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Applying Simulation and Logistics Modeling to Transportation Issues

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ABSTRACT

This paper describes an application where transportation logistics and simulation tools are integrated to create a modeling environment for transportation planning. The Transportation Planning Model (TPM) is a tool developed for the Department of Energy (DOE) to aid in the long-term planning of their transportation resources. The focus of the tool is to aid DOE and Sandia National Laboratory (SNL) 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 integrates graphical user interfaces, logistics optimizing tools, and simulation modeling. Using the TPM an analyst can easily set up a shipment scenario and perform multiple "What If" evaluations. The TPM has been developed on personal computers using commercial off-the-shelf software tools under the *WINDOWS®* operating environment.

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 Special Nuclear Material (SNM) within the continental United States. In the past few years, the stockpile reductions treaties and the reorganization of the DOE weapons complex have 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 over the next 10 or more years. The Transportation Planning Model (TPM) tool, recently completed by SNL, supports the total systems logistics planning required to meet DOE needs.

The design approach has been to develop a rapid modeling environment which will allow analysts to easily set up a shipment scenario and perform multiple "What If" evaluations. For a given set of conditions set up by the analyst, the TPM generates data to support the evaluation of issues such as:

a) optimum DOE fleet and courier (driver personnel) sizes

b) resource balancing at DOE base sites

c) shipment backlogs which may occur

d) capacity for additional work

e) efficient routing of shipments and the transportation costs

f) length of time required to transport a quantity of material or components

g) effect of altering vehicle maintenance or courier training policies

h) effect due to site closure, opening, or restructuring

i) expected vehicle and courier utilization's

j) frequency of routes and site traffic

TPM COMPONENTS

The TPM has been designed and implemented as a set of integrated software components as shown in Figure 1. An analyst using the TPM begins by defining a shipment workload scenario. The shipment scenario is then passed to the Shipment Scheduler component which schedules the trips which will deliver the shipments. Finally, the trips are executed by the Operations Model component which simulates the facilities that manage the vehicle and personnel resources. Each of the TPM components is discussed in detail below.

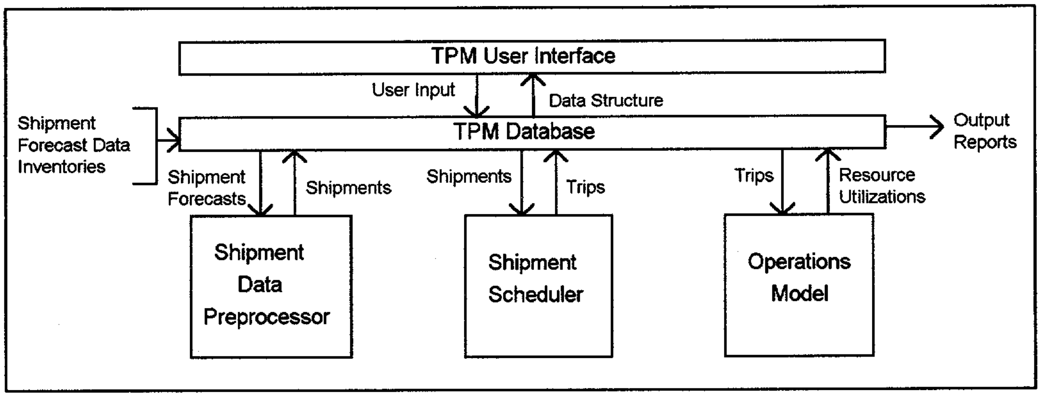

Figure 1 - TPM System Components

User Interface and Database

The TPM User Interface (UI) is the means by which the user controls and accesses the various components of this tool. The UI and the TPM Database have been developed in Microsoft *ACCESS®* 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. For each TPM component a graphical menu and forms driven user interface is provided to aid the user in the entry of shipment or modeling information. 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. When the user has set up a modeling scenario and is ready to run the Scheduler or Operations Model components, the TPM Database automatically formats and exports the input files required by these components. These files contain the data and parameters as set up by the user through the TPM UI.

A large amount of user input is required to provide the flexibility of creating numerous modeling options and configurations. To help balance the ease of use versus flexibility trade-off in the user interface, reasonable defaults are provided for most modeling parameters. In addition, the interface has been designed to emulate the familiar Microsoft "Wizards" approach when setting up modeling parameters and data. The set-up "Wizard" procedure guides the user through a sequence of forms that display the modeling options and parameters which the user may modify.

The main function of the TPM Database 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.

At each stage of the TPM processing, the user can view or print output reports and graphs. Each component has its own set of automatically generated reports which summarize, in tables and graphs, the data generated by the component. Through the TPM UI the user selects a set of reports to view or print and the reports are generated by TPM Database software.

Shipment Data Preprocessor

The Shipment Data Preprocessor (SDP) is the first step in constructing a scenario. Its main function is to build shipments to be used as input for the Scheduler component. Like the TPM Database and TPM UI, the SDP has been implemented using *ACCESS* Basic, available in *ACCESS*® 2.0.

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, shipment forecast 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. A group of these shipment specifications is called a shipment workload projection.

Also available to the analyst is the ability to generate shipment workload projections that build upon previously defined shipment workloads. By combining various projections in different ways, the analyst can create different workload scenarios to address various "What If" questions. For example, the analyst may have several sets of User Defined shipments that he would like to "add" to a shipment workload of weapon retirements. By adding these shipments together, the analyst can see how the workload of the more traditional shipments is affected by the additional workload, and therefore plan more effectively. The database keeps track of these workload combinations, and allows the user to add their own notes for clarification and future reference.

Output graphs for the SDP allow the analyst to view the shipments for any projected workload, the number of vehicles required for these shipments, and many other statistics used to make the shipment workload projections. By analyzing these graphs and reports, the analyst can determine if their defined scenarios are reasonable, or if different shipment workload projections should be done.

Shipment Scheduler

The TPM Shipment Scheduler takes as input the shipment workload projections 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 TPM Scheduler has been implemented using the *CAPS Logistics Toolkit*® available 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 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 security reasons, the DOE runs its trips in convoy formation. For each trip, the routing algorithms determine the base site from which the trip will originate, the shipments which will be serviced, the size of the convoy, total trip miles and time, the number of required overnight breaks, the trip cost, and the number of driver overtime hours accrued during the trip. Trips are routed over a true United States interstate and highways road network. All trips terminate at the same DOE base site from which they originated. 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 output trip information is imported into the TPM Database after each execution of the Scheduler.

The user may set up and execute several Scheduler runs before moving on to the Operations Modeling component of the TPM. Each Scheduler run is uniquely identified by the TPM Database and the user may add notes which are archived with each run.

Using the available output reports, the user has the ability to take a shipment scenario and evaluate the impact on the trip scheduling of altering scheduling constraints, cost factors, and/or base site locations. The most favorable trip scheduling solutions can then be passed on to the Operations Model for further evaluation.

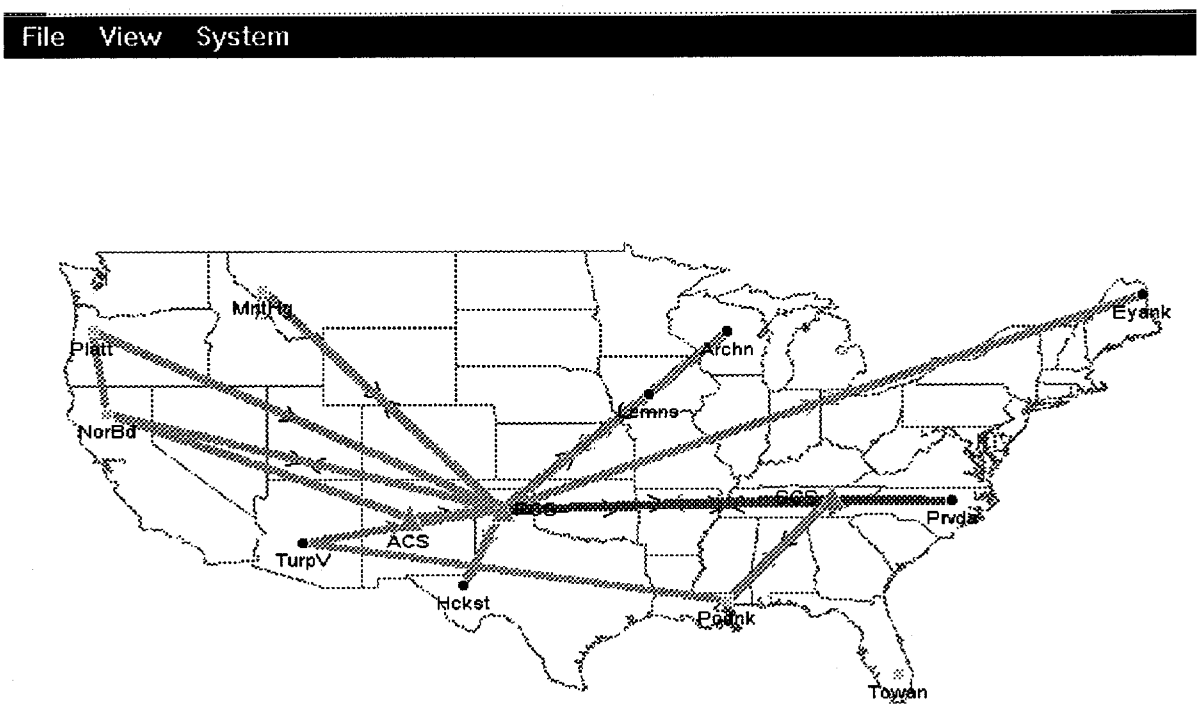

Figure 2 - TPM Shipment Scheduler Component

Operations Modeling

The trips generated by the Scheduler as well as DOE base site data are used as input to the Operations Model. An example screen from the execution of the Operations Model is shown in Figure 3. The TPM Operations Model has been implemented using AT&T Istel's *WITNESS®* simulation package.

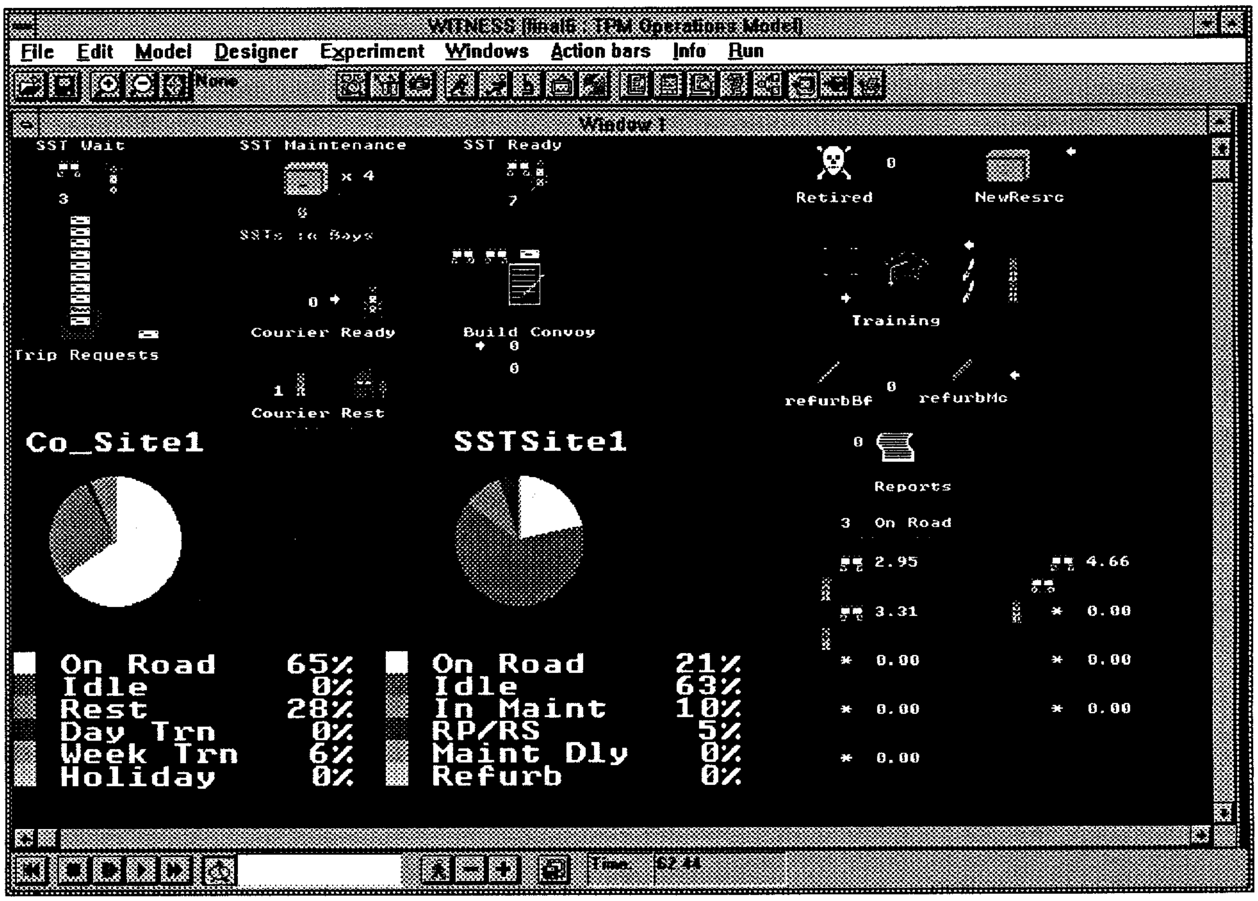

Figure 3 - TPM Operations Model Component

The management of both the vehicle and personnel resources at each DOE base site is simulated as well as the size and operational hours of the maintenance facilities. 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 duration 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 a trip's shipment becomes ready for movement, 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 "rests" for a required period before reentering the resource pool. If resources are not obtainable for a trip during the trip's window, i.e., the period of time specified to ship the cargo, then the trip is counted as "backlogged."

After a run is complete, the user may want to change their input parameters and rerun their model. The user can change resources at courier sites, administrative policies such as training, required maintenance, and the number of personnel in a courier unit. The modified model can then be re-run. The user can iteratively solve a problem of load balancing between sites and large backlog queues to determine the effects of a resource or policy changes by comparing runs.

Output of the TPM Operations Model includes data on trip, personnel, and vehicle statistics. Data is collected on a monthly interval basis while the Operations Model is executing. Trip execution data for each trip processed includes trip departure times, wait times before departure, and the backlogged shipment tracking. Courier unit utilization data collected includes time spent on-road, in rest, in training, on leave, and idle. Similar data is collected for the vehicle utilization including time spent on-road, waiting for maintenance, in maintenance, and idle. The output statistics data is imported into the TPM Database after execution of the Operations Model.

DYNAMIC MODELING

Rather than being a static model of the current DOE transportation system, the TPM is truly a rapid modeling environment capable of dynamically constructing the logistics and simulation models based on user input. The current DOE transportation system is the base model - but it is not static. The user can easily add new shipment sites to the logistics network in the Shipment Scheduler. For the Operations Model, the user has the ability to change resource sizes and make policy changes in the maintenance and training activities. The actual number and location of DOE base sites is user definable, which effects both the Scheduler and the Operations Model. All the possible system configuration and modeling options are set up through the User Interface and then the actual logistics and simulation models are dynamically created.

Not only are the logistics and simulation models dynamically created from one scenario to the next, they can also change dynamically within a scenario. Realistically, the DOE system will change over the ten or more years that a scenario covers, so the TPM has provided the capability for many parameters to dynamically change over time, while the models are running. For instance, DOE base sites can open, close, and move on a fiscal year basis. Cost parameters can be specified by fiscal year. Training schedules and fleet and courier sizes can also change by fiscal year.

By changing these parameters, future DOE policy changes can be modeled to determine the effect on the transportation system as whole. The decision to shuffle resources between base sites, or move or close a base site may have unanticipated results, and these various "What Ifs" can be modeled quickly and easily. Because policy changes can be quite costly, the analysts' ability to model these potential changes is extremely beneficial and insightful.

MERGING OPTIMIZATION AND SIMULATION

Having both an optimizing scheduler component and a simulation component makes the TPM a more effective planning tool for the DOE system analyst. The Shipment Scheduler provides the analyst with a close to optimal plan for shipping the cargo specified in the projected shipment workload. By looking at the number of trips scheduled for each base site, the analyst can estimate the amount of resources (fleet and personnel) required at each base site over the projected time span. An underutilized base site can be easily detected and the analyst can consider scenarios where that site is closed. On the other hand, several very long trips from one site might suggest the need to open or move a base site closer to the shipment activity.

Once a reasonable shipment plan is determined, the Operations Model is initiated. The model attempts to execute the shipment plan. The output from the model provides the analyst with the expected resource utilization and any shipment backlogs which occur. Problems such as inadequate throughput in vehicle maintenance or an imposing personnel training schedule can be easily detected. Taking all this information together, the analyst is able to determine the numbers of resources required at each base site and predict where problems may arise in meeting the shipment plan. Issues such as moving resources, expanding maintenance facilities, or adjusting personnel training can be addressed.

If a problem is detected in the Operations Model which can not be easily overcome, then the analyst can go back to the Shipment Scheduler and try another shipment plan. By executing the optimizing and simulation components in series, the analyst is able to determine the best DOE system configuration for effectively and efficiently meeting its future shipment obligations.

FUTURE DIRECTIONS

One problem with providing the capability to rapidly set-up and execute several scenarios is the tremendous amount of data that is generated. The analyst must manually compare and analyze this data to draw conclusions. A direction for future development is giving the analyst an intelligent tool to help in processing this data. This tool will compare results between two or more runs to show the sensitivities of a suggested change.

Other areas under consideration are adding the capability to automatically make recommendations for optimal resource sizing (fleet and personnel) and DOE base site locations over time. This tool may be a type of expert system or neural net system that could learn as more runs are performed. The goal of these post processing/data analysis tools is to reduce the number of iterative steps required to come to a solution.

CONCLUSIONS

The development of the TPM was completed at the end of fiscal year 1995. Early in fiscal year 1996 the system will be delivered to users and training on the use of the system will be provided. It is anticipated that the TPM will be used to support a variety of studies including:

1) An operations study to determine the major configuration issues facing the current DOE transportation system as it moves toward the year 2000 and beyond. Given the expected, traditional DOE shipment workload, this study will identify the number and location of resources which will be required to meet the shipment requirements.
2) New business initiative studies which are looking at possible new customers for the DOE transportation system. The TPM will be able to evaluate the impact of new workloads on the DOE system. Again, the number and location of resources can be determined as well as required adjustments in operating policies.
3) Waste material disposition studies. When considering options for the processing and disposal of waste material, the TPM can provide data on the transportation costs, the impact to the DOE transportation system, and the length of time required to perform the required movements.

Even though the TPM development was focused toward a particular application and transportation system, it has rendered useful ideas for designing and planning other perhaps more generic rapid modeling environments for transportation systems. By integrating available tools a powerful modeling environment can be developed with a minimal (but not trivial) programming effort. A consistent graphical user interface customized to the application domain helps the user build complex logistics and modeling scenarios rapidly and with a reduced likelihood of error. A database is essential for the organization, storage, and retrieval of the scenarios executed. Logistic optimization tools provide efficient solutions to transportation flow problems. Finally, simulation models evaluate the impact of operational polices, facilities, and available resources on the throughput of the transportation system.

DISCLAIMER

LIST OF FIGURES