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SIMULATING ONE DIMENSION OF SAFETY AND OPERATIONAL EFFICIENCY AT A NUCLEAR POWER PLANT

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ABSTRACT

The authors simulate a safety subsystem at an operating nuclear power plant. Analysis is performed on simulation runs of the working model, along with reasonable modifications to the current subsystem. The results are then used to make suggestions to improve operations.

1 INTRODUCTION

This paper is concerned with using simulation to understand one dimension of safety and operational efficiency at the Indian Point 3 nuclear power plant (usually abbreviated IP 3) in Buchanan, NY. The work control system under study uses the "problem identification document" (abbreviated "PID") process. We use simulation to understand the current process, as well as to study certain feasible modifications to this process that might cause an improvement in system performance.

Indian Point 3 is one of two nuclear power plants located at Buchanan, NY, about 50 miles north of New York City. Indian Point 2 is operated by the Consolidated Edison Company of New York; Indian Point 3 (abbreviated IP 3) is operated by the New York Power Authority. This study is restricted to operations at the IP 3 plant.

Operational efficiency, and especially safety, are extremely important at a nuclear power plant, and there are many processes that come under that heading. At the IP 3 plant, the work control system is used to support those goals. Apparently, this system was not studied by any simulation technique prior to coming on line, over one year ago at this time.

2 THE BASE MODEL

The work control system is initiated by a problem identification document (PID). Any worker at the facility can issue a PID, if they notice what they believe is a situation that is potentially dangerous or can be improved. Once initiated, the PID is forwarded to the operations department for review. Here, trained, licensed personnel perform a safety significance review of the problem.

The next phase in the process requires operations to send the PID to the work control center. At this point, planners check the PID for duplicates, look at the priority, assign the PID to the appropriate department for resolution and await feedback on scheduling the work activity. The feedback is provided by the installation department.

PIDs having certain importance (such as something that needs immediate attention) are given precedence over all other PIDs. These are designated high priority or "A" priority PIDs, and are expedited through the system. PIDs of lower priority are "bumped" from service if a high priority PID requests service.

Both operations and work control personnel that are assigned to PIDs work 8 hours a day. Currently, there is one operations person available per day, who operates effectively as a single server. There are two work control personnel available, who perform as parallel single (identical multiple) servers. Figure 1 below summarizes the process.

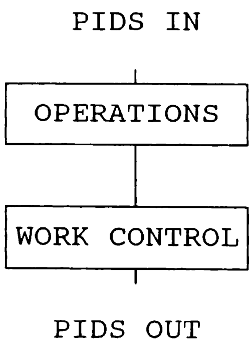

Figure 1: PID Flow

3 SIMULATION MODEL SPECIFICS

The purpose of this study is to model the process as PIDs move through the system, to understand efficiencies and inefficiencies in the system, and, ultimately, to see if it is possible to "significantly" improve PID throughput (improve the time it takes for PIDs, both low and high priority, to move through the system).

Given the importance of this system, the model is fairly uncomplicated. A direct representation of the base model described above was created using the GPSS/H language (See Schriber (1990), Wolverine (1989)).

Operations review was modelled as a single-server. This service is available 8 hours a day, and was modelled as such in the base model. A small percentage of the PIDs were rejected by operations review for various reasons. These "rejects" were not forwarded to the next stage of the system, and left the system.

The remainder of the original PIDs were analyzed by work control. There are two workers in this unit, also available 8 hours a day. They were modelled as identical parallel servers in the base model. Once the PIDs had been analyzed by work control, they were assigned to another group and effectively left the system we are studying.

To provide consistency, the time frame of the simulation was chosen to be a seven-day Monday to Sunday period. Since the plant operates 24 hours a day, PIDs can arrive at any time during that period. It is clear that the work accumulates, causing a large amount of unprocessed PIDs to be awaiting staff in the morning. In attempting to improve PID throughput, we modified the base model to better deal with this situation.

4 SELECTING THE INPUT PARAMETERS

We were indirectly supplied with interarrival time and service time data from the operating history of IP 3. The data described approximately one year's operation of the plant. The descriptive summary statistics are accurate over that time period. The time series of interarrival times for the PIDs appeared to be stationary over time. The remainder of the selection process was mainly heuristic. The selection of the input distributions was aided by the Chi-square test, in the sense that the distribution was selected that appeared "best" in that test. Other "heuristics" were also used to confirm the distribution selection.

Approximately 10% of the PIDs were priority "A", which preempted normal PIDs. We used the exponential distribution to model interarrival time, with a mean of μ = .7 hours (42 minutes). The operations review was modelled as a single-server with normally distributed service time, having parameters μ = .167 hours (10 minutes) and σ = .028 hours (1.67 minutes). Approximately 2% of the PIDs were rejected by operations review for various reasons. Work control service time was modelled as a normal distribution with parameters μ = .333 hours (20 minutes) and σ = .055 hours (3.33 minutes).

Fifty independent replications of the base model (described above) were run, using the GPSS/H simulation language, to generate meaningful statistics.

5 ANALYSIS AND DISCUSSION OF THE RESULTS

The goal of this system is to provide adequate safety at minimal cost. Since we don't have access to economic data, we will not attempt a cost-benefit analysis. For brevity and clarity, we will only report on some of the important output measures, especially PID throughput.

Important output random variables of this system include the total time a PID spends in the system, and the total time a priority "A" PID spends in the system. A simulation was run with the parameters listed above, and the output variables successfully approximated what is known about the system ("face validation"), in the opinion of a staff person (Madu and Kuei, (1993); Personal communication, (1993)). The results are listed in the Table 1 and Table 2 below, as part of model 1, or the "basic model". We also perturbed the basic model to see what improvements could be made to the output variables. In model 2, we increased the basic model's hours of operation from 8 hours to 16 hours. In model 3, we added a third server in work control to the basic model. In model 4, we used the basic model but added a second operations review server.

Table 1: Summary Statistics: Utilization

	Model 1	Model 2	Model 3	Model 4
Operations				
Server 1	.713±.011	.366±.006	.700±.014	.412±.008
Server 2*				.297±.028
Work Control				
Server 1	.748±.127	.458±.008	.622±.008	.739±.016
Server 2	.667±.019	.268±.005	.474±.011	.660±.021
Server 3*			.290±.010	

*Does not appear in all models

Table 2: Summary Statistics: Time in System

	Model 1	Model 2	Model 3	Model 4
All Pids				
Mean	7.97	2.46	7.77	7.64
95% Confidence	(7.80,8.14)	(2.38,2.54)	(7.61,7.93)	(7.51,7.77)
Priority "A" Pids				
Mean	6.11	1.95	5.80	6.30
95% Confidence	(6.11,6.11)	(1.80,2.10)	(5.48,6.12)	(6.03,6.57)

Accuracy beyond two decimal places in model 1

The basic model, model 1, can be used to benchmark resource utilization and PID throughput. Both the operations and work control servers were used approximately 70% of the time. Because of the sixteen hour no-service period, most of the workload occurred at the beginning of the shift, and diminished as the shift approached the eight hour mark. This implies the feasibility of redeploying these servers to other tasks, if necessary, late in the work day. Total PID time in the system averaged just under 8 hours for all PIDs, and just over 6 hours for PIDs with "A" priority; for PIDs that arrived during work hours, this average dropped to just over 2.5 hours. These numbers can be compared with the theoretical expected time of .5 hour or 30 minutes. The 2.5 hour average is high partly because of the queue that formed just before the eight hour shift was about to begin.

Model 2 extended the work day for all servers to 16 hours. As expected, this drastically lessened PID throughput time. All PIDs passed through this averaging about 2.5 hours, and the A priority PIDs averaged about 2 hours. However, utilization of the resources was very low.

Model 3 added a third server to the work control group. The results show that this doesn't drastically improve throughput time because of the bottleneck at the single server in the operations group.

Model 4, suggested by model 3, added a second worker to the operations group. This is less expensive than model 2, and the results show it. The utilization of the two operations servers is very low.

6 CONCLUSIONS AND SUGGESTIONS

The results suggest that current practice may not be the best strategy to manage the movement of PIDs through the system. Of the four models tested, model 2, which extended the work day, gave the best performance (at a high level of significance), but suffered from poor resource utilization. The major performance inhibitor in the base model is the obvious bottleneck in the operations department at the beginning of the work day. This suggests one tactic, assigning a second operations person at the beginning of the day. Another option, unless economic conditions dictate otherwise, is to run the PID system for a longer period of time. An overall strategy would combine the two tactics, given the availability of operations staff. Production runs of the simulation model with various times for the extended work day and second operations person gave descriptive statistics that suggested this would be an "optimum" decision.

The results presented in the table allow the four PID models to be evaluated on the basis of cost, if information on relevant cost parameters become available.

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