SIMULATION MODEL FOR THE WIPP TRANSPORTATION AND DELIVERY SYSTEM*

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ABSTRACT

Simulation modelling is a powerful analysis tool used to evaluate complex systems or processes. The modeling concept was utilized to evaluate the performance of the Waste Isolation Pilot Plant (WIPP) transportation and delivery system. The model will assist in analyzing the responsiveness of the components in the system to the variations in waste generation schedule, system failures, and material handling options.

BACKGROUND

The United States Department of Energy's (DOE) WIPP is a first of its kind repository designed to demonstrate safe disposal of transuranic (TRU) waste in bedded salt 2,150 feet underground. Contact handled (CH) TRU waste -- waste with low beta or gamma emitting radionuclides that can be handled without anticontamination clothing or additional shielding -- will be transported to the WIPP in Nuclear Regulatory Commission (NRC) certified containers known as TRUPACT-II. The TRUPACT-II is the cornerstone of a transportation system designed for extraordinarily safe transport of TRU waste from ten DOE sites to the WIPP. This paper will describe the transportation system and discuss how a simulation model can be used to develop economical operating parameters for the system.

A primary objective of the DOE for the transportation system is to minimize the total or "life cycle" cost of operating and maintaining its fleet of TRUPACT-IIs. The life cycle cost is computed for a given system configuration by considering the initial fleet procurement cost, the operating and maintenance costs per mile, costs of operating the container (i.e., loading or unloading), and idle time. Clearly, minimizing the life cycle cost requires maximizing the payload to be shipped in each shipment and minimizing the operating cost and idle time.

Optimizing the payload is complicated by restrictions imposed by the Certificate of Compliance for TRUPACT-II that limits the mixing of various waste types and containers, the payload weight, and the thermal loading in a package, which is related to the gas generation potential of the radionuclide loading in the waste. Load management programs are used by the users of the TRUPACT-II to meet these limitations. Minimizing the operating costs is complicated by restrictions imposed by regulations, required handling procedures, and waste operator dose minimization. These complicating factors make analysis of the life cycle costs very difficult.

In order to maximize the payload, it is also worthwhile to evaluate the development of design alternatives to the TRUPACT-II. Two alternatives that are being considered are a half-height TRUPACT-II (designed to carry seven heavy drums or one waste box rather than 14 lighter ones or two waste boxes), and a lightweight TRUPACT-II, which could carry 14 drums of intermediate weight. Including alternative designs in the fleet configuration requires consideration of development, testing, and certification costs in the life cycle estimate.

ANALYTICAL APPROACH

Initial attempts at computing life cycle costs were made using a LOTUS 1-2-3 spreadsheet. A difficulty with this approach is that simplifying assumptions must be made regarding cycle times for various activities. Oversimplification of assumptions may prove to be detrimental to the accuracy of the life cycle costs. To explicitly model the WIPP transportation system, including a more realistic representation of the cycle times, a FORTRAN-based simulation program, TRUSIM, was developed. This problem specific program proved to be too inflexible, and rapidly changing operating parameters could be incorporated only with great difficulty. To overcome these limitations, it was decided to use a commercial, general purpose simulation program, SIMAN, a personal computer (PC) based simulation language. SIMAN was chosen for the following reasons:

1. The program provides the required flexibility,
2. Programming support and consulting services were readily available, and
3. The language had been previously used to model the WIPP waste handling process, so there was familiarity with the language.

Simulation offers numerous advantages in modeling a system like the WIPP transportation system. Some of the significant benefits include:

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- Components of the transportation system can be tested before committing to acquisition or implementation of the resources,
- Bottlenecks can be identified in the system, and operations adjusted to prevent their occurrence,
- Operating procedures or policies can be explored without disrupting ongoing operations,
- Variables that are critical to performance can be identified and the interaction of these variables can be explored,
- "What if" questions or situations of which we have limited knowledge and experience can be explored.

Although these benefits are significant, simulation (as with any modeling technique) must be used with care. Some limitations that should be considered include:

- Simulation analysis can be time consuming and expensive,
- Results can be difficult to interpret.

THE SIMAN MODEL

The SIMAN model incorporates the components of the transportation and delivery system, including the WIPP and generator sites, trailers, TRUPACT-IIs, equipment breakdown, transshipment, and the interstate highway system. The model is designed to account for the constraints each of these components place on the throughput of material. The model is driven by the waste generation rates and waste inventory at each site. Waste is defined by waste container type and weight category. The waste data is derived from the "Integrated Data Base for 1991: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics" (IDB). The IDB is an annual compilation of current data on inventories and characteristics of commercial and government-owned radioactive waste, and current projections of future waste and spent fuel to be generated.

The data from the IDB is utilized for the four data files that are required to execute the simulation model. Each file is updated during the model's execution. The data files are:

1. STOREINV.DAT - This data file stores the initial inventories for each generator site. There are two classifications of stored inventory for each site, stored 7-packs (seven 55-gallon drums), and stored SWBs (Standard Waste Boxes). Each category has weight classifications required for loading TRUPACT-IIs. The inventories listed in this file will decrease at the rate specified in the WSTRATE.DAT file and the TOSHIP.DAT file will be updated accordingly.
2. NEWGEN.DAT - This data file stores the projected newly generated waste for each site. The inventories listed in this file will decrease at the rate specified in the WSTRATE.DAT file and the TOSHIP.DAT file will be updated accordingly.
3. WSTRATE.DAT - This data file defines the rate at which the stored and newly generated waste packages are produced. This file removes the inventories from the STOREINV.DAT and NEWGEN.DAT files and updates the TOSHIP.DAT file.
4. TOSHIP.DAT - This file contains the inventories of packages which are ready to be shipped to the WIPP facility or to another generator/storage site (transshipment).

The inventories in the data files above can be manipulated for any increase or decrease of the inventories, and any changes in weight categories in the waste. This flexibility is very beneficial because waste processing alternatives (i.e., waste compaction, incineration and grouting, etc.) are considered during the life of the WIPP. For example, waste compaction would increase the weight of the waste packages, but decrease the number of total packages. These changes can be easily incorporated in the model.

The parameters of the model can also be changed from the users menus. These short-term changes include fleet size, trailer configurations, TRUPACT-II configurations, site operations (shifts), site loading equipment, site shipping priorities, trailer bays per site, and maximum trailer operations per sites.

For any given simulation run, several output reports are generated to assist the user in analysis of the run. These collections of SIMAN statistics have been embedded within the transportation model. The user may access these statistics at any time during the simulation run through the use of the debugger. The final report at the end of the run is also available. These reports have been carefully streamlined to provide only essential data of the simulation run. Overabundance of statistical data may confuse the user. The statistical data available include trailer load efficiency, trailer turns per week, arrival rate at the WIPP, bay utilization (by site), trailers waiting at the WIPP, shipments per year (by site), and packages removed per year (by site). The trailers are further analyzed by tracking their failure rates, empty moving/not moving rates, and full moving/not moving rates.

PRIMARY PURPOSE

The primary purpose of the transportation model is to determine the operational requirements of WIPP and the generator site to transport and emplace the stored and newly generated wastes within the design life of the WIPP. These operational requirements include the TRUPACT-II fleet size, number of shifts, loading and unloading time, and number of docks. Proper configuration of these parameters will minimize the total, or life cycle cost of operating and maintaining the transportation and delivery system.

ESTABLISHING A BENCHMARK MODEL

The first step in the analysis is to create a benchmark model that can meet the criteria established for the transportation system. The mission of WIPP is to end the interim storage of TRU waste generated after 1970. The benchmark simulation assumes that there are no alternate TRUPACT-II designs, that each trailer will carry three TRUPACT-IIs, and that the loading and unloading times are non-constraining. The average vehicle speed used is 30 m.p.h. (includes inspections and stops). The distance traveled between sites and the WIPP is fixed (maximum use of the interstate highway system). These values will not be altered for the purpose of this study. The schedule of each of the sites is set to the current operating standards.

The remaining major variables are the schedule of waste generation and the current inventory of waste. This schedule is defined by site, waste container type, and package weight. For the purposes of this study, this schedule will be accepted as an accurate representation of the waste packages for the life of the simulation. The primary goal of the benchmark simulation is to determine if the waste inventories can be transported to the WIPP and to establish the maximum fleet size required to facilitate the movement.

After the initial parameters are set, the simulation model is run to determine the output statistics for analysis. A simulation run of this type requires multiple replications to accurately compute a confidence interval on the key parameters being studied. Ten replications will be used for this case, each with different random number seeds, to produce ten independent runs with the same initial parameters. The random number seeds will affect the starting point for the random number generators, and will therefore create independent simulation runs using the same schedule. From these ten observations, a confidence interval can be calculated on the mean number of trailers required.

The second phase of analysis is to determine the groups of variables to which the simulation is most sensitive. The method of analysis will remain the same. A series of replications of a given model and parameters will be run. The results will be measured against the benchmark case, and amongst the alternate cases. This series of alternative groups will begin to provide insight to the variables that provide the greatest benefit to throughput.

It is important to consider that a simulation with a large number of configuration variables might exceed the boundaries of a comprehensive study. The number of combinations of variables, and variable levels, will produce a design of experiment tables that exceeds the amount of time available to study the simulation. For this reason, any reasonable method to constrain the number of combination of runs will be used to focus on a practical solution.

For example, it is anticipated that the waste generation rates at the generator sites, the unloading time at the WIPP, and the fleet size will be the three important system constraints. Runs with multiple replications will be made while varying only one of these values. The results of these simulation runs will then be compared amongst the other previous runs.

The third phase of analysis is to make simulation runs that include changing multiple input values from the benchmark scenario. Using the results of the runs from the second phase, selected combinations of runs will be made to focus the user on the best set of initial parameters for the simulation. This method will replace the exhaustive design of experiment techniques with a practical method of locating the most pertinent parameters to which the model is sensitive.

CONCLUSION

The DOE is using a simulation model to examine the effect of operation parameters on the ability to transport and process waste at the WIPP. The model has been validated to the current system use, and analysis is under way to examine possible configuration, operating changes, and their long-term effects. The simulation model allows the flexibility to initiate a variety of system changes and study their effect over the 25-year life of the project.

The waste handling process has already been modeled at WIPP, this is the Contact-Handling (CH) model. In the future, joint analysis of these two models is possible by exchanging data between the transportation model and the waste handling model. Trailer arrival rates can be determined from the transportation model and used as input into the waste handling model. This will provide the ability to determine how changes at the generator sites affect the handling of waste at the WIPP facility.