easier to use, but the fear is that the analysis will be simplified into oblivion. Each manager must decide at what point averages and simplifying assumptions gloss over the real problems. Using a simple model may not reveal some of the subtle problems, thus the real problem will never be attacked. The models need to have the ability to do more detailed analysis without the intense clerical effort. This could be accomplished with better preprocessors and automatic data extraction techniques.

The analysts and staff people always want models with more detail, because there biggest challenge is to make the models have credence. However, the managers want a productive model that they can use in their daily work. They will not use a model unless it is an interactive model, that can do "what if" games. The best solution would be for the analysts to prepare a base case model and have the manager run simple "what if" games. Actually, taking this idea one step further, the managers wouldn't even have to run the model, if there were a matrix of results that would some how communicate the sensitivity of the results to different variables.

For complex problems such as service planning and track maintenance planning, the LP programs are useless. These are the areas where simulation has the ability to reveal issues related to equipment utilization, loco assignment, and other details that would be impossible to formulate in a so called "linear" algorithm.

7 Bill Sheppard

Title: General Superintendent Service Control & Transport Analysis

Company: Conrail

Date: April 15, 1989

7.1 Important Models:

YCM

7.2 Discussion of Specific Models

The YCM looks at yard connections. The inputs to the model include all of the inbound trains and cars, as well as the destinations of the proposed outbound trains. -The model then calculates the best time to dispatch each outbound train. This can be used as a planning model.

7.3 General Comments

Mr. Sheppard's department doesn't use any models for planning purposes. The models each require a separate data base that have different formats from the Conrail data base. This is too much maintenance time and cost. Part of the problem is eliminated because 50% of the trains are encumbered by contract freight, and this percentage is growing. Many of the algorithms in the models are missing the mark. They fail to look at the long term implications of going to single track mainline for example. The cost of train delay is no longer an issue that is hard to quantify. Train

delay is unacceptable. Period. The customers can deal with one or two hours of delay, but not missed connections that would delay freight for a day or more. Speed in decision making is important, and the models take too long to run from start to finish. Additional problems with models include the fact that they need to be customized to each railroad's special needs, and the output must be interpreted by sophisticated experts.

This group instead used data bases and reports that are available on the Conrail mainframe. They have the ability to parse and transform data with very little effort. This information is then discussed at weekly, interdepartmental planning meetings.

8 Mike Smith

Title:

Company: Burlington Northern Railroad Company

Date: April 15, 1989

8.1 Important Models:

RECAP / TEM

TPS

BN line capacity model

SPM / ABM / TSS

TRACS

PHOENIX / RPM

SCAN

TMCost

8.2 Discussion of Specific Models

RECAP is used only by the Research & Development Department at BN. Contractors actually run the model. It is used for very complex analysis.

The BN TPS generates fuel consumption estimates for the whole railroad system. It is also used as an input to the line capacity model, SCAN. The model is used in the Operations department by analysts to perform analysis with complex inputs and complex outputs. The original TPS came out around 25 years ago.

The SPM family of models is used by the R&D and the Transportation Departments. The model is run by either analysts or assistant managers. The interdepartmental service by design group is also looking to use the model. The complex analyses that are performed have complex inputs.

The SCAN model is complex. It is a rigorous model that is being used by R&D to study the benefits of ARIES.

8.3 General Comments

Middle to upper level managers have no time to run the models. They interpret the results and revise the inputs for the next iteration. Models should be run at the most complex level as time, data, and theory permits. Simple inputs means that the model gives simple answers. There is a need for one model to be able to do both simple-simple and complex-complex types of analyses. The benefits are that the users can turn to one source for the model and that the analyses can evolve from simple to complex within the framework of the model.

9 Carl Van Dyke

Title: Vice President

Company: ALK Associates

Date: April 17, 1989

9.1 Important Models:

SPM

ABM

TSS

The family of TPC models

RCM

PMM

C-model

CN Yard Capacity and Design Model

RECAP / TEM

PTNM

CSX IEDS

9.2 Discussion of Specific Models

The SPM family of models, including the ABM and TSS have been used by Operations Planners, Facilities Planners, abandonment studies, and network rationalization studies. Although it doesn't have a broad "horizontal" set of applications, it is used by the transportation department, operations planning, and interdepartmental task forces. In theory the model was to be used for setting service standards, but this has never been done outside the original case studies at M.I.T. The most logical place for that to occur would be the marketing departments. The work done at CSX/Sea-Land Intermodal is the closest the model has ever come from breaking out of its traditional applications. There the model was used to study proposed business strategies that were introduced by the marketing department, finance department, operating department and planning department. The model was adapted to look at the flows of intermodal boxes instead of rail cars. The CN is currently using the model as a tool in contract management. They run the model to test if the current operating plans will meet the service standards that are written into the various customer contracts. If they cannot be met, the plan must be changed to accommodate that contract. That may lead to operating plans that are iterations on the blocking plan and train schedules produced by those systems.

In terms of the "vertical" versatility of the SPM, the reports have been used over the years by every level of manager, including the President down through to the field officers. Recently the user base has expanded to include some people who are not knowledgeable about computers. Besides analysts the model has been run by Managers and Directors of Service Planning. In general, the model base case and

maintenance always requires MIS support. SPM is definitely used to look at problems at different levels of complexity. It is very easy to start out an analysis with simplifying assumptions, then go back and make the inputs more rigorous. A good example of that is the PMAKE functions that can start off as gate cut off times, the next iteration would be calibrated PMAKEs, and a final iteration would study the PMAKE multipliers. There are examples of cases that were studied using simple inputs for a simple analysis, simple inputs for a complex analysis, complex inputs for a simple analysis, and complex inputs for a complex analysis. CN is actually doing parallel implementation of the model, looking a an abstraction of their system with 70 nodes and with 700 at the same time. The NS is doing similar work to what CSX did in the past by modelling a 50 node intermodal network separate from their main system. Often the simple/complex analyses and at times all of the levels of analysis are done to prove or disprove the value of decisions that were made on the fly.

The Line capacity models including RCM, PMM, and the C-model require very detailed levels of input. The PMM is very similar to the RCM except that it has the additional ability to look at multiple lines. These models are always run by analysts within the operations departments. The models are not oriented to varying levels of detail.

The TPC models need the full blown detail to run properly. There are analyses performed that look at generic routes, like "hilly" rather than detailing the exact geometry of a specific route. The models have found use in both the engineering and mechanical departments of railroads. An example of a specific analysis is testing 2 tracks vs 1 track with passing siding configurations. Questions that the TPC is used to address can be motivated by the Marketing department, but they do not run the models.

The PTNM is the most versatile model available today. Its versatility is dependent on the full data base that defines the position of rail lines. This is distributed with the model. With this data base, the model can be used at different levels of detail. It has been used by all the departments in a railroad to look at the effects of like closures, mergers, and cooperative operating agreements. The model can be used to study market shares. The model is only used by analysts, but at a low level of detail it has the potential to be used by senior level management as demonstrated by Ron Drucker, President of CSX Technology, who used the model for a whole day as part of a demonstration.

9.3 General Comments

The OR models that are developed at the railroads are important planning tools if they are used in that capacity. CSX is using IEDS successfully, and NS uses their freight car distribution model to create policy on a month by month basis for rules governing empty car placement.

Appendix 2

TRACS Manual

Chapters 6, 7, and 8

6 Control Program

The TRACS Control Program is the superstructure that binds all of the program modules and sub-modules together. In addition, the Control Program is responsible for printing the introductory screens, the analysis introductory screen, and performing the PESOS analysis.

6.1 Linking Together the Modules

The Control program calls the stand-alone program modules and sub modules by doing a call to the system from a compiled PASCAL file. Therefore, any program module can be improved and "slid" into the superstructure like a plug in the back of your computer links together the various pieces of hardware.

The stand-alone programs can be run from outside the Control Program by typing the name of the Module. For example, TRAFFIC, ROUTE_TRACK, COST, and RAILWEAR are all legitimate commands that can be typed at the DOS command line prompt. To run the Reports file, type MAKE_OUT which stands for "make output".

PESOS are a special TRACS feature which allows the user to perform "canned" analyses. In effect, the PESOS feature is a glorified batch file which prompts the user for the necessary inputs, and creates outputs.

6.1.1 Introductory Screens

The cover of this User's Guide is the first screen you should see when you type 'TRACS' at the DOS prompt.

The second screen looks very much like the first page on the inside of this User's Guide. It contains the mandatory information about who designed and implemented TRACS, and who holds the copy rights on the material.

6.1.2 Main Menu

The third screen you will find is the main Control Program Menu. This menu is dynamic; that is to say, it only shows the user those options which are available to him. TRACS has been designed so that it is not necessary for every user to be able to run every piece of the package. Therefore, some of the editions will not have the INSTALL programs. If these do not appear on your main menu, do not fret because the data that you need to run TRACS is still with your package, assuming that it has been properly copied to your machine. If you are one of the lucky people who does not have to deal with the INSTALL programs, you can feel good about not having to wade through all of the gory detail and complex data that is found in those programs.

6.1.3 Running an Analysis

At the Run an Analysis option of the main Control Program Menu, you will be asked to enter your name, and an analysis name. This is important to keep track of who did which analyses and when they were performed. A team of people may be using TRACS together, and many iterations of the problem will be run. TRACS passes this information unto the Reports Module, so you can identify each iteration.

You are asked if you want to review the Input files that are listed in the CALFIL.INP. This is a last chance to change the files that are going to be used as inputs to the analysis. The files that are in the current list are the ones that were most recently edited, built, or used. You may want to review the files just to double check that what you want to use is actually there. Another option that is open is to prepare sets of input files ahead of time, and then run a whole series of analyses at once, by simply changing the file selection each time. If you are a user who does not have access to a Maintenance Policy INSTALL Sub

```
        ┌─────────────────────────────────┐
        │  1.  Maintenance Policy         │
        └─────────────────────────────────┘
           2.  Component & Condition

           3.  Traffic

           4.  Route_track

           5.  Cost

           6.  Run an Analysis

           7.  Reports

           8.  Exit to DOS
```

Position box over selection,
Then press the <Enter> key.

Enter user name. Mike

Enter analysis name. Test_17

Enter planning horizon. (1-100 yrs.) 45

Do you wish to review and/or change input files? (y/n)

Maintenance File ==>   GOOD.MNT

Traffic File   ==>   CASE.TRF

Route_track File ==>   HILLCURV.RTP

Cost File   ==>   STANDARD.CST

```
┌─────────────────────────┐
│  All changes made.      │
└─────────────────────────┘
```

255

Module, you may still have a choice of several Policy files to choose from. Choosing from among the listed files using this Control Program is the only way you can choose other files.

6.2 PESOS

PESOS is the program that allows a user to run "Post Economic Sensitivity Options". They are "Post", because they must be run after a base case TRACS analysis is completed and run. They are "Economic" because the reports that they produce compare a test case with the base case by comparing economic statistics for the subdivision or the route file used. PESOS are "Sensitivity" tests in that they allow a user to vary one or a set of inputs to TRACS and re-run the case to see the effect on the results. And finally, PESOS are "Options" since a user can choose not to run them, in which case much CPU time is saved (PESOS can take a long time to crunch through all of the different programs) and a lot of file storage space is saved. (PESOS automatically saves all of the PESOS reports, because of the time spent in producing them). PESOS real benefit to the user is that they eliminate the need for the user to sort through all of the input screens, developing alternative files, researching which values are dependent on other values, and running a series of analyses and combining the results together. Instead, the pre-packaged analyses in PESOS takes care of all of the bookkeeping, the data formatting, and the report generation.

6.2.1 The Scope of PESOS

As you can see on the first PESOS menu, which you will find by selecting the PESOS option from within the REPORTS Module, there are several general categories of tests that can be performed. Version 1.1 of TRACS only has option 1, TRAFFIC Analysis implemented. If users of TRACS like PESOS, they should suggest others that might be helpful.

PESOS are useful for common analyses that are done often. In this way, you can run the analysis many times with a limited number of key strokes and file handling. You will reduce the chance of making a mistake, or overlooking an important input.

PESOS are also potentially useful for very complex analyses that require a lot of changes in input files. Right now, there are no PESOS of this sort implemented. One drawback is that very complex analyses tend to be specialized to a particular company, or not run very often. However, this would be a good way to use TRACS as an input to other models, or reports.

Following are examples of the first two menu screens you will find in Rail PESOS.

RAILWEAR PESO

```
╔══════════════════════════════════════╗
║  1.   Traffic Class Analysis         ║
╚══════════════════════════════════════╝

   2.   Metallurgy Analysis

   3.   Lubrication/Grinding Analysis

   4.   Planning Horizon Analysis

   5.   Review Previous PESOS Analyses

   6.   Leave PESOS
```

257

```
┌──────────────────────────────────────────────────────────────────────┐
│ OPTION 1: Incremental Cost of Adding of Subtracting a Portion of Traffic│
└──────────────────────────────────────────────────────────────────────┘

  OPTION 2: Calculating the Incremental Cost of 1MGT of Each Car

  OPTION 3: Analyze Growth/Decline Rate

  Return to PESOS Main Menu
```

Traffic Class Analysis   Rail PESOS Report
Option 1   Input Screen
==

      Analysis File: HOGSHEAD.OUT   ==>   HOGSHEA1.OUT
      Traffic File: HEAVY.TRF   ==>   HEAVY1.TRF
        Route File: FILLMORE.RTP   ==>   FILLMOR1.RTP

| Gross Weight of | Annual MGT, Base Case | | | Annual MGT, Test Case | | |
Car in Tons	1st Yr	5th Yr	% Growth	1st Yr	5th Yr	% Growth
30	10	5	0	2	2	0
50	10	10	0	2	2	0
80	10	4	0	2	2	0
110	0	5	0	2	2	0
130	0	0	0	2	2	0

6.2.1.1 PESOS Traffic Analysis Option 1

This analysis tests the effect on various statistics for a route when groups of traffic are added or subtracted from the current traffic base. For example, a railroad may decide to accept a third party double stack train over its route or suspect that a concrete plant might start trucking some of its sand. This is not a trivial analysis for the first time TRACS user. The user would have to create a base case traffic file, a test case traffic file, and two route files; reflecting the difference in the current and expected annual MGT. The joint effect on the engineering costs can be easily tested using this PESOS. After developing the base case, choose PESOS and edit the year one traffic numbers in the first input screen.

```
Traffic Class Analysis                                  Rail PESOS Report
Option 1                                                Summary of Inputs
==============================================================================

          DATE: 2/09/89     TIME: 22:03            Discount Rate: 12.3%
    MAINT FILE: C:\TRACS\DATA\LIMITS.MNT        Planning Horizon: 34 years
     COST FILE: C:\TRACS\DATA\STANDARD.CST      Length of Route: 127 miles
```

Gross Weight of Car in Tons	Annual MGT, Base Case			Annual MGT, Test Case		
	1st Yr	5th Yr	% Growth	1st Yr	5th Yr	% Growth
30	10	5	0	2	2	0
50	10	10	0	2	2	0
80	10	4	0	2	2	0
110	0	5	0	2	2	0
130	0	0	0	2	2	0

<PgDn> To View Results

259

Running PESOS will build all of the alternative files for you, change the entries in the CALFIL.INP file, and run the same deterioration models that you used for the base case. The reports list the key economic statistics, and some brief engineering data, to help frame the financial data. The reports are automatically saved. You can print a copy immediately by choosing the <P> option at the bottom of the screen.

```
Traffic Class Analysis                              Rail PESOS Report
Option 1    .                                       Summary of Outputs
=======================================================================
```

Statistic	Base Case	Test Case		
Analysis File	LAWRENCE.OUT	LAWRENC2.OUT		
Traffic File	HEAVUNIT.OUT	HEAVUNI2.OUT		
Route File	HILLY.RTP	HILLY2.RTP	Difference	% Change
Avg Wheel Load lbs.	28,000			
Annual MGT	45			
Average $/mi./yr.	15,000			
Average $/yr./MGT	700			
Total EUAC	12,000			
Total NPV	125,000			
EUAC $/MGT/yr.	1,035			

```
<C> Create File, <P> Create & Print File, <PgUp> View Inputs, <Esc> Exit
```

6.2.1.2 PESOS Traffic Analysis Option 2

This option allows a company to check their current traffic. One important input to pricing, is the incremental cost of the last MGT of traffic of the type in question. This PESO calculates the incremental rail costs of that last MGT of traffic for each weight of car present in a traffic mix. Depending on the mix, the total MGT, and the condition of the rail, this could be very different.

As in option 1, the manual functions that would be required to do this analysis are quite involved. There would have to be at least 5 traffic files, 2 route files, and 6 bridge files. That means you would have to run the analysis 6 times. All of the required data manipulations would get tedious.

6.2.1.3 PESOS Traffic Analysis Option 3

This is different than Option 1 in that this assumes that you will maintain your current traffic, but the future trends may be different than what you had originally assumed in the base case. In option 1 we tested the immediate change of traffic mix, but this option tests the effect of more subtle, gradual changes in traffic due to growth and decline of different classes.

The input screens are the same for options 1 and 3; you just edit different things. In this option, you can choose to edit the growth rate, in which case the predicted fifth year traffic level will change, or you can change the fifth year traffic level to what you think it might be, and the growth rate will automatically be calculated.

6.2.2 Examples Using PESOS

6.2.2.1 Adding Intermodal Traffic, Deleting Passenger Traffic

Many operating people say that light intermodal trains operate like passenger trains. But, from an engineering standpoint, the two may be quite different. Use the Option 1 PESOS and delete some passenger trains, and replace them with an equivalent number of intermodal trains. Even though they may operate similarly, remember to check the weights of intermodal and passenger equipment.

6.2.2.2 Incremental Cost of a Traffic Mix, High MGT

Now, use a route file with about 80 annual MGT, and run a base case with a traffic file of your choice. This case is more interesting if you choose a traffic file with many different trains and cars. Run PESOS Option 2 and take note of the incremental cost of the heaviest cars.

6.2.2.3 Incremental Cost of a Traffic Mix, Low MGT

Use the same traffic mix, but reduce the annual MGT in the route file to about 20. Use this as your new base case, and run Option 2. Compare the output from this PESOS run to the last example. You should see neat things happen !!!!!

6.2.2.4 Effect of Expected Growth

As a final exercise in PESOS, run a base case with zero growth for all train types. Use Option 3 to develop a test case with 10% growth in intermodal and a 5% growth in heavy unit trains. Intermodal cars may weigh around 100 tons, while heavy unit train cars should be of the 130 ton type.

```
Traffic Class Analysis                                      Rail PESOS Report
Option 2, Marginal Costs                                    Summary of Results
================================================================================

            DATE: 2/09/89    TIME: 22:03              Discount Rate: 12.3%
     MAINT FILE: C:\TRACS\DATA\LIMITS.MNT         Planning Horizon: 34 years
      COST FILE: C:\TRACS\DATA\STANDARD.CST        Length of Route: 127 miles


                    |    Annual MGT,  Base Case    |   Statistics for Last MGT
  Gross Weight of   |------------------------------|------------------------------
   Car in Tons      | 1st Yr | 5th Yr | % Growth   |      EUAC      |  $/1000 GTM
  ------------------|--------|--------|------------|----------------|--------------
           30       |   10   |    5   |     0      |                |
           50       |   10   |   10   |     0      |                |
           80       |   10   |    4   |     0      |                |
          110       |    0   |    5   |     0      |                |
          130       |    0   |    0   |     0      |                |
  ------------------------------------------------------------------------------
```

<C> Create File, <P> Create & Print file, <PgUp> View Inputs, <Esc> Exit

7 Explanation of the TRACS User Interface - Input Modules

7.1 Introduction

TRACS contains three different programs that enable a user to create or edit input files: **TRAFFIC, ROUTE/TRACK** and **COST**. The input programs can be run from the control program.

7.1.1 General Features in All Input Modules

Every input screen consists of one or more fields into which an input value can be typed. When an input screen first appears, the cursor will be positioned at the first field, and the program is ready to read in the first input value. Input values can be character strings, integers or real numbers.

To get from one field to the next the **<Down Arrow>** key can be used.
After the last input value of the screen has been typed in, an activity menu will appear at the upper right corner of the screen to show what the options are for the next screen or the next input program.

To move between fields and screens, special keys are used. For most keyboards, a significant number of these keys, such as **<Insert>**, **<PgUp>** or **<Right Arrow>**, can be found on the number pad. In order for these keys to work correctly, the **<Num Lock>** key needs to be Off. If an input program seems to be stuck at the same screen or field, check the **<Num Lock>** key.

7.1.2 Definition of Keys used in an Input Field

When the input value is a character string:

1. The program makes no distinction between upper and lower case characters. "FILENAME" is considered to be the same string as "filename".

2. Do not use blank spaces in a character string; everything after a blank space will be ignored. Use an underscore _ to separate words in a longer string. "HEAVY_UNIT" instead of "HEAVY UNIT".

3. Use only letters, numbers and the underscore. Characters such as @, $, #, % will not be recognized.

4. Character strings can be changed by typing over each letter. To correct or change part of a string, use the right and left arrow keys to place the cursor at any position in the string and type over the mistakes.

5. Use the delete key to delete characters to the right of the cursor, the backspace key to delete characters to the left of the cursor.

6. Use the insert key to insert a character at the position of the cursor.

When the input value is an integer:

1. The right and left arrow keys cannot be used to change just one digit in an integer. To change the value of an integer, the whole number needs to be typed in.

2. The delete key can be used to remove digits, starting at the right-most digit. Once all digits have been removed, the number 0 is left in the field.

3. If an integer falls outside the range a message will appear at the bottom of the screen. Use the delete key to remove the number and type in a number that falls within the range that is shown in the message.

When the input value is a real number

1. The cursor will be placed at the position of the decimal point. The integer part needs to be typed in first, followed by the decimal point and the decimal part, after which the cursor will return to the position of the decimal point.

2. The delete key can be used to remove digits to the left of the decimal point.

3. If a real number falls outside the range, a message will appear at the bottom of the screen. Use the delete key to remove the number and type in a number that falls within the range that is shown in the message.

7.1.3 Definition of Keys used to move between Input Fields

If the input fields appear as single blocks on the screen, the down arrow key can be used to get to the next field, the up arrow key can be used to get back to the previous field. Pressing the up arrow key from the first field on the screen will bring a user to the last field on the screen. Pressing the down arrow key from the last field on the screen will display a menu on the bottom of the screen that shows the options for the next input screen or program.

If the input fields appear as part of a table, the up, down, left and right arrow keys can be used to move anywhere within the table and type in values. To get back to the fields before the table, place the cursor at the top left field of the table and press left arrow key. To get to fields after the table or leave the table, place the cursor on the bottom right field in the table and press the right arrow key.

To read the on line help screens that are provided with every field, bring the cursor to a field and press <F1>.

If at any point in the screen all input values look correct as they appear, press <Esc> and choose an option from the activity menu that will appear at the upper right corner of the screen. See the next section for the choices.

7.1.4 Definition of Keys used to move between Screens.

Any time a user presses <Esc> or moves past the last field on the screen, an activity menu will appear at the upper right corner of the current input screen to display the options that exist for moving to another screen or another program. In most cases the following options will exist:

1. <F10> to quit. Pressing <F10> will bring back the menu from the control program. <F10> should only be used in case of emergencies. Whatever file a user is editing at the time WILL NOT BE SAVED.

2. <PgDn> for the next level of detail. If more detailed input screens exist, pressing <PgDn> will bring up the next screen, with the cursor positioned in the first field. If no more detail is available pressing <PgDn> will present a user with the current screen again, where the cursor will be positioned one field down from the field that was most recently edited.

3. <PgUp> for the previous level of detail. If the current screen is not the first screen in a sequence of input screens, pressing <PgUp> will bring up the previous level of detail, with the cursor positioned in the first field. If no previous screens exist, pressing <PgUp> will present a user with the current screen again, where the cursor will be positioned one field down from the field that was most recently edited.

4. <Esc> to save the current file and return to the control program menu. There are two options for saving the file :

1. Save the file under its current name. To do this, press enter at the prompt.

2. Save the file to a new name. This will be a good option to use when you have been editing an existing file and made some changes.

This way you can save the old version of the file as well as the new   version, and compare the results of analyses run with the two files.

5. **<Right Arrow>** to go to the next item, staying on the same level of detail. In the Traffic input program, one level of detail will require inputs for a number of cars or trains. To work on a screen that reads inputs at the same level of detail as the current screen, but for the next car or train in the traffic mix, press the Right Arrow key.

In the Route/Track input program the Right Arrow key can be used to work on the next segment in the subdivision.

In the Cost input program the Right Arrow key can be used to work on the next screen in the same category.

6. **<Left Arrow>** to go to the previous item, staying on the same level of detail. In the Traffic input program, one level of detail will require inputs for a number of cars or trains. To work on a screen that reads inputs at the same level of detail as the current screen, but for the previous car or train in the traffic mix, press the Left Arrow key. In the Cost input program the Right Arrow key can be used to work on the previous screen in the same category.

6. Pressing any other key will bring up the current screen again, where the cursor will be positioned one field down from the field that was last edited. If **<Esc>** was pressed by accident and there are still fields on the screen that need to be edited, or if a user went past the last field in the screen only to discover that some previous fields need editing, this option will be very helpful.

7.2 Traffic Module Screens

These screens enable the user to create a new traffic file or edit an existing traffic file. The file will be saved and its name will be placed in the list of input files to be used by RAILWEAR.

7.2.1 Screen #1 - Choosing a Filename

This screen will display a listing of all files in the directory C:\TRACS that have the extension **.TRF**. If no such files are found or if this directory cannot be read, the user will be asked to indicate in what other directory the traffic files may be found.

To edit an existing file, type its name as it occurs in the listing. To create a new file, give it a name that is different from all the files in the listing. The program will automatically give the extension **.TRF** to all traffic files that are created or edited.

If the name of an existing file was given, and no editing is required, the user can press **<Esc>** to leave the Traffic Module at this point.

```
                    TRAFFIC INPUT: SCREEN 1 OF 4

THIS IS A DIRECTORY OF THE EXISTING TRAFFIC FILES


DEFAULT.TRF
LARRY.TRF
OLIVER.TRF
BRANCH.TRF
HEAVUNIT.TRF
LITEUNIT.TRF
MANYLOCO.TRF
MIXED.TRF
PASSENGE.TRF
LARRT.TRF
CASE.TRF




TYPE THE NAME OF THE FILE YOU WANT TO USE: DEFAULT.TRF
```

7.2.2 Screen # 2 - Describing a Traffic Mix.

This screen enables the user to enter the names of up to 7 train types that make up the traffic mix in this file. A name can be up to 12 characters long. No blanks are allowed in these names.

For every train type indicate the number of trains that travel over the subdivision in each direction per week. When entering these numbers, keep in mind that the traffic file that will be created will describe the traffic mix in terms of percentages and not in terms of numbers of trains or numbers of cars. If the traffic mix consists of Intermodal trains and Heavy Unit trains, entering 1 Intermodal train per week and 2 Heavy Unit trains per week in each direction will result in the same traffic file as entering 10 Intermodal trains per week and 20 Heavy Unit trains per week in each direction. This approach has two advantages. First, the same traffic mix can be used on route segments with widely differing MGT. Second, a user can define the traffic mix in terms of trains and cars, which is much easier than calculating the percentage of MGT for each car type.

Finally, enter the percent increase or decrease for this train type that is expected for the coming five years. This way the deterioration modules can be run with a different traffic mix each year to model deterioration rates under changing traffic conditions.

If <Esc> is pressed at this point, default values will be used to describe the trains and their cars.

TRAFFIC INPUT: SCREEN 2 OF 4

TRAFFIC FILE: DEFAULT.TRF
Fill in name of each traintype, number of trains going in each direction weekly, and the projected growth or decline

type	number east	number west	percent growth/decline
EMPTY	14	7	0
INTERMODAL	7	7	0
LIGHT_UNIT	3	7	0
HEAVY_UNIT	4	7	0
MIXED	17	17	0
PASSENGER	7	7	0
	0	0	0

7.2.3 Screen # 3 - Describing a Train

A series of screens will appear, one for each train. For each train, type in the number of cars and locomotives that have gross weights in each of the categories that appear in the screen. Use the <Right Arrow> key to go to the screen that describes the next train in the traffic mix. Use the
<Left Arrow> key to go to the screen that describes the previous train in the traffic mix.

If <Esc> is pressed at this point, default values will be used to describe the cars in each train.

```
                  TRAFFIC INPUT: SCREEN 3 OF 4

TRAFFIC FILE:DEFAULT.TRF   TRAIN TYPE:HEAVY_UNIT
The following equipment typically makes up this traintype.
Enter the number of units of each Gross Weight (Net and Tare) in one train
```

locomotives					cars				
200	180	160	140	130	130	100	80	50	30
4	0	0	0	0	0	90	0	0	0

```
speed category  :    7
```

7.2.4 Screen # 4 - Describing a Car or Locomotive

A series of screens will appear, one for each car or locomotive. Use the <Right Arrow> key to go the screen that describes the next car or locomotive in the traffic mix. Use the <Left Arrow> key to go to the screen that describes the next car or locomotive in the traffic mix.

This is most detailed screen in the Traffic Module. If <Esc> if pressed at this point no default values need to be calculated; all values that are used to build the traffic file have been specified by the user.

```
              TRAFFIC INPUT: SCREEN 4 OF 4

TRAFFIC FILE:DEFAULT.TRF    CAR TYPE:LOC130

DATA FOR THIS CAR
```

number of axles	2
wheelload	32500
unsprung mass	3500
wheel diameter	40
center of gravity	90

7.3 Route/Track Module Screens

These screens enable the user to create a new Route/track file or edit an existing Route/track file. The file will be saved and its name will be placed in the list of input files to be used by RAILWEAR.

7.3.1 Screen # 1 - Choosing the Approach

When creating a Route/track file, two different approaches can be chosen. The Percentage approach enables a user to describe a subdivision by indicating what percentage of the subdivision consists of tangent track, what percentage consists of curved track etc. To choose this approach type <P> at the cursor. The Segment approach enables a user to describe a subdivision by specifying the length, curvature, gradient and other values for each segment. To choose this approach type <S>.

7.3.2 Screen # 2 - Choosing the Filename

If the **P** approach was chosen, this screen will display a listing of all files in the directory **C:\TRACS** that have the extension **.RTP**. If the **S** approach was chosen, this screen will display a listing of all files in the directory **C:\TRACS** that have the extension **.RTS**. If no such files are found the user will be prompted to give the name of other directories that may contain Route/track files.

To edit an existing Route/track file, type the name of the file as it is displayed in the listing. To create a new Route/track file, give the file a name that is different from all the files in the listing, and type this name at the location of the cursor. The program will automatically give the correct extension to the new file.

If an existing file is chosen and no editing needs to be done, <Esc> can be pressed at this point to leave the Route/track module.

```
            ROUTE/TRACK INPUT- PERCENT APPROACH: SCREEN 2 OF 7

    THIS IS A DIRECTORY OF THE EXISTING ROUTE/TRACK FILES


                       HILLGOOD.RTP
        LARRY.RTP      HILLPOOR.RTP
        CARL.RTP       FLATPOOR.RTP
        J1.RTP         HILLCURV.RTP
        HILLS.RTP      CURVES.RTP
        FLATGOOD.RTP   LANDMART.RTP
        FLATEXC.RTP
        OLIVER.RTP
        MNTGOOD.RTP
        MNTEXC.RTP
        MNTPOOR.RTP
        HILLEXC.RTP




    TYPE THE NAME OF THE FILE YOU WANT TO USE: HILLCURV.RTP
```

7.3.3 Screen # 3 - The Subdivision

If an existing file was chosen, the program will read the entire file and go through the data distillation process to calculate the values for total length, number of segments, overall condition and other variables which give a general description of the entire subdivision. The values will be displayed in this screen.

If a new file was chosen, the program will read in a default file, MITDEF.RPD in case of the Percentage approach, MITDEF.RSD in case of the
Segment approach and go through the data distillation process.

On this screen the annual MGT is displayed, as it was calculated from the traffic file that was edited most recently. If a new Route/track file was chosen, the MGT will be set to match this MGT from the traffic file. If an existing Route/track file was chosen, the MGT will not be reset. The number calculated from the traffic file is only displayed for the user's information.

If the value of a variable on this screen is changed by the user, all values that are dependent on this variable will be changed by the program.

If <Esc> is pressed at the end of this screen, a Route/track file will be saved in which the data for each segment are chosen based on the information given in this screen and the reference tables in the default file. If <PgDn> is pressed the user will be able to edit the values that were chosen for each segment.

7.3.3.1 The Percentage Approach

Changing the values of variables in this screen will affect the Route/track file in the following manner:

Changing the total length will cause the program to recalculate the length of each segment.

Changing the annual MGT will cause the program to reset the pointers to records in the metallurgy file, rail parameters file, tie materials file and ballast file.

Changing the FRA class will cause the program to reset the pointers to records in the rail condition file, tie condition file and surface file. It will also change the speed limit so that every speed that is typed in by the user on following screens will be checked against this speed limit.

Changing the answer to the lubrication question will cause the program to reset the pointers to records in the friction file.

Changing the answer to the grinding question will cause the program to reset the pointers to records in the grinding file.

Changing the percentages will cause the program to add or delete segments, and recalculate the lengths of all segments. If a non-zero percentage is entered in any of the 3 cells in the tangent column, the program will create 2 segments of equal length, one with 0 degree curvature and the other with 1 degree curvature. The sum of the lengths of these two segments will equal the percentage of the total length that was given by the user. If a non-zero percentage is entered in any of the other 9 cells the program will create 3 segments of equal length, which will have curvature that falls in the required category. The sum of the lengths of these three segments will equal the percentage of the total length that was given by the user.

ROUTE/TRACK FILE:HILLCURV.RTP

```
Total length of route:  28
Annual MGT from traffic file  33
Annual MGT :H
Environment:TF
FRA Class  : 3
Is grinding used ?    :N
Is lubrication used ?:N
```

FILL IN PERCENTAGES

grade curve	tangent	low	medium	high
flat	0.00	10.71	10.71	10.71
gentle	14.29	21.43	21.43	10.71
steep	0.00	0.00	0.00	0.00

7.3.3.2 The Segment Approach

Changing the values of variables in this screen will affect the Route/track file in the following manner:

Changing the total length will cause the program to recalculate the length of each segment.

Changing the annual MGT will cause the program to reset the pointers to records in the metallurgy file, rail parameters file, tie materials file and ballast file.

Changing the FRA class will cause the program to reset the pointers to records in the rail condition file, tie condition file and surface file. It will also change the speed limit so that every speed that is typed in by the user on following screens will be checked against this speed limit.

Changing the answer to the lubrication question will cause the program to reset the pointers to records in the friction file.

Changing the answer to the grinding question will cause the program to reset the pointers to records in the grinding file.

Changing the number of segments will cause the program to recalculate the length of each segment.

ROUTE/TRACK INPUT- SEGMENT APPROACH: SCREEN 3 OF 7

ROUTE/TRACK FILE:BOSTWORC.RTS

```
Total length of route:   60
Annual MGT from traffic file   33
Annual MGT :M
Environment:TF
FRA Class  : 3
Number of segments   :  9
Is grinding used ?   :Y
Is lubrication used ?:Y
```

7.3.4 Screen # 4 - Choosing a Segment

To choose a segment in the subdivision, type its number at the cursor.

```
ROUTE/TRACK FILE:HILLCURV.RTP
```

```
The total number of segments is 28 .

Type the number of the segment to be
edited next. To quit type 0.        1
```

7.3.5 Screen # 5 - Details for each Segment

This screen is split into two halves. Once the values on the left half of the screen are entered, the values for the right half of the screen are calculated and displayed. In the percentage approach, the values for percent grade, degree curve, and segment name cannot be changed by the user, because they are set as a result of the table in screen 3. In the segment approach, all values can be changed by the user. Changes in the left half of the screen will affect the data for this segment in the following manner:

If the percent grade is changed, the program will choose a different speed for this segment.

If the degree of curvature is changed, the program will reset the pointers to records in the metallurgy file, rail parameters file, tie material file, fasteners file, ballast file, friction file and grinding file. Changing the degree of curvature will also cause the speed and superelevation on the segment to be recalculated.

If the length of the segment is changed, the number of turnouts on the segment will be recalculated. In the segment approach the beginning milepost will also be changed.

If the annual MGT is changed, the program will reset the pointers to records in the metallurgy file, rail parameters file, tie material file, ballast file, friction file and grinding file.

In the right hand side of the screen, the speed for a speed category 1 train cannot be changed to a value that is greater than the speed limit, which was chosen based on the FRA class of the entire subdivision. If the speed for a category 1 train is changed, superelevation and the speed for trains in every other speed category will be recalculated.

ROUTE/TRACK INPUT: SCREEN 5 OF 7

ROUTE/TRACK FILE:HILLCURV.RTP   SEGMENT NAME: 2   SEGM.1 OF 28

```
ROUTE
Percent grade:    0.00
Degree curve :    2.00
Length of segment:  1.00
Annual MGT    :    80
```

ROUTE/TRACK FILE:HILLCURV.RTP   SEGMENT NAME: 2   SEGM.1 OF 28

```
ROUTE                          RAIL
Percent grade:    0.00         Weight:     2
Degree curve :    2.00         Metal :     2
Length of segment:  1.00       Condition  2
Annual MGT    :    80
                               TIES        FASTENER
                               Material: 3  Spike/Clip: 1
                               Condition 1  Plate     : 6
                                            Anchor/Pad: 9

                               SURFACE
                               Material:   1
                               FRA class   5

                               Speed of a speedcategory 1
                               train    :    34
```

273

7.3.6 Screen #7 - More Details for each Segment

All the values that appear on this final screen are derived from inputs in the previous screens. There is no further level of detail.

All values that are displayed on this screen were chosen as a result of values entered in previous screens. This is the most detailed screen in the Route/track. Once this screen has been edited no more default values need to be calculated for the current segment; all values that describe this segment have been specified by the user.

The <Right Arrow> key can be pressed to edit the next segment. The <Left Arrow> key can be used to edit the previous segment. <PgUp> can be pressed to return to the segment menu and choose a segment other than the next or previous segment to work on.
<Esc> can be pressed to save the Route/track file with all the changes that have been made.

ROUTE/TRACK INPUT: SCREEN 7 OF 7

ROUTE/TRACK FILE:HILLCURV.RTP   SEGMENT NAME:2   SEGM.1 OF 28

speed on this segment:	speedcategory							
	1	2	3	4	5	6	7	8
	34	32	30	28	26	24	20	0

Superelevation: 6.00
Number of turnouts: 3
Lubrication code: 7

Grinding	code	frequency
high rail	1	0
low rail	1	0
gage face	1	0

7.4 Cost Module Screens

7.4.1 Screen # 1 - Choosing a Filename

This screen will display a listing of all files in the directory C:\TRACS that have the extension .CST. If no such files are found or if this directory cannot be read, the user will be asked to indicate in what other directory the cost files may be found.

To edit an existing file, type its name as it occurs in the listing. To create a new file, give it a name that is different from all the files in the listing. The program will automatically give the extension .CST to all cost files that are created or edited.

If the name of an existing file was given, and no editing is required, the user can press <Esc> to leave the Cost Module at this point.

```
                        COSTING FILE: SCREEN 1 OF 5

THIS IS A DIRECTORY OF EXISTING COST FILES


 STANDARD.CST










TYPE THE NAME OF THE FILE YOU WANT TO USE: STANDARD.CST
```

7.4.2 Screen # 2 - Financial Data.

In this screen the user is asked for data that will be used for a variety of cost calculations. The Percentages are entered as numbers between 0 and 100 %. Since the TRACS version 1.1 does not yet have reports for accounting applications, the tax rate and depreciation rates are not used.

```
                    COSTING INPUT: SCREEN 2 OF 5

COST FILE : STANDARD.CST

  ┌─────────────────────────────────────┐
  │ ┌─────────────────────────────────┐ │
  │ │                                 │ │
  │ │  FINANCIAL DATA                 │ │
  │ │  ─────────────                  │ │
  │ │                                 │ │
  │ │  Discount Rate:    10.00 %      │ │
  │ │                                 │ │
  │ │  Inflation Rate:    3.00 %      │ │
  │ │                                 │ │
  │ │  Income Tax Rate: 20.00 %       │ │
  │ │                                 │ │
  │ │  Depreciation Type:    S        │ │
  │ │                                 │ │
  │ │  Assets are depreciated         │ │
  │ │           over  25   years      │ │
  │ │                                 │ │
  │ └─────────────────────────────────┘ │
  └─────────────────────────────────────┘
```

COST FILE : STANDARD.CST

```
Option 1 : Give less detailed cost inputs.
           If this option is chosen, only general
           cost reports can be created.

Option 2 : Give detailed cost inputs.
           If this option is chosen, detailed cost
           reports can be created.

           Type 1 or 2, for Option chosen :   1
```

7.4.3 Screen # 3 - Menu.

The user can edit a cost file at two levels of detail. The first approach is by giving less detailed, more general cost inputs, such as the cost of rail relay projects per mile, the average gang size, etc. To choose this approach, type 1 at the menu. The second approach is by giving highly detailed, more specific cost inputs, such as the costs of different types of rail, the hourly wages of each different gang, etc. To choose this approach, type 2 at the menu. In order to save time, you may want to edit the low level cost inputs first, then look at the detailed costs. For example, if you know that most of your laborers are paid $12.00 an hour, you can enter that at the low level input for wages. Then, when you edit the detailed cost inputs, all of the wage numbers will be $12.00 and you will only have to edit the few atypical cases.

7.4.4 Screen # 4 - Choices for Less Detailed Cost Inputs.

This screen displays the different options that a user has for giving less detailed cost inputs. To choose an option, type its number. The screen also offers the option to save the cost file and quit, or to continue with more detailed cost inputs.

COSTING INPUT: SCREEN 4 OF 5

COST FILE : STANDARD.CST

```
+-----------------------------------------------------------------+
| MENU OF CHOICES FOR LESS DETAILED COST INPUTS                   |
+-----------------------------------------------------------------+
| 1. Unit costs for rail projects and maintenance activities.     |
|                                                                 |
| 2. Average labor and machinery costs for Rail Project gangs.    |
|                                                                 |
| 3. Average labor and machinery costs for Rail Maintenance gangs.|
|                                                                 |
| 4. Unit costs for tie projects and maintenance activities.      |
|                                                                 |
| 5. Unit costs for surface projects and maintenance activities.  |
|                                                                 |
| 6. Go to the editing screens for more detailed cost inputs.     |
|                                                                 |
| 7. Save cost file and return to control program.                |
+-----------------------------------------------------------------+
|   Type the number between 1 and 7 for menu choice :   1         |
+-----------------------------------------------------------------+
```

7.4.5 Screen # 5 - Unit Costs for Rail Projects and Maintenance.

In this screen the user is asked to enter costs per mile for several different Rail Projects and Maintenance activities. There are two columns for each cost, one labeled DERIVED and one labeled USER DEFINED. In the DERIVED column the unit costs are displayed as they are calculated using more detailed cost information. To derive the cost per mile for a rail relay, for example, the cost of rail, fasteners labor and machinery are used. If the numbers in the DERIVED column are displayed in green, the detailed costs that are used to calculate the unit cost are the same as the default costs. However, if the number is red, then the user has previously edited some high level costs which affect the unit cost.

In the USER DEFINED column, the user can decide to enter different unit costs. This is helpful for testing the sensitivity of the various reports to total costs. The questions that can be answered using this approach are :

1) What happens to the EUAC if rail relay costs go up by 25% ?

2) What happens to the total costs for some future year if the cost of grinding is cut in half ?

If you want to compare the test costs with the derived costs, you can only look at reports that are based on the low level costs.

COST FILE : STANDARD.CST

RAIL LOW-LEVEL UNIT COSTS

		Derived	User Defined
Relay	$/mile	234567	234567
Transposition	$/mile	33465	44567
High-Low	$/mile	198736	197545
Annual Grinding	$/mile/yr	300	350
Annual Lubrication	$/mile/yr	301	351
Annual Defect Repair	$/mile/yr	456	567

TIES LOW-LEVEL UNIT COSTS

		Derived	User Defined
Out-of-face renewal	$/mile		
Tie Program	$/mile		
Tie Treatment	$/mile		
Spot Tie Renewal	$/mile/yr		

SURFACE LOW-LEVEL UNIT COSTS

		Derived	User Defined
Raise, Line & Surface	$/mile		
Annual Surfacing	$/mile/yr		
Ballast Renewal	$/mile		
Undercutting & renewal	$/mile		
Ditching	$/mile		
Subgrade stabilization	$/mile		
Annual washout	$/mile/yr		

7.4.6 Screen # 6 - Average Costs for Project Gangs

In this screen the user is asked to enter the average or typical costs for Project Gangs. In the case of rail, this includes relay gangs, transposition gangs and high-low gangs. This number will eventually be downward asserted to tie gangs and surfacing gangs as well.

COST FILE : STANDARD.CST

PRODUCTION GANG LOW-LEVEL UNIT COSTS

		Derived	User Defined
Gang Hours Worked	hrs/day	0.0	0.0
Gang Size		0	0
Gang Wage	$/hr	0.00	0.00
Work Train Cost	$/mile	0.0	0.0
Transport Cost	$/job	0.0	0
Machinery Cost	$/day	0.0	0

7.4.7 Screen # 7 - Average Costs for Maintenance Gangs.

In this screen the user is asked to enter average costs for Maintenance gangs. These include defect repair gangs, turnout maintenance gangs, oiler gangs and grinder gangs.

COST FILE : STANDARD.CST

MAINTENANCE GANG LOW-LEVEL UNIT COSTS

		Derived	User Defined
Gang Hours Worked	hrs/day	0.0	0.0
Gang Size		0	.0
Gang Wage	$/hr	0.00	0.00
Work Train Cost	$/mile	0.0	0.0
Transport Cost	$/job	0.0	0
Machinery Cost	$/day	0.0	0

7.4.8 Screen 8 - Choices for More Detail Cost Inputs.

This screen displays all the choices for the detailed cost input screens. To choose a screen, type its number at the prompt. There are screens developed for the other track components as well. However, there are no numbers in these screens, because those deterioration modules are not yet implemented in Version 1.1 of TRACS.

```
                    COSTING INPUT: SCREEN 4 OF 5

COST FILE : STANDARD.CST

╔═══════════════════════════════════════════════════════════════╗
║  ┌─────────────────────────────────────────────────────────┐  ║
║  │   MENU OF CHOICES FOR DETAILED COST INPUTS              │  ║
║  ├─────────────────────────────────────────────────────────┤  ║
║  │ 1. Labor and machinery costs for rail Relay projects.   │  ║
║  │ 2. Labor and machinery costs for rail Transpose projects.│ ║
║  │ 3. Labor and machinery costs for rail High-Low projects.│  ║
║  │ 4. Labor, machinery and material cost for Lubrication.  │  ║
║  │ 5. Labor and machinery costs for Turnout replacement.   │  ║
║  │ 6. Labor and machinery costs for Turnout maintenance.   │  ║
║  │ 7. Labor and machinery cost for Grinding.               │  ║
║  │ 8. Material cost - Rail.                                │  ║
║  │ 9. Material cost - OTM (Other Track Material).          │  ║
║  │ 10.Material cost - Ties.                                │  ║
║  │ 11.Material cost - Ballast.                             │  ║
║  │ 12.Save cost file and return to control program.        │  ║
║  ├─────────────────────────────────────────────────────────┤  ║
║  │   Type the number between 1 and 12 for menu choice :  1 │  ║
║  └─────────────────────────────────────────────────────────┘  ║
╚═══════════════════════════════════════════════════════════════╝
```

7.4.9 Screen 9 - Labor and Machinery costs for Relay Projects.

In this screen the user is asked to give labor and machinery costs for relay projects.

```
COST FILE : STANDARD.CST
```

```
RAIL RELAY LABOR AND MACHINERY COSTS
─────────────────────────────────────────

Gang Hours per Working Day        8.0   hours

Gang Size                          30

Gang Wage                       14.50   $/hr

Work Train Cost for Material   500.00   $/mile

Cost of Gang&Machinery Transport  999   $/job

Cost of Relay Machinery           999   $/day
```

7.4.10 Screen 10 - Labor and Machinery Costs for Transposition Projects.

In this screen the user is asked to give Labor and Machinery costs for transposition projects.

```
COST FILE : STANDARD.CST
```

```
RAIL TRANSPOSITION LABOR AND MACHINERY COSTS
─────────────────────────────────────────────

Gang Hours per Working Day         8.0   hours

Gang Size                           20

Gang Wage                        15.00   $/hr

Work Train Cost for Material    500.00   $/mile

Cost of Gang&Machinery Transport   999   $/job

Cost of Transposition Machinery    999   $/day
```

7.4.11 Screen 11 - Labor and Machinery Costs for High - Low projects.

In this screen the user is asked to give Labor and Machinery costs for High - Low projects.

COST FILE : STANDARD.CST

```
RAIL HIGH-LOW LABOR AND MACHINERY COSTS
_____

Gang Hours per Working Day        8.0   hours

Gang Size                          20

Gang Wage                        14.50   $/hr

Work Train Cost for Material  .  500.00 $/mile

Cost of Gang&Machinery Transport   999 $/job

Cost of High-Low Machinery         999 $/day
```

7.4.12 Screen 12 - Labor, Machinery and Materials Costs - Lubrication.

In this screen the user is asked to give Labor, Machinery and Material costs for Lubrication.

COST FILE : STANDARD.CST

```
LUBRICATION LABOR AND MATERIALS COSTS
─────────────────────────────────────────────

Gang Hours per Working Day          8.0   hours

Gang Size                             2

Gang Wage                          15.00  $/hr

Cost of Lubrication Machinery     300.00  $/day

Cost of Lubricant                      0  $/lb

Cost of Lubrication Applicator       100  $/each
```

7.4.13 Screen 13 - Grinding.

In this screen the user is asked to give Labor and Machinery costs for grinding.

```
COST FILE : STANDARD.CST
```

```
GRINDING LABOR AND MACHINERY COSTS
_____

Gang Hours per Working Day        8.0    hours

Gang Size                          10

Gang Wage                        20.00   $/hr

Cost of Grinder                 1000.0   $/hr
```

7.4.14 Screen 14 - Material Costs - Rail

The rail types displayed on this screen are all the rail types that are currently in the metallurgy file. If the user changes any of these costs they will be saved back to the metallurgy file.

```
COST FILE : STANDARD.CST
```

```
MATERIAL COSTS -- RAIL

Scrap Value     100      $/ton
Disposal Cost   10       $/ton

Rail Type        | Cost ($/ton)

1.  STANDARD     | 400.0
2.   PREMIUM     | 450.0
3.    SUPERP     | 500.0
4.
5.
6.
7.
8.
9.
```

288

7.4.15 Screen 15 - Material Costs - OTM

The OTM types displayed on this screen are all the OTM types that are currently in the
Fastener file. If the user changes any of these costs they will be saved back to the
Fastener file.

```
COST FILE : STANDARD.CST
```

MATERIAL COSTS -- OTM			
Scrap Value 100 $/ton Disposal cost 50 $/ton			
OTM Item	Cost ($/each)	OTM Item	Cost ($/each)
1. CUT_SPK	0.05	11. RUBBRPAD	0.30
2. SPR_CLP	0.55	12. POLYPAD	0.30
3. COMP_CLP	0.55	13.	
4. 8X14PLAT	1.20	14.	
5. 8X14PLAT	1.20	15.	
6. 7X13PLAT	1.20	16.	
7. 8X14PLAT	1.20	17.	
8. 9X6PLAT	1.20	18.	
9. SPR_ANCH	0.40	19.	
10. DRV_ANC	0.40	20.	

8 Report Module Screens

The Report Formatting Module contains a number of menus to direct the user through the different categories of reports to the individual report(s) he wants to see. If you ever request the Report Module to do something and the screen flashes or you get an empty table, it is because that option is not currently available and is probably being worked on as you read this manual.

The first screen of this module will ask you for a directory that contains the output file(s) created by RAILWEAR. For this release, all of these files will be in the C:\TRACS directory, so just press <Return>. If some error occurs, type "c:\TRACS" at the prompt. Then a list of all output files available will be displayed. The name of each file will be the analysis name appended with a ".OUT", indicating its function as an output file from RAILWEAR. Type the name of a displayed file, with or without the ".OUT" suffix, to see reports created from that analysis.

It is important that you DO NOT manually manipulate the output files, because an incorrect format will cause an error in the Report Module. It is quite acceptable to view the output files in a text editor, as long as they are not modified in any way.

Examples of the Report Module's introductory screens follow.

```
Formatting the TRACS output, ----                    Preliminary information
═══════════════════════════════════════════════════════════════════════════

Available output files:

   LAR.OUT
   TEST_17.OUT




Name of file to be used: test_17.out
```

8.1 Report Module Important Menu Screens

You will notice that after the Preliminary Information screens, the title of the analysis you are examining will be written at the top of the screen.

This screen prompts the user for a particular category of report. In future releases, there will be reports available on results from a tie model, a surfacing model, and more; these options are currently listed on the main menu. However, because Version 1.1 has just the RAILWEAR model, all other options beside "1. Rail" will do nothing. Moving the yellow box to the first line and pressing <Return> or typing the number 1 anywhere on the screen will cause a menu displaying all the options for rail reports to appear. To create reports from another analysis, just press the <Esc> key at this screen. You must also do this if you wish to leave the Report Module.

Here is the Main Menu that will be displayed.

Paste Main menu screen.

```
Formatting the TRACS output, TEST_17                          Main menu
═══════════════════════════════════════════════════════════════════════
                     Select from the following categories:
                   ┌─────────────────────────────┐
                   │ 1.  Rail           .       . │
                   └─────────────────────────────┘

                     2.  Ties

                     3.  Surface and subgrade

                     4.  Total track structure

                     5.  Signals and crossings

                     6.  Bridges and buildings

                     7.  Switches and sidings

                     8.  Yards and terminals

                     9.  Total right-of-way

   Press <Esc> to exit from this menu.
```

8.2 Introductory Rail Report Screen

The menu displayed here lists all of the types of reports that can be created with respect to rail. Again, a yellow box will appear, and you can move this box to the different options with your arrow keys. Also, some letters and numbers will work. The letter "C", when pressed, will move the box to the Cost side of the screen, and the letter "E" will move it to the Engineering column. A number key will select the appropriately numbered line in the current column. Otherwise, an option can be selected by moving the box to that option and pressing <Return>.

Here are some examples of how to work with this menu:

Joe Accountant wants to see reports showing the cash outlays for grinding on this subdivision. He first presses the "C" key and then the "2" key, since grinding is a planned activity that is considered routine maintenance. Joe's boss, however, likes arrow keys, and suggests pressing the down and right arrow keys in succession, and then typing <Return>.

Robbie "Super Premium" Railman wants to find out how much he and the rest of his Relay Gang will be getting paid in the next couple of years, but pressing the right arrow key doesn't seem to work. The computer jockey, who's desk Robbie is at, tells him that the arrow keys will not work if the <Num Lock> key has been pressed. He presses <Num Lock> to turn it off, moves the box to "1. Projects" under the Cost Reports column, and presses <Return>.

The categories themselves are relatively self-explanatory. Project reports will detail activities or costs regarding rail replacement or transposition projects, while maintenance reports describe more minor or planned activities like grinding, lubrication, and spot repairs. The total category includes reports that contain information from both of these categories, like overall total expenditures or summary reports. Subdivision Statistics involve statistical figures for the entire subdivision modeled, like average wear rates. Traffic class analysis is selected when you want to determine the cost differences associated with changing the modeled traffic.

Here is what the Introductory Rail Report Screen will look like:

Introductory rail report screen goes here

```
Formatting the TRACS output, TEST_17          Introductory rail report screen
═══════════════════════════════════════════════════════════════════════════════


         Engineering reports                       Cost reports
     ─────────────────────────                  ──────────────────

    ┌─────────────────────────┐
    │1. Project               │               1. Project
    └─────────────────────────┘
     2. Maintenance                            2. Maintenance

     3. Total project & maintenance            3. Total project & maintenance

     4. Subdivision statistics                 4. Subdivision statistics

                                               5. Rail PESOS




Press <Esc> to return to main menu.
```

A Table/Graph option will appear at the bottom of the screen after a category is selected. As of now, the graphs are not implemented, and pressing <Return> proceeds to the next screen. The following sections will detail what happens when you select each of the categories.

8.3 Rail Engineering Reports

The reports are separated into two major classes: engineering and cost. First, the engineering reports give specific detailed information about material consumption, project scheduling, and labor requirements. In addition, the engineering reports include summary presentations of totals for a whole subdivision, and average material lives for the subdivision.

8.3.1 Project Engineering Reports

The next menu lists specific reports available for this category. An option is chosen the same way as before, and the <Esc> key returns the user to the previous menu. These types of reports are helpful to people in a company who do project planning. A project is defined by the TRACS program as a scheduled maintenance activity. These are not routine things done by a section gang, but rather major rehabilitation projects that require specialized gangs and equipment.

Rail project eng report screen here.

```
Formatting the TRACS output, TEST_17          Rail project engineering reports
================================================================================


               ┌────────────────────────────────────┐
               │ 1. Project activity by year         ║
               └────────────────────────────────────┘

                 2. Project schedule by segment, format 1

                 3. Project schedule by segment, format 2

                 4. Material requirement by year

                 5. Labor requirement by year

                 6. Create/print selected tables (graphs)




Press <Esc> to return to previous menu.
```

8.3.1.1 Project Activity by year

This report details the major projects predicted by RAILWEAR. This is a verbose description of each project classified by segment and year. From this screen, as with any other report screen, you can make a printout of the displayed report, save the report in a file for later use, or just exit to the previous menu. Future releases will have a Table to Graph option for each report, where you may choose to view (and print or save) the associated graph. This report may be helpful to a road-master as a planning tool. It lists the kind of metallurgy that is presently in each segment and the type of metallurgy that the maintenance policies specify should be used when it is replaced. Each year has a summary of the activity for that year, and a description for those segments that have projects.

first engineering report here

```
FL4          0.00-6.67
  Transpose existing 132STD rail.

GL2          0.00-1.67
  Transpose existing 132STD rail.

GL3          0.00-1.67
  Transpose existing 132STD rail.

GL4          0.00-1.67
  Transpose existing 132STD rail.
_____
                         1995

SUMMARY:
==> RELAY total of 24.99 miles of rail.

FM5          0.00-5.00
  Replace existing 132STD rail with 132PRM rail.
```

```
The entire report may not fit onto this screen. Use the up and down arrow keys
to move up or down one line. <PgUp>, <PgDn>, <Home>, and <End> work normally.
<C> to create file, <P> to create and print file, <Esc> to exit to menu.
```

8.3.1.2 Project Schedule by Segment, Format 1

The first screen will ask the user to identify the projects to include in the table. For example, the manager responsible for ordering specialized equipment for transporting rail to relay sites will not be interested in transpositions; he can choose to have display only relays and high-low projects. The table itself displays the length of rail needed for this project for each segment. You may choose this report for a brief summary of the expected projects, while the totals in the top column can give you more general information. Again, you can print this report, save it, or do nothing with it.

first project schedule report screen here

```
This table may include, at your discretion, figures for up to ten years

of the predicted miles of track per segment to be transposed, relaid, or

replaced by the High-Low method.

Please select those maintenance techniques you would like to have

displayed in this table (type "y" or "n" for each):


          TRANSPOSE? y HIGH-LOW? y RELAY? y


      Is this the information you want?
```

SEGMENT NAME AND MILEPOSTS	1997			1998			1999		
	TPOSE	HI-LO	RELAY	TPOSE	HI-LO	RELAY	TPOSE	HI-LO	RELAY
TOTAL			25.02			50.00			
FT0 0.00- 20.00						20.00			
FT1 0.00- 20.00						20.00			
FL2 0.00- 6.67			6.67						
FL3 0.00- 6.67			6.67						
FL4 0.00- 6.67			6.67						

```
CONTROL KEYS:  ,  , <PgUp>, <PgDn>, <Home>, <End>, <H> for help,
<C> to create file, <P> to create and print file, <ESC> to exit to menu.
```

8.3.1.3 Project Schedule by Segment, Format 2

The purpose of this report is the same as the previous one, except project types are abbreviated and not given separate columns. There are also no total figures given. An 'R' designates a relay, a 'T' designates a transposition, and an 'H' designates a high-low. This may be easier to read than the previous report.

SEGMENT NAME AND MILEPOSTS	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
FT0 0.00- 20.00										R 20.00
FT1 0.00- 20.00										R 20.00
FL2 0.00- 6.67	T 6.67								R 6.67	
FL3 0.00- 6.67	T 6.67								R 6.67	
FL4 0.00- 6.67	T 6.67								R 6.67	
FM5 0.00- 5.00							R 5.00			

```
 ,  , <PgUp>, <PgDn>, <Home>, <End>, <H> for help,
<C> to create file, <P> to create and print file, <ESC> to exit to menu.
```

8.3.1.4 Material Requirement by Year

This table details the specific material quantities that are predicted for projects only. The numbers of spikes, plates, etc. needed per mile are calculated from the information entered in the Install program, or if they were not entered, from default values. This would be helpful to a manager who was responsible for warehousing materials, material requisition, or material control.

material requirement screen

MATERIALS REQUIRED	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
115STD(tons)										10120
132PRM(tons)							5806		5813	
7X13PLAT										10368
CUT_SPK	17293						38864		38911	77760
SPR_ANCH	13690						13674		13690	27360
8X14PLAT	11529						12954		1297C	552

```
, <PgUp>, <PgDn>, <Home>, <End>, <H> for help,
<C> to create file, <P> to create and print file, <ESC> to exit to menu.
```

8.3.1.5 Labor Requirement by Year

The number of gang days required is displayed for each gang type on this table. Also, the total number of gang days is given for each year. This report is useful in determining future hiring policies. These numbers are calculated from gang productivity inputs or default productivities. Remember that these figures are only involved with rail projects, not routine maintenance.

labor requirement screen

RAIL PROJECT LABOR REQUIREMENTS

GANG TYPE	Gang days									
	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL	12.5						8.3		8.3	16.7
Transpose gang	12.5									
High-low gang										
Relay gang							8.3		8.3	16.7

```
Relay gang size : 30
Transpose gang size : 20
High-low gang size : 20
```

<C> to create file, <P> to create and print file, <Esc> to exit to main menu.

8.3.1.6 Create/Print Selected Tables/Graphs

This screen will ask you, for each rail project engineering report, whether you want a printed version and/or a copy saved on disk. If you decide to print a particular report, it will also be saved, assuming that a report worthy of being printed is also worthy of coming back to later. In later releases, there will be an option to print existing reports (i.e., those saved from previous analyses). Saved and printed reports will have a line identifying the user who ran the analysis and the time RAILWEAR began it.

Should the user decide to print or save (create) a report, the next screen will ask them what file name to save it under. Rail Project Engineering reports will automatically have the suffix ".RPE", Rail Maintenance Cost reports will be appended ".RMC", etc. If the user decides that the default name is acceptable, he can just hit <Return> to accept that name. Typing "exit" will terminate saving or printing of the file.

create report screen goes here

```
Formatting the TRACS output, LAR              Rail project engineering reports
================================================================================


    RAIL PROJECT ENGINEERING REPORT #1 : Project activity by year
    RAIL PROJECT ENGINEERING REPORT #2 : Project schedule by segment, format 1
    RAIL PROJECT ENGINEERING REPORT #3 : Project schedule by segment, format 2
    RAIL PROJECT ENGINEERING REPORT #4 : Matrial requirements
    RAIL PROJECT ENGINEERING REPORT #5 : Labor requirements



                    Print this report?    (Y,N)




Press <Esc> to return to previous menu.
```

8.3.2 Rail Maintenance Engineering Reports

These are engineering reports which list data only for routine activities. In the case of rail, routine activities include grinding, lubrication, and spot defect repair. These reports are helpful to road-masters who need to plan their work schedules for various lines. They may also help higher level managers test the cost of better maintenance vs. better materials.

8.3.2.1 Defect Repair Schedule by Segment

This report is not implemented yet, but will show the expected number of spot rail replacements that are to take place in the up coming years.

8.3.2.2 Material Requirement by Year

This is identical to the Project Material Requirement table, except that the only material listed is lubrication and lubrication applicators. TRACS does not yet model defects, and there are not really any materials consumed by a grinding gang. The cost of wheels and fuel is included in the cost/hr. figure which is input in the cost module.

8.3.2.3 Labor Requirement by Year

The number of gang days required is displayed for each gang type on this table. Also, the total number of gang days is given for each year. This report is useful in determining future hiring policies and for scheduling work duty for the various gangs. As in the report for project labor requirements, these numbers are calculated from gang productivity inputs or default productivities. Remember that these figures are only involved with rail projects, not routine maintenance.

8.3.2.4 Create/Print Selected Rail Maintenance Reports

Same as 1.3.1.6 from above.

8.3.3 Rail Total (Comprehensive) Engineering Reports

These reports aggregate the two previous sets of reports. The totals in each category are simply the sum of the project and maintenance data.

8.3.3.1 Material Requirement by Year

This is essentially identical to the reports of the same name under the Project and Maintenance headings. It sums the contribution from both Projects and Maintenance.

8.3.3.2 Labor Requirement by Year

Here we can look at total labor for this subdivision. This may be helpful to a contract negotiator who is reviewing what the labor needs have been and are expected to be for various functions.

8.3.3.3 Create/Print Selected Total Rail Engineering Reports

Same as 1.3.1.6 from above.

8.3.4 Rail Engineering Subdivision Statistics

These reports are meant to give a user an overview of the condition and needs of this subdivision. These reports are very similar to the information produced by the old TMCost model. In fact, if you start out with new rail, and choose a planning horizon of 100, you can exactly reproduce the type of analysis that TMCost performed. The subdivision engineering statistics are presented at two levels of detail. A menu appears, which lists three options. Displaying the option to either view the associated report or to save/print it is at the end.

8.3.4.1 Detailed Rail Statistics

This report serves to give specific statistical information for the entire subdivision rather than specific segments. Numbers are given for the average miles transposed, relaid, and high-lowed per year. One can also find information such as average life and wear rates about all of the curve/metal combinations that exist in the route file. Average numbers of defects will be included once a fatigue module is installed in TRACS.

paste the first subdivision statistics

```
        Route file: C:\TRACS\DATA\LANDMART.RTP
        Traffic file: C:\TRACS\DATA\CASE.TRF
        Average annual MGT : 37.9
        Average miles transposed per year : 2.50
        Average miles high-lowed per year : 0.00
        Average miles relaid per year      : 10.00
        Total Length of Route : 100.01 miles
           Degree Average Wear Rates  Average Defect Rates  Average Rail Lives
Metallurgy Curve     (in/100MGT)      (defects/mile/year)        (years)
_____

 STANDARD
  PREMIUM
   SUPERP




<C> to create file, <P> to create and print file, <Esc> to exit to main menu.
```

8.3.4.2 Summarized Rail Statistics

This report combines all of the different metallurgies, curves, and traffic into one set of statistics. These averages are weighted by length of segment. This kind of report is useful in identifying anomalies in a subdivision, a very bad route, or a very good route. For example, if a road-master submits a budget which calls for extraordinarily high expenditures for increased rail lubrication, this report would be an easy way to identify if he, in fact, was dealing with a route with excessive wear problems.

paste the second subdivision statistics

```
Route file: C:\TRACS\DATA\LANDMART.RTP
Traffic file: C:\TRACS\DATA\CASE.TRF
Total Length of Route: 100.01 miles

        Average annual MGT: 37.9

        Average Wear Rate : 0.000 in/100MGT

    Average Defect Rate : 0.0 defects/yr

        Average Rail Life : 0.0 years
```

<C> to create file, <P> to create and print file, <Esc> to exit to main menu.

8.3.4.3 Create/Print Subdivision Rail Statistics Reports

Same as 1.3.1.6 from above.

8.4 Rail Cost Reports

The cost reports simply take the engineering data and calculates the predicted cash flows for each year by multiplying each of the engineering activities by a unit cost. In addition to the cash flows, the cost reports include reports that are useful for economic analysis. The discount rate and other financial data, which is not yet incorporated into the model, will be used in preparing reports especially designed for tax accountants, budget officers, economists, and regulatory purposes.

8.4.1 Rail Project Cost Reports

Reports from this menu will display only costs generated by rail projects like transpositions, relays, and high-lows.

rail project cost report menu

```
1. Material costs

2. Labor costs

3. Cost summary, current dollars

4. Project costs by year, current dollars

5. Project costs by year, inflated dollars

6. Economic cost summary, NPV & EUAC

7. Create/print selected tables (graphs)
```

Press <Esc> to return to previous menu.

8.4.1.1 Material Costs

This report details the specific costs of materials for each year. This is only material consumed by with rail projects. The names of the various materials are contractions of the names that are used in the component files from INSTALL. You can view any materials that do not fit on the screen by using the down arrow key, or the <PgDn> command.

project material costs table

MATERIAL COST	Thousands of dollars									
	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL	20						2636		2639	4094
115STD										4048
132PRM							2613		2616	
7X13PLAT										12.4
CUT_SPK	0.9						1.9		1.9	3.9
SPR_ANCH	5.5						5.5		5.5	10.9
8X14PLAT	13.8						15.5		15.6	18.7

, , <PgUp>, <PgDn>, <Home>, <End>, <H> for help,
<C> to create file, <P> to create and print file, <ESC> to exit to menu.

8.4.1.2 Labor Costs

Gives the break down of specific costs for workers associated with rail projects. A total figure for each year is also shown. This report would be useful to some one planning for employment needs, someone doing labor negotiations, or someone interested in work force reductions.

project labor costs

RAIL PROJECT LABOR COSTS

GANG TYPE	Thousands of dollars									
	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL	30.0						29.0		29.0	58.0
Transpose gang	30.0									
High-low gang										
Relay gang							29.0		29.0	58.0

```
Relay gang salary : $14.50/hr
Transpose gang salary : $15.00/hr
High-low gang salary : $14.50/hr
```

`<C>` to create file, `<P>` to create and print file, `<Esc>` to exit to main menu.

8.4.1.3 General Costs

The costs associated with this report are summarized, general costs. Examples are costs associated with new rail for the projects, Other Track Material (OTM), Labor, and Equipment. This report may be useful when a general overview, rather than specific information, is desired. The costs are not discounted so they can be used for Capital Budget Planning.

general costs table

RAIL PROJECT COST SUMMARY, CURRENT DOLLARS										
Thousands of dollars										
	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Total	50						2142		2145	3106
New rail							2090		2093	3003
OTM	20						23		23	46
Labor	30						29		29	58
Equipment										

```
<C> to create file, <P> to create and print file, <Esc> to exit to main menu.
```

8.4.1.4 Project Costs by Year, Current Dollars

These are the total costs associated with rail projects for each year. This can be used for a more general view than the General Costs table. These costs, which are neither inflated nor discounted, offer a more aggregate presentation than the report which was broken up into expense areas. (The term "current dollars" refers to the fact that the costs predicted for any year are not discounted back to the current year, while unit costs are not inflated. To some users, the costs shown in this report would more properly be called "constant dollars", since all costs are estimated using the base year costs represented in the cost files. If, for example, the cost file used in an analysis was developed several years ago, then this report would certainly not display current dollars, but it would still be showing constant dollars.)

total costs table

```
RAIL PROJECT CAPITAL EXPENDITURES, CURRENT DOLLARS
```

YEAR	$ COST in Millions	YEAR	$ COST in Millions
1989	0.050	1994	0.000
1990	0.000	1995	2.142
1991	0.000	1996	0.000
1992	0.000	1997	2.145
1993	0.000	1998	3.106

```
Total rail project expenditures : $7.444 million.
```

<C> to create file, <P> to create and print file, <Esc> to exit to main menu.

8.4.1.5 Project Costs by Year, Inflated Dollars

This table is the result of inflating the last report an equivalent amount each year. The program assumes constant inflation at the rate which is input in the financial data input screen of the costs module. This report will be helpful to capital planning groups, to financial analysts, and may be of general interest to strategic planning groups.

rail project inflated costs table

```
┌─────────────────────────────────────────────────────────────────────────┐
│                                                                           │
│        RAIL PROJECT CAPITAL EXPENDITURES, INFLATED DOLLARS                │
│                                                                           │
│              │ $ COST in                      │ $ COST in                 │
│      YEAR    │ Millions             YEAR      │ Millions                  │
│      ────────┼──────────            ──────────┼──────────                 │
│      1989    │ 0.050                1994      │ 0.000                      │
│                                                                           │
│      1990    │ 0.000                1995      │ 2.558                      │
│                                                                           │
│      1991    │ 0.000                1996      │ 0.000                      │
│                                                                           │
│      1992    │ 0.000                1997      │ 2.717                      │
│                                                                           │
│      1993    │ 0.000                1998      │ 4.053                      │
│      ────────┴──────────            ──────────┴──────────                 │
│      Total inflated costs : $9.379 million.                               │
│      Inflation rate : 3.0%.                                               │
│      Planning horizon : 100 years.                                        │
│                                                                           │
└─────────────────────────────────────────────────────────────────────────┘
```

`<C> to create file, <P> to create and print file, <Esc> to exit to main menu.`

8.4.1.6 Rail Project Economic Summary

The values in this report are the result of combining all of the other information on rail projects. The Net Present Value (NPV) is the economic present value of all of the future cash flows, discounted to their current worth. The NPV is often used to do project evaluation studies, determine priority for capital investment, and measuring return on investment. The NPV and EUAC are both calculated on the cash flows which occur between the current year, '0' and the planning horizon that is listed. The various reports that we have just looked at, only list their respective statistics for the first ten years of the planning horizon. However, in order not to distort the economic analysis, it is necessary to predict the future projects beyond the ten years, and take into account the costs associated with them.

The Equivalent Uniform Annual Cost is the stream of constant annual cash flows that has the same NPV as the projected "lumpy" cash flows. The EUAC takes into account the discount value, and spreads the "lumpy" cash flows into an even distribution over the whole planning horizon. The EUAC could be used by marketing and pricing officials to analyze the costs of different traffic. Since the traffic levels are relatively stable from year to year, the EUAC helps to spread the costs of a future project to all of the traffic which is responsible for presently deteriorating the tracks.

rail project economic table

RAIL PROJECT ECONOMIC SUMMARY

Total Net Present Value Costs : $3.911 million.

Equivalent Uniform Annual Cost : $0.391 million.

Discount Rate : 10.0%.

Planning Horizon : 100 years.

<C> to create file, <P> to create and print file, <Esc> to exit to main menu.

8.4.1.7 Create/Print Selected Rail Project Cost Reports

Just as in the Rail Project Engineering section, this option will prompt the user for reports to be printed and/or saved in a file.

8.4.2 Rail Maintenance Cost Reports

These are the same reports as those found in the Project Cost Report Menu, but useful for routine Maintenance applications rather than Projects.

8.4.2.1 Material Costs

This is currently the only functional report in this section. Also, the only lubrication and applicators are included in the report.

8.4.2.2 Labor Costs

The cost of routine maintenance is the cost that is normally associated with section gang work. The productivity of the section gangs are highly dependent on traffic density, and thus the costs can be a point of interest. In low density territories, there just aren't as many problems to fix as in high density line. Therefore, the section gang spends a lot of time travelling around from repair to repair. However, in high density lines, it is often difficult to take the track out of service, even for a short time period, to repair it. The result is again, low productivity.

8.4.2.3 General Costs

This report shows the break down of all maintenance expenses by labor, materials, and equipment. The report may show that one of these areas accounts for a much a higher percentage of the total in maintenance than in project. It may be, that given a shortage of materials, increased maintenance would be better than increased rail relays; but given a shortage or high cost of labor, replacement would be preferable.

8.4.2.4 Maintenance Costs by Year, Current Dollars

These are the total costs associated with rail maintenance for each year. This report can be used for a more general view than the General Costs table. These costs are not discounted and offer a more aggregate presentation than the report which was broken up into expense areas. (The term "current dollars" refers to the fact that the costs predicted for any year are not discounted back to the current year, while unit costs are not inflated. To some users, the costs shown in this report would more properly be called "constant dollars", since all costs are estimated using the base year costs represented in the cost files. If, for example, the cost file used in an analysis was developed several years ago, then this report would certainly not display current dollars, but it would still be showing constant dollars.)

8.4.2.5 Maintenance Costs by Year, Inflated Dollars

This table is the result of inflating the last report an equivalent amount each year. The program assumes constant inflation at the rate which is input in the financial data input screen of the costs module.

8.4.2.6 Rail Maintenance Economic Summary

Similar to the Project economics report, this report lists the key data for maintenance activity. Since maintenance activity is routine and annual by definition, the EUAC is going to be very close to the actual value in current dollars which is spent each year.

8.4.2.7 Create/Print Selected Rail Maintenance Cost Reports

Just as in the Rail Project Engineering section, this option will prompt the user for reports to be printed and/or saved in a file.

8.4.3 Rail Total (Comprehensive) Cost Reports

These reports combine the cost information for project and maintenance. They are very useful for analyses that model complex scenarios. The cost savings gained in one area, may be partially offset by higher costs in other areas. These total reports help identify the existence of real net benefits.

8.4.3.1 Material Costs

This is a dis-agregate report which lists each type of rail, fastener, etc. separately. The costs are sums of the material costs from Projects and Maintenance activities.

8.4.3.2 Labor Costs

This is the total labor requirements table from the engineering reports, multiplied by the wage rate for each type of gang. As in all of the cost reports, a direct correlation can be made. Note that the wage rates are listed at the bottom for reference sake.

8.4.3.3 General Costs

Combining the project and maintenance costs together tends to blur the distinctive requirements of each. At an aggregate level, the break down of total costs into the various categories helps managers get a feel for the amount of money being spent on recoverable assets vs. expense items.

8.4.3.4 Total Costs by Year, Current Dollars

These are the total costs associated with all rail maintenance and projects for each year. (The term "current dollars" refers to the fact that the costs predicted for any year are not discounted back to the current year, while unit costs are not inflated. To some users, the costs shown in this report would more properly be called "constant dollars", since all costs are estimated using the base year costs represented in the cost files. If, for example, the cost file used in an analysis was developed several years ago, then this report would certainly not display current dollars, but it would still be showing constant dollars.)

8.4.3.5 Project Costs by Year, Inflated Dollars

This table is the result of inflating the last report an equivalent amount each year. The program assumes constant inflation at the rate which is input in the financial data input screen of the costs module.

8.4.3.6 Rail Total Economic Summary

Similar to the Project economics report, this report lists the key data for all activities.

8.4.3.7 Create/Print Selected Rail Total Cost Reports

Just as in the Rail Project Engineering section, this option will prompt the user for reports to be printed and/or saved in a file.

8.4.4 Subdivision Rail Cost Statistics

This menu lists reports that are available that summarize the cost data for the whole subdivision. Presently there is only one report available, but suggestions are welcome for alternative formats for this same information, or different statistics that may be relevant at the subdivision level.

8.4.4.1 Detailed Rail Statistics

This report calculates many of the costs in terms of the traffic that is on the route. Rather than identifying each type of traffic, and trying to allocate the costs equitably, the report is only intended to give statistics for the average. It must be recognized that some of the traffic will cause more damage, thus is more costly to run. These numbers are useful, however, in determining if certain prices are within a reasonable range to achieve profitability and regulatory requirements. The PESOS feature should be studied closely, in order to calculate costs and statistics for individual traffic types.

rail detailed costs statistics of sub stats goes here

```
Route file: C:\TRACS\DATA\LAN6      *
Traffic file: C:\TRACS\DATA\CASE.TRF
Cost file: C:\TRACS\DATA\STANDARD.CST
Average Wheel Load: 23722 lbs.      Average MGT: 37.86
Discount Rate: 10.00 %              .  Planning Horizon: 100 years

Average Project Dollars per Mile per Year: $8270.22.

Average Maintenance Dollars per Mile per Year: $3137.79

Average Dollars Spent per Mile per Year: $11408.01

Average Dollars per MGT: $30135.11

EUAC per MGT per Year: $18885.13

Dollars Spent per Thousand GTM: $0.189
```

<C> to create file, <P> to create and print file, <Esc> to exit to main menu.

8.4.4.2 Create/Print Selected Reports

Just as in the Rail Project Engineering section, this option will prompt the user for reports to be printed and/or saved in a file.

8.4.5 PESOS

The reports generated in this section are discussed in Chapter 6, the Control Program. The PESOS will analyze the costing differences when adding or subtracting portions of traffic.

8.5 Option to Run Again

The final menu in the Report Module consists of two entries. The first option allows the user to return to the first screen and create reports for a different analysis than before. Since each report is saved with the name of the user who performed the analysis and the time it was done, there should be no confusion as to which reports are associated with a particular analysis. Make sure, however, that if the computer asks you if you want to overwrite an existing report, be sure that you do not need the existing report before saying yes. Because the reports are *not* sorted by analysis, this possibility may frequently arise.

The second option merely returns the user to the New Analysis Screen. If you wish to exit TRACS altogether, you must currently go through this screen (the analysis name will not matter, and will not be recorded if RAILWEAR is not run) to the red Main Menu, and choose "6. Quit".

exit screen goes here

Formatting the TRACS output, LAR   Option to run again

```
                          Select an option:



                    1. Choose a new directory

                 ╔═══════════════════════════════╗
                 ║ 2. Exit Report Module         ║
                 ╚═══════════════════════════════╝
```

APPENDIX 3

Comments and Criticisms

From the M.I.T Track Advisory Committee

on TRACS Version 1.0

MEMORANDUM

TO: TRACS Advisoy Group

FROM: L.A. Shughart and C.D. Martland

DATE: FEB 7, 1988

RE: Feedback on TRACS Version 1.0

1 BACKGROUND

The Halloween version of TRACS, which has been since dubbed Version 1.0, was distributed to a small group of volunteers from the M.I.T. Track Advisory Committee. The volunteers agreed to test the model and provide criticisms about the approach and implementation. They recognized that the model was not complete, contained bugs, and could only analyze small scenarios. In addition to commenting about the software, the volunteers were also asked to critique the draft version of the TRACS User's Guide. Follow up phone calls were made in mid December and mid January.

Following is a list of people who were given a test version of TRACS:

    HR - Hillary Rawert, Director Cost & Economic Planning KCS

    RR - Randy Rao, Director Economic Analysis CSX

    GR - Gene Reinhart, Manager Budgets AT&SF

    AR - Al Reinschmidt, Director Track Research, AAR

    AA - Alvaro Auzmendi Engineering Economist AAR

    JE - Jim Eshelby, Director Rail Scheduling BN

CD - Christy Dunham, Industrial Engineering CR

RM - Roy McElvern, Manager Engineering Systems CP Rail

MH - Mike Hargrove, Director Engineering Economics, AAR

TB - Tom Berry,

Following is a list of other people who offered comments on TRACS

TP - Tom Pulkrabek, Manager Special Projects KCS

BH - Bill Holmes, KCS

JK - Jack King, KCS

PM - Per Madsen, Industrial Engineering CR

DS - Dave Staplin, Directory of Quality Control, CSX

CM - Carl Martland, Principle Research Associate

LS - Larry Shughart, Research Assistant, TRACS

XK - Xenia Kwee, Chief Undergraduate Programmer

BB - Chris Majoros, Undergraduate Programmer

JS - Joe Saleeby, Research Assistant, TRACS

OS - Oliver Shyr, Research Assistant, TRACS

RM - Rabi Mishalani, Research Assistant, BN

JG - Jimmy Gleason, Undergraduate Programmer

In addition to the volunteers, two research assistants at M.I.T. who were not familiar with railroads or the old TMCost model were given the task of preparing example analyses and performing sensitivity tests on the model. This "bank examiner" approach, with Joe Saleeby and Oliver Shyr acting as the detectives, was a systematic test of each aspect of the changes made to RAILWEAR as well as the TRACS package as a whole.

Many comments were received at the demonstration of TRACS to the advisory committee, and these are included as well. The next section discusses the comments by grouping them in the following categories:

1) Bugs

- M.I.T. said a feature was working properly, but it was not

- A formulation or algorithm was implemented incorrectly

- The results were inconsistent with prior knowledge

2) Unfinished Items

- Some reports did not contain numbers

- The RAILWEAR model was not sensitive to factors

- The manual was incomplete or deficient in some area

- Structure was designed but not implemented

3) Small Changes

- Additions or changes that require less than a days work and will not alter the structure or theory of the model

- Problems with clarity and terminology

4) Major Changes

- Add different modules, reports, and calculations

- Change the structure of the RAILWEAR model

- Increase the efficiency and speed of existing programs

5) General comments on the model

- Ease of use

- Screen appearance

- Positive comments

Many of the comments were made by several people. The memo summarizes the issues raised, lists the people who addressed the issue, and notes what was changed in the TRACS program in response. The last section discusses potential enhancements that could be made to TRACS in response to the comments that are marked as "No Action Taken" and plans that the development team has that have not yet been implemented.

2 Comments and Criticisms

2.1 Bugs

COMMENT	PERSON(S)	ACTION TAKEN
The Control Program screen for inputting the analysis is a pain. It does not work properly when an analysis name already exists. The Install Modules only be available to designated users.	AA, JS, OS, LS, CM, MH	Larry Taylor implemented a new Control Program without the bugs which will only ask for analysis name when the deterioration modules are entered. The install Sub-Modules are now available only to designated users.
The TRACS package should start out with a menu. Users like menus and don't want to start out immediately answering questions	BH	The new control program does have a lead off menu, with the analysis input screen moved to the deterioration module.
Feet of Rail Replaced per defect repair should be a maximum of 80' since some rail companies will have welded two 39' rails together and replace this	LS	Limits were updated
The rail materials input screen in the maintenance Policy screen have two pointers in one box. This is confusing; the help screen should list the options available	LS	Screen was improved in re-working of maintenance input module. Help screens were changed.
The traffic file input editor does not recognize blank lines or zeroes in the input train matrix.	LS, JS	The code now searches all of the lines for possible trains. This makes it easier to edit existing files.
The subdivision statistics reports need a line item containing the length of the route	MH	Implemented
Only distributed on 5 1/4 inch disks	RR	Randy gained access to a computer with both type of drives. We may want to consider offering a 3.5" option with the next release
The Code is hard wired to the C: drive	PM, CD	Has been changed to default to current drive
After finishing the last entry in a screen, the cursor exits the screen, but it should stay	AA	The addition of Activity menus fixes this problem

COMMENT	PERSON(S)	ACTION TAKEN
The Calculation of traffic mix is based on the number of cars in each car type, and should be weighted by the total gross tons in each car type.	AA	The formulation was changed
Maintenance material requirements show materials required for all ten years even though the planning horizon is less than ten years	AA	
In the Route/Track Module, Environment should only accept "w, t, d, n, f, m" error otherwise.	LS	No Action Taken
In the Route/Track Module, FRA Class should be limited to 1 - 6, error otherwise.	LS	No Action Taken
Locomotive weights in the Traffic Input Module should allow for 200 gross ton units	JK	New Module has this change

2.2 Unfinished Items

COMMENT	PERSON(S)	ACTION TAKEN
An example graph could show the potential for graphics within TRACS	LS, BB , GR	Identified first graph to be made, "Summary Rail Project Cost, Current Dollars" No Action Taken
The Cost Input Module was only a bare necessity adaptation of TUCost. It should contain levels of detail and financial data that was not in the old model.	LS, JE, CM, BB , TP	The first screen is now a financial data input screen. The second screen is a low level input screen which allows a user to input unit costs for different activities.
The hourly wages that are all in one screen should be separated into their respective gang input areas	LS	The re-worked Cost input screens include this change.
The subdivision statistics report was not completed, but was designed. This report should be expanded to enable users to perform the exact same analysis that was done with the old TMCost model	LS, CM, MH	The new report contains wear rates, rail life and places for defect rates. This info is available for all combinations of curve and metal in the subdivision

The Subdivision statistics report should be implemented in a summary report (LS) or eliminated (MH) (This is a very broad brush report which enables a user to look at the sub division on the most aggregate level.)	LS MH	Implemented as a summary report, even though some users may never need to use it.
Calculate a credit for scrap value of rail and OTM plus an expense for disposal costs	LS	Cash flow calculation updated to reflect this
Many of the file structures are not completed in the User's Guide and are important to people who want to do data base dumps and conversion from RECAP files	LS, MS, XK, CM	This has been included into the new Technical Manual
Some had trouble following the flow of input screens or didn't realize that some of the high level of detailed inputs could be bypassed without even reviewing them	CM, BH	Added screen titles and a label saying which screen number is currently being displayed. Need to clarify in User's Guide that each module has its own color. Also, need to have a flow chart with screen map.
Waiting impatiently for Ties and Surfacing	BH	Tie model was put into project proposal to the AAR
The option to create and print a file for a report from the report screen does not work for most reports	JS, AA, LS, BB	Some have been changed; others have not yet been implemented
The third sub-module of Install called the Reference Module is not finished	XK, LS	There are now file editors to edit the default route and traffic files. The manual will have to be updated to reflect this addition
The planning horizon should be allowed to go up to 100 years.	LS, MH, CM, AA, RR,	The RAILWEAR model is now producing cycles, and the reports can use them for NPV and EUAC calculations
The PESO for traffic analysis had strong support from everyone.	everyone	The PESO is currently being implemented to do three types of traffic analysis. Add or subtract a combination of traffic, analyze growth rates, calculate the incremental cost of the last 1MGT for each traffic type.
The code for the Report Module is sparsely commented	LS, CM, AA, XK	Some action taken, more needed.
There are too many files in one directory. We need sub-directories to better organize all of the files	LS, AA, CM, OS	Two directories were made, but a lot of questions came up about maintaining complicated directory trees.

COMMENT	PERSON(S)	ACTION TAKEN
Turnout Life in MGT should default to a number greater than zero.	MH, LS	All defaults have been reviewed and will be reasonable values for those people who cannot separate a model from the data in the model
No grinding and lubrication of tangent tracks is allowed	JS	Xenia fixed this in RAILWEAR and in the maintenance policy files
The grinding and lubrication policies for a segment do not change over the life of the segment. Should be a function of metallurgy and of the age of the rail.	MH, LS, XK, CM	No Action Taken

2.3 Small Changes

COMMENT	PERSON(S)	ACTION TAKEN
The program should be compiled with a co-processor option to increase speed for people with those type machines	XK, MS, CM, MH	Turbo5 has an option which allows the software to be compiled once, and it will automatically recognize if a chip exists
The control program should allow a user to review the names of the files that will be used in a run of RAILWEAR immediately before the program is run.	MH	The new Control Program lists the four most important files in the CALFIL.INP and allows the user to select a new file from a directory of existing file.
The control program will have a screen which allows the user to mark which right of way components they would like to simulate in this analysis	LS	No Action Taken
The control program main menu screen should increment itself each time the user returns to the screen in order to help the user remember which modules have and have not been run.	LS	Implemented in new Control Program
For project productivity, branch line and low MGT can be considered as one value, therefore eliminating a variable and an input	LS	New Maintenance Policy Screens reflected this change
Titles need to be added to each Maintenance Policy Input screen so the user can tell if there is additional inputs on another screen related to the same area	LS, JG, AA, XK	Titles were added to match the main menu, as well as displaying "screen 1 of 2" etc.

The rail current condition file should be expanded to take advantage of the full spectrum of wear categories	RM	We have tested the model, and found that choosing the proper current conditions is very important. We intend to offer a bigger example file
The first menu of the reports screen should be expanded and reordered to lay the foundation for additional deterioration models	LS	Change made.
The label in the report menu should be changed to reflect the terminology used by the railroad people, i.e. budgeting reports, economic reports, etc.	LS, GR, TP,	There were changes made, but it seems you can't please all of the people all of the time and there are still may be problems with the terms "Current and Constant dollars" (MH)
The cost reports should be changed so that the numbers are in the same units as much as possible. This will decrease confusion	LS, TP, GR	This has been done. Most of the reports are in thousands of dollars with some in millions
Could add a report which shows predicted inflated costs over a future plan	GR, LS	A report was added which shows the total costs of each year, inflated at a rate input at the financial input screen
The Control Program needs to display a message like "Processing" between actions to let the user know that something is happening	AA	No action taken
The help screens should disappear after you are done reading it	AA	The new help screens have this feature
The printed reports should contain a list of input files used and the time and date of the analysis	AA, MH, JS, OS, CM, TP	Each report now has a header containing the information
The Traffic Input Module now has a calculation for the number of trains per week. This could be used to recommend an input for annual MGT to the Route/Track File	TP, LS, XK, DS, HR,	There is a box in the Route/Track editor which recommends a number based on the current traffic file in the calfil.inp file.
The calculation for lube applicators should be changed so that one fourth of the applicators are replaced every 25% of an applicators life, rather than having them all "bought" at the beginning of a cycle	LS, MH	No Action Taken
Weight of OTM scrapped per mile for the various activities should be in the Maintenance Policy File	LS	New Maintenance Policy Input Module has this change

2.4 Major Changes

COMMENT	PERSON(S)	ACTION TAKEN
The manual is too thick. There is a lot of information that would not interest a casual user of TRACS.	AA, CM	Manual was split into a User's Guide and a Technical Manual. The Install Program was separated from TRACS, consequently, three Install Supplements were created.
The Maintenance Policy Input Sub-Module should be redesigned so that each area of policy can be selected from an introductory menu. This main menu should be expanded to anticipate the addition of tie and surfacing models.	LS, AA, JS, OS	The Main Menu was implemented. New Maintenance Policy Screens were made to better organize the information input by the user.
The relay, transpose, and hi-low limits should be different depending on track density	LS, CM, JE, RM	Expanded the input screens and the install data base to reflect the new parameter
Relay Limits should be taken out of the metallurgy file and put into the rail parameters file since they are more of a function of rail cross section and not rail metallurgy	LS, AA, XK, CM	This was done, but it was further noted that limits are a function of traffic density, so these are excessive. May want to implement them as a maximum allowable, and then use the other relay limits from the Policy file as a more refined input

The fastener file is not comprehensive, and does not allow combinations of fasteners i.e. such as plate and spike.	LS, XK, Chris M	The fastener file was redesigned, and the route file was redesigned with multiple pointers to fastener.
The bottom of each screen is cluttered with directions, and in many cases there are options that are not available such as saving to a different name, moving to next record without going through a menu	LS, MH, JS, AA	Activity Menus were developed which pop up when a user pressed <Esc>. The messages at the bottom of the screen are limited to two. <Esc> and <F1> for help.
Need full screen editors for traffic, route-track, and Cost. Some people will want to do nerd level editing all of the time	AA	No Action Taken
A menu which allows the user to choose parts of the cost file to edit would be helpful	AA	The new cost input module will allow a user to choose topic areas from a menu
RAILWEAR should be able to handle more than about 35 segments	AA, CM, XK, LS, JS, MS, MH,	The model can now handle hundreds of segments as a result of the elimination of many variables, the elimination of Wnum.dat file (since we now have a calibration routine this file is no longer needed in the model), and the commenting out of Other factors (since there are none implemented)
We need to create a printer setup routine to handle and prepare the program for different printers	AA	Talked to Rob Fellows who said that it would be best handled by re-programming printers. Our reports work on IBM printers and also on laser printers if they have a proprinter emulation option.
The Bridge file should contain the project schedules and rail cycles in decimal years in order to show the benefit of different policies and traffic mixes	CM, MH	This has been done down to tenths of a year. The cycles are in decimal for relay, but not for high low, and Transposition.

2.5 General Comments

Recognition of the varying levels of analysis that are possible: Even after a few days of work, people still felt that TRACS is a very difficult and involved model.	RR, TB, CM, MS, DR,	The manual needs to emphasize how editors can combine with main frame data dumps to increase usefulness. Case studies may be needed to clarify how TRACS can be used at various levels of detail.

Within a few days, people were able to do simple analysis with supplied files or with their own inputs, but then they wanted to jump directly to complex analysis using actual route geometry for large portions of their system.

Ease of getting started:

a. Since the model takes a half hour or so to load on the computer, it takes a long time to get to the point of conducting simple analyses. This deters someone from trying the model if they don't anticipate having to use it.   DS

b. Very specific instructions on loading TRACS and running the first analysis was very helpful. TRACS is a big improvement over TMCost.

JS, AA

Overall reaction to TRACS:

It's certainly a nice model.   TB

The model seems to be working fine, although I don't particulary like the colors.   GR

The screens certainly give the model a professional appearance that enables you to sell the results to senior management   PM

Version 1.0 was installed successfully and readily by people familiar with typical procedures for installing programs on hard disks. The manual should continue to be updated so that it provides step-by-step instructions for new users. However, TRACS is probably too complicated a model to be run within a few minutes by a first time user.

3 Future Work

3.1 Control Program

3.1.1 PESOS

There are many PESOS that could be implemented. We have said that we are trying to write the PESOS to do analyses that everyone normally does. One possibility that falls into this category is Technology assessment. For example, given a traffic mix, and maintenance policies, the Peso could calculate statistics for different rail metallurgies in different curves. Another potential PESO is meant to study the trade-offs in high capital costs and low maintenance vs. low capital costs and high maintenance. For example, it may be cheaper to use standard rail and lubricate a lot, rather than use super premium rail.

Another reason for writing a PESO is that a certain analysis is very complex and many assumptions may be overlooked if the analysis is done manually. One PESO could deal with the problem of adding or subtracting incremental traffic to a subdivision that requires a change in the FRA class. The cost allocated to this traffic should reflect the increased capital investment etc. but might also contain a credit for decreased maintenance costs.

3.1.2 Other Features

As we add deterioration Modules, the control program will become increasingly important. It will keep track of all of the sub-directories, and files that will be used. It will also allow the user to turn off and on different component deterioration modules.

3.2 Install Module

Since the Install module is a new concept, it would be useful to develop several detailed analyses showing how some of the features of Install can be best exploited.

3.3 Input Modules

TRACS may need full screen editors for traffic, route-track, and Cost. Some people will want to do nerd level editing all of the time

3.4 Reports

The Reports Module was designed with the intent of including graphics capabilities within the TRACS framework. This is a feature that is supported by many of the people on the task force but has not even been studied as to its feasibility and the time investment required.

We also promised reports for applications in accounting. It might be possible to work closely with AREA committee 11 on this.

3.5 Other Deterioration Models

The grinding and lubrication policies for a segment do not change over the life of the segment, whereas they should be functions of metallurgy and of the age of the rail. This should be implemented along with the Fatigue model.

We have laid the groundwork for using a matrix of outputs from PHOENIX as the basis for a fatigue model. If this matrix is in terms of defect life at different

percentiles, then the matrix could be generated by any rail fatigue model or by an expert system, similar to the structure of the Matrix of forces which is used as an input to RAILWEAR.

Possibilities for a tie model were discussed extensively at the June 1988 meeting of the Advisory Group. Ballast and subgrade deterioration also need to be researched.

The fatigue, tie, and surfacing models will all need a common approach to describing track quality. The CIGGT models that were incorporated in TMCost Version 2 used CN indices, but there are other options, such as the indices used by AMTRAK. The AMTRAK system is straight-forward and could easily be incorporated into the structure of a deterioration model much like the CIGGT tie model or the one proposed by MIT. The Amtrak system also has the advantage that most of the major railroads are probably familiar with it because the AMTRAK geometry car is run over member roads on a routine basis.

Simple deterioration model for other right of way components, such as crossings, signals, bridges, sidings, could also be incorporated into TRACS. Costs for these components, for example, could be modelled as a fixed plus a variable cost. For example, crossings could be modelled in terms of the initial cost, the fixed cost per year for maintenance and the estimated lives in low, medium, and high tonnage situations. This would be better than not having those costs accounted for at all and might even turn out to be reasonably accurate.