ASSOCIATION OF AMERICAN RAILROAD'S NETWORK MODEL

Wayne K. Minger
Association of American Railroads
Washington, D. C.

John N. Cetinich
Southern Pacific Company
San Francisco, California

Abstract

Major U.S. railroads are investing over $200,000 to develop a model capable of simulating a railroad network. The model will be capable of determining the effect of major changes in facilities, train schedules and priorities, classification strategies, levels and mix of traffic. The model is in SIMSCRIPT for three different computers with primary emphasis on flexibility, efficiency, and user convenience.

1. INTRODUCTION

1.1 Railroad Environment

American industry has made increasing use of latter day technological achievements and the railroad industry is no exception. Diesel power, centralized traffic control, welded rail, and computer assisted analysis are examples of technology which has already been incorporated in many railroads. One of the peripheral benefits of assimilating technology has been an improved atmosphere for accepting change and this in turn has provided an impetus to re-examine the entire system of railroad operations.

Most railroad transportation operations have several things in common. Each has a large number of variables. Each has extensive interaction between the variables with large fluctuations. And each transportation operation influences the other. An average Class I railroad manages 3,000 miles of track and a fleet of 400 locomotives and 20,000 cars of many different types. Capital expenditures average $15 million a year. In order to move cars economically, they must be collected from hundreds of industrial sidings, sorted into groups at various yards, consolidated into trains, and transported to other industrial sidings or interchange. Improvements in the transportation process could easily save a railroad $5 million a year.

1.2 Need for Network Model

Most efforts to analyze the railroad operating system have been either superficial or severely limited to scope. The majority of techniques such as queuing theory, linear programming, etc., would require measurement of all of the system interactions which is not economically possible, nor are they equipped to handle all of the variables. Another difficulty is that these techniques optimize on a predefined measure of effectiveness. In the railroad industry, such a measure has not been agreed upon. Therefore, simulation has been the method of investigation most often used to analyze operations.

Some notable efforts in simulating portions of the operating system have already been achieved. Models of terminals, over the road, and diesel assignment operations are examples. These models are very detailed and descriptive of those functions and are useful in analyzing problems which can be invetigated in those terms. They fail, however in describing the interaction of one terminal with another, over-the-road influence on adjacent terminals, diesel assignment interaction with car thruput performance, etc.

The railroad industry has recognized the need for a tool to help analyze transportation operations from a systems approach and, consequently, authorized through the Association of American Railroads the development of a Railroad Network Model.

2. MODEL FEATURES

The design of this model has placed primary emphasis on user convenience, flexibility, and efficiency. Too often models are developed which are capable of describing a system adequately but which have features prohibitive of their usage. Some of these prohibitive features are:

(1) mountains of data in exact form
(2) statistical functions not economically available
(3) excessive computer running time-cost
(4) reams of detail output
(5) large changes in data base to reflect small changes in system
(6) only one level of detail permitted
(7) inability to run on more than one computer configuration

Considerable effort has been made to avoid these problem areas, yet at the same time provide a model adequately capable of representing a railroad system.

The AAR Network Model is being programmed in SIMSCRIPT I.5 for the Univac 1108, CDC 6400, and the IBM 360/65. Core size will be 65K words except for the 360/65 which will be 512K bytes. Expected running time is one hour of CPU time to a week of real time for typical system using the CDC 6400 as a base.

These three machines were specified because this type of application is most economically run on a large core, high speed CPU, qualities of each of these machines. Secondly, most roads do not have this type of computer on their property with the possible exception of some 360/65's. It is anticipated that most railroads will rent time from a service bureau to run the model. To insure that a nearby computer was available to all roads, it was decided that capability of running the model on different configurations was mandatory and that at least one of these specified computers should be available to any user.

SIMSCRIPT was chosen over FORTRAN because of contractor preference. Reasons cited were:

(1) SIMSCRIPT is model oriented rather than computer oriented.
(2) SIMSCRIPT automatically provides facilities for time flow representation, event sequencing, dynamic storage allocation, attribute filing and data initialization.
(3) SIMSCRIPT is more amenable to model changes.
(4) SIMSCRIPT language communicates model description more efficiently.

Generally, the choice was one of a more powerful and adaptable language with shorter programming time compared to a less powerful and adaptable language which has greater computer running time efficiency.

The model is divided into three parts--a preprocessor, main model, and post processor. This permitted a more modular approach to development and enables many modifications of components without requiring changes in the entire model. Another reason for separation is that it is extremely doubtful that all three portions would simultaneously fit in core.

Although this is a general model, it was necessary to allow users to represent their particular system in an efficient manner. The preprocessor has extensive data checking - editing routines and consistency checks on the raw input. Conversion of the raw data to a more exact form for simulation by the preprocessor removes much of the effort of input preparation by the user and also makes changes easier. Many options are available to permit presentation of an environment by means of parameter specification. The model is also flexible enough to accept deterministic or stachastic representation of most components. The choice would depend on either the user's data base or problem requirements. Also, the model is capable of being able to represent components of the system at varying levels of detail.

The last feature is very important. If we can assume that the level of detail specified is more or less proportional to the accuracy of the representation of the system, then greater detail implies greater accuracy of representation (within the limits of sensitivity). Obviously, certain problems require greater accuracy than others in order to make rational decisions. The user should be able to specify only that level of detail necessary to attack a specific problem. In developing the Network Model, we considered the upper limits of detail to be something less than that of a terminal model, over-the-road model, or diesel assignment model. If a user felt that such a high level of detail was necessary, he could use the Network Model first to get a feel for interaction effects and then use a component model for a more detailed simulation. However, if the nature of the problem suggested a more simplified representation, the user would not be required to prepare all of the data for a very detailed model. We have, therefore, provided simpler representation of nodes and links.

The model output contains provision for history traces and detailed event information, but is predominately concerned with summary statistics in graphical form where possible. The analyst can also specify by option only that information which he desires. It was specifically intended to cut down on pages and pages of output with an analyst spending great amounts of time selecting data and preparing summary tables for analysis. This permits the analyst to quickly determine what is happening in the simulation and why.

3. MODEL STRUCTURE

3.1 Network

Figure 1 is an example of an existing railroad network. By network, we mean all or any portion of a railroad which can be represented by a group of nodes connected by links. In the real world cars will be taken from node to node over links by locomotives. Figure 2 shows how a portion of the existing system can be represented schematically. In this specific case, the nodes and links represent major terminals and main track and disregards branch lines and small yards.

3.2 Nodes

In general, a node represents a terminal or yard. The usual functions performed by a yard are receiving and inspection of inbound trains, classification of cars, assembly of cars into trains, and inspection and dispatching of outbound trains. While the functions for all yards are usually similar, the manner in which the functions are performed varies from yard to yard, being primarily controlled by geography and policy. For example, one yard may set aside certain tracks for receiving trains and other tracks for dispatching them. Another yard may reserve tracks for both receiving and dispatching or may even use classification tracks for receiving and dispatching if the other tracks are full. Figure 3 is a list of the functions which the model can represent.

The model permits a node to represent other entities than just a yard. A node can represent a geographical area, a proposed yard, a junction of main line track, an industrial siding, or a place where connections with another road are made. Functionally, the node represents a place where cars or trains originate or terminate, where the consist or direction of a train may change, where trains arrive and depart, or where tasks are performed on cars or trains. Figure 4 illustrates the use of links and nodes in representing a junction of two major track sections. In example A, the user has assumed that there is no interaction on the link BC with trains from A; thus, a train can go directly from A to B without interfering with a train going from B to C. In example B, the user has interference, will probably permit only one train at a time through node D, and will assign a task to trains at D of zero time. This forces trains to queue around D and can represent the congestion on link BD caused by trains going from A to B or B to A with trains from B to C or C to B.

Depending on the function the user desired, a node can be described at various levels of detail. A simple level of detail for describing the rate at which car groups may pass through a node can be a constant such as 100 cars/hour or a function of train type or class such as 200 cars/hour for high speed manifest trains and 100 cars/hours for regular manifest trains. Rate may be a function of number of cars in the terminal such as 100 cars per hour if terminal is 25% full, or 50 cars/hour if terminal is 50% full. Or the user may wish to assign different tasks to different trains such as change crews or pick up any cars in same direction. Each task would then have its own processing rate. The model would assign resources to perform these tasks if needed, and the train would depart on the completion of its assigned work or scheduled departure time whichever was later.

The user may wish to specify that a node has unlimited capacity in which case trains are always permitted to enter; limited capacity, such as 1,000 cars, so that trains are held outside the node if capacity is reached; or to break the node into separate receiving, classification, departure areas.

In using the model, one of the most difficult problems will be for the user to determine which level of detail is necessary to yield the degree of accuracy needed. Figure 5 illustrates some of the possible levels of detail which might be desired. All nodes and links will not require the same level of detail within a given run and it is quite possible that level of detail of a given node will be changed for alternative problems.

3.3 Links

A link usually represents main line track between terminals. Figure 6 is a portion of our previous network showing Chicago and GRAP nodes and the link between. The link symbolically represents the main line track between Chicago and GRAP. In reality, it could be single, double, or more tracks, or it may be hypothetical track. The function of the link is to provide a means to get trains from one node to another, to establish a travel time, and to increase that travel time by delays due to main line interference, if necessary.

There are several ways that links may be represented. Figure 3 shows some different ways that links may be represented and how the attributes of the link may be changed to portray the desired level. In its most simplified form, a link would have a constant rate, such as two hours per train to transverse Chicago to GRAP; unlimited capacity in terms of any number of trains may occupy a link at a given time; and no interference due to meets or passes. A more detailed representation would be to have link travel time as a function of train class or type. One hour for class I, two hours for class 2, and so on. An even more complex representation would be to have train running time as a function of TPC calculation since we know that weight/power directly affects the train's speed.

In the simple case, we were not concerned about the number of trains the link could accommodate simultaneously. If in reality there were double tracks in both directions between CHIC-GRAP, this could well be a very accurate representation. However, if there were only a single track, then the user would want to limit the number of trains which occupied the link at one time to 5, 6, 10 or whatever. The result of this representation would be to force the model to hold trains in the nodes whenever the capacity was reached. Likewise, the model will calculate when meets normally occur and assign some fixed delay to the trains by decision rules.

3.4 Traffic

Railroad cars enter the network grouped into cuts. A cut is a group of cars with identical origin, destination, traffic class, and origination time. All cut attributes are prespecified by the user as part of the model's input. Presumably the user has collected this car data from historical samples or has a statistical cut generation program.

Cuts may enter the system individually at their origination point or as part of an exogenous train. At time of origination, the cuts may or may not be required to perform certain tasks before classification. Classification is the process of sorting and aggregating cars into groups. In the physical world, this would involve placing cars on one or more classification tracks. Each train departing the yard has a list of classification groups which that train is permitted to carry. When a train is ready to be assembled, cars are removed from the current inventory of classification groups associated with the train until the capacity of the train is reached. The outbound train is then assembled, goes through outbound operations and departs carrying cuts of cars to the next node where the cycle starts again.

In addition to the regular classification process, cuts may be quick switched (transferred directly from inbound area to the outbound train because they have been classified at a previous node) or go through special operations such as icing, weighing, repair, etc.

3.5 Schedules

All schedules are prespecified by the user as part of the input. Included is a description of each train's route, arrival schedule, and departure time at nodes, take list of permissible traffic, capacity limitations, etc. The model will permit trains to depart before or after schedule, depending on circumstances. An output report showing the degree of conformance to schedule is an important measure of service of the network. The report also helps to indicate where a train encounters delay most often.

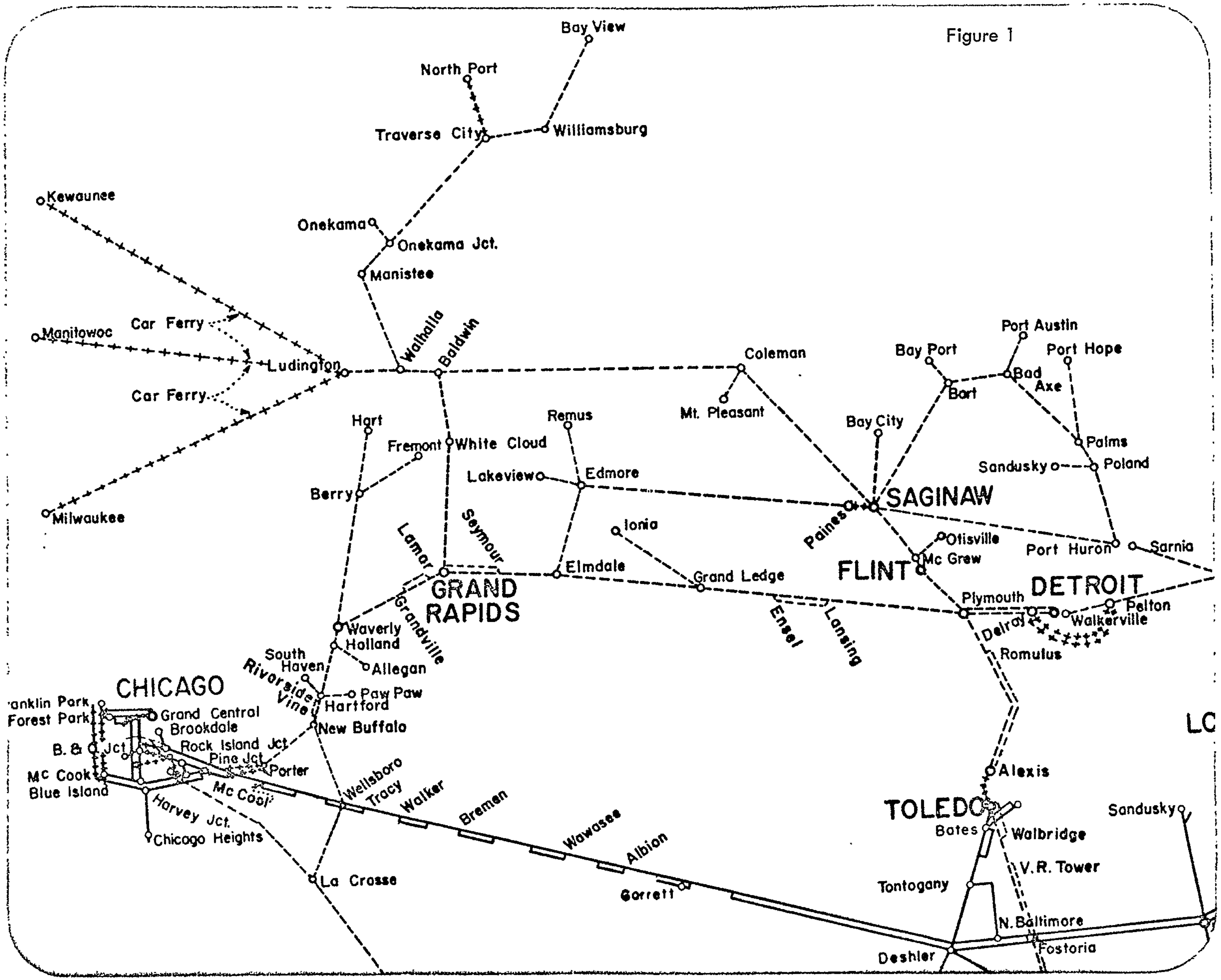
In the real world, some trains do not have a schedule but are assembled only if a particular group of traffic has more cars than usual or if the yard gets clogged. These trains are called traffic actuated trains. The model avoids the problem of when and where to generate extra trains by having all trains scheduled. An attribute of each train is the minimum number of cars required to run. If the minimum number is zero, the train always runs just as if it were a real world scheduled train. If the minimum number is greater than zero, the train runs only if there is sufficient traffic so that it acts as if it were a traffic actuated train.

4. CONCLUSION

Presently, the Pilot Model is in the process of being debugged and should soon be ready for validation. Upon completion of the Pilot Model, an extensive evaluation will be made to specify the features of the Final Model. The Final Model should be operational on the CDC 6400 by July and the two other machines by September, 1970. A major training effort of railroad personnel will take place when the model is fully operational.

The AAR Network Model is a tool that could save the railroad industry millions of dollars. The model gives railroad management a firsthand opportunity to observe the effect on the operating system of the major interactions of many components. The model provides an opportunity to inexpensively pretest ideas without putting them into actual practice. The model also provides the opportunity to know where to make minimum improvements in components to yield maximum improvements in the system.

The opportunity exists for railroad management to use this model for transportation planning. But as computers increase in size and speed, railroad management could link into real time data collection systems and expand the model to assist in decision making on daily railroad transportation operations. This expansion is certainly feasible from a technical standpoint but it remains to be seen whether or not it can be economically justified.



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North Port
Traverse City
Williamsburg
Kewaunee
Onekama
Onekama Jct.
Manistee
Car Ferry
Manitowoc
Ludington
Car Ferry
Walhalla
Baldwin
Coleman
Mt. Pleasant
Port Austin
Bay Port
Port Hope
Bad Axe
Bart
Hart
Fremont
White Cloud
Remus
Bay City
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Edmore
SAGINAW
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Elmdale
Grand Ledge
FLINT
DETROIT
Plymouth
Pelton
Walkerville
Delray
Romulus
Waverly
Holland
Grandville
Allegan
Ensel
Lansing
South Haven
Riverside
Vine
Paw Paw
Hartford
New Buffalo
CHICAGO
Franklin Park
Forest Park
Grand Central
Brookdale
B. & O. Jct.
Rock Island Jct.
Pine Jct.
Porter
Mc Cook
Blue Island
Mc Cool
Harvey Jct.
Chicago Heights
Wellsboro
Tracy
Walker
Bremen
Wawasee
Albion
Garrett
La Crosse
Alexis
TOLEDO
Bates
Walbridge
V. R. Tower
Sandusky
Tontogany
N. Baltimore
Fostoria
Deshler

Figure 1

Figure 2

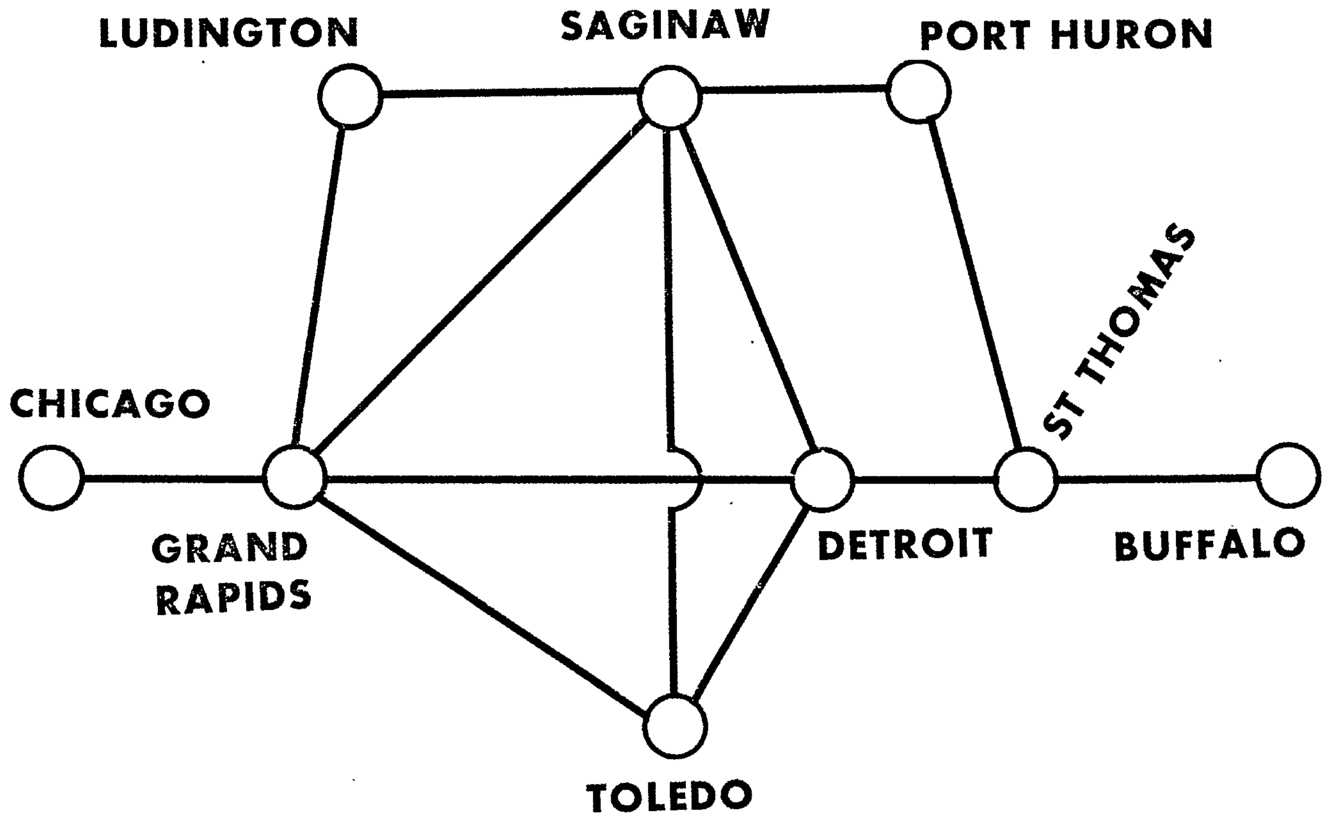

LUDINGTON
SAGINAW
PORT HURON
ST THOMAS
CHICAGO
GRAND RAPIDS
DETROIT
BUFFALO
TOLEDO

Figure 3

LIST OF MAJOR PROCESSES OF YARD

1. Receive Train in:

   A. Receiving area: may have separate or combined R & D, or in class area.

   B. Main Track

   C. Classification area: assume distinct from receiving area, i.e., industry, connections.

2. Double train if too long for area inbound.

3. Inspect, bleed, check for Bad Orders (inbound)

4. Quick Switch

5. Set off cars

6. Flat Yard Classification: assume all cars in train finished at same time, may wish to define more than one classification job, i.e., one for each lead.

7. Hump Yard Classification: assume cuts are available as processed, may wish more than 1 hump.

8. Reclassify: for small capacity yards may be necessary for certain trains.

9. Service type operations: ice, weigh, clean, repair, livestock.

10. Assemble train.

11. Inspect, pump air (outbound).

12. Pick up cars.

13. Double train in departure area.

14. Depart train from:

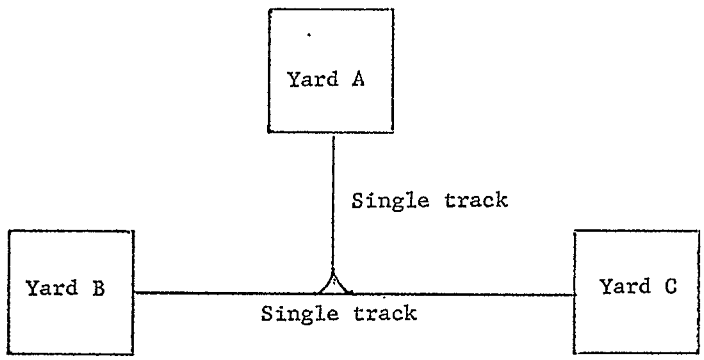
    A. Departure area: may have separate or combined R & D, or in class area.

    B. Main Track

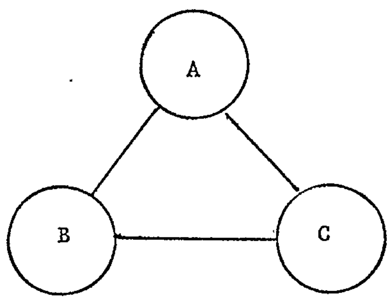
    C. Classification area: assume distinct from regular departure area, i.e., industry, connect.

Figure 4

REAL WORLD

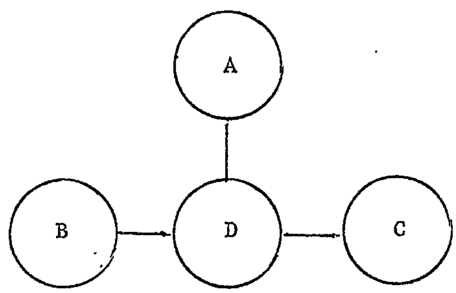


EXAMPLE A



Assumes no interaction of trains to and from A on link BC.

EXAMPLE B



Assumes interation on link BC.

Illustration of how "Y" section of track can be represented.

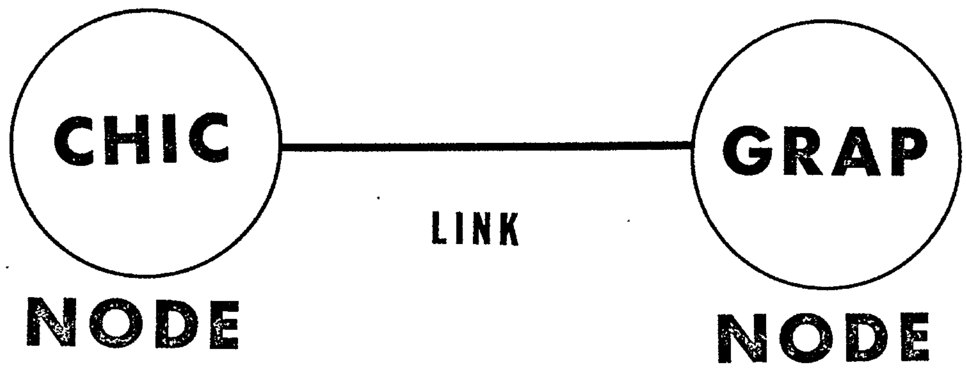
Figure 5

NODE GRAP

LEVELS OF REPRESENTATION

LEVEL	RATE	CAPACITY	COMPLEXITY
A. SIMPLE	CONSTANT	UNLIMITED	NO DELAYS OR INTERFERENCE
B. DETAILED	FUNCTION OF TRAIN TYPE ★ ★ ★ ★ ★ FUNCTION OF CARS IN NODE	LIMITED	DELAYS DUE TO CONGESTION
C. VERY DETAILED	FUNCTION OF WORK COMPLETED	RECEIVING CLASS. DEPARTURE	ASSIGN RESOURCES, DEFINE TASKS, RATES FOR WORK

Figure 6



LEVELS OF REPRESENTATION

LEVEL	RATE	CAPACITY	COMPLEXITY
A. SIMPLE	CONSTANT TIME	UNLIMITED	NO INTERFERENCE
B. DETAILED	FUNCTION OF TRAIN TYPE	LIMITED	MEETS CALCULATED
C. VERY DETAILED	FUNCTION OF WEIGHT/POWER		PASSES CALCULATED

BIOGRAPHY
W. K. Minger

Mr. Minger is the Manager of Special Projects, Association of American Railroads, Data Systems Division. Past experience has included the development and usage of large scale simulation models for technical analysis of railroad transportation operations. Most recently, he is responsible for the development of the AAR Network Simulation Model and a Loss and Damage statistical data system.

Mr. Minger graduated with a B.S. in Management Science from Case Institute of Technology in 1962 and obtained a MBA from Western Reserve University in 1968. Professional affiliations include the Washington Operations Research Council and TIMS.

BIOGRAPHY
J. N. Cetinich

Mr. Cetinich is the Manager of Analytic Services for the Southern Pacific Company. He has an extensive background in Civil, Mechanical, and Industrial Engineering, merger economics, corporate planning and transportation operations. He is currently directing the development of several large scale computer models.

Mr. Cetinich graduated with a B.S. in Industrial Engineering from the University of California at Berkeley in 1951. He is a registered professional Civil and Industrial Engineer in California. Professional affiliations include TIMS, AIIE, and the Railway Systems and Management Associations.