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Running Scenarios Using the Waste Tank Safety and Operations Hanford Site Model

E. J. Stahlman

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Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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Summary

The Waste Tank Safety and Operations Hanford Site Model provides managers the ability to evaluate potential strategies, decisions, and events concerning waste tank safety and operations at Hanford. To simulate a strategy, the user must first clearly articulate the strategy. Once the strategy is identified, scenarios may be developed by first identifying which parameters in the model are related to the strategy, setting the parameters in the model to duplicate the strategy, and then running the simulation. By comparing the results of various simulations, the user will then be able to identify potentially successful strategies. This document provides guidance for users of the model in developing, running, and analyzing results of management scenarios.

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1.0 Introduction

Management of the Waste Tank Safety and Operations (WTS&O) at Hanford is a large and complex task encompassing 177 tanks and having a budget of over $500 million per year. To assist managers in this task, a model based on system dynamics was developed by the Massachusetts Institute of Technology. The model simulates the WTS&O at the Hanford Tank Farms by modeling the planning, control, and flow of work conducted by Managers, Engineers, and Crafts.

The model is described in *Policy Analysis of Hanford Tank Farm Operations with System Dynamics Approach* (Kwak 1995b) and *Management Simulator for Hanford Tank Farm Operations* (Kwak 1995a). This document provides guidance for users of the model in developing, running, and analyzing results of management scenarios. The reader is assumed to have an understanding of the model and its operation. Important parameters and variables in the model are described, and two scenarios are formulated as examples.

2.0 Organizing and Planning Scenarios

The purpose of the WTS&O model is to help managers evaluate potential strategies associated with managing tank operations. This is accomplished through management scenarios that represent particular sets of strategies, decisions, and events that are simulated to predict how the system will behave. The results of the simulations of different scenarios can then be compared to help identify the most promising strategies. Once a set of promising strategies is identified, they may then be further evaluated using other tools and techniques.

There are three primary steps to analyzing scenarios. First, the manager must define the scenario. Next, the model must be configured to represent the strategies, decisions, and events described in the scenario definition. Finally, the model must be simulated and the results analyzed. The range of scenarios that the user may evaluate is defined by the scope of the model. The model is designed to be a comprehensive management analysis tool that addresses high-level workforce, vendor, and material issues within the Central Management, Operations and Management (O&M), Characterization, Safety, and Upgrades sectors. Concepts embodied in the model include the following:

- Budget - Each of the five sectors has a prescribed budget. Changes in budget levels affect the amount of work that can be accomplished.

- Changes - The model addresses both the magnitude and frequency of changes affecting the system. These include both internal and external changes.

- Delays - Delays reflect the duration of certain activities and the impacts on completing scheduled work, including material acquisition, planning work, and compliance work.

- Productivity - Productivity levels affect how much work an employee can accomplish. Separate productivity levels are defined for Managers, Engineers, and Crafts.

- Milestones - Milestones may be enforced or allowed to slip as work backs up.

- Work Factors - Work Factors describe the level of different types of ancillary work required in support of the long-term identified work. These include administrative, unanticipated, planning, task management, sector review, and vendor review. Increasing the levels of these types of work pulls workers away from accomplishing the long-term identified work and will result in either increased budgets or slipped work schedules.

- Quality - Quality levels define the level of acceptable work that employees generate. Separate quality levels are defined for Managers, Engineers, and Crafts.

- Training - The amount of time spent training affects an employees productivity and quality. The user may change the amount of time workers spend training and the effectiveness of training.

- Work Rates - Work Rates define how much work an employee can accomplish in a year.

- Work Levels - Work Levels define the quantity of work that must be completed. The model is initialized with levels of work for each sector. The amount of this work that should be completed each year is dependent on the projected project life time.

By changing the parameters associated with each of these concepts, the user can implement and simulate a wide range of scenarios.

3.0 Changing Parameter Values

Although the model has over 1000 parameters, most scenarios will require changing the values of only a small number of these. (Although Vensim does not differentiate between types of variables, in this document, parameters represent inputs to the model, while variables hold model outputs.) The majority of the useful parameters are available directly through the application environment (see Figures 1 and 2). These parameters include those related to budget level (Budget Factor A), changes (Rate Factor and Magnitude), delays (Material, Vendor, Planning, and Compliance), productivity (Managers, Engineers, and Crafts), and work factors (administrative, unanticipated, planning, task management, sector review, and vendor review).

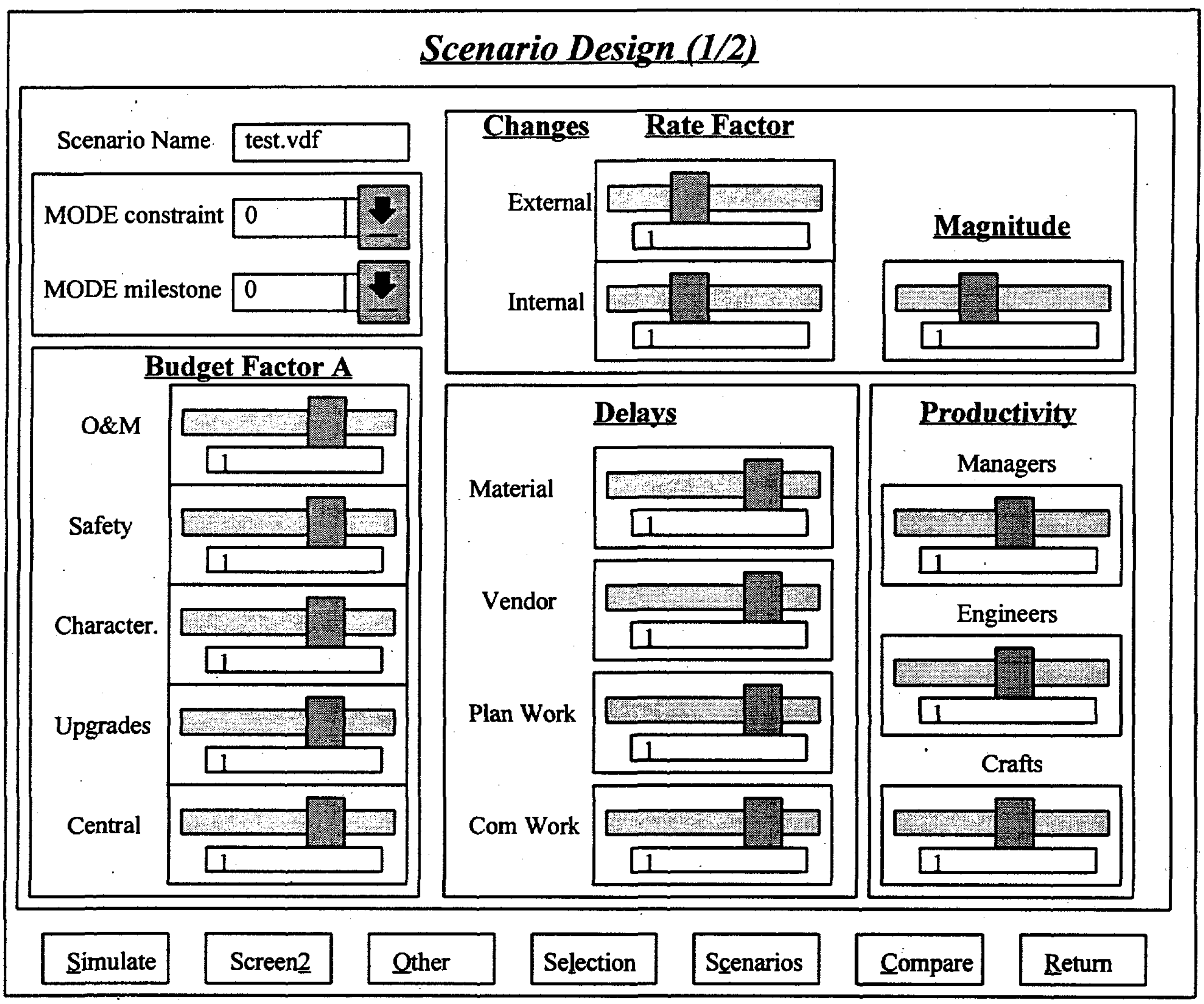


Figure 1. New Scenario Screen (Screen 1)

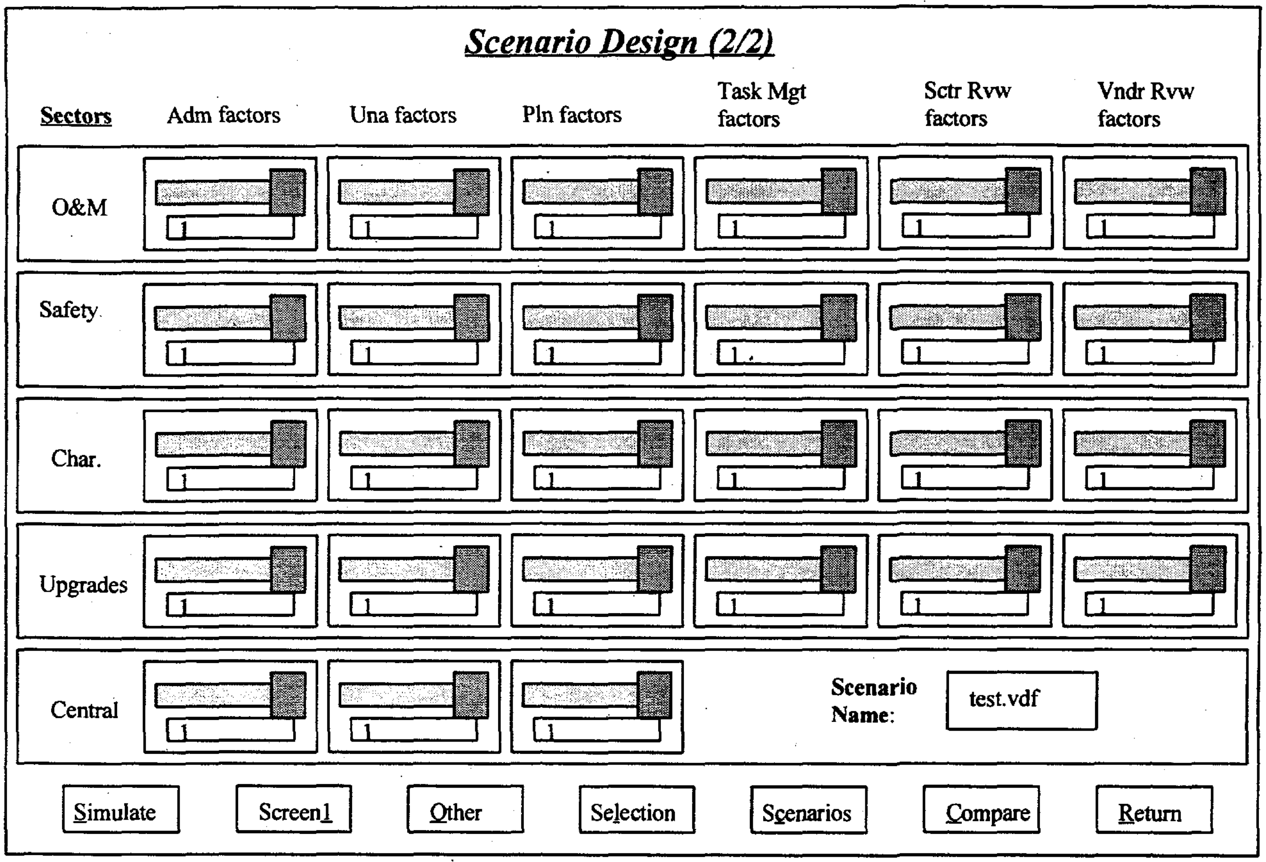


Figure 2. New Scenario Screen (Screen 2)

Access to all of the parameters in the model is available through the "Other" button in the second scenario design screen. Upon selection of this button, a new window appears, listing all of the parameters in the model (see Figure 3). Because of the limited number of characters allowed for parameter names, the names are rather cryptic. For a description of the abbreviations, see Kwak (1995b). Also note that the parameter names used in the model do not map directly to the names in the Vensim simulator front end. For example, the parameter name for the Budget Factor A for the O&M sector is "BDGT fctr A[OM]." The brackets ("[" and "]") following a parameter name indicate the parameter is an array and contain the index into the array. The Parameter Changes window shows that there are five BDGT fctr A parameters with the indexes of OM, S, C, UP, and CM. The indexes correspond to O&M, Safety, Characterization, Upgrades, and Central Management sectors, respectively.

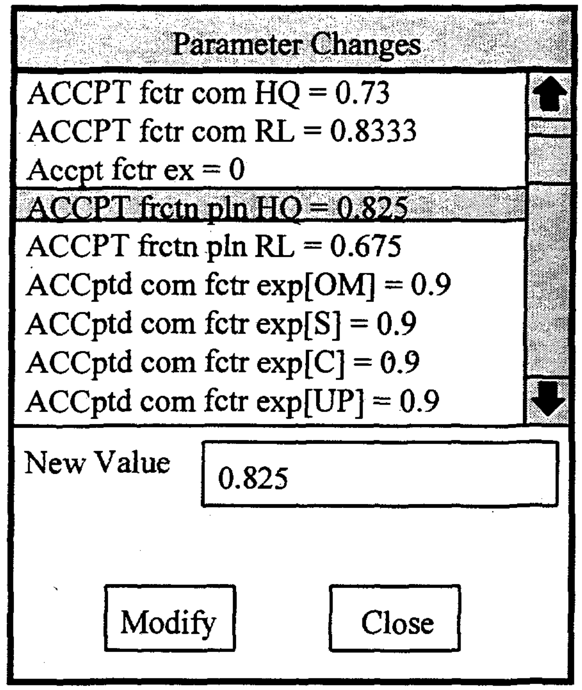


Figure 3. Parameter Changes Window

4.0 Building Scenarios

The model is initialized to represent waste tank safety and operations as they were planned in 1992 with the assumption of a 40-year project life. The start date of the model is set to 1995 because three years have already past, so the simulation is only 37 years long. Running the model with these values constitutes a baseline scenario, to which all other scenarios may be compared. Values may be changed to update the model to reflect changes since 1992, or changes may be made representing hypothetical changes that have not yet occurred. In either case, the important parameters associated with a scenario need to be identified and changed accordingly.

Building a scenario involves five steps:

1. define the scenario
2. identify pertinent parameters
3. determine and assign values of pertinent parameters
4. run the simulation
5. identify important outputs and analyze results.

The first step in evaluating a scenario is to fully describe it. This should be done independent of the model. Once the scenario is understood, it must then be imposed on the model by identifying the relevant parameters and assigning them values corresponding to the scenario definition. For example, a simple scenario is to determine the effect an increase in productivity would have on progress. In this case, the three parameters of interest are the productivity of Managers, Engineers, and Crafts, as shown in the lower right-hand side of Figure 1. The user configures the model by moving the slide bar of each of these parameters to the right until the corresponding value changes to the new productivity (it may be easier to type the values directly into the numeric field). Figure 4 shows the input screen after the parameter values have been changed, as compared with to the default values in Figure 1. The simulation is started by selecting the "Simulate" button.

Once the simulation is complete, the user is presented with a screen showing the progress of one of the model's variables over time (Figure 5). To analyze the scenario, to compare several scenarios, or to see a graph of other model variables, then use the screens accessible through the "Select" or "Analyze" buttons. For example, the "Variable" button in the Analysis screen opens a small window that lists all of the variables in the model. When the variable of interest is selected, the graph of its performance will be displayed. Two output variables commonly of interest are "progress project" and "Cumm Exp Bdgt." The amount of planned work accomplished is tracked by "progress project," while the cumulative budget spent is contained in "Cumm Exp Bdgt." There are copies of each of these variables for each of the four work sectors (O&M, Characterization, Safety, and Upgrades), but no variable contains a sum of the values of these variables. The Central Management sector has no corresponding indexes for these, and other variables because they apply only to the four work sectors and not to Central Management.

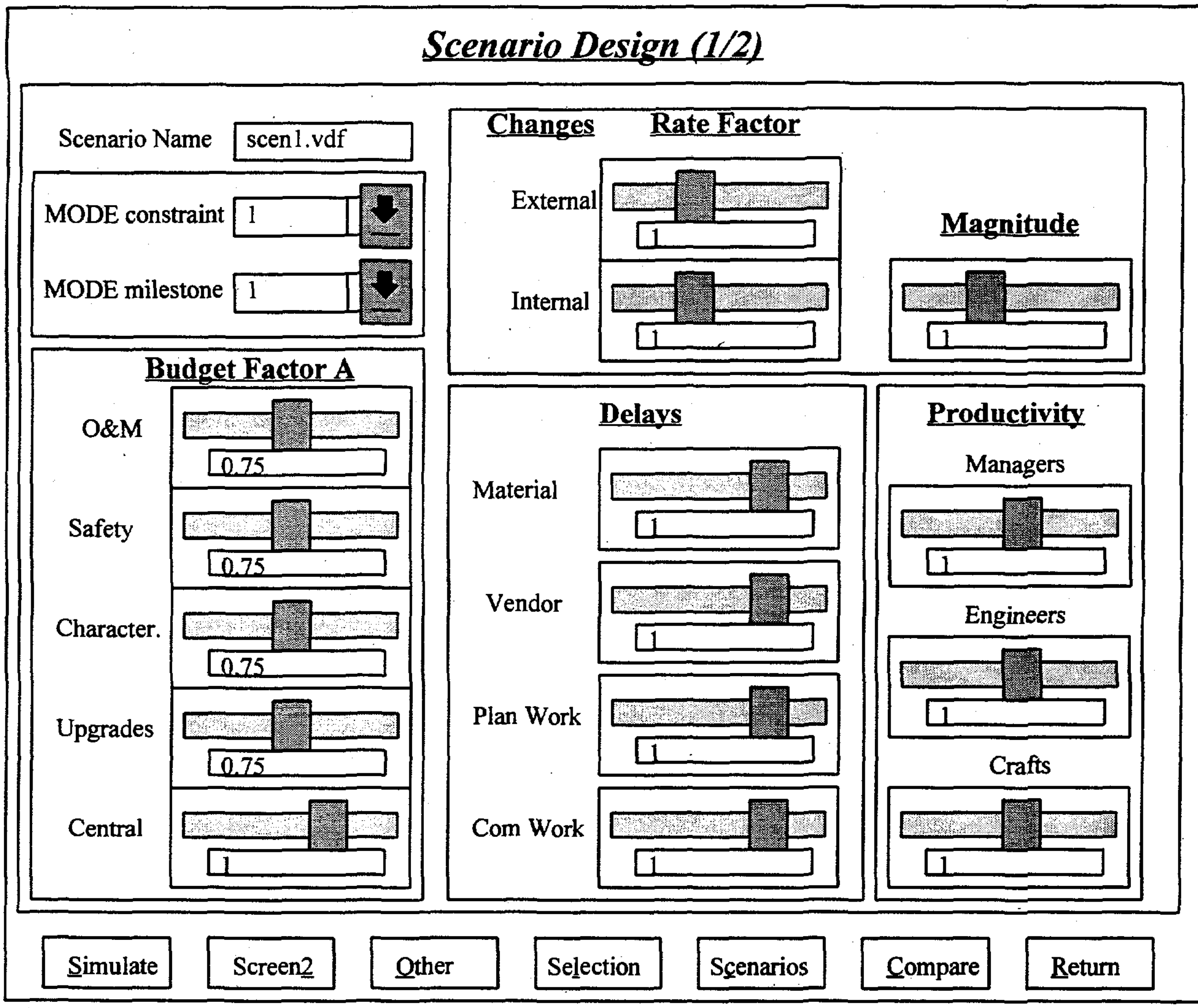


Figure 4. Update Parameter Input Screen

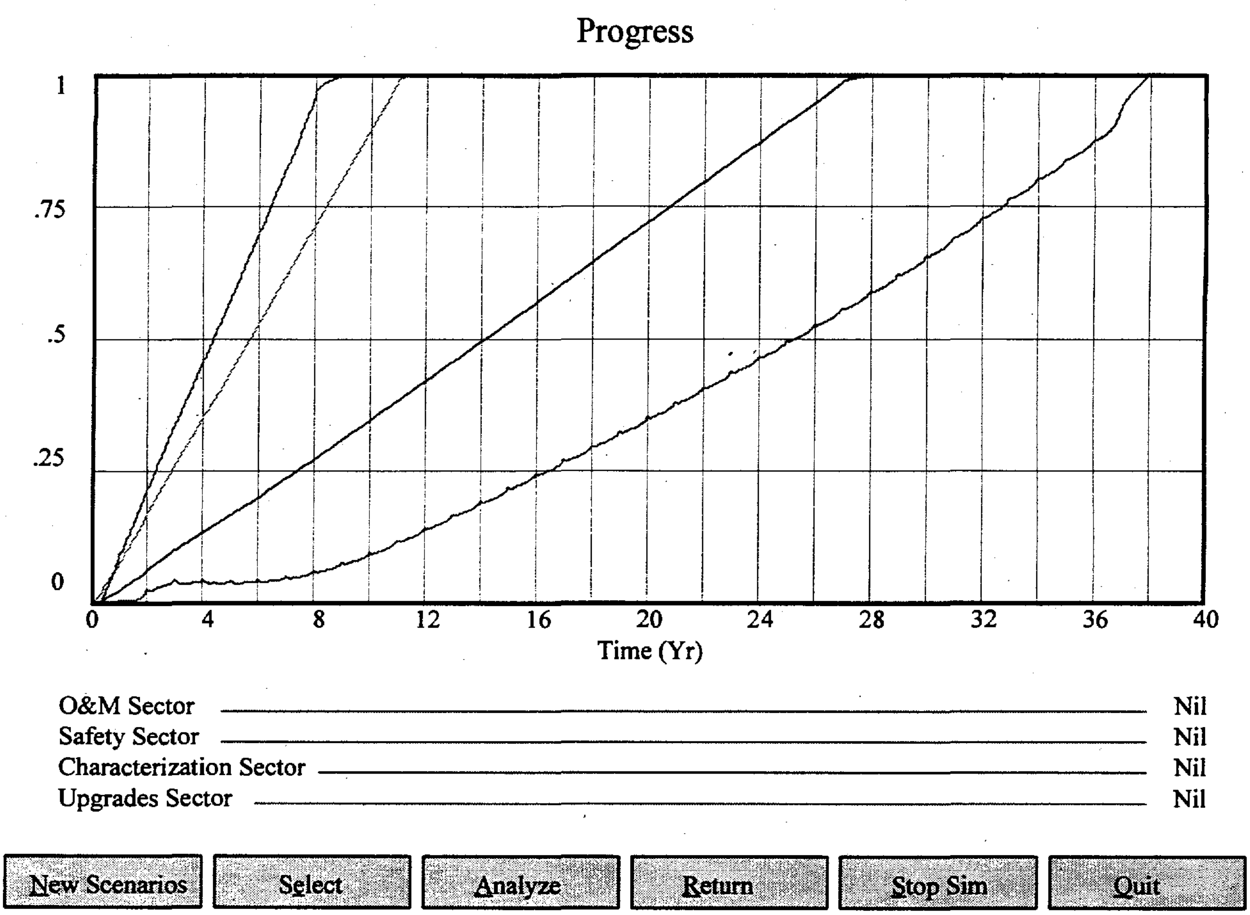


Figure 5. Simulation Run Screen (on the screen, the lines in the figure are differentiated by color)

5.0 Example Scenarios

This section provides two examples of how to build and analyze scenarios. The first scenario compares various budget cutting strategies by modifying the budget factor parameters. The second scenario builds on the first scenario by posing the question of what increases in productivity would be required to offset a budget cut. This type of scenario could be used as the basis of a re-engineering project to establish productivity improvement goals.

5.1 Uniform Versus Distributed Budget Cuts

Hanford has experienced recent budget cuts and anticipates additional cuts. How to apply these cuts is a difficult task. Through the model, however, it is easy to evaluate strategies to determine which ones are promising. Once a set of promising strategies is identified, it may be further evaluated using other tools.

Two budget cutting strategies are to uniformly apply the budget cut across all sectors or to target less critical sectors with heavy budget cuts, while maintaining full funding in critical sectors. To investigate the effects of these strategies, three scenarios are defined. The first scenario provides full funding to all sectors. The second and third scenarios apply a 24% budget cut using two different distributions: applying the budget cut uniformly across all four sectors and cutting 5% from the O&M and Characterization sectors and 42% from the Safety and Upgrades sectors. The Central Management sector is not considered in these scenarios because its budget is relatively small.

As a measure of the model's performance, "progress project" and "Cumm Exp Bdgt" are chosen as output variables to monitor. The variable "progress project" is a measure of the percentage of planned work actually completed. Because the model has a planned 40-year life, "progress project" for all four sectors should be 1.0 by the end of 40 years. The variable "Cumm Exp Bdgt" holds the cumulative budget expended by each sector. Obviously, smaller values of "Cumm Exp Bdgt" are better. Together, these variables provide a good measure of the performance of each scenario. Remember that the simulation will last only 37 years because the model has been calibrated such that 1995 is the fourth year of the 40-year horizon.

Implementing and simulating these scenarios involve five parameters in the main input screen (Figure 1): MODE constraint and the Budget Factor A parameters for the O&M, Safety, Characterization, and Upgrades sectors. When the application is first launched, each of the parameters is initialized to default values. This represents the base case. To simulate the budget cutting scenarios, two changes must be made. First, MODE constraint is set to 1.0 so that changes in Budget Factor A affect the simulation. Second, the values of the four Budget Factor A parameters are set according to the specific scenario. Table 1 shows the three potential scenarios based on three combinations of Budget Factors. The first column lists the variable or parameter name, and the second column lists the specific sector. The last three columns represent the values of the variables and parameters for the three scenarios.

The first scenario shown in Table 1 provides a baseline to compare the other scenarios. The second scenario represents a uniform budget cut of 24% across all sectors. This represents a budget cut of about $316.95 million based on budgets given in Table 2 (based on the parameters WK ini[xsctrs]). The third scenario represents targeted cuts that are approximately equal to the cuts made in the second

Table 1. Budget Cut Scenarios

Parameter/Variable	Sector	Scenario		
		Baseline	2	3
Budget Factor A (Input)	O&M	1.00	0.76	0.95
	Safety	1.00	0.76	0.58
	Characterization	1.00	0.76	0.95
	Upgrades	1.00	0.76	0.58
progress project (Output)	O&M	0.94	0.02	0.63
	Safety	1.00	1.00	1.00
	Characterization	1.00	1.00	1.00
	Upgrades	1.00	1.00	1.00
Cumm Exp Bdgt (Output)	O&M	2,314	1,997	2,251
	Safety	492	514	505
	Characterization	1,372	1,403	1,377
	Upgrades	1,579	1,619	1,577
	Total	5,757	5,533	5,710

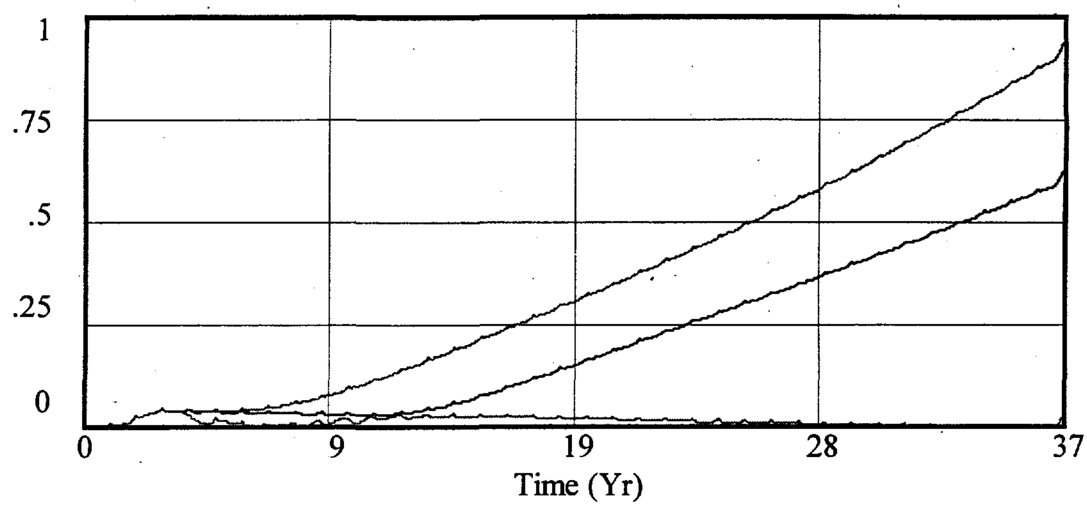
Table 2. Sector Budgets (WK ini[xsctrs])

Sector	Budget (millions $)
O&M	291.02
Safety	227.36
Characterization	345.93
Upgrades	456.33
Total	1,320.64

scenario but are non-uniformly distributed. Thus, potentially less critical sectors bare the burden of the budget cuts, while the critical sectors remain almost fully funded.

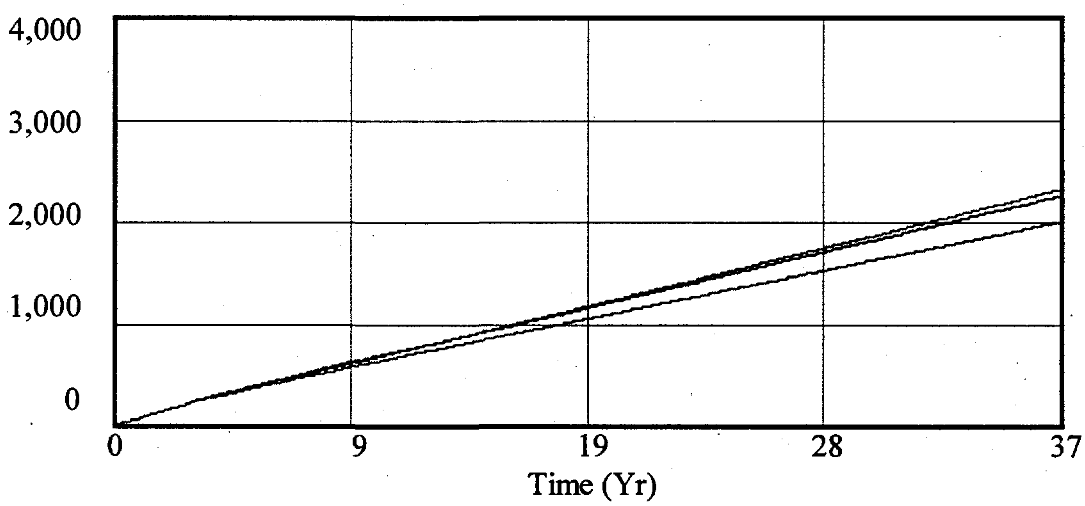
Table 1 indicates that the non-uniform distribution of budget cuts (Scenario 3) is far superior to a uniform budget cut (Scenario 2). All three scenarios expend about the same budget; however, the uniform budget cut scenario only completes about 2% of the work in the O&M sector, while the non-uniform scenario completes about 63% in the O&M sector (see Figures 6 and 7). The other sectors in all three scenarios complete 100% of their planned work. The reason for this is that the O&M sector is more sensitive to budget cuts than the other sectors because this sector has no time to recover from work not completed early in the project before the end of the project (year 37). The other sectors are less sensitive because they are scheduled to complete the work long before year 37, providing them with a cushion for completing their work.

This example illustrates only two budget cutting alternatives. Additional simulations may be run to evaluate other combinations of budget cuts as well as the effects of larger or smaller budget cuts.



progress project[OM] - SCEN1 ———— Nil
progress project[OM] - SCEN2 ———— Nil
progress project[OM] - SCEN3 ———— Nil

Figure 6. Transient Behavior of progress project[OM] (on the screen, the lines in the figure are differentiated by color)



Cumm Exp Bdgt[OM] - SCEN1 ———— M$
Cumm Exp Bdgt[OM] - SCEN2 ———— M$
Cumm Exp Bdgt[OM] - SCEN3 ———— M$

Figure 7. Transient Behavior of Cumm Exp Bdgt[OM] (on the screen, the lines in the figure are differentiated by color)

5.2 Increase Productivity Offsetting Budget Cuts

"Do more work with less resources" is the goal of process improvement projects at Hanford. One of the first steps in a business process re-engineering project is to establish measures of success. The WTS&O model can help establish what these measures should be. In the previous budget-cutting scenarios, each scenario illustrates the effects of budget cuts, given all other factors remain constant. A question may now be: "What improvements in productivity are required to offset the budget cut?"

The specific issue defined in this example is what productivity improvements are required to offset a 5% budget cut in the O&M sector (all other budgets remain constant). The related model parameters are the Budget Factor A for the O&M sector and the Productivity of Managers, Engineers, and Crafts. All of these are found in the opening scenario definition screen given in Figure 1. Table 3 presents the input values for these parameters and the corresponding outputs of the "progress project" and "Cumm Exp Bdgt" variables. The baseline scenario is the same as defined in the previous example. Scenarios 2 through 5 illustrate the effects of the 5% O&M budget decrease with various changes in Productivity for Managers, Engineers, and Crafts (-5%, 0%, +5%, and +10%, respectively). The 5% decrease in productivity is to investigate a worst case scenario in which productivity actually declines after the re-engineering project.

The results of the simulation runs show that a 10% increase in productivity will offset the 5% budget cut, while a 5% increase in productivity will offset most of the negative effects of the budget cut. Figure 8 illustrates the relationship between productivity and progress. The results of the simulation may now be used to set goals for the re-engineering project: the project will result in a 10% improvement in productivity. Notice, however, that this set of simulations does not provide direction in how to accomplish the productivity increase.

Table 3. Re-Engineering Scenarios

Parameter/Variable	Type	Scenario				
		Baseline	2 (-5%)	3 (+0%)	4 (+5%)	5 (10%)
Budget Factor A (Input)	O&M	1.00	0.95	0.95	0.95	0.95
	Safety	1.00	1.00	1.00	1.00	1.00
	Characterization	1.00	1.00	1.00	1.00	1.00
	Upgrades	1.00	1.00	1.00	1.00	1.00
Productivity (Input)	Managers	1.00	0.95	1.00	1.05	1.10
	Engineers	1.00	0.95	1.00	1.05	1.10
	Crafts	1.00	0.95	1.00	1.05	1.10
progress project (Output)	O&M	0.94	0.45	0.62	0.84	0.95
	Safety	1.00	1.00	1.00	1.00	1.00
	Characterization	1.00	1.00	1.00	1.00	1.00
	Upgrades	1.00	1.00	1.00	1.00	1.00
Cum. Exp. Bdgt. (Output)	O&M	2,314	2,305	2,229	2,209	2,173
	Safety	492	534	493	477	469
	Characterization	1,372	1,442	1,372	1,346	1,326
	Upgrades	1,579	1,651	1,581	1,560	1,548
	Total	5,757	5,932	5,675	5,592	5,516

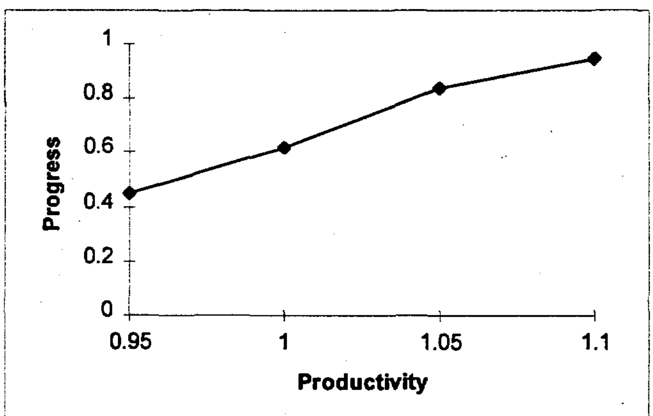


Figure 8. Effect of Productivity on Progress

6.0 References

Kwak, S. 1995a. *Management Simulator for Hanford Tank Farm Operations*, EL95-105 Massachusetts Institute of Technology, Cambridge, Massachusetts.

Kwak, S. 1995b. *Policy Analysis of Hanford Tank Farm Operations with System Dynamics Approach*, Ph.D. Dissertation, Massachusetts Institute of Technology, Cambridge, Massachusetts.

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