Proceedings of the 2002 Winter Simulation Conference
E. Yücesan, C.-H. Chen, J. L. Snowdon, and J. M. Charnes, eds.

SIMULATION ANALYSIS OF THE UNITED STATES MILITARY ACADEMY RECEPTION DAY

Dominik Nogic
Michael Nowatkowski

Dept. of Systems Engineering
United States Military Academy
646 Swift Road
West Point, NY 10997, U.S.A.

ABSTRACT

Each June approximately 1200 new cadets (NCs) are welcomed to the United States Military Academy (USMA) during Reception Day (R-Day). Amid the mass shuffling of bodies and the yelling of the upper-class cadet cadre, all 1200 NCs must completely in process. Changes are made to the in processing system in attempt to make it more efficient. However, the effect of these changes can only be gauged once a year during the following R-Day. In an attempt to expedite the refinement process, the R-Day administrators approached our design team to create a simulation model that could be used to analyze the effect of proposed changes to the system prior to R-Day 2002. Using ProModel® simulation software, our team created a simulation of the in processing system and conducted a statistical analysis of the results in order to recommend improvements to the structure of the system.

1 INTRODUCTION

Every year in June, roughly 1,200 recently graduated high school seniors and prep school students arrive at the United States Military Academy (USMA) to begin their transition from civilians and enlisted soldiers into cadets and future officers. The first hurtle that all new cadets (NCs) must jump is the completion of their first day called Reception Day (R-Day). Historically, in processing occurred in the Arvin Gymnasium complex.

However, in 2000, USMA began a massive renovation of the facility destroying many of the locations used for R-Day in processing. Thus, the Academy was forced to find a new location for NC in processing. Therefore, in the summer of 2000, the class of 2003 became the first West Point class to be in processed in Thayer Hall.

This year marked the second year that Thayer Hall has been used for R-Day. Each year, the process has been refined and streamlined, reducing wait times and making the system more efficient. The system in its entirety consists of twelve separate stations that all NCs must go through. Unfortunately, R-Day only happens once a year; therefore, the planners must wait an entire year to see how proposed changes to the system will affect the average total time that a NC will spend in the system. There has been no way to predict exactly how proposed changes will affect the system. This proved to be a particular problem since Arvin Gymnasium will be under construction until 2008.

With this in mind, R-Day planners approached our research team, requesting that we create a simulation model in order to test the effects that several proposed changes would have on the system. In particular they were interested in the effects of system structure changes to several of the in processing station and also the effects of alternate arrival cycle distributions. Ultimately, the planners wanted to minimize the time it takes an NC to get through the system with a minimum numbers of employees manning the stations. They also expressed a desire to reduce the total time that the system is in operation. Since we would be creating a simulation, we can see in real time, the effect that proposed changes would have on the system.

In order to create this model we used a systematic approach to problem solving that ensured that we produced an accurate and effective model. Through the use of stakeholder analysis we determined the specific objectives of our clients. Using these objectives, it was then possible to use the simulation model to conduct a thorough statistical analysis of the model and the alternatives. Specifically, the use of design of experiment (DOE) and experimental design processes allowed us to see if proposed changes to the base model had a statistically significant effect on the objective values.

Ultimately, the goal of this analysis was to create a tool that would facilitate and aid the decision making process for how to best organize and configure the Thayer Hall system. We feel that through the use of simulation software we were able to accurately gauge the effect that slight changes on the model had on the objective values and were able to recommend to the planners the best way to configure the R-Day Thayer Hall system so that their objectives were met with the utmost resource efficiency.

This report will be broken into two main sections. The first will describe the methodology and technical approach used to create the simulation model. The second part will discuss the technical approach used to analyze the results of our alternatives.

2 R-DAY THAYER HALL SIMULATION AND ANALYSIS METHODOLOGY

In the following sections we describe the process used to create our base case model and the subsequent alternative models and the analysis techniques used to evaluate them.

2.1 Simulation Methodology

Though R-Day actually encompasses four separate locations around West Point, our analysis was focused only on the in processing at Thayer Hall and the effect that changes to the system structure and input distributions will have on the in average processing time for the NCs and the total operation time of the system. Therefore, we determined that we first had to create a base case simulation that modeled the existing Thayer Hall structure. Then, we adapted the base case model to analyze the effects of proposed changes to the system (Figure 1). In general our base model was characterized by locations, entities, and arrival driven by several overarching assumptions.

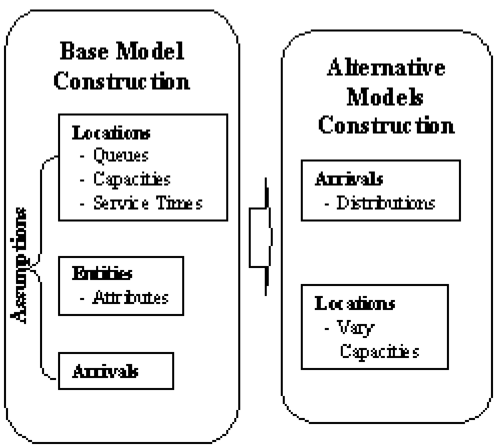

Figure 1: Simulation Methodology

In our base model construction we defined the locations, entities and arrivals into the system. These were modeled using general underlying assumptions. Our alternative models included changes to location capacities and arrival distributions.

In order to analyze the effect of structure and arrival rate changes to the base case model, alternative models construction consisted of altering the sub-components of the locations and the input distributions used for driving the arrival rates into the system.

2.1.1 Base Case Construction

In the following sections we describe the four components of Base Case Construction: locations, entities, arrivals, and assumptions.

2.1.1.1 Locations

NC in processing at Thayer Hall is broken into thirteen independent stations with substations. These are in order:

1. Baggage Drop Off
2. Admissions Department Check In
3. Identification Card Issue
4. Dental Record Drop Off
5. Treasury Registration
6. Basic Items Issue Point
   a. Basic Items Issue Point Scan
7. Changing Room
8. Tattoo Registration
9. Brief For Medical Stations
   a. Pharmacy Prescription Drop Off
   b. Optometry Glasses Pickup
   c. Specific Medical Requirements Check
10. Army Oath Packet Pickup
    a. Administering of Briefing and Oath
11. Immunizations
12. Cadet Company Assignments
13. Cadet Company Holding Areas.

NCs enter the system at the drop off point on the fourth floor were they proceed to, and complete station one. The NC then heads to the third floor were he complete stations two through ten. Stations eleven through 13 are back on the third floor.

Capacities for each of the stations and substations as well as the number of servers was articulated in the problem definition during our stakeholder analysis. Service time distributions for each station was derived using the Geer Mountain Software Corp. Stat::Fit® tool based on service time data collected during R-Day 2001 (reference Table 1. Notes: 1. Basic Items Issue point operates in an assembly line fashion. Thus 50 NCs can enter this station. 2. There are no servers in changing area. 3. Distribution is for single tattoo. 4. NC exit system once they enter company holding area.)

Also in order to add realism to our model we determined queue capacities for each station. This capacity was based on the space available in the hall outside of the station, and the approximate space that each NC would take up while standing in the hall. We also took into account transit from location to location based on data from R-Day 2001.

Table 1: Location Attribute Summary

Location	Capacity	Servers	Service Time Distribution
1	10	10	65.1+W(4.56,116)sec
2	6	6	4.22+ER(10.8,3.59)sec
3	6	6	8+P6(2.38,11.4,39.8)sec
4	2	2	U(20,22)sec
5	4	4	U(1.75,2.25)min
6	50	12	T(8,10,12)min
6a	6	6	.1+W(3.69,24.8)sec
7	32/20	N/A	T(3,5,6)min
8	4	4	T(1,2,3)min
9	20	1	T(7,8,9)min
9a	2	2	T(.33,1.18,2.5)min
9b	4	4	T(1.5,2,2.25)min
9c	8	8	U(7,15)min
10	16	8	U(.25,2)min
10a	100	5	500+G(19.1,20.5)sec
11	6	6	T(2,3,3.5)
12	8	4	T(.42,.83,1.25)
13	Infinite	N/A	N/A

2.1.1.2 Entities

In our model, a single entity is defined as a NC making his way through the entire system. However, for many locations during R-Day in processing the flow of a NC is determined by particular attributes of that NC. Thus, it was necessary to assign NCs the following attributes as they entered the system:

- First letter of last name
- Gender
- Whether or not they are USMA Preparatory School Cadet Candidate (Prepsters)
- Whether they need to see the treasurer
- Whether they have a tattoo(s)
- If they have a prescription medication
- Whether they need to pick up glasses
- Whether they need to see a specialty doctor.

Each of these attributes was assigned at random based on data collected at R-Day 2001 was used throughout the system to direct flow. For example, the line that NCs enter at stations 1, 2, 3 and 10 is based on the first letter of their last name. Gender dictates which changing room the NC enters at station 7. Identifying Prepsters is also necessary because these NCs skip stations 5, 8 and 9b since they have already completed the requirements of these stations while at USMA Prep School. Furthermore, Prepsters are traditionally the first NCs to enter the in processing system so it is important to be able to identify and label these individuals for arrival distribution purposes.

Adding attributes was simply another way that we ensured the base model accurately reflected actual R-Day in processing flow in Thayer Hall.

2.1.1.3 Arrival Distribution

When NCs show up on R-Day, they are given a welcome briefing at a location and are then brought by bus to Thayer Hall. In trying to create a base model that accurately represented Thayer Hall we decided to set up our initial arrival distribution bases on the arrival data at Thayer Hall from R-Day 2001. To do this the time horizon was broken into 15 minute blocks creating the user defined distribution where Prepsters arrive in the first 30 minutes of operation.

2.1.1.4 Assumptions

In order to model the system a few simplifying assumptions had to made.

1. NCs enter the system at the drop off point and do not exit the system until they reach the company holding area.
2. 1200 NCs enter the system continuously.
3. 200 of the NCs are Prepsters.
4. All NCs arrive within a 4.5 hour window.
5. All NCs go to each location in the correct order.

In reality not all cadets will make it through the entire system. Inevitably there are a few NCs who will decide that the academy is not right for them, prior to entering the company holding area. However, these NCs do not make up a significant number.

Also as previously mentioned NCs arrive in the system by the bus load, not continuously. However, since the number of arrivals is defined over 15 minute blocks, we are still inputting the same amount of cadets over a particular 15 minute interval.

Each year there are also a few NCs who arrive into the system for various reasons past the 4.5 hour window. However, the number of these NCs is small and will ultimately end up skewing our analysis.

Finally, our model does not take into account decisions made by personnel that may end up altering the flow of NCs in the system. We do however take into account those attributes which will cause a NC to skip a particular location (see section 2.1.1.2 Entities).

2.1.2 Alternative Models Construction

Based on client interface, we determined two approaches that would be used to alter the model in order to reduce the average NC time in system and to reduce the overall operation time of Thayer Hall in processing. These were to alter the structure of the system by changing location capacities or the number of servers, and to alter the input distributions policy by which the NCs arrived.

2.1.2.1 Locations

During our initial client interface with R-Day planners, several locations where identified for analysis based on the performance of the system during R-Day 2001. Specifically, the tattoo checking station and the optometry stations were causing long delays in the system due to blocking. Therefore, our stakeholders were explicit in their request to analyze the affect of adding servers to these stations. Our clients also expressed an interest in the effect of reducing the number of oath rooms would have on the system.

Based on initial runs of the simulation model consisting of only these two changes, we determined that substantial entity blocking was also occurring at the medical briefing station, the optometry station and the immunization stations. Therefore, we included changes to these stations in our analysis. The current server configuration for these stations is as follows:

- Tattoo Check: 2 servers per room
- Medical Briefing: 1 room
- Optometry Station: 2 servers per room
- Oath Briefing: 5 rooms
- Immunization Station: 6 servers.

In order to alter the capacities of these stations without having to create an entirely different model for each alternative, we made use of macros in the ProModel® processing code. These macros allowed us to select how many servers we wanted each of the five stations in question, prior to running the simulation.

2.1.2.2 Arrivals

Early in the modeling process our clients also expressed an interest in determining the effect that changing the arrival process would have on the objectives values of average time in system and total system operation time.

Since NCs are brought to Thayer Hall from the welcome briefing location by bus, it is possible to control flow into the system over the 4.5 hour window by scheduling the briefings and shuttle buses to follow the desired NC arrival policy. Since NCs are instructed to arrive to the welcome briefing building uniformly, there will always be enough NCs to meet the distribution input distribution requirements. In particular, the R-Day Commander wanted us to test an arrival policy that followed a normal distribution.

The R-Day Commander was also interested to see if the objective times could be reduced by having the Prepsters enter the system after the rest of the NCs have gone through, instead of before, which is the way it has been traditionally done.

We developed five different policies for input distributions spanning the 4.5 hour window to compare to the base case results. These were:

- Triangular: mean = 2.25 h min = 0 h max = 4.5 h (Prepsters arrive over the first hour)
- Triangular: mean = 1.75 h min = 0 h max = 3.5 h (Prepsters arrive over the last hour uniformly)
- Normal: mean = 2.25 h stdev = . 75 h (Prepsters arrive over the first 1.5 hours)
- Uniform: min = 0 max = 4.5
- (Two forms were used, one where Prepsters arrived over the first hour and one where they arrived over the last hour).

Clearly this is a far from exhaustive list of possible input distributions. Our decision to use these five distributions with these particular parameters was based mostly on the desire to see a difference between constant arrival rates, such as those produced by the uniform distribution, and varied arrival rates such as those created by the triangular and normal distributions. Another reason these distributions were chosen is because they would be easy to implement. The simplicity of the distribution's structure would make briefing and shuttle bus scheduling much easier than a distribution with complex structure.

Again in order to for us to alter the arrival rates into the system without creating separate models for each of the five alternative distributions, we created macros within the simulation that allowed us to change arrival rates and the time horizon of Prepsters entering the system.

2.1.3 Model Implementation

The base case simulation process coding took approximately four months. Extensive efforts were made to ensure the accuracy of the design. While some simplifying assumptions had to be made, we felt that they did not drastically effect the validity of the model. Average NC time is system for R-Day 2001 was approximately 120 minutes. Our base case model produced a mean time of 200 minutes. We feel that the assumptions that we made can account for the 40 minute difference. Furthermore, we feel that modifications to the system will have a proportional impact on time no matter what the initial average time is system is.

Before beginning the one month process of alternatives generation, our base model was accredited by our clients who confirmed the validity of our initial results.

2.2 Analysis of Alternatives Methodology

In order to analyze the effects of variations in the alternative models, we realized that two separate approaches would be necessary. For system structure modification effects on the objective values we performed a Design of Experiment, we utilized a 2^{k-1} Half Factorial Design using Minitab® statistical analysis software. To analyze the benefits of alternate arrival distributions we conducted a Two Sample T-Test hypothesis test for difference in means of independent samples (see Figure 2).

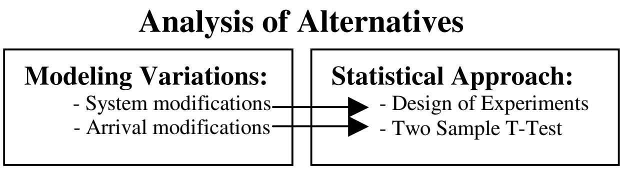

Figure 2: Analysis of Alternatives Methodology

2.2.1 System Structure Modification

Since we were interested primarily in the effects that location modification would have on the average NC time in system, the use of a factorial design seemed logical. Based on our stakeholder analysis, we knew that the following structural changes could be made to the model:

- as many as two servers could be added in each tattoo registration station
- as many as three additional medical briefing rooms could be added
- as many as four additional immunization stations could be added
- one oath room could be added
- as many as two servers could be added to each optometry stations.

Thus our low level for each factor was defined as the number of servers in the original configuration and our high factor levels were defined as the maximum allowable additions.

While a factorial design was appropriate for our analysis, the prospects of conducting a full 2^5 design seemed cumbersome for our level of analysis. Since we were testing six distinct arrival distributions we realized that a separate factorial design would have to be made for each distribution. Using a full factorial design, 32 scenarios would have to be created for each distribution in order find the average time in system for all possible combinations of low and high factor levels. Therefore, a total of 192 individual scenarios would have to be created in ProModel® using the macros.

Clearly, inputting this many scenarios was not efficient. By utilizing an design generator of $E = ABCD$, were A through E represent our five factor variables (see Table 2), a 2^{5-1} design reduced the number of required scenario generations to 16, totaling 96 scenarios for all six distributions. This approach proved much more manageable.

One shortcoming of using a fractional design however, is that information provided by the design about higher order interactions between factors is limited. In a resolution V design such as a 2^{5-1}, the defining relation $I = ABCDE$ is used to derive the alias structure for the design and the required factor level scenarios (see Table 2). A through E are our factors where: A = Tattoo Registration Servers, B = Medical Briefing Rooms, C = Immunization Stations, D = Oath Rooms and E = Optometry Servers. The table on the left shows the required scenarios based on the alias structure. On the right we see the associated values for the factors. Notice that the level of E is based on the design generator $E = ABCD$.

In this type of design, no main effect or two-factor interaction is aliased with any other main effect or two-factor interaction. However, two-factor interactions are aliased with three-factor interactions. The implication of this is that we were only able to gather good information about the main effects of the factors and the first order interactions (Montgomery et al. 1998, p. 383). For our analysis however, we were primarily concerned with main effects of the factors. Furthermore, in most cases, the higher order interaction effects are not usually significant to the response variable.

Table 2: 2^{5-1} Factorial Design Required Scenario Table

	A	B	C	D	E
1	-	-	-	-	+
2	+	-	-	-	-
3	-	+	-	-	-
4	+	+	-	-	+
5	-	-	+	-	-
6	+	-	+	-	+
7	-	+	+	-	+
8	+	+	+	-	-
9	-	-	-	+	-
10	+	-	-	+	+
11	-	+	-	+	+
12	+	+	-	+	-
13	-	-	+	+	+
14	+	-	+	+	-
15	-	+	+	+	-
16	+	+	+	+	+

	A	B	C	D	E
1	2	1	6	4	6
2	4	1	6	4	4
3	2	4	6	4	4
4	4	4	6	4	6
5	2	1	10	4	4
6	4	1	10	4	6
7	2	4	10	4	6
8	4	4	10	4	4
9	2	1	6	5	4
10	4	1	6	5	6
11	2	4	6	5	6
12	4	4	6	5	4
13	2	1	10	5	6
14	4	1	10	5	4
15	2	4	10	5	4
16	4	4	10	5	6

With our methodology established, we then ran the 16 required scenarios for each of the six arrival distributions in order to determine the average NC time in system. By conducting a regression analysis and an analysis of variance (ANOVA) for the results of the base case distribution, we were able to determine which main effects and two-factor interactions were significant to the objective value.

2.2.2 Arrival Distribution Modification

In order to compare the effects of alternate arrival policy distributions on the average time in system we determined that a hypothesis test for the difference in means was appropriate. Since each distribution was simulated under 16 configurations we had to establish criteria for which means to compare. We concluded that if a certain configuration yielded the lowest average time in system for all six input distributions, a pair wise comparison of these values would allow us to determine which distribution was most effective.

The decision to use a two sample t-test was made because each of the six simulation models used independent random number generators. As a result, the variance of each model was different, ruling out the use of a paired t-test.

2.2.2.1 Required Sample Size

To determine the number of replications of each of the six distributions needed in order to achieve a desired 95% confidence, we made use of equation 1, where *n* is the required sample size and *w* is the desired width of our value for average NC time in system.

$$n = 2\left(z_{\alpha/2} \cdot \frac{\sigma}{w} \right) \tag{1}$$

For a desired confidence of 95% we used a *z*-value of 1.96 and our desired width for mean time is system was +/- 1 minute. The standard deviation for each model was determined by running 20 replications sample for each distribution in its base case configuration.

2.2.2.2 Two Sample t-Test

Once the required sample size for each arrival distribution model was determined, and the mean and standard deviation of each scenario was calculated we conducted a pair wise two sample t-test of means between the distributions for the scenario yielding the least average time in system. If our confidence interval (equation (2)), contained zero, we failed to reject our null hypothesis that the means of the two distribution models in comparison were significantly different.

$$(\bar{x}_1 - \bar{x}_2) - hw \le \mu_1 - \mu_2 \le (\bar{x}_1 - \bar{x}_2) + hw . \tag{2}$$

In other words, an interval containing zero implied that there was so significant effect of changing the arrival distribution.

In our confidence interval equation, half width (*hw*) was defined as:

$$hw = t_{df,\alpha/2} \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} \tag{3}$$

and the degrees of freedom for the t statistic was found using equation (4) below.

$$df = \frac{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2} \right)^2}{\frac{\left(s_1^2/n_1\right)^2}{n_1 - 1} + \frac{\left(s_2^2/n_2\right)^2}{n_2 - 1}} . \tag{4}$$

We first compared each of the alternative distributions to the base case distribution to determine which alternatives produced a significantly reduction in mean wait time. Those distributions that did result in a lower mean were then compared pair wise to each other to determine which distribution yielded the lowest NC time in system.

3 RESULTS

The following sections summarize the results of our analysis of factor effects and arrival distribution variation.

3.1 Design of Experiment Results

Based on our required sample size for each distribution, we ran the appropriate number of simulation replications for each of the factor combination scenarios. We then placed the average NC time in system for the scenarios into the factorial design in order to determine the main effects and two-factor effects for each of the locations. Based residuals calculated by regression and ANOVA, we determined that the following main effect factors and two-factor interactions significantly impacted the mean time in system:

- A: tattoo registration servers
- B: medical briefing rooms
- C: immunization stations
- A*C: interaction between tattoo station and immunization station
- B*C: interaction between medical station and immunization station
- A*B: interaction between tattoo and medical stations.

A graphical representation of this analysis can be seen in the normal probability plot of effects of the base case distribution (Figure 3).

As can be seen from the plot, those locations and interactions whose residuals deviate substantially from the standardized normal line are considered outliers and thus have a significant effect on the objective values.

Using Minitab® statistical analysis software, we then were able to conduct a regression analysis of the mean times of the scenarios in order to determine the effect that a

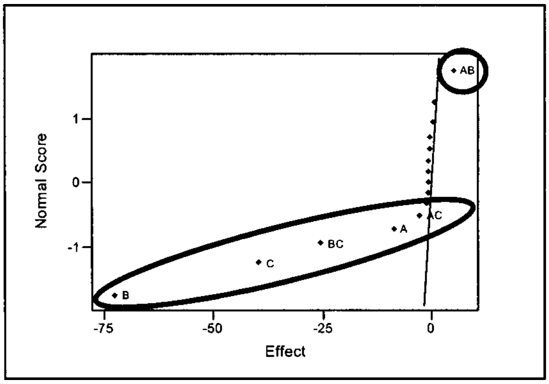

Figure 3: Normal Probability Plot of Main Effects and Two-Factor Interactions

Table 3: Summary of Main Effects and Two-Factor Interaction Effect

	Original Dist	Triangular (Prep Last)	Triangular	Normal	Uniform	Uniform (Prep Last)
A	-8.78	-8.73	-7.84	-6.74	-8.28	-11.85
B	-72.35	-65.7	-75.79	-75.71	-73.74	-54.81
C	-39.54	44.95	-32.96	-30.95	-38.35	-56.82
AC	-2.62	-2.98	-2.1	-1.45	-2.07	-4.06
BC	-25.39	-30.44	-20.44	-19.8	-23.57	-38.43
AB	5.24	4.28	4.89	3.92	5.08	5.76

shift from the low level to the high level of the factor had on the objective value.

As can be seen from Table 3, the shift from one medical briefing station to four medical briefing stations clearly had the most profound effect on the average time in system with a time reduction ranging from 54 to 75 minutes. This was followed by the addition of four immunization stations, the interaction between adding additional medical briefing rooms and immunization stations, the addition of two more servers per tattoo registration room and the interaction between increasing tattoo servers and immunization stations.

It is also interesting to note that the interaction between the tattoo registration station and the medical briefing station actually increases the mean time in system, even though additional servers are being added to both stations. The reason that this occurs is because the increased flow output caused by these two stations which are located back to back in the model, is causing a backlog in pharmacy, optometry and specific medical check stations which follow it. The increased wait time in these queues is enough to cause the average time in system per new cadet to actually increase by as much as five minutes.

Ultimately, the scenario which provided the best objective value for each distribution was scenario 16, which included the high level for each of the five factors. The implication of this alternative is that 13 additional personnel must be used as servers. However, these personnel are all West Point employees who can be shifted to the Thayer Hall system without the incursion of addition labor costs.

3.2 Two Sample t-Testing Results

To determine if changing the arrival distributions had any impact on the objective values, we conducted a pair wise test of difference in means first comparing the alternative distributions against the base case distribution, and then the alternative distributions against each other. A summary of our pair wise comparisons is included in Table 4, where 1= Base Case Distribution, 2= Triangular (Prepsters Last), 3= Triangular, 4= Normal, 5= Uniform, 6= Uniform (Prepsters Last). The top five rows show the comparison to the base distribution while the bottom six show comparisons between the alternative distribution. The lower and upper bounds of the confidence interval are included in the last two columns. Those comparisons with statistically significant decreases in means are highlighted with gray.

Table 4: Summary of T-Test Results

Dist 1	Dist 2	x_1	x_2	x_1-x_2	Lower	Upper
1	2	102.6	100.65	1.95	0.699	3.201
1	3	102.6	101.1	1.5	0.767	2.233
1	4	102.6	101.55	1.05	0.314	1.786
1	5	102.6	101.81	0.79	-0.088	1.668
1	6	102.6	107.1	-4.5	-5.548	-3.452
2	3	100.65	101.1	-0.45	-1.692	0.792
2	4	100.65	101.55	-0.9	-2.144	0.344
2	6	100.65	107.1	-6.45	-7.878	-5.022
3	4	101.1	101.55	-0.45	-1.165	0.265
3	6	101.1	107.1	-6	-7.035	-4.965
4	6	101.55	107.1	-5.55	-6.587	-4.513

As can be seen from the table, the triangular (Prepsters last), triangular, and normal distributions had NC mean times that were significantly less than the base case distribution. However, a comparison between these three distributions found no significant difference. Therefore, we are 95% confident that any of these three input distributions configured with the all high level factor scenario will produce the shortest average NC time in system which is approximately 100 minutes.

While the mean times for these three arrival policy distributions are similar, their total operating times are different. The triangular (Prepsters last) distribution produces a average total system operating time of 7.1 hours, while that of the triangular distribution is 7.6 hours, and a time of 7.9 hours for the normal input distribution. Therefore, using total systems operation time as the final decision tool, we recommended that the arrival policy of a triangular distribution with the Prepsters arriving last be used.

4 FUTURE WORK

While we were able to recommend to our clients a location and arrival policy distribution plan that reduced the average NC time in system, thus meeting our modeling objectives, we are far from complete system optimization. There are certain aspects of our system configuration and arrival distribution analysis that could be considered to make even better recommendations for R-Day 2003.

In our location DOE analysis, our factorial design was only able to give us the effects of going from the low level factors to the high level factors. One thing that we were unable to determine was the effect that adding only a single server to a location would have on the objective values. Using ProModel's® SimRunner software package, we hope to, in future iterations of this design, be able to determine the effect of single server addition by running full ranges of factor levels instead of just the high and low levels.

Another location-oriented consideration for future analysis is to explore the system layout. In our problem definition we were not given the flexibility to change the order in which NCs flowed through the system. Through an in depth layout analysis, it may be possible to better group and balance location service times in order to increase the amount of flow through the system. There are currently some stations in our model with utilization rates as low as 60%. While some of this can be attributed to a lack of NC arrivals into the system, a majority of it is because NCs are blocked waiting in queues at other stations with longer service times. If we can increase these rates throughout the model, we will find that total time in system and total system operation time will decrease dramatically.

In our analysis, we only examined the five arrival distributions whose parameters were rather arbitrarily picked. One future consideration for arrival distribution analysis is to perform a design of experiments for individual parameters for distributions. By refining our parameters, we should be able to impact the objective values more than we are in our current models.

Another consideration is to add a control gate at the system entry point in order to control individual entries into the system. Our current analysis looked at altering the rates at which NC are brought to the Thayer Hall System over the 4.5 hour window. Currently the NCs enter the system as they arrive. By controlling the rates that individual NCs enter the system through distribution analysis, it may be possible to further reduce the average time in system and total operation time.

5 CONCLUSIONS

Through the application of model development and alternatives analysis, we feel that we have given our clients an insight into R-Day planning that they never previously had. Through the use of simulation, we were able to take our stakeholders initial recommendations and tell them immediately the impact that these proposed changes would have on their objective values.

While additional analysis should be considered to further stream line the system, the analysis that we completed far surpasses, both in quantity and in quality, any previous endeavors. Through the use of simulation analysis, what was once blind guess and check decision making, is now highly objective and quantifiable decision analysis.

REFERENCE

Montgomery, Douglas, George Runger and Norma F. Hubele. 1998. *Engineering Statistics*. New York: John Wiley & Sons.

AUTHOR BIOGRAPHIES

DOMINIK NOGIC is a recent graduate from the Department of Systems Engineering at the United States Military Academy, in West Point, New York. He received his BS in June 2002. Following graduation and commissioning into the Ordnance Corps, he will attend the Ordnance Officer Basic Course at Aberdeen Proving Grounds, Maryland. His first duty assignment will be at Ft. Carson, Colorado. His research interests are in simulation modeling, output analysis and production and operations management. His email address is <dom_nogic@yahoo.com>.

MICHAEL NOWATKOWSKI is an Assistant Professor in the Department of Systems Engineering at the United States Military Academy. He received his masters degree in electrical and computer engineering from Georgia Institute of Technology in 2000. His research interests include simulation modeling and analysis. He is an active duty Army Signal Corps officer, holding the rank of major. His e-mail address is <nowatkom@us.army.mil>.