

NETWORK SIMULATION OF A MAJOR RAILROAD

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ABSTRACT

This paper describes a MODSIM III-based object-oriented network simulation model specifically developed for modeling railroad operations of Union Pacific Railroad. The transportation network simulation model is a strategic planning tool for determining if there are adequate resources to achieve the next year's projected business and the train schedules to transport that business.

1 INTRODUCTION

Strategic planning is a critical component of operating a large railroad. The lead times required to purchase/lease locomotives, train crews, and build additional track on the line or in terminals requires the ability to predict resources needs well in advance. While capabilities exist today to predict each of these resources individually, knowing the interaction of these resources is critical to determining tradeoffs and insuring that a transportation plan based on projected market forecasts is achievable and cost effective. To model these interactions and identify potential bottlenecks, Union Pacific developed a Network Simulation Model to evaluate the achievability of future transportation plans. Figure 1 illustrates the strategic planning process flow where the network simulation is used.

2 DEVELOPMENT APPROACH

The requirements were defined using SIMPROCESS for a high level representation. Once the requirements were defined, SIMPROCESS was again used to further define the specific logic and the level at which each resource would be modeled. Once the logic was defined, the actual application was built in MODSIM III on an NT platform. The decision to drop down to the lower level code of MODSIM III was based on the level of detail of the business logic to be represented and to provide the ability to expand and enhance the model. The ease of use and

quick model building capability of SIMPROCESS and the power and flexibility of MODSIM III provided a powerful combination of prototyping and development that was essential to obtaining Senior Level support and as well as providing a robust and scaleable system.

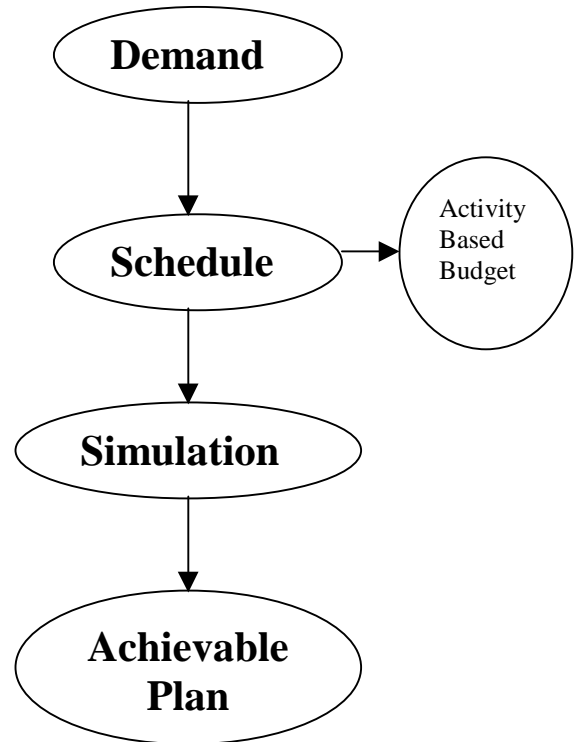


Figure 1. Strategic Planning Process Flow

3 MODEL INPUT

There are five critical resources associated with operating a railroad - crews, locomotives, mainline track, terminals, and rail cars. The Network Simulation Model simulates all of these resources except rail cars. In addition to current and projected information on these resources the simulation requires a train schedule, network topology,

business policies that affect the use of resources and the movement of trains. Details of inputs are as follows:

3.1 Locomotives

- Data is retrieved from mainframe and put into MS Access.
- Initial distribution on the network is based on history.
- They can be modeled at the unit or horsepower level.
- Locomotives can be added or removed from a train enroute.
- The maintenance and servicing of locomotives is also modeled.

3.2 Mainline

- Data is received as a direct input from a client/server system called Intelligent Track Network
- Capacity is based on the maximum trains on a segment at one time.
- Trains are spaced onto the mainline.
- Different speeds are used for Premium, Manifest, and Bulk trains.
- Scheduled track maintenance is also modeled.

3.3 Terminals

- Data is retrieved from mainframe and put into MS Access.
- Capacity is modeled for receiving tracks, hump lead and hump, and departure tracks.
- Scheduled enroute consist changes, inspections, and refuelings are modeled.

3.4 Crews

- Data is retrieved from mainframe and put into MS Access.
- Crews are modeled at the seniority district level.
- Simulation tracks crews and replaces the crew if they can not reach the scheduled crew change point prior to reaching federal crew on-duty time limits.
- Crew rest and crews waiting at away from home crew locations is modeled based on labor agreements.

3.5 Train Schedules

- Data is retrieved from a Paradox database and put into MS Access.
- Contains all planned trains based on the market based forecast.
- Schedules are specified by day of week and starting and ending dates.

3.6 Topology

- Topology is received as a direct input from a client/server system called Intelligent Track Network.
- Based on an arc and node structure with some clustering in congested areas.
- A utility is used to verify all new schedules and routes.
- Simulation has entire network database, but the capability is provided to model smaller segments.
- Topology can also be created using a drag-and-drop approach. Figure 2 shows topology of a small network segment.

4 HOW THE SIMULATION WORKS

The MODSIM III-based simulation engine creates trains from the schedule file. Trains compete for resources such as crews, locomotives, and mainline. The movement of trains on mainline is animated. The model writes simulation events to output files. The simulation is run for a specified number of weeks.

Although the actual implementation of the behaviors of model objects is much more complex, a high level overview of the processing logic is described below.

4.1 Station Logic

There are three types of trains. The station logic is different depending on the type of the train. Through trains have crew change, locomotive change, pick-up, set-out, refueling, and inspection. Originating trains acquire departure track, build train, acquire locomotive(s), acquire crew, and depart to mainline. Terminating trains acquire receiving track, release locomotive and crew. They can either switch to hump lead or classification track, and release receiving track.

4.2 Crew Change Logic

Crew is removed from train, delayed to model rest period, and placed into a crew pool at the station. Crews are stored by district class in two pools: 1) crews which are at their home station, and 2) those who are away from home.

A crew is selected from the pool according to the district class specified by the schedule. Crews which are away from home have precedence over those which are at home. If a crew from the desired seniority district is not available, the train waits for one to become available -- congesting the track it occupies as it waits.

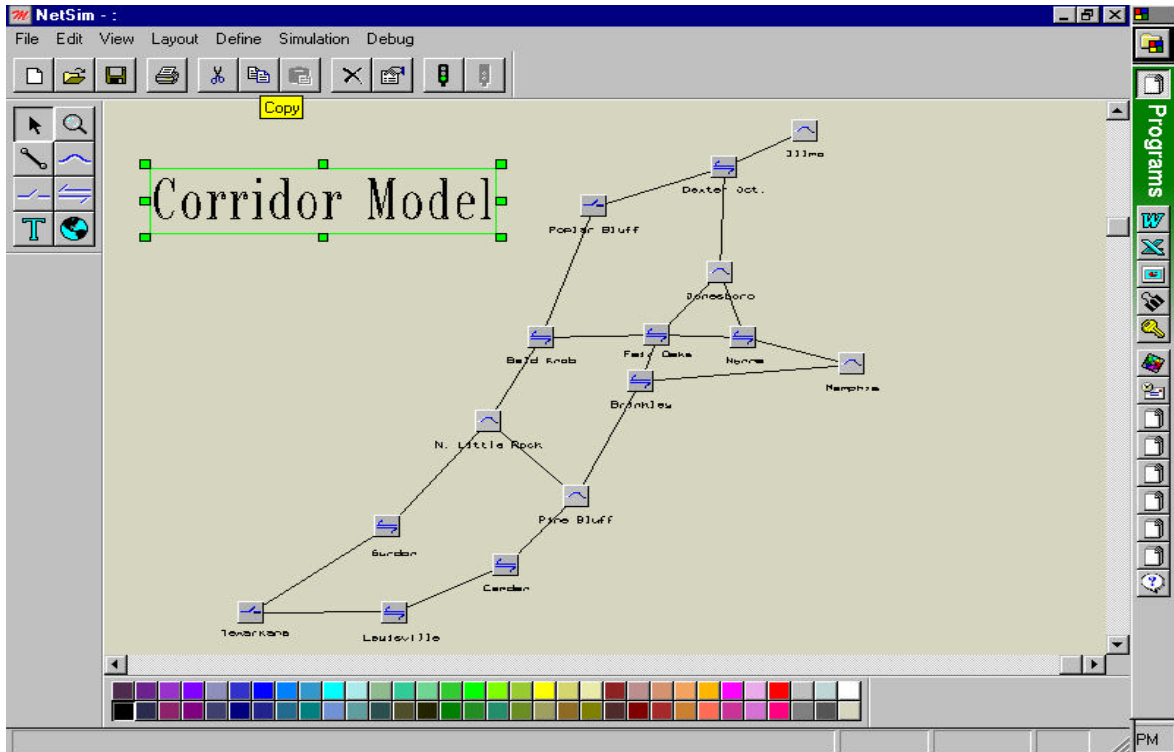


Figure 2: Topology of a Small Network Segment

Trains entering the simulation are given a DEFAULT crew if no district class is specified in the first point in the schedule.

4.3 Locomotive Change Logic

Locomotive changes are similar to crew changes except locomotives receive maintenance before being placed into the station's locomotive pool.

4.4 Track Logic

For a train originating at station A and terminating at station B, track logic is played out as follows:

1. Acquire departure track at station A
2. Acquire Main Line A-B
3. Release departure track at station A
4. Acquire receiving track at station B
5. Release Mainline A-B
6. Release receiving track

4.5 Scheduled Track Events

- Mainline -- travel time = distance / speed
- Speed may be different for Premium/Bulk/Manifest trains
- Receiving track -- Disassemble train, release crew, release locomotive
- Through track -- refuel, inspect, crew change, locomotive change, set-out, pick-up (performed in parallel)
- Departure Track -- build train, acquire loco/crew (performed in series)

4.6 Track Delays

Track delays are caused by:

- Insufficient capacity at succeeding track (congestion) - - wait until succeeding track is available.
- Insufficient resources at the station (Locomotives/Crews) -- wait until resource is available.
- Insufficient separation on succeeding track (congestion) -- wait until sufficient time gap from previous train.

5 MODEL OUTPUT

The following are the critical outputs used to measure the achievability of the transportation plan.

- Trains that could not depart on time due to the non-availability of the four critical resources modeled.
- Surplus and deficit areas for crews and locomotives.
- Crew and locomotive utilization rates.

An example of the crew reports is shown in Figure 3. In addition, ad hoc reports can be built to evaluate each train or each location for any event in the simulation. All reports are generated from the trace file into MS Access.

6 CONCLUSIONS

The Network Simulation Model is currently being used to perform ad-hoc “What-If” scenarios to evaluate proposed process changes. This model provides the first capability to evaluate all critical resources network wide and observe the interactions of resources. Preliminary uses of the model have shown the tradeoffs that can be made between hiring additional crews and building additional track. Such tradeoffs are not intuitive and could not be objectively

evaluated in the past. The Network Simulation Model will be used to evaluate the 1999 Annual Operating Plan.

AUTHOR BIOGRAPHIES

MYRON LEWELLEN is the General Director of Operation Systems at Union Pacific Railroad in Omaha, NE. He holds a MS degree in Operations Research from the Air Force Institute of Technology. He has been involved with simulation, optimization, and artificial intelligence in transportation, logistics, and resource planning for 18 years.

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Crew Performance Statistics

			TimeOnTrain	TimeOnRest	Time Available	Time On Layoff	Crew Utilization With Deadhead	Availability
Summary for District:	DC	Totals	750.34	4680.00	30309.12	0.00		
Crews	205	Average:	3.66	22.83	147.85	0.00	0.16	0.88
		Standard Deviation:	18.78	5.81	30.27	0.00	0.10	0.18
Summary for	RE01	Totals	7382.47	1048.00	6628.22	0.00		
Crews	49	Average:	150.66	21.39	135.27	0.00	1.02	0.81
		Standard Deviation:		8.85	47.94	0.00	1.15	0.29
Summary for District:	RE03	Totals	415.32	512.00	1239.78	0.00		
Crews	13	Average:	31.95	39.38	95.37	0.00	0.42	0.57
		Standard Deviation:		2.22	46.90	0.00	0.02	0.28
Summary for District:	RE04	Totals	629.46	80.00	139.85	0.00		
Crews	2	Average:	314.73	40.00	69.93	0.00	2.11	0.42
		Standard Deviation:		0.00	0.14	0.00	0.30	0.00
Summary for District:	RE05	Totals	674.35	637.59	2817.93	0.00		
Crews	27	Average:	24.98	23.61	104.37	0.00	0.29	0.62
		Standard Deviation:		20.28	75.49	0.00	0.21	0.45
Summary for District:	RE06	Totals	116.29	272.00	243.61	0.00		
Crews	5	Average:	23.26	54.40	48.72	0.00	0.46	0.29
		Standard Deviation:		49.77	67.67	0.00	0.40	0.40
Summary for District:	RE07	Totals	447.42	640.00	1672.38	0.00		
Crews	18	Average:	24.86	35.56	92.91	0.00	0.36	0.55
		Standard Deviation:		26.49	47.40	0.00	0.22	0.28

Figure 3: Crew Utilization Report