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DEVELOPMENT OF A TRANSPORTATION PLANNING TOOL

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ABSTRACT

This paper describes the application of simulation modeling and logistics techniques to the development of a planning tool for the Department of Energy (DOE). The focus of the Transportation Planning Model (TPM) tool is to aid DOE and Sandia analysts in the planning of future fleet sizes, driver and support personnel sizes, base site locations, and resource balancing among the base sites. The design approach is to develop a rapid modeling environment which will allow analysts to easily set up a shipment scenario and perform multiple "what if" evaluations. The TPM is being developed on personal computers using commercial off-the-shelf (COTS) software tools under the *WINDOWS®* operating environment. Prototype development of the TPM has been completed.

INTRODUCTION

The DOE owns and operates a fleet of highly sophisticated trailers, tractors, and escort vehicles for the purpose of safely and securely transporting weapons and SNM within the continental United States. In the past few years, the stockpile reductions treaties and the reorganization of the DOE weapons complex has drastically changed the projected shipment workload for the DOE transportation system. In addition, the DOE is striving to operate its fleet more efficiently without compromising the safety and security of weapon transport. This project developed from the need to have a tool to aid DOE and Sandia analysts in planning the future size, location, and operation of the DOE fleet. The tool being developed by SNL will support the total systems logistics planning required to meet DOE needs.

SYSTEM OBJECTIVES

At the present time, calculations to determine the effects of the changing world situation on the DOE transportation system are done manually. Often times the calculations require iterative processes in order to analyze one or more of the variables. These manual calculations are slow, laborious, and subject to error.

The objective of the Transportation Planning Model (TPM) is to rectify this condition through the use of state-of-the-art computer simulation techniques. The TPM is being structured to allow a non-technical analyst, either at Sandia or DOE, to input shipment schedule data of their choice and to apply current or revised transportation operational rules to derive an answer to the scenario they have created. With the TPM, this sort of "what-if" type of analysis can be done quickly and accurately. In addition, parametric studies which are very difficult to perform with manual calculations, can be readily accomplished using the TPM.

For a given set of conditions (singular or parametric) established by the analyst, the model can provide answers to queries such as the following:

- efficient scheduling and routing,
- optimum fleet and courier sizes,
- optimum convoy sizes,
- resource balancing at courier sites,
- shipment backlog,
- capacity for additional work,
- effect of altered maintenance or training procedures,
- effect due to site closure, opening, or restructuring,
- effect of changed vehicle load configuration,

- effect of additional or reduced workload,
- number of shipments by cargo type, location, date, etc.,
- vehicle utilization, e.g., active, loading operations, rest, deadheading, etc.,
- frequency of routes and site traffic.

DESIGN APPROACH

The TPM is being designed and implemented as a set of integrated software tools as shown in Figure 1. The TPM User Interface and Shipment Data Preprocessor interact with a supporting database to provide the automation required to easily import external shipment schedules, format the data, and execute the scheduling and modeling components of the TPM. The TPM Scheduler converts shipment information into planned trips, i.e., routes, convoy sizes, and courier section assignment. The Operations Model simulates the execution of the planned trips with a given set of resources and under defined operating policies. Each of these components is discussed in detail below. The entire model executes on a personal computer under the *WINDOWS®* operating environment.

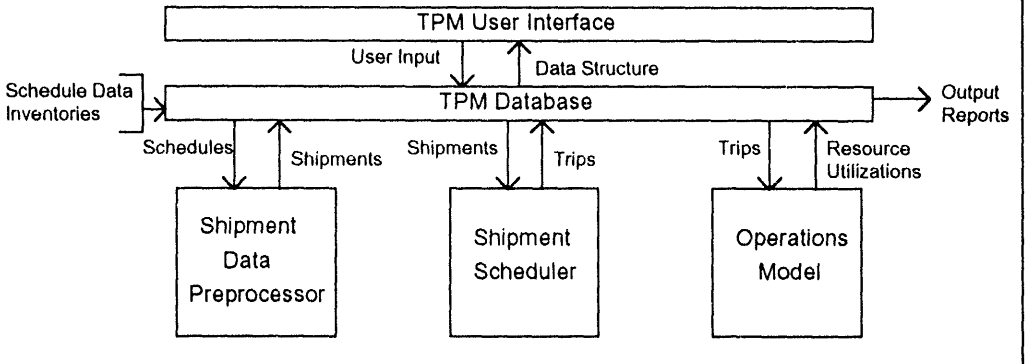

FIGURE 1: TPM System Components

User Interface

The TPM User Interface (UI) is the means by which the user controls and accesses the various components of this software. The UI has been developed in Microsoft *ACCESS®*, Version 2.0, giving the user the familiar Microsoft *WINDOWS®* environment and programming standards. There is also a context-sensitive Help system with key words to help the user navigate, operate, and understand the TPM.

The UI provides high level control for the TPM, initially showing the user the TPM Main Window that can launch the Shipment Data Preprocessor, the Scheduler, and the Operations Model components. This main window is essentially the cornerstone of the system, giving the user a step by step approach in developing their "What If" scenarios. Before initiating the processing of any component of the TPM, the user is able to alter the applicable modeling parameters through the TPM UI. Thus, even though different commercially available software packages are being used in this highly integrated system, the user never enters any of these software packages directly. This gives the user a single, uniform interface, and gives the TPM an added level of data protection and process flow control.

Data Import and Shipment Preprocessing

The first step in analyzing the transportation system requirements of the DOE is to project what the DOE shipment workload will be in future years. Various long-term schedules exist for much of the cargo moved by the DOE, however none of these schedules alone include all the information necessary to completely specify the required shipments. For example, schedule data from an external source may list the number of weapons for retirement, but not the locations of these weapons, their shipping requirements, or any logistics information such as planned base closures. The Shipment Data Preprocessor (SDP) provides the capability to automatically import these different schedules and supporting data, such as site inventory data, from the original text, database, or spreadsheet files. The SDP then performs the logic necessary to transform the input schedule data into a set of shipment specifications. Each shipment specification includes the shipping site, receiving site, the quantity of cargo, the number of vehicles required to move the cargo, the date the cargo will be available for shipment, the length of time DOE has to make the shipment once the cargo is available (also called the shipment window), the purpose of the shipment, and the shipment priority.

The SDP also allows the user to input shipment data into a User Defined category. This gives the user the ability and flexibility to include unique and nontraditional shipments that are not listed in any schedules. By adding these User Defined shipments, the user can see how the workload of the more traditional shipments is affected by the additional workload, and therefore plan more effectively.

Trip Scheduling

The TPM Scheduler takes as input the shipment information generated by the Shipment Data Preprocessor and schedules the trips required to move the shipment cargo. An example screen from the execution of the Scheduler is shown in Figure 2.

The entire set of shipment data is scheduled one month at a time. In a given month, the Scheduler looks at all shipments available for pick-up and, using routing algorithms with a minimizing objective of either distance, time, or cost, determines the best routes and convoy sizes to service the shipments. For each trip, the routing algorithms determine which courier section to start from based on the goal of the minimizing objective. All trips terminate at the same courier section from which they originated.

Trips are routed over a true United States interstate and highways road network. In addition, the Scheduler is able to account for the special scheduling constraints of the DOE system such as maximum length of trip and maximum convoy sizes.

The TPM Scheduler has been implemented using the *CAPS Logistics Toolkit*® available

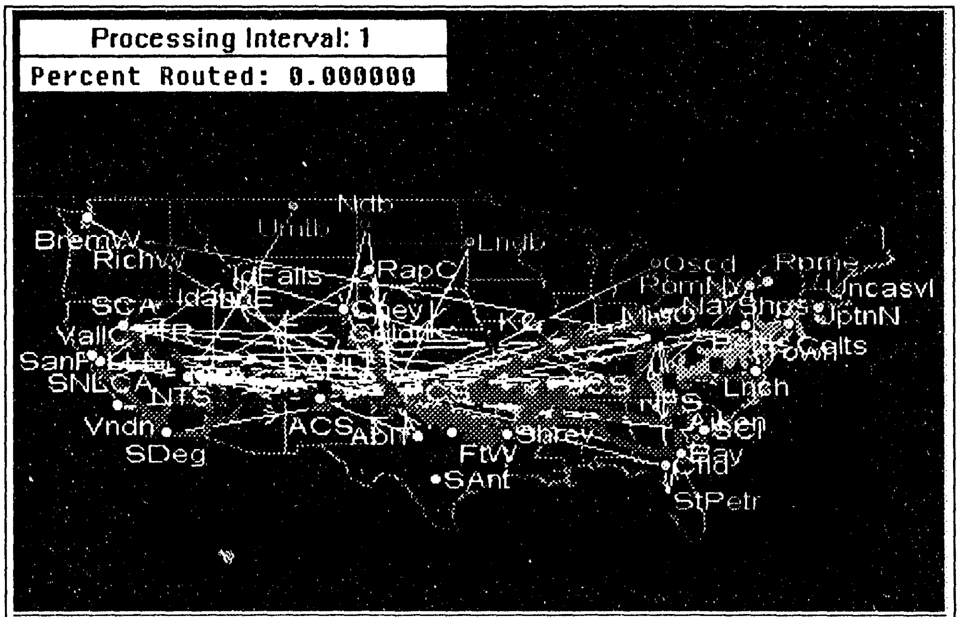

FIGURE 2: Sample Scheduler Display

from Computer Aided Planning and Scheduling (CAPS) Logistics, Inc. of Atlanta, Georgia. The *CAPS Logistics Toolkit*® is a set of logistics planning and scheduling tools for transportation systems. The Toolkit includes a macro programming language which allowed us to custom program the Toolkit to meet the unique requirements of the TPM.

Output of the TPM Scheduler is a text file containing the set of trips required to move the input shipment load. For each trip, the courier section, convoy size, shipments serviced, length of the trip in miles, and length of the trip in time is specified. Trip timing includes on-road time loaded, on-road time deadheading (traveling without cargo), time spent in over night rest, and time spent loading and unloading the vehicles. The trip information is imported into the TPM Database.

using AT&T Istel's *WITNESS*® simulator package.

For vehicles, the size and operational hours of the maintenance facility is modeled. To model the vehicle throughput in the maintenance facility, historical maintenance records were collected which tracked the labor hours logged for each of the maintenance activities. This data was used to define the sampling distributions from which the model obtains the maintenance durations for each maintenance activity when a vehicle enters the maintenance facility.

For the couriers, administrative policies are modeled including post-trip rest periods, annual training, holidays, and leave. The couriers are modeled as courier units, where one unit has adequate personnel to staff a convoy. When on

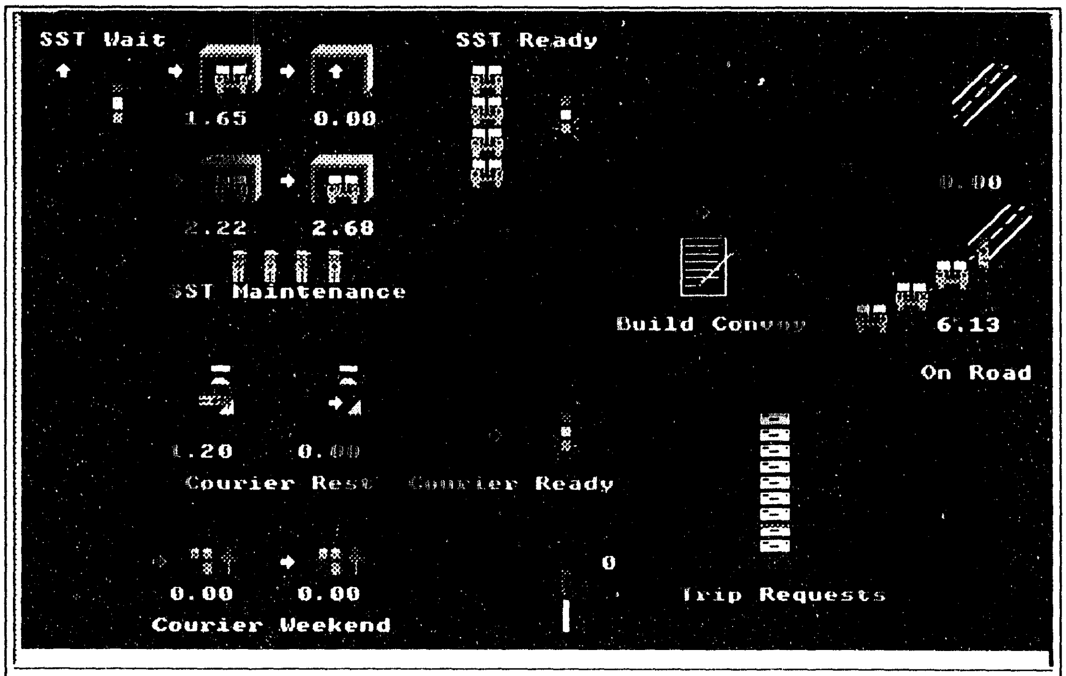

FIGURE 3: Sample Operations Model Display

Operations Modeling

The management of both the vehicle and personnel resources at each DOE courier base is simulated in the TPM Operations Model. An example screen from the execution of the Operations Model is shown in Figure 3. The TPM Operations Model has been implemented

the road, both normal and overtime hours earned by the courier unit are accumulated and tracked.

Input to the Operations Model is the set of trips defined by the Scheduler. When a trip's shipment available date is reached, the Operations Model assigns the necessary resources to the trip as soon as the resources are available. For the duration of the trip, the assigned resources are considered to be "on-road" and unavailable for other trip assignments. After completion of a trip, vehicles are sent to maintenance and the courier unit is made unavailable for a required rest period. If resources are not available for a trip during the trip's shipment window, i.e., the period of time specified to ship the cargo, then the trip is counted as "backlogged."

Output of the TPM Operations Model is three text files. Data is written to these files on a monthly interval basis (in simulation time) while the Operations Model is executing. The first file contains trip execution data for each trip processed. This data includes trip departure times, wait times before departure, and the backlogged shipment tracking. The second file contains courier unit utilization data such as time spent on-road, in rest, in training, on leave, and idle. Overtime hours accrued are also recorded. The third file contains similar information for the vehicles including time spent on-road, waiting for maintenance, in maintenance, and idle. The data in output files is imported into the TPM Database after execution of the Operations Model.

Database Support

The TPM Database, like the TPM User Interface, has been implemented in *ACCESS®* 2.0. Its main function is the organization and storage of all the data imported and generated while running the TPM. For any scenario set up by the TPM user, a catalogued history is created which documents the creation date, the input schedule data used, modeling parameter values, and any notes the user may want to add to help clarify the contents of the scenario. The user may set up and execute several scenarios at one sitting, or set up part of a scenario and then later return to finish. In addition, a scenario may be built upon the data set up for a previous scenario. This saves the user some time in setting up the scenarios and allows the user to incrementally build upon a base scenario under evaluation.

At each stage of the TPM processing, the user can view or print various output reports and graphs, all of which are automatically generated by the TPM Database. Furthermore, before the TPM UI launches the execution of the Scheduler or the Operations Model, the Database automatically formats and exports the data files required as input by these components. The files contain the data and parameters as set up by the user through the TPM UI.

PROTOTYPE DEVELOPMENT RESULTS

After the high level design approach of the TPM system was formalized, it was decided to implement a first phase or "prototype" of each of the TPM components. In this way, software incompatibilities, model validity, and other problems could be identified before a large amount of time and effort was invested in the project. The first prototype developed was the Operations Model. This was followed by the Scheduler prototype. The final prototype incorporated the TPM User Interface, Shipment Data Preprocessor, and the TPM Database.

Operations Modeling Results

The prototype Operations Model simulated the operation of one of the DOE courier bases. To validate the model, recent historical data on actual trips run by this courier base was obtained and used as input to the model. The resource utilization results matched well with the results of a manually calculated analysis based on the same historical data set.

In addition, the model was tested under a fictitious high load scenario and a fictitious low load scenario. In the high load scenario, the DOE system was most limited by vehicle availability. That is, there were not enough vehicles to supply the trips. However, simply adding more vehicles did not improve the overall supply of vehicles for trips. Without expanding the maintenance facility or shortening some of the maintenance activities, there was no real increase in the number of vehicles available for trips. Clearly, this showed the importance of looking at the total system operation when planning for the future.

The complete TPM Operations Model will include the simulation of all the DOE courier bases.

Scheduler Results

The prototype Scheduler was the most complete prototype developed, containing roughly 85 percent of the functionality that is expected to be required for the full TPM system. Again, we were able to test the Scheduler functionality with historical data of actual shipment requests moved by the DOE. Our first execution of the historical data resulted in the creation of trips that tended to be much longer, serviced more shipment requests, and required larger convoys then were actually run by the DOE. Even though all the "hard" scheduling constraints, such as maximum length of trip and maximum convoy size, were implemented properly in the Scheduler, some of the softer, human related constraints were not represented. In reality, it is difficult on the couriers to run lengthy trips back-to-back. By adjusting some of the parameters and the fleet profile in the prototype Scheduler, we were able to reduce the average length and convoy size of the trips generated. To better represent the "soft" scheduling constraints, the full TPM Scheduler will allow the specification of both an absolute maximum limit and a preferred limit for some of the parameters.

Furthermore, the prototype Scheduler created trips with the objective of minimizing the distance traveled. The full Scheduler will allow trips to be formed based on minimizing trip cost. This may make the creation of longer trips less attractive due to overtime hours earned and the cost of boarding the couriers for additional overnight rests.

User Interface, Shipment Data Preprocessing, and Database Results

The last prototype, which required the development of the User Interface, the TPM Database, and part of the Shipment Data Preprocessing functionality, has not completed test and evaluation. However, the User Interface was demonstrated to our customers, and was well received. The customer will be allowed to work with the prototype system and provide feedback on its capabilities and interface. Early results from this prototype development indicate the smooth integration of user interface, database, and data processing functionality.

CONCLUSIONS

The Transportation Planning Model will provide the rapid modeling environment necessary to evaluate the impact of changing requirements on the DOE transportation system. The development of the TPM to date has put in place the structure required for the efficient and spiral implementation of the remaining TPM features.

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