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MBA PROFESSIONAL REPORT

Utility of Computer Model for Detailing

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March 2004

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As the Navy and the DOD focus on technology and training to provide a lean, well-trained and capable military response force, it becomes imperative that the occupational training Navy personnel receive is optimally utilized by placing them in jobs utilizing their training to meet fleet mission requirements. Optimized sailor assignments that meet command requirements would better meet the utility function of the labor supplied to match the labor demanded within the labor market, i.e., the optimal match of sailors and command billet qualities.

This research provides a quantitative analysis to compare the Navy's current detailing process, to a proposed IT matching algorithm process. The purpose is not to summarily prove that an IT program is better than the current human detailing process, but to demonstrate quantitatively, using an IT matching algorithm, that both sailor and command utilities can be better satisfied. Thus, enhancing Sea Warrior in creating a stable labor market where both the needs of sailors' and commands' are met in support of Sea Power 21 and Joint Vision 2020.

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UTILITY OF COMPUTER MODEL FOR DETAILING

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As the Navy and the DOD focus on technology and training to provide a lean, well-trained and capable military response force, it becomes imperative that the occupational training Navy personnel receive is optimally utilized by placing them in jobs utilizing their training to meet fleet mission requirements. Optimized sailor assignments that meet command requirements would better meet the utility function of the labor supplied to match the labor demanded within the labor market, i.e., the optimal match of sailors and command billet qualities.

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LIST OF ACRONYMS

ABC	Activity Based Costing
ADM	Admiral
ANOVA	Analysis of Variance
AS	Aviation Support Equipment Technician
CEC	Continental US East Coast
CGC	Continental US Gulf Coast
CJCS	Chairman of the Joint Chiefs Staff
CNO	Chief of Naval Operations
CNW	Continental US North West
CSW	Continental US South West
CVN	Conventional Nuclear Carrier (Loosely applied – Carrier)
EDPROJ	Enlisted Distribution Projection System
EPMAC	Enlisted Placement Management Center
ETM	Enlisted Transfer Manual
EVAL	Evaluation
IT	Information Technology
JASS	Job Advertising and Selection System
MBA	Masters of Business Administration
MIIS	Monterey Institute of International Students
NAVPERSCOM	Naval Personnel Command
NEC	Naval Enlisted Classification Code
NPS	Naval Postgraduate School
OPL	Outside Continental US
PRD	Projected Rotation Date
SAS	Statistical Analysis System
TUM	Take Up Month

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I. INTRODUCTION

A. OBJECTIVE

In any labor market, be it automotive or US Navy, the objective is to achieve equilibrium between the labor market supply and demand. In the civilian sector this is achieved through wage increases and decreases; unfortunately for the military, wages are fixed regardless of job, causing market equilibrium has to be managed by other means. The Navy's objective is to optimally man command billet requirements with a well-trained and ready force that is "faster, more lethal, and more precise…professional" (CJCS 2) in the face of "reductions in crew size" (ADM Clark 14). To meet the CNO's mission goal requires more than a heuristic "rule of thumb, strategy, method…to improve the efficiency" (Slagle 3) of the Navy's labor market. Currently, detailers apply individualized methods of assigning sailors to command billets in batches that typically average 45 sailors and 60 available command billets. The current system of human detailing allows sailors to maximize their assigned utility through Enlisted Duty Preference Sheets which list their preferences for assignment and through personal contact with the detailer via phone conversations, e-mail or in person. However, not every sailor is satisfied with their assignment, and by the same token not all commands are satisfied with their sailor assignments. This inherent dissatisfaction implies the need for a more effective matching of sailors to available commands.

The objective of this research is not to prove that an IT process is better than human detailing, but to show that an IT process that is currently being utilized to manage the supply and demand of other labor markets, will not only improve sailor's and command's utility overall, it provides detailers with a tool to meet the needs of both the sailor and command optimally and fairly. This creates a stable labor market where both the sailor's and command's utility have been maximized, achieving the Navy's mission to optimally man and utilize sailor training "so that they can contribute their fullest to mission accomplishment" (ADM Clark 15).

B. BACKGROUND

This research continues the research by Suan Jow Tan and Chee Meng Yeong, "Designing Economics Experiments to Demonstrate the Advantages of an Electronic Employment Market in a Large Military Organization." Their research examined using an IT process to enhance the Navy's enlisted detailing process. By utilizing NPS and non-NPS students acting as detailers, this research project will provide a robust, quantitative set of data for analysis to support the presumptions about the effectiveness of IT based detailing. The participants in this experimental sample represent the detailing population, so the actions mimic the benefits of using an IT program; particularly that a stable labor market can be achieved within the Navy, fulfilling the Navy's goal of providing highly qualified and well trained sailors to command billets requiring their expertise.

Before describing the experimental set-up and analyzing the data gathered, an overview of the detailing process will be presented, followed by a summary of how labor markets work. After explaining the experimental design and how the exercises were performed, the data will be analyzed, followed by conclusions and remarks about the research and the results.

II. LABOR MARKETS AND THE DETAILING PROCESS

A. NAVY DETAILING PROCESS

The process of filling command billet vacancies is broken into three elements or areas of management, Allocation Control, Manning Control and Assignment Control, where detailing is just one of the functional elements (Schlegel 5). Allocation Control is managed

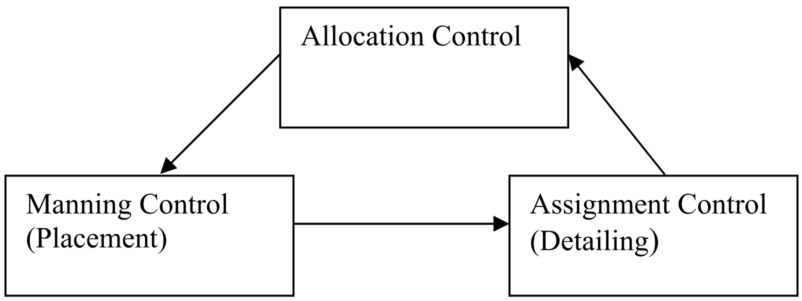

Figure 1. The Distribution Management Control System
From: *An Activity Based Costing Analysis of the Department of the Navy's Enlisted Detailing Process*

by Navy Personnel Command (NAVPERSCOM) and the Enlisted Placement Management Center (EPMAC), whose mission is to ensure that sailors are distributed equitably across all commands, based upon the Enlisted Distribution Projection System (EDPROJ) utilized in the allocation process. Sailor placement is controlled by Manning Control who communicates to the Assignment Control agency command vacancies, the priority of billets/vacancies to be filled first and required training to fulfill those billets. Assignment Control is where all the information is consolidated and the process of 'detailing' begins.

> This process can be stated as matching a Sailor with a job assignment based on the Navy's needs, the Sailor's needs, and the Sailor's preferences. This matching process must consider the skills, experience and seniority of the Sailor with the skills, experience and seniority required for the job. In addition, there can be a multitude of rules,

regulations and policies that govern the eligibility for a Sailor's assignment (7).

B. LABOR MARKET IN THE NAVY

As stated previously, within any labor market an equilibrium or stability point is reached when the labor demanded from a given market matches the availability of labor supplied. In one economics book it is stated that, "The forces of supply and demand will drive a competitive labor market to its equilibrium point – the point where the labor

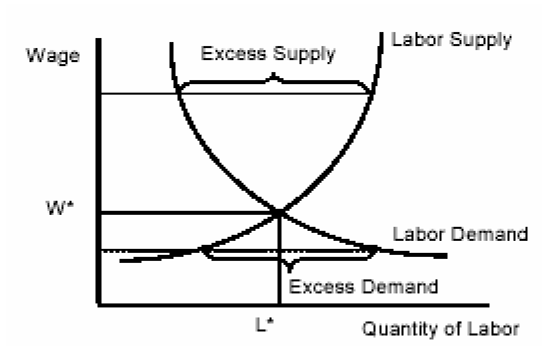

Figure 2. Market-Based Labor Market

supply and labor demand curves intersect" (Lieberman & Hall 241) Within most all labor markets, the major force that acts upon labor supply and labor demand is wages. A disparity between the amount of labor supplied and the amount demanded creates an excess supply or demand, as shown in Figure 2. If wage rates are too high, the supply of labor is greater than the amount demanded. Conversely, if wage rates are too low, the demand for labor is greater than the supply of labor. While labor wages have a major influence on the equilibrium point of the labor supply and demand, there are subtle, yet important "nonmonetary job characteristics" (244) that also influences labor market equilibrium. These aspects can include a job's location, work environment, promote-ability aspects, content or challenge, satisfaction and so on (Gates and Nissen 94). For the Navy, these aspects are how billet requirements are filled, by effectively matching sailors with the necessary skill sets to the prioritized requisitions in such a manner as to best satisfy the individual sailor's duty preference (ETM Section 1306-110 1).

C. INTERPLAY OF NAVY LABOR MARKET AND DETAILNG

Detailers are trained to fill specific billets within the Navy; in an ideal market, available billets with specified requirements or demands are filled by sailors trained specifically for those billets. Unfortunately, between CNO billets and Manning Control Authority (MCA) priorities, command requirements, a sailor's duty preference and numerous policies, the balance between the Right Person and the Right Job is not achieved, thereby creating instability between the labor supplied and the labor demanded. This instability is typically an Excess Demand, where the number of billets is greater than the number of available sailors (Butler and Molina 40).

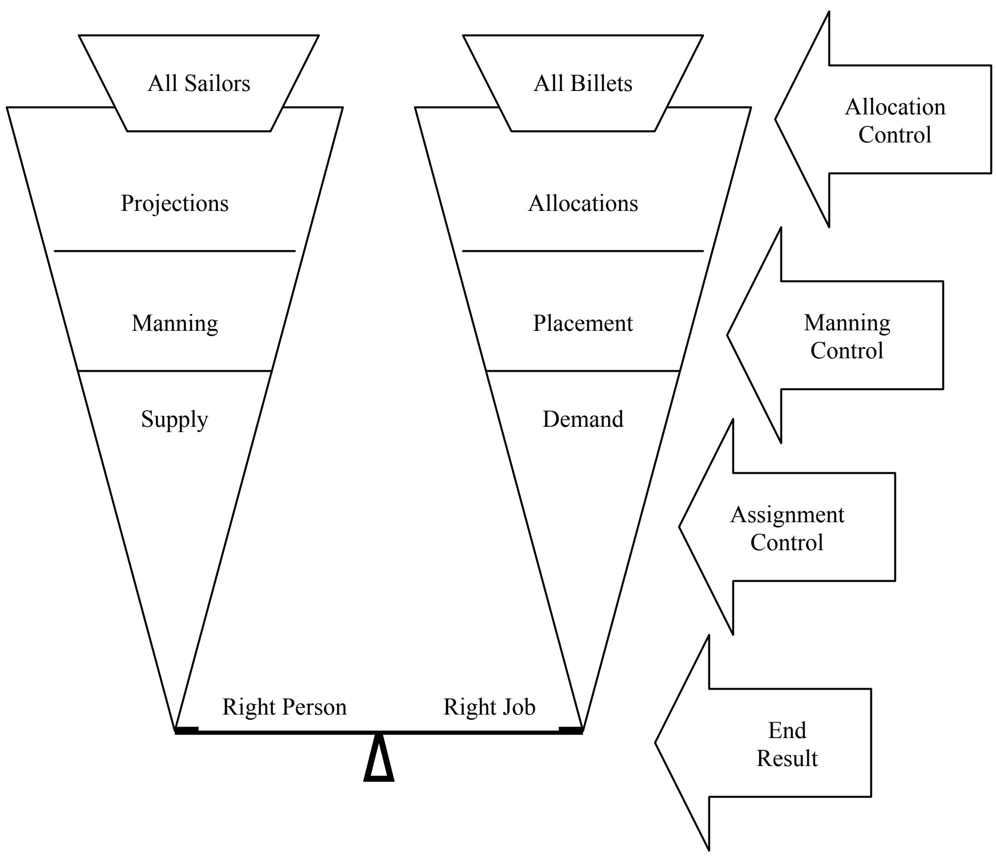

Figure 3. "The Right Person in the Right Job at the Right Time"
From: *Enlisted Distribution Overview Self-Study Guide*

The detailing process is the final link to assigning sailors to billets where all aspects and considerations of each stakeholder, mandate and policy has been addressed and the best possible assignment has been made. As Figure 3 shows, this is a delicate balancing act that is a labor intensive, demanding and daunting task to achieve every two weeks.

III. ECONOMIC EXPERIMENT

A. DESIGN OF THE ECONOMIC EXPERIMENT

The experimental design is based upon data analysis functions within Excel and an IT program to create an optimized solution. Excel is used for its random number generator function to develop a stylized depiction of the AS community based upon an actual representation of the AS community, these representations assign utility values to the sailors and commands, each having individualized characteristics and preferences. A heuristic approach was used in assigning these values. The IT program takes the information generated from Excel, cross references information, and generates an optimal assignment solution of sailors to commands where all assigned pairs are stably matched.

B. ASSIGNING UTILITY VALUES

Utility values are assigned through eight different steps (AS Sailor Summary, AS Billet Summary, AS Sailor Structure, AS Billet Structure, Generate AS Sailor, Generate AS Billet, AS Sailor Preferences and AS Billet Preferences). This process derives utility values for each sailor over every command and each command over every sailor assignment. (Appendix B provides a detailed description for each of the eight processes.)

To create a program that would generate a realistic model to represent the AS community's structure, a base of approximately 45 sailors were identified and categorized by the following constraints: Pay Grade, Projected Rotation Date (PRD), Training/Navy Enlisted Classification Codes (NECs) and past performance evaluations (EVAL). Statistics and distribution patterns of the sailors' characteristics, based upon the sample population, were then used in Excel's random number generator to create a stylized representation of the AS community. This stylized model can generate multiple representations of the AS community that mimic the different sailor and command characteristics occurring during the normal detailing process. A similar process was also utilized to generate the AS command billet structure, based upon the command defined characteristics: Region/Location, NEC requirement, Pay Grade requirement, Platform and Take-Up Month (TUM).

AS sailor and available command billet utility values (AS Sailor Preference, AS Billet Preference) were generated using the following variables for sailors and billets, respectively: Pay Grade, NECs, PRD, EVAL, Preferred Location and Platform (ship type); Pay Grade, NECs, PRD, TUM, EVAL, Platform and Region. Additionally, the characteristics most influential in both sailor and command utility (denoted High 1 and High 2) were identified utilizing the random number generator. This designation assumes that choices are purely random, having no discernable pattern that can be represented.

To generate a utility value for each of the specified variables, a heuristic approach to assigning a value was used. This is demonstrated in the figure below, taken from AS Sailor Preference.

Location Preference

Preferred Location \ BIllet Location	CEC	CGC	CNW	CSW	OPL
CEC	5	4	3	2	1
CGC	4	5	2	3	1
CNW	1	3	5	4	2
CSW	1	3	4	5	2
OPL	2	3	1	4	5

CEC	Continental US - East Coast (e.g., Norfolk)
CGC	Continental US - Gulf Coast (e.g., Jacksonville)
CNW	Continental US - Northwest (e.g., Bremerton)
CSW	Continental US - Southwest (e.g., San Diego)
OPL	Outside Continental US – Pacific/Atlantic (e.g., Japan, Italy)

Table 1. Location Utility Value Assignment

In Table 1, the numbers represent a scalar value to determine a utility, 1 being the lowest and 5 being the highest value. For instance, if a sailor's preferred choice is CSW, we assumed they would prefer CNW (a value of 4) to CGC (a value of 3) to OPL (a value of 2) to CEC (a value of 1), with their preferred choice of location being a 5. The numbers assigned represent a preference of choice to determine a utility given a sailor's request for an assigned billet location. Values were assigned based upon the assumption(s) that sailors would prefer the same coast assignment over the opposite coast or OPL. These preferences are consistent with those stated in the Enlisted Master File for AS sailors.

The same principles were used in assigning values to NECs, platform, Pay Grade, and so forth. The values assigned to NECs within the AS community, which has over 14 different NECs, some being in-rate specific (AS-related) and some non-rate specific. To simplify the design, NECs were categorized into six groups; an additional category was added, Other NEC (for non-rate specific NECs), to reflect this consolidation. In this category, the maximum value that could be generated is a 5, meaning that the sailor's NEC matched the command's requirement. Values from 1-4 meant that the sailor had other in-rate NECs ranging from 1 NEC to 4 NECs. A 0.5 value is in this category implies that the sailor has an NEC outside of their rate.

To define sailor and command preference priorities the terms High 1 and High 2 were utilized. These were randomly generated, as stated above, based upon the assumption there is no discernable pattern in choices of preference by sailors or commands; these two terms represent what the sailor's or command's primary considerations are for assignment, High 1 being their first concern followed by their second concern, High 2.

Once utility values are assigned to each of the sailor and command variables being considered, a batch of sailors and command billets is generated. An overall utility is derived for each potential assignment/pairing that can be made, sailor to command and command to sailor. It is then broken down into two tables, representing each sailor's derived utility for each of the possible command assignments and each command's derived utility for each of the possible sailor assignments. These two tables are then analyzed and regenerated in Rank Order preference representing Sailor Rank Order preferences and Command Rank Order preferences. The Rank Order number/value is then used as a scalar to represent a sailor's/command's utility, where the objective is to make assignments that minimize Rank Order values.

C. AN OPTIMAL SOLUTION

An optimization problem is something in "which we want to minimize or maximize."[1] In this case, the objective is to minimize sailor and command Rank Order values. The objective function is defined by known or unknown variables that affect the objective function's value and constraints. Typically objective functions are multi-objective optimization problems, considering a multitude of different variables. Many optimization problems involve a single objective function. In the case of detailing sailors to available billets, an optimization solution would be to minimize the Rank Order of the total assignment value, the sailor Rank Order preference value plus the command Rank Order preference. This implies trade-offs between the sailor and command variables, where one sailor and/or command may lose value while another sailor/command gains value in the assignment function. These types of solutions are good for investment decisions or determining process time, but in deciding sailor and command assignments it may represent a poor solution.

The IT program generates a Pareto optimal solution. A Pareto optimal solution is a solution where "there is no other outcome that makes every player at least as well off and at least one player strictly better off. That is, a Pareto Optimal outcome cannot be improved upon without hurting at least one player."[2] The IT program does this by taking the sailor and command utilities, after transposing them into sailor and command Rank Order preferences and generating stable matches of assigned pairs; a matching is "stable if it is not blocked by any individual or any pair of agents" (Roth & SotoMayor 3).

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[1] *What is Optimization?* www-fp.mcs.anl.gov/otc/Guide/OptWeb/opt.html
[2] *Pareto Optimal*. www.gametheory.net/Dictionary/ParetoOptimal.html

IV. THE EXPERIMENT

A. EXPERIMENT DESIGN

As stated earlier, this paper was designed to compare and analyze the Navy's detailing process outcome to an IT program in achieving the CNO's goal of optimally manning billets. To do this, two separate exercises were generated and performed. Exercise 1 provided participants with similar information to what the detailer would view and then asked them to detail the sailors to commands, trying to optimize both sailor and command preferences. In Exercise 2, participants were provided the same information that the IT Program uses to generate its outcome. The justification for this exercise is to determine whether detailers that are provided the same information as the IT program could do just as well as the IT solution. Both detailing exercises optimize a batch of 15 sailors available for detailing to a batch of 20 commands. (See Appendix A for the instructions provided to the participants.)

B. EXERCISE 1

Participants were asked to detail 15 sailors to 20 possible command billets, given similar information as details are provided with respect to sailor characteristics and command requirements. The following example, Table 2, is an example from the instructional pages from Exercise 1.

	Grade	Primary NEC	Other NEC	PRD	EVAL	Preferred Platform	Preferred Region
Sailor 1	4	7612	0	3	2	CVN (High 1)	CSW (High 2)
Sailor 2	5 (High 1)	7612	1	2	4	AIMD (High 2)	CGC
Sailor 3	5	7607 (High 2)	2	2	3	LHA/LHD	CSW (High 1)

	Grade	Primary NEC	Take Up Month	EVAL	Platform	Region
Command 1	5	7607	3 (High 1)	(High 2)	CVN	CNW
Command 2	4 (High 2)	7607 (High 1)	3		LHA/LHD	CSW
Command 3	4 (High 1)	7612 (High 2)	3		LHA/LHD	CNW
Command 4	6	7699	1 (High 2)	(High 1)	CVN	CNW

Table 2. Exercise 1 Sailor and Command Assignment Guide

As discussed in the Design of the Economic Experiment, only six sailor and command characteristic categories were utilized. Sailors were defined by five specific characteristics and two sailor choice preferences; commands were defined by six command specific characteristics. There are numerous other defining characteristics that could be included, but the categories that were chosen were found to be the major concerns for sailors being assigned to a command and for commands being assigned a sailor (Butler and Molina 74-81). The rational for limiting sailor and command characteristics will be discussed in the Conclusions section of this paper.

The instructions for this exercise were to assign sailors to commands in a way that maximized the sum of sailor and command Rank Order preferences. The guidelines to assigning sailors to billets were: 1 - Every sailor had to be assigned; 2 – Commands could only be assigned once; 3 – Sailors could not be assigned to commands greater than one(1) Pay Grade up or down from their current Pay Grade. Besides providing the characteristics of the sailors and commands, information was also given about their major or highest priority concerns for assignment, High 1 and High 2. These simply imply, for example, that Sailor 1's highest priority assignment was to be assigned to a carrier (CVN) on the south-west coast (CSW), but it is more important that they be assigned to a carrier over location. Command 1 prefers that the sailor reports on time and has a good EVAL, but it is more important that the sailor reports on time.

C. EXERCISE 2

For Exercise 2, utility values where derived from Excel for every possible sailor to command and command to sailor assignment and transposed into a prioritized Rank Order list for each sailor's command preference and each command's sailor preference. With this information, participants were asked to detail a group of 15 sailors and 20 commands, minimizing the sum of sailor and command Rank Order values. An example of this information, drawn from the instructions for Exercise 2, is shown below. In actuality, the same sailors and commands were used in both experiments, they were just presented differently.

Sailor Preferences over Billets

Rank Order: Command	Sailor 1	Sailor 2	Sailor 3
1	2	1	1
2	3	4	2
3	1	3	4
4	4	2	3

Command Preferences over Sailors

Rank Order: Sailor	Command 1	Command 2	Command 3	Command 4
1	3	3	1	3
2	2	1	2	2
3	1	2	3	1
4				

Table 3. Exercise 2 Sailor and Command Assignment Guide

D. EVALUAITON OF ASSIGNMENTS

For both exercises, participants were evaluated on how well they minimized the total sum of the rank order preferences, as implied by their assignments in Exercise 1 and as directly determined by their assignments in Exercise 2. The lower the score, the better the participants did in their assignments. As an example, utilizing the figures above, if Sailor 1 is assigned their first Rank Order choice (Command 2) this generates a score of 1, for the sailor; Command 2s Rank Order preference for Sailor 1 is 2. Therefore, that assignment has a total score of 3 (2 + 1).

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V. DATA ANALYSIS

A. OVERVIEW

A total of four detailing exercises were performed, creating a data base for analysis of 103 participants/data points. The sizes of the sample groups 1 thru 4 were 37, 13, 42 and 11, respectively. Of these sample groups, 1, 2 and 4 were Naval Postgraduate School (NPS) MBA students; sample group 3 was MBA students from the Monterey Institute of International Students (MIIS). The MIIS students served as a check to see if there is a difference between military and non-military approaches to assigning sailors to commands. After each experimental exercise, the Rank Order values for both the sailor and command were summed, providing a total value for that assignment. Each of these assignment values was then summed to provide a combined utility value for all of the assignments made by each participant. Additionally, sailor and command Rank Order values were separately summed for each participant's assignments to analyze preferences between sailor and command assignments. All of these values; sailor Rank Order value, command Rank Order value and combined Rank Order value were compared to each other and to the IT program.

The overall results of all four detailing experiments yielded similar results. In general, the variance in combined Rank Order values approximately tripled from Exercise 1 to Exercise 2 creating a higher Total Rank Order value, and command preferences appeared to have priority in both exercises when sailor/command assignments were compared. The following sections will briefly describe the four experimental exercises with some statistical information to demonstrate the variances between each of the experiments. This will be followed by analyzing the data as a whole, including justification for compiling the data. For additional statistical information about each of the experimental exercises, see Appendices C, D, E and F.

B. DETAILING EXPERIMENT RESULTS

The statistics in the following figures summarizes the results from Detailing Experiments 1, 3, and 4. In comparing the data from Exercise 1 to Exercise 2, standard deviations approximately tripled and variance in assignment totals increased nearly eight times. In addition, the overall assignment average increased, representing a decline in the overall utility value received by the batch of sailors and commands being detailed. In each of the exercises, except Exercise 2 of Detailing Experiment 4, the commands received a lower Rank Order value on average than the sailors, implying a bias toward command preferences in making assignments. (Remember, the participants' objective as the detailer was to optimize both sailor and command utility by minimizing their Rank Order preference values.)

Detailing Experiment 1

Exercise 1	
Sailor Avg	4.61
Command Avg	4.55
Assignment Avg	4.58
Std Dev	1.048
Variance	1.099

Exercise 2	
Sailor Avg	6.03
Command Avg	5.39
Assignment Avg	5.71
Std Dev	2.717
Variance	7.382

Detailing Experiment 3

Exercise 1	
Sailor Avg	4.33
Command Avg	4.28
Assignment Avg	4.30
Std Dev	1.119
Variance	1.253

Exercise 2	
Sailor Avg	5.74
Command Avg	4.87
Assignment Avg	5.30
Std Dev	2.881
Variance	8.302

Detailing Experiment 4

Experiment 1	
Sailor Avg	4.86
Command Avg	4.34
Assignment Avg	4.60
Std Dev	0.679
Variance	0.461

Experiment 2	
Sailor Avg	3.27
Command Avg	6.27
Assignment Avg	6.65
Std Dev	2.845
Variance	8.092

Table 4. Experiments 1, 3 and 4 Statistical Data

C. DETAILING EXPERIMENT TWO

In the second detailing experiment, as shown in Table 5, average Rank Order values decreased in Exercise 2 compared to Exercise 1, instead of increasing as in the other detailing experiments. Sailors also received a lower or improved Rank Order value than commands in Exercise 2, implying more of a sailor bias in making sailor/command assignments. Another interesting result from this experiment is that the assignment average for Exercise 2 decreased compared to Exercise 1, vice increasing as seen in the other Experiments, and standard deviation remained relatively unchanged.

Detailing Experiment 2

Exercise 1	
Sailor Avg	4.58
Command Avg	4.41
Assignment Avg	4.49
Std Dev	0.848
Variance	0.72

Exercise 2	
Sailor Avg	2.64
Command Avg	3.56
Assignment Avg	3.10
Std Dev	0.8645
Variance	0.7473

Table 5. Experiment 2 Statistical Data

D. ANALYSIS OF THE DETAILING EXPERIMENT DATA

Before consolidating the four detailing experiments into one for analysis, the individual detailing experiments had to be compared to each other for statistical differences. The statistical analysis used SAS to test for differences between the detailing experiments within each exercise, Exercise 1 and Exercise 2. An additional test was performed to test for statistical difference between the different exercises for each experiment and as a whole. A third statistical test was performed to provide information about how the difference in information provided for detailing may affect sailor/command assignments and differences in assignment values.

The hypothesis for these tests was that the means of the four experiments are equal. Statistically, the Null and Alternative Hypothesis were:

$$Ho: \mu_1 = \mu_2 = \mu_3 = \mu_4$$

$$Ha: \mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4$$

In each of the tests performed, a .95 certainty was used, or $\alpha = .05$. For these tests, the object was to show that with the specified certainty level, in this case a certainty of 0.95, that the means (μ) of the groups analyzed are equal or not statistically different.

The first results using SAS were ***t***-tests and Analysis of Variance (ANOVA), testing for statistical differences between the experiment means (μ) of Exercise 1 and 2. To interpret the results of the ***t***-tests, SAS generated Confidence Limits, Confidence Intervals, and then highlighted the paired experiments that were outside of the stipulated Confidence Limits with respect to a .95 certainty. For the ANOVA tests, the probability greater than 'F' (Pr > F) has to be greater than α, (Pr > F) > (α = 05), for the experiment means to be equal with a 0.95 certainty; Fail to Reject the Null Hypothesis. With a value less than $\alpha = .05$, (Pr >F) is less than $\alpha = .05$, implies the means are not equal, Fail to Accept the Null Hypothesis, and the experiment group means are not equal. The latter would imply the need for further analysis and difficulty in combining the experimental data.

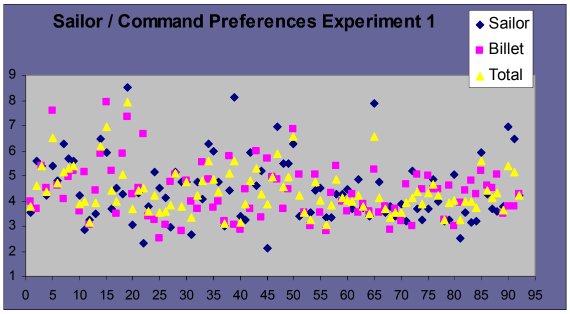
For Exercise 1, the ANOVA test implied a Failure to Reject the Null Hypothesis, [(Pr > F) = 0.1834] > [α = .05], as well as the ***t***-tests results. As for Exercise 2, the ANOVA test implied a Failure to Accept the Null Hypothesis, [(Pr > F) = .0359] < [α = .05]. The ***t***-test produced the same results, but provided greater detail. The ***t***-test generated the same (Pr > F) value, but the Confidence Limits provided information about which paired experiment means did not match. The two strictest test, Bonferroni and Tukey ***t***-tests, highlighted the pairing of experiments 2 and 4 as being outside the Confidence Limits. From this information, a conclusion can be made that Exercise 1 detailing results can be compiled to represent one set of data points, but not Exercise 2 with certainty.

As pointed out in the Detailing Experiment Results, the statistical results from Experiment 2 differed in comparison to the other experiments; standard deviation and variance stayed relatively the same from Exercise 1 to Exercise 2, whereas in Experiments 1, 3 and 4 standard deviations almost tripled and variances increased nearly eight times. To test the assumption that Experiment 2 is possibly causing the rejection of the null hypothesis for Exercise 2, an additional ***t***-test was done using Excel statistical analysis tool. Excel will only analyze the same number of variables between groups when doing a two-by-four ANOVA two-factor with replication test, so eight random participant samples were used from each of the Detailing Experiments. (Eight being the maximum number of valid participant results within each of the experiments.) The results from this ANOVA test were compared to the ANOVA two-factor test done by SAS, both generating approximately the same (Pr > F) values; Excel's value was 0.1234 and SAS's value was 0.1239. A second ANOVA two-factor test was done using Excel without Detailing Experiment 2s data. For this, Excel produced a (Pr >F) = 0.7233.

From the information provided by SAS and Excel, the conclusions made is that the different experiment groups within Exercise 1 and Exercise 2 are representative of each other and can be combined and analyzed as one set of data points. Although combining Detailing Experiment 2, Exercise 2 results with the other three experiment groups is less certain, Experiment 2 was a small group consisting of only 13 detailing participants; 4 of the 13 participants assignment results were invalid/unusable due to sailor/command assignment errors made by the participants. In using the results from Experiment 2, the conclusion is the 9 useable data results will not invalidate Exercise 2 analysis for comparisons to Exercise 1.

E. COMPARING OF EXERCISE 1 AND EXERCISE 2

In analyzing the compiled data, the results mimic Experiments 1, 3 and 4; where standard deviations and variances increased by approximately the same factors, 3 and 8 times respectively from Exercise 1 to Exercise 2, commands received lower Rank Order values than sailors for both exercises, and average assignment value increased from Exercise 1 to Exercise 2. These results can be seen in the following figure and table.



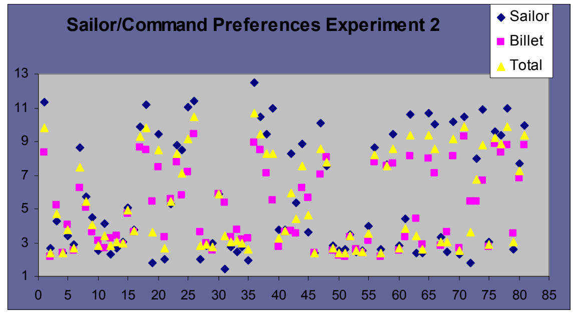


Figure 4. Consolidated Experiment Assignments

Consolidated Experiment Results

Experiment 1	
Sailor Avg	4.44
Command Avg	4.37
Assignment Avg	4.40
Std Dev	0.918
Variance	0.842

Experiment 2	
Sailor Avg	5.75
Command Avg	5.08
Assignment Avg	5.41
Std Dev	2.812
Variance	7.907

Table 6. Consolidated Assignment Statistics

VI. CONCLUSIONS AND REMARKS

A. CONCLUSIONS

The data from this research shows participants made better matches (assignments) with more detailed information about sailor/command assignment preferences (Exercise 1), compared to being provided sailor/command assignment choices in preference Rank Order. Additionally, there is an apparent distinction in Exercise 2 between participants who understood how the IT matching algorithm actually made assignments to those with a lesser understanding. Analyzing Figure 4 in the previous section and the figures in Appendix F, there is a clear separation between the assignment values of the data points. There is a group of assignment values that average around 3, approximately the same value as the algorithm, and a group of assignment values that average around 8. Thus, the conclusion is that either the detailing participants understood the process for using rank order preferences (those grouped around Rank Order 3) or that they did not (those grouped around Rank Order 8). A final observation from the data shows a bias is tended toward command preferences over sailor preferences.

B. IMPLICATIONS

The implications pertaining to the conclusions is the heart of this research. As stated from the beginning of this paper, the research goal was to provide quantitative data to the suppositions made earlier by Schlegel, Butler and Molina, and Short, that an IT process could improve the detailing process. Each of the these theses addressed different aspects of the Navy's detailing process from an Activity Based Costing (ABC) analysis, to the detailing process effectiveness/satisfaction and sailor/command preferences, respectively; each addressed the same issue, the need to improve the current detailing process. The implications of this research mirrors their research results: an IT process could free up resources, improve sailor and command satisfaction with the detailing process - while achieving market equilibrium, and improve the detailing process. These three implications will be addressed in reverse order, highlighting their importance.

While it was shown that the detailing participants did worse making assignments on average when provided the same information as the IT process, this can be remedied in one of two ways: by allowing an IT matching algorithm to provide the Pareto Optimal solution after sailor/command Rank Order preferences have been generated, or allow detailers to generate the same Pareto Optimal solution, given a little guidance as to how the process iteration is done, once the IT process has generated sailor/command Rank Order preferences. This iterative process is shown below in Figure 5.

	Sailor														
Rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	17	4	12	14	12	5	3	19	12	13	9	3	12	16	10
2	10	3	1	5	2	7	4	17	1	2	13	4	16	12	5
3	5	6	6	7	14	14	6	11	6	5	20	9	19	19	13
4	7	10	18	2	17	2	9	8	16	3	11	20	17	4	2

	Billet																			
Rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	9	3	2	6	6	11	6	6	6	5	7	8	8	7	7	8	5	7	14	7
2	3	4	12	2	4	2	7	2	12	1	6	9	10	5	9	9	9	6	9	6
3	7	15	6	12	15	12	8	12	2	6	5	13	7	6	3	7	13	2	13	1
4	13	10	1	7	5	10	5	1	1	4	9	3	3	9	13	3	8	12	8	2
5	2	6	7	1	2	7	9	10	5	3	3	14	4	3	6	13	14	5	2	12
6	12	1	10	10	12	6	11	9	9	15	1	7	15	1	2	6	1	1	12	5
7	6	5	11	11	10	1	3	7	10	7	13	2	2	13	12	14	7	10	5	9

Sailor														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
~~17~~	4	~~12~~	~~14~~	~~12~~	5	~~3~~	~~19~~	12	13	9	3	~~12~~	~~16~~	~~10~~
10		1	~~5~~	~~2~~		~~4~~	17					16	~~12~~	~~5~~
			7	14		6							19	~~13~~

Figure 5. Generating a Pareto Optimal Solution

To decide sailor/command assignments, the IT algorithm can start with either the sailors' or commands' first choices for assignments, reflecting the sailor-biased and command biased approaches, respectively. This discussion will consider the sailor-biased approach, though in this example both outcomes are the same. Once all sailors are tentatively assigned to their most preferred billet, identical choices by multiple sailors are cross-referenced to the commands' Rank Order preferences. The command with the highest Rank Order preference is assigned that sailor. In this case, starting with sailor

Rank Order preferences, sailor 9 is assigned to command 12 because sailor 9 is ranked higher than sailors 3, 5 and 13 according to command 12's Rank Order preferences, and sailor 12 is assigned to command 3 because sailor 12 is ranked higher than sailor 7 according to command 3's Rank Order preferences. This is the first iteration of assignments for this batch. In subsequent iterations, unmatched sailors are provisionally assigned to their next best choice; any ties created by these new assignments are again broken by the commands' preferences. This iterative process is continued until all sailors are assigned or have exhausted their stated preferences

With this iterative process, the resulting outcome is the same as the IT matching algorithm. This is true whether sailor or command Rank Order preferences are used to make the initial assignments; and the probability that sailor and command biased assignment outcomes are different has been minimal in other labor markets (Roth and Peranson 729). With the aid of an IT process to generate sailor/command assignment preferences and/or assignments, the multiple hours detailers spend consolidating, analyzing, making contact and dealing with sailors is reduced dramatically; detailers can spend more time interacting with sailors and commands, and less time on the mechanics of making assignments.

In short, whether the Pareto Optimal solution is obtained by the detailer using sailor/command Rank Order preferences or through an IT matching algorithm, sailor and command objectives are met, assignment value is increased and labor market supply and demand requirements are met. By regenerating Figure 4 and adding a line to represent the average value of assignments made using either of the above processes, Figure 6, shows the value of using either solution. As a reminder, Assignment Averages were 4.40 for Exercise 1 and 5.41 for Exercise 2, where the object of each exercise was to minimize Rank Order value, i.e.: the lower the score the better. The Assignment Average for the IT process was 2.8 (sailors average being 2.0 and commands average 3.6), this is a definite improvement over the current detailing process.

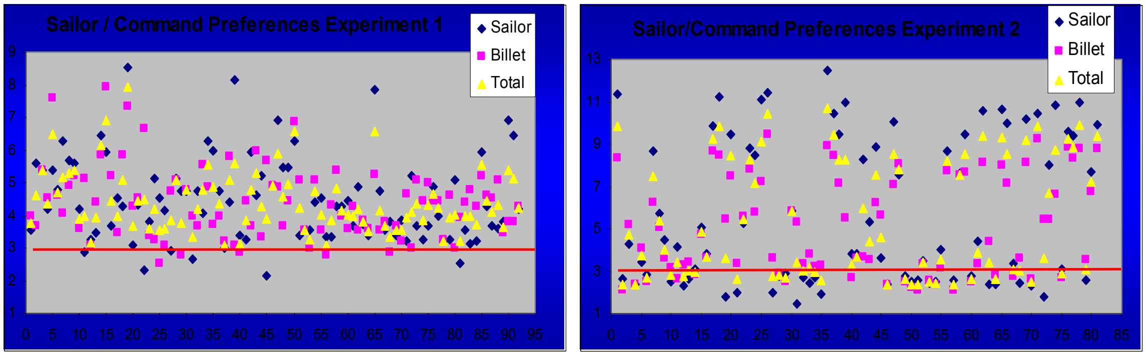


Figure 6. Consolidated Data with IT Process Averages

Improved sailor and command assignments create a higher satisfaction level from the detailing process among both sailors and commands. This reflects how the needs of the labor market supply and demand are being met. One concern here is that sailors and commands are provided the right incentives to behave honestly concerning their preferences for assignment, thereby creating a stable outcome (Roth and Sotomayor 10). This is fostered by allowing sailors to view command preferences for sailor assignments and providing them with the knowledge about how assignments are made. This includes the knowledge that assignments are based on Rank Order preference values, expectations are managed and incentives are provided to act 'honestly.' Additionally, by allowing commands to have an input to specific assignment preferences enhances the goal of achieving market equilibrium with a shrinking personnel force.

The last implication of using an IT process is freeing-up resources. On average, a detailer spends over 1,000 hours annually dealing with the sailors' assignments and advice; approximately half of the time detailers spend is directly related to detailing activities (Schlegel 44). These 1,000 hours do not account for the time spent reviewing the Job Advertising and Selection System (JASS), command requirements and priorities and making assignments every two weeks. Using an IT process, this information is consolidated, analyzed and processed instantly, providing Rank Order preferences of the specified batch of sailors and commands. Additionally, time spent by sailors negotiating for orders, looking at JASS, submitting Duty Preference sheets and sending e-mails is alleviated. These unproductive hours not only equate to lost time but lost money and detailing ineffectiveness.

There are numerous intertwined implications in adopting an IT process to aid in the detailing process. Sailor satisfaction with the detailing process affects retention, retention affects mission readiness and mission readiness effects the Navy's operational readiness and budget. The Navy's current detailing process lacks the ability to meet the demands placed upon it to achieve the CNO's goal of "ensuring the right skills are in the right place at the right time" (ADM Clark 14), thereby guaranteeing a labor market equilibrium to meet the demands of Joint Vision 2020. In today's age of technology, IT processes can provide the Navy with the tools and solutions to optimally assign the next generation of sailors to optimal mission requirements.

C. REMARKS FOR FURTHER RESEARCH

Recommend further research that considered having detailers as the participants in the experimental exercises performed in this project. Using detailers as the participants would validate the supposition made from this research, that the results attained from the experimental data are representative of the detailing community.

Some further research for consideration: 1) Continuing work done by Schlegel to analyze how the freeing of detailing recourses would impact the detailing process, 2) Continue the analysis done by Short surveying how enlisted personnel would react and their perceived satisfaction of an IT process of assignment verses the current detailing process or 3) Start a pilot program to assign personnel utilizing an IT process, analyzing detailer, sailor and command perceived satisfaction with the process.

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APPENDIX A: EXPERIMENTAL INSTRUCTIONS

Navy Personnel Detailing Task

(Based off of Suan Jow Tan, and Chee Meng Yeong experiment design)

General

You are acting as an enlisted detailing specialist assigned to match two groups of AS (Aviation Support Equipment Technician) sailors with jobs at several naval commands that require being filled with the most qualified sailor. The Navy has a policy of filling the needs of naval commands while recognizing the importance of considering the sailors' specific job preferences. Your task is to fill command billets with the best-qualified sailor, while considering the sailor's preferences according to the information provided. You will assign sailors to jobs in batches. Two batches of sailors are rotating from a shore job to a sea job, in pay grades E4 (lowest), E5 and E6 (highest). The command billets and sailor pools or batches have been randomly generated from a stylized description of the AS community.

You will be required to fill two separate batches of command billets with the sailors available. Both batches will include fifteen sailors and twenty commands, reflecting the Navy's chronic shortage of personnel. A list of both command and sailor preferences will be given for each exercise; and the first batch of sailors has to be assigned a job and completed before information about the next batch of sailors will be distributed. For both exercises you will be asked to analyze the information given and assign the sailors to the available billets considering command requirements and sailor preferences. A separate sailor assignment sheet will be used for each batch of sailors being detailed. After making your decisions, you will complete the sailor assignment sheet provided with these instructions. Consider both sailor and command preferences to the maximum extent practical. Your job is to match commands with their most preferred sailors, and sailors with their most preferred jobs, to the maximum extent possible. As described below, your specific objective is to minimize the sum of the rank-order preferences for all sailors and matched commands.

After completing both experiments, your total rank-order preferences will be summed for all sailors and matched commands in both exercises. Experimental payments, in lottery tickets, will be based on these total scores as follows:

Lowest Total	**12 Tickets**
Second Lowest Total	**10 Tickets**
Third Lowest Total	**8 Tickets**
Fourth Lowest Total	**6 Tickets**
5th – 10th Lowest Total	**4 Tickets**
11th – 20th Lowest Total	**1 Ticket**

PARTICIPANT CONSENT FORM

1. **Introduction.** You are invited to participate in a study of the U.S. Navy's enlisted assignment process. With information gathered from you and other participants, we hope to analyze the impact information and algorithm-based assignment mechanisms have on the quality of sailor assignments. We ask you to read and sign this form indicating that you agree to be in the study. Please ask any questions you may have before signing.

2. **Background Information.** The Naval Postgraduate School, Graduate School of Business and Public Policy is conducting this study.

3. **Procedures.** If you agree to participate in this study, the researcher will explain the tasks in detail. There will be one session lasting approximately two hours in duration, during which you will be expected to complete a number of simulated enlisted sailor assignments.

4. **Risks and Benefits.** This research involves no risks or discomforts greater then those encountered in an ordinary classroom setting.

5. **Compensation.** There is no compensation for participating in this study, however, consistent with standard experimental methodology in economics, participants can earn modest compensation based on the quality of the decisions made during the experiment. The compensation basis is explained in the experimental instructions. A copy of the results will be available to you at the conclusion of the experiment.

6. **Confidentiality.** The records of participants in this study will be kept confidential. No information will be publicly accessible which could identify you as a participant.

7. **Voluntary Nature of the Study.** If you agree to participate, you are free to withdraw from the study at any time without prejudice. You will be provided a copy of this form for your records.

8. **Points of Contact.** If you have any further questions or comments after the completion of the study, you may contact the research supervisor, Dr. William R. Gates: (831) 656-2754; brgates@nps.navy.mil.

9. **Statement of Consent.** I have read the above information. I have asked all questions and have had my questions answered. I agree to participate in this study.

-- --------------------------
Participant's Signature Date

-- --------------------------
Researcher's Signature Date

MINIMAL RISK CONSENT STATEMENT

NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA 93943
MINIMAL RISK CONSENT STATEMENT

Participant: VOLUNTARY CONSENT TO BE A RESEARCH PARTICIPANT IN: Experimental Analysis for Enlisted Sailor Assignments.

1. I have read, understand and been provided "Information for Participants" that provides the details of the below acknowledgments.

2. I understand that this project involves research. An explanation of the purposes of the research, a description of procedures to be used, identification of experimental procedures, and the extended duration of my participation have been provided to me.

3. I understand that this project does not involve more than minimal risk. I have been informed of any reasonably foreseeable risks or discomforts to me.

4. I have been informed of any benefits to me or to others that may reasonably be expected from the research.

5. I have signed a statement describing the extent to which confidentiality of records identifying me will be maintained.

6. I have been informed of any compensation and/or medical treatments available if injury occurs and is so, what they consist of, or where further information may be obtained.

7. I understand that my participation in this project is voluntary, refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled. I also understand that I may discontinue participation at any time without penalty or loss of benefits to which I am otherwise entitled.

8. I understand that the individual to contact should I need answers to pertinent questions about the research is Professor Bill Gates, Principal Investigator, and about my rights as a research participant or concerning a research related injury is Professor Rudy Darken, IRB Co-Chair. A full and responsive discussion of the elements of this project and my consent has occurred.

____
Signature of Principal Investigator Date

____
Signature of Volunteer Date

____
Signature of Witness Date

PRIVACY ACT STATMENT

NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA 93943
PRIVACY ACT STATEMENT

1. Purpose: Enlisted sailor assignment data will be collected to enhance knowledge, and to develop decision support systems or assignment algorithms to improve the enlisted sailor assignment process.

2. Use: Enlisted sailor assignment data will be used for statistical analysis by the Departments of the Navy and Defense, and other U.S. Government agencies, provided this use is compatible with the purpose for which the information was collected. Use of the information may be granted to legitimate non-government agencies or individuals by the Naval Postgraduate School in accordance with the provisions of the Freedom of Information Act.

3. Disclosure/Confidentiality:

   a. I have been assured that my privacy will be safeguarded. I will be assigned a control or code number, which thereafter will be the only identifying entry on any of the research records. The Principal Investigator will maintain the cross-reference between name and control number. It will be decoded only when beneficial to me or if some circumstances, which are not apparent at this time, would make it clear that decoding would enhance the value of the research data. In all cases, the provisions of the Privacy Act Statement will be honored.

   b. I understand that a record of the information contained in this Consent Statement or derived from the experiment described herein will be retained permanently at the Naval Postgraduate School or by higher authority. I voluntarily agree to its disclosure to agencies or individuals indicated in paragraph 2 and I have been informed that failure to agree to such disclosure may negate the purpose for which the experiment was conducted.

   c. I also understand that disclosure of the requested information, including my Social Security Number, is voluntary.

____

Signature of Volunteer Name, Grade/Rank (if applicable) DOB SSN Date

Exercise 1

Instructions

This job-matching exercise is to be completed as a single batch. This simulates the process that Navy enlisted detailers use as they job-match sailors to vacancies when the job openings arise and sailors become available. There are a total of 15 sailors and 20 commands in this batch.

There are two lists: a batch of 15 sailors, with information about both their characteristics and their job preferences; and a batch of 20 command billets with information about their characteristics and their sailor preferences. The information about preferences indicates how the sailors rank the available jobs, and how the commands rank the available sailors. Your job as detailer is to assign sailors to jobs considering both sets of characteristics and preferences.

Your objective is to minimize average rank-order preferences across both commands and sailors. A command's/sailor's first choice would be a rank-order preference = 1, second choice would be rank-order 2, third choice would be rank-order 3, etc. Score is based on the total (sum) rank-order preference of your assignments, for both sailors and matched commands; the lower the score the better. The total rank-order score would be 30 if all 15 sailors were assigned to their most preferred job (rank-order 1) and every filled billet received their highest ranked sailor. The total rank order score would be 60 if all sailors and commands received their second ranked choice, etc.

Command Preferences

Different command billets require different skill sets and experiences to perform the wide variety of jobs. These differences are specified through Navy Enlisted Classification Codes (NECs), Pay Grade/Rank (E4 thru E6 here) and Performance Evaluations (EVAL) that are ranked from 1 thru 5 (5 being the highest score). An additional command concern is the reporting sailor's Projected Rotation Date (PRD). Typically, command billets are filled at the time of vacancy, but commands prefer earlier report dates as opposed to later dates. Each command has individual rankings over the sailors available to fill open billets, determined by their preferences with respect to Pay Grade, NEC, PRD and EVAL ranking. These characteristics are weighted differently from command to command, base upon specific command preferences. The following table provides a quick reference to the categories stated above.

Pay Grade	Primary NEC Training Level	Other NEC	PRD	EVAL Ranking
E4 E5 E6	General NEC (E4 – E6) 7600 Equip Maintenance NEC (E4 – E6): 7607, 7612, 7614 Maintenance Management NEC (E5 – E6) 7699	NECs earned beyond primary NEC. NECs outside of the AS rating counted as 0.5.	Months to sailor's planned rotation date 1,2 or 3 months	1-Don't Promote 2-Promote (Low) 3-Promote (High) 4-Must Promote 5-Early Promote

Explanatory Notes:

a. Pay Grade indicates the sailor's pay or rank level. There are nine enlisted pay grades, designated E1 to E9; to simplify, this experiment only considers the middle three pay grades E4, E5 and E6. Detailers can assign a sailor to a job that is rated one Pay Grade up or one down, if options within the sailor's Pay Grade are poor matches and the sailor being assigned is otherwise qualified. Commands would prefer a sailor that is over qualified (assigned one down) to one that is under qualified.

b. Primary NEC is a numerical code referring to the primary (most recent) training received by a sailor. The preference is for the Sailor to have already obtained the NEC before being assigned to a billet requiring that NEC. Alternatively, the sailor must be trained while on the job, either formally or informally, at the expense of the sailor's assigned command.

c. Other NEC is the number of NECs the sailor has earned beyond the primary NEC. NECs outside of the AS rating count as one half of an NEC. Additional NECs indicate the sailor has received training in the past that might apply to the current job.

d. Eval ranking indicates the likelihood of being promoted, and represents the sailor's last formal evaluation.

e. Each command's top two priorities over sailor characteristics, for sailors being assigned to their command, will be annotated as 'High 1' and 'High 2', respectively.

Sailor Preferences

A sailor's main interests in ranking potential jobs concern command location, platform type (e.g., ship), Pay Grade and NEC. Each sailor has different preferences or weighting of command characteristics, implying each sailor will have their own set of preferences over the jobs that are available. They will rank their preference to maximize their own utility. The table below lists the attributes that sailor consider crucial to the job-matching exercises.

Pay Grade	NEC	Preferred Location		Platform
E4	General NEC (E4 – E6) 7600	CEC	Continental US - East Coast (e.g., Norfolk)	CVN
E5	Equip Maintenance NEC (E4 – E6): 7607, 7612, 7614	CGC	Continental US - Gulf Coast (e.g., Jacksonville)	LHA/LHD
E6	Maintenance Management NEC (E5 – E6) 7699	CNW	Continental US - Northwest (e.g., Bremerton)	LPD
		CSW	Continental US - Southwest (e.g., San Diego)	MSC
		OPL	Outside Continental US – Pacific/Atlantic (e.g., Japan, Italy)	Other Sea

Explanatory Notes:

a. Pay Grade indicates the sailor's pay or rank level. There are nine enlisted pay grades, designated E1 to E9; to simplify, this experiment only considers the middle three pay grades E4, E5 and E6. Detailers can assign a sailor to a job that is rated one Pay Grade up or one down, if options within the sailor's Pay Grade are poor matches and the sailor being assigned is otherwise qualified. If there are no good matches within the grade level, sailors would prefer to be assigned one grade level up as opposed to one grade level down.

b. NEC numerical numbers refer to specific training received by a sailor or preferred for a sailor filling a specific billet. Sailors prefer to be assigned to jobs for which they are already qualified (matching NEC), rather than receiving training while on the job.

c. Location indicates the geographic location of the job posting or sailor's preference, as defined above.

d. Each sailor's top two priorities over command characteristics, for potential assignments, will be annotated with the words 'High 1' and 'High 2', respectively.

Example

The following is an example of what you will see in this detailing exercise:

	Grade	Primary NEC	Other NEC	PRD	EVAL	Preferred Platform	Preferred Region
Sailor 1	4	7612	0	3	2	CVN (High 1)	CSW (High 2)
Sailor 2	5 (High 1)	7612	1	2	4	AIMD (High 2)	CGC
Sailor 3	5	7607 (High 2)	2	2	3	LHA/LHD	CSW (High 1)

	Grade	Primary NEC	Take Up Month	EVAL	Platform	Region
Command 1	5	7607	3 (High 1)	(High 2)	CVN	CNW
Command 2	4 (High 2)	7607 (High 1)	3		LHA/LHD	CSW
Command 3	4 (High 1)	7612 (High 2)	3		LHA/LHD	CNW
Command 4	6	7699	1 (High 2)	(High 1)	CVN	CNW

SSN (Last 4) _______________

Sailor	1	2	3
Command Assigned			

Evaluation of Detailing

Command and Sailor preferences shown here reflect rank-order preferences for both commands and sailors. Your goal is to minimize the total sum of rank-order preferences across both commands and sailors. Scores will be calculated according to the rank-order preferences implied by your assignments.

Rank	Sailor 1	Sailor 2	Sailor 3	Billet 1	Billet 2	Billet 3	Billet 4
1	Billet 2	Billet 1	Billet 1	Sailor 3	Sailor 3	Sailor 1	Sailor 3
2	Billet 3	Billet 4	Billet 2	Sailor 2	Sailor 1	Sailor 2	Sailor 2
3	Billet 1	Billet 3	Billet 4	Sailor 1	Sailor 2	Sailor 3	
4		Billet 2	Billet 3				

Exercise 2

Instructions

For this exercise, the command and sailor preferences from experiment 1 have been analyzed and ranked to indicate which command best fits each sailor's preferences, and which sailor best fits each command's preferences. There are a total of 15 sailors and 20 commands in this experiment. This job-matching exercise is to be completed as a single batch. This simulates the process that Navy enlisted detailers use as they job-match sailors to vacancies when the job openings arise and sailors become available.

There are two tables of information; one is a batch of 15 sailors giving their preference over which command they prefer, ranking them from 1 to 20 (1 being their first choice, 20 being their last choice), and one is a batch of 20 commands listing their preferences over sailors being assigned, ranking them from 1 to 15 (1 being their first choice, 15 being their last choice). Your job as detailer is to make job assignments considering both sets of preferences.

Your objective is to minimize average rank-order preferences across both commands and sailors. A command's/sailor's first choice would be a rank-order preference = 1, second choice would be rank-order 2, third choice would be rank-order 3, etc. Score is based on the total (sum) rank-order preference of your assignments, for both sailors and matched commands; the lower the score the better. The total rank-order score would be 30 if all 15 sailors were assigned to their most preferred job (rank-order 1) and every filled billet received their highest ranked sailor. The total rank order score would be 60 if all sailors and commands received their second ranked choice, etc.

Example

The following is an example of what you will see in this detailing exercise:

Sailor Preferences over Billets

Rank Order	Command	Sailor 1	Sailor 2	Sailor 3
	1	2	1	1
	2	3	4	2
	3	1	3	4
	4	4	2	3

Command Preferences over Sailors

Rank Order	Sailor	Command 1	Command 2	Command 3	Command 4
	1	3	3	1	3
	2	2	1	2	2
	3	1	2	3	1
	4				

Assignment Sheet

SSN (Last 4) _______________

Experiment 1/2

Sailor	1	2	3	4	5	thru	15
Command Assigned							

SSN (Last 4) ____________

Experiment 1

Sailor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Command Assigned															

SSN (Last 4) __________

Experiment 2

Sailor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Command assigned															

SSN (Last 4): ____________

Service: ____________

Sex: M / F

Cirric: ____________

QUESTIONNAIRE

1. During this detailing exercise, what factors were considered most pertinent in your assignment?

Experiment 1:

____

____

Experiment 2:

____

____

2. What is the ranking order of the factors that you used? (i.e. which factor did you look at first, followed by which other factor, and so on)

Experiment 1:

____

____

Experiment 2:

____

____

3. What factors were not considered at all? Why not?

Experiment 1:

____

____

Experiment 2:

____

____

4. How can this detailing simulation exercise be further improved upon?

Experiment 1:

____

____

Experiment 2:

____

____

Please e-mail the results of these experiments when they are available.

My e-mail address is:____

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APPENDIX B: SAILOR AND COMMAND ASSIGNMENT DESCRIPTION

Prepared by Dr. Bill Gates

SimAS

SimAS is an Excel-based process to generate a representative list of billets and sailors for the AS community. Billet and enlisted sailor characteristics reflect the AS Enlisted Master File (EMF) and the AS Billet File, with some simplifications. SimAS also develops utility functions for sailors across billets and billets across sailors, reflecting hypothetical sailor, command and Navy-wide preferences. The final output includes lists of sailors and billets that are ready for assignment and two matrices that list the sailor's utility for each billet and the billet's utility for each sailor. Assignments can be evaluated by the utility generated, rank-order of the assignments made, or quasi-prices and surplus values derived from the utility measures. This documentation describes how SimAs develops sailors, billets and the respective utilities.

AS Sailor Summary

The AS Sailor Summary worksheet highlights several characteristics of the AS EMF dated 06-02. Three main simplifications are incorporated in this summary.

- AS NECs have been consolidated into 6 categories. The NECs in SimAS include the following NECs from the EMF:
  - 7600 includes None, 7222, 8364, 8880
  - 7607 includes 7601, 7603, 7606, 7607
  - 7612 includes 7610, 7612, 7616, 7617
  - 7614 includes 7614 and 7618
  - 7699 includes7699
  - 9500 includes all other (non-AS related) NECs
- AS sea and shore platforms have been consolidated into the following categories:
  - Shore Platforms
    - AMID
    - Other 1
  - Sea platforms
    - CVN
    - LHA/LHD
    - LPA
    - MCS
    - Other 2
- All locations have been grouped into five regions as follows:
  - CEC Continental U.S., East Coast (e.g., Norfolk)
  - CGC Continental U.S., Gulf Coast (e.g., Pensacola)
  - CNW Continental U.S., Northwest (e.g., Washington)
  - CSW Continental U.S., Southwest (e.g., San Diego)
  - OPL Outside the Continental U.S., Pacific and Atlantic

Details about how specific locations are allocated to these categories are available if desired.

After making these simplifications, AS Sailor Summary characterizes the AS enlisted community by location, grade, NECs (1-5), SSC, gender, preferred location and platform, marital status and dependents. This synopsis assumes that the data fields are complete for all fields except preferred location and type (blanks in marital status and dependents implies single sailors and no dependents). Preferred location and platform are measured as percentages, implicitly assuming that the reported data represents the entire population. The data summarized in AS Sailor Summary merely counts entries from the EMF, and forms the basis for AS Sailor Structure and Generate AS Sailors.

AS Billet Summary

The AS Billet Summary worksheet highlights several characteristics of the AS Billet file. The same simplifications are made regarding NECs, location and platform. After making these simplifications, AS Billet Summary characterizes the AS billets by location, grade, NEC (platform data is reported in AS Billet Structure). As with AS Sailor Summary, the data summarized in AS Billet Summary merely counts entries from the Billet File, and forms the basis for AS Billet Structure and Generate AS Billets.

AS Sailor Structure

AS Sailor Structure reports the frequency of Sailors in the EMF by SSC, Grade, Region and primary NEC, using the data from AS Sailor Summary. The frequency for each combination of characteristics, and the corresponding index number (frequency times 10,000, in this case) forms the basis for the AS sailors generated in Generate AS Sailors.

AS Billet Structure

AS Billet Structure reports the frequency of Billets in the Billet file by SSC, Region, primary NEC, and Grade using the data from AS Billet Summary. The frequency for each combination of characteristics, and the corresponding index number (frequency times 10,000, in this case) forms the basis for the AS billets generated in Generate AS Billets. For reference, this sheet also includes a summary of the AS billet structure by region, primary NEC, SSC, and platform.

Generate AS Sailors

Generate AS Sailors creates the hypothetical AS sailors based on the frequencies calculated in AS Sailor Summary and reported in AS Sailor Structure. Sailors are formed by column, beginning with Sailor 1 in column B. Rows 2 – 6 (colored gold) generate indices to identify the sailor's SSC, grade, region, primary NEC, number of additional NECs, preferred location, preferred platform and number of dependents (all five indices are uniform random variables between 0 and 10,0000, generated using:

Tools: Data Analysis: Random Number Generating in Excel). To generate all 5 index numbers for the 60 sailors in this base case, the following values should be entered in the Random Number Generating dialog box:

Sailor Characteristic Indices

- Number of Variables: 60
- Number of Random Numbers: 5
- Distribution: Uniform
- Parameters: Between 0 and 10000
- Random Seed: Blank
- Output Options: Output Range $B$2:$BI$6

For different numbers of sailors, the number of variables and the final column of the output range would change accordingly.

The sailor characteristics are reported in rows 7-17 (colored light orange). The sailor index in row 2 forms the basis for SSC, grade, region and primary NEC (rows 7-10). Using the sailor index, these entries are determined by looking up the sailor characteristics in AS Sailor Structure that have the corresponding index number (using the VLOOKUP function).

The number of additional NECs (row 11; NEC 9500 is counted as 0.5), preferred location (row 13), preferred platform (row 14), and number of dependents, including spouse (row 14), are similarly based on the NEC, location, platform and dependents indices generated in rows 3 – 6. The lookup tables for these variables are generated at the bottom of the Generate AS Sailors worksheet, based on the data in AS Sailor Summary.

Months to Planned Rotation Date (PRD), row 16, and Promotability (or past performance evaluation), row 17, are generated as discrete random variables, using: Tools: Data Analysis: Random Number Generating in Excel. The values and corresponding probabilities used to generate these values are summarized in this worksheet (PRD: J56:K58; Promote: M56:N60). To generate these values, the following entries should be used in the random number generating dialog box:

PRD

- Number of Variables: 60
- Number of Random Numbers: 1
- Distribution: Discrete
- Parameters: Value and Probability Input Range: $J$56:$K$58
- Output Options: Output Range $B$16:$BI$16

Promote

- Number of Variables: 60
- Number of Random Numbers: 1
- Distribution: Discrete
- Parameters: Value and Probability Input Range: $M$56:$N$60
- Output Options: Output Range $B$16:$BI$16

For different numbers of sailors, the number of variables and the final column of the output range would change accordingly. The distribution of PRD and promotability can be changed on this sheet as appropriate.

Finally, region number (row 12) is an index that is used in the utility calculations (as column numbers in a VLOOKUP function), and is based on the region where the sailor is currently located (row 9).

Generate AS Billets

Generate AS Billets creates the hypothetical AS billets based on the frequencies calculated in AS Billet Summary and reported in AS Billet Structure. Billets are formed by row, beginning with billet 1 in row 3. Columns B and C (colored gold) generate indices to identify the billet's SSC, grade, region, primary NEC, and platform (both indices are uniform random variables between 0 and 10,0000, generated using: Tools: Data Analysis: Random Number Generating in Excel). To generate both index numbers for the 75 billets in this base case, the following values should be entered in the Random Number Generating dialog box:

Billet Characteristic Indices

- Number of Variables: 2
- Number of Random Numbers: 75
- Distribution: Uniform
- Parameters: Between 0 and 10000
- Random Seed: Blank
- Output Options: Output Range $B$3:$C$77

For different numbers of billets, the entries in the Number of Random Numbers and the final row of the output range would change accordingly.

The billet characteristics are reported in columns C - M (colored light orange). The billet index in column C forms the basis for SSC, region, primary NEC and grade (columns D - G). Using the billet index, these entries are determined by looking up the billet characteristics in AS Billet Structure that have the corresponding index number (using the VLOOKUP function).

The platform (column H) is similarly based on the platform index generated in column B. Translation between the platform index and the platform specification is based on the platform data reported in the AS Billet Structure worksheet (Q22-Q28).

Billet visibility (column I), billet priority (column J) and Take Up Month (column K), are generated as discrete random variables, using: Tools: Data Analysis: Random Number Generating in Excel. The values and corresponding probabilities used to generate these values are summarized in this worksheet (Visibility: N3:O7; Priority: N9:O12; Take Up Month: N15:O17). To generate these values, the following entries should be used in the random number generating dialog box:

Visibility

- Number of Variables: 1
- Number of Random Numbers: 75
- Distribution: Discrete
- Parameters: Value and Probability Input Range: $N$3:$0$7
- Output Options: Output Range $I$3:$I$77

Priority

- Number of Variables: 1
- Number of Random Numbers: 75
- Distribution: Discrete
- Parameters: Value and Probability Input Range: $N$9:$O$12
- Output Options: Output Range $J$3:$J$77

Take up Month

- Number of Variables: 1
- Number of Random Numbers: 75
- Distribution: Discrete
- Parameters: Value and Probability Input Range: $N$15:$O$17
- Output Options: Output Range $N$15:$O$17

For different numbers of billets, the number of variables and the final row of the output range would change accordingly. The distribution of visibility, priority and take up month can be changed on this sheet as appropriate.

Finally, the location and platform indices are used in the utility calculations (as column numbers in a VLOOKUP function), and are based on the region and platform for this billet (columns E and H, respectively).

AS Sailor Preferences

AS Sailor Preferences calculates the utility each sailor derives from each billet. The values on this sheet are color coded as follows: pale blue: utility values; light turquoise: utility function parameters; yellow: variables specified by analyst; light green: calculations used to check inputs for consistency; lavender: summary calculations (maximum utility and number of non-zero utilities); dark gray: parameters not used in these calculations (used for billet utilities).

Sailor utility is based on up to five properties of the proposed billet: location, platform, visibility, grade and NEC. Scores for each of these characteristics range from 0 (completely unacceptable) to 5 (most preferred). The scoring rules used in the utility calculations are provided across the top of this worksheet. The yellow shaded entries in these tables are the scores used in the calculations, and can be changed as appropriate. The corresponding utilities will change accordingly.

Sailor utilities can be calculated in two ways: multiplicative (Cobb-Douglas) and additive. Both have strong and weak points. For the multiplicative specification, if one characteristic is completely unacceptable to the sailor, sailor utility for the billet will be zero, indicating that the billet is completely unacceptable. For the scores used here, this primarily occurs when there is a mismatch between the billet and sailor's pay grade (more than one up or down). On the other hand, Cobb-Douglas utility functions imply interactions between characteristics (the location might affect the utility the sailor receives from the visibility parameter). This may or may not be the case. The additive utility function avoids the interdependency problem, but favorable characteristics can outweigh the impact of an unacceptable characteristic (a sailor may have a high utility for a billet that is more than one pay grade up or down if all other characteristics are a good fit).

In these calculations, the entry in cell J6 allows the analyst to switch between additive (enter: +) or multiplicative (enter: *) specifications. Any other entry in this cell will generate "+/* ????" for all utility values, prompting the analyst to make a conscious decision (no default).

The two utility functions are specified as follows:

Multiplicative

$$U = C_1^{a_1} * C_2^{a_2} * C_3^{a_3} * C_4^{a_4} * C_5^{a_5} ....$$

Additive

$$U = a_1C_1 + a_2C_2 + a_3C_3 + a_4C_4 + a_5C_5 .....$$

Where: $a_1 + a_2 + a_3 + a_4 + a_5 + ... = 1$ in both cases.

In these formulas, the C values are the scores for each relevant characteristic, as indicated in the yellow shaded entries at the top of the As Sailor Preferences worksheet. The a_is are the equation parameters determined in the worksheet (light turquoise shaded cells in the AS Sailor Preferences worksheet). Total utility in the multiplicative specification can vary from 0 to 5; total utility in the additive specification can vary from less than one (but greater than zero) to 5. Utility will never equal 0 in the additive specification, with the characteristic scores used here.

In the AS Sailor Preferences, the a_is are based on randomly generated numbers that vary from 0 to 10. These values are recorded in cells M18:BT22, using the following entries in the random number generating dialog box:

Sailor Preferences

- Number of Variables: 60
- Number of Random Numbers: 5
- Distribution: Uniform
- Parameters: Between 0 and 10
- Random Seed: Blank
- Output Options: Output Range $M$18:$BT$22

For different numbers of sailors, the number of variables and the final column of the output range would change accordingly.

In calculating the a_is from these random numbers, two adjustments were made. First, it is unclear the extent to which sailors will consider grade and NEC in their billet preferences. It is likely that these factors are considered (though there are ample examples of sailors requesting billets more than one up or down from their grade and outside their NEC), but they may not receive the same weight as location, platform or visibility. Therefore, a scaling factor has been added to specify the weight placed on grade and NEC relative to location, platform and visibility. This scaling factor is in cell Y17 on the AS Sailors Preferences worksheet. If the value is 0 (1), all weight is placed on location, platform and visibility (grade and NEC); if Y17 = 0.5, the weight is distributed equally between grade and NEC on one hand and location, platform and visibility on the other.

The second modification involves the weight placed on location versus platform. The preferences specified in the EMF indicate that 80% of the responding sailors place more priority on location than platform. Therefore, a scaling factor is added in cell M17 for the platform parameter. When this scale is set to .35, the location parameter exceeds the platform parameter for 47 of the 60 sailors (close to 80%); the platform exponent exceeds the location exponent in 13 of 60 cases (close to 20%). The impact if the scaling factor is determined by the values in row 16 and the results of this check are reported in cell R17.

Finally, the lavender shaded cells at the bottom and to the right of the sailor preference matrix indicate the maximum utility by column (the maximum utility for any one sailor across all billets) and row (the maximum utility any sailor receives from a particular billet). The averages for these maximum utilities are also reported. The number of zero utility values is also reported by column (the number of completely unacceptable billets for each sailor) and row (the number of sailors that find a particular billet completely unacceptable).

AS Billet Preferences

AS Billet Preferences calculates the utility each billet derives from each sailor. The values on this sheet are color coded as above: pale blue: utility values; light turquoise: utility function parameters; yellow: variables specified by analyst; light green: calculations used to check inputs for consistency; lavender: summary calculations (maximum utility and number of non-zero utilities); dark gray: parameters not used in these calculations (used for sailor utilities).

Billet utility is based on up to six properties of the proposed sailor: four representing the command's preferences (grade, NEC, PRD, promotability), and two representing Navy wide preferences (sea/shore rotation and PCS costs). Scores for each of these characteristics range from 0 (completely unacceptable) to 5 (most preferred). The scoring rules used in the utility calculations are provided across the top of this worksheet. The yellow shaded entries in these tables are the scores used in the calculations, and can be changed as appropriate. The corresponding utilities will change accordingly.

As with sailors, billet utilities can be calculated using a multiplicative (Cobb-Douglas) or additive structure. In these calculations, the entry in cell J6 allows the analyst to switch between additive (enter: +) or multiplicative (enter: *) specifications. Any other entry in this cell will generate "+/* ????" for all utility values, prompting the analyst to make a conscious decision (no default).

The two utility functions are specified as follows:

Multiplicative

$$U = C_1^{a_1} * C_2^{a_2} * C_3^{a_3} * C_4^{a_4} * C_5^{a_5} * C_6^{a_6} ....$$

Additive

$$U = a_1C_1 + a_2C_2 + a_3C_3 + a_4C_4 + a_5C_5 + a_6C_6 .....$$

Where: $a_1 + a_2 + a_3 + a_4 + a_5 + a_6 .... = 1$ in both cases.

In these formulas, the C values are the scores for each relevant characteristic, as indicated in the yellow shaded entries at the top of the As Billet Preferences worksheet. The a_is are the equation parameters determined in the worksheet (light turquoise shaded cells in the AS Billet Preferences worksheet). Total utility in the multiplicative specification can vary from 0 to 5; total utility in the additive specification can vary from less than one (but greater than zero) to 5. Utility will never equal 0 in the additive specification, with the characteristic scores used here.

In the AS Sailor Preferences, the command relevant a_is are based on randomly generated numbers that vary from 0 to 10. These values are recorded in cells A30:D104, using the following entries in the random number generating dialog box:

Billet Preferences

- Number of Variables: 4
- Number of Random Numbers: 75
- Distribution: Uniform
- Parameters: Between 0 and 10
- Random Seed: Blank
- Output Options: Output Range $A$30:$D$104

For different numbers of billets, the number of random numbers and the final row of the output range would change accordingly.

The Navy-wide preferences (the relevance of sea/shore rotation and PCS costs) are the same for all billets. These values are specified in cells H3 and H4. These values must sum to one, so only the PCS cost weight, in cell H3, is shaded yellow; the value in H4 is automatically calculated as (1-H3).

In calculating the a_is from these inputs, one adjustment was made. The relative weight placed on command versus Navy-wide characteristics is included as a variable (cells M3 and M4). As above, these values must sum to one, so only the Navy weight, in cell M3, is shaded yellow; the value in M4 is automatically calculated as (1-M3). If the value is 0 (1), all weight is placed on Navy relevant characteristics (command relevant characteristics); if M3 = M4 = 0.5, the weight is distributed equally between PCS costs and sea/shore rotation on one hand and grade, NEC, PRD and promotability on the other.

Finally, the lavender shaded cells at the bottom and to the right of the sailor preference matrix indicate the maximum utility by column (the maximum utility the billets receive from any one sailor) and row (the maximum utility any billet receives across all sailors). The averages for these maximum utilities are also reported. The number of zero utility values is also reported by column (the number of completely unacceptable billets for each sailor) and row (the number of sailors that find a particular billet completely unacceptable).

Generating New Representative Sailors and Billets

To generate a new set of sailors and billets requires the following steps, specified by worksheet:

- **Generate AS Sailors**
  - Generate new random variables for the Sailor Preference Indices (uniform random variables)
  - Generate new values for sailor PRD and promotability (discrete random variables)
- **Generate AS Billets**

    - Generate new random variables for the Billet Preference Indices (uniform random variables)
    - Generate new values for billet visibility, priority and take-up month (discrete random variables)
- **AS Sailor Preferences**
    - Generate new random values for sailor preferences (uniform random variables)
    - Adjust location/platform preference and grade/NEC weight as appropriate
    - Adjust scoring values as appropriate
- **AS Billet Preferences**
    - Generate new random values for billet preferences (uniform random variables)
    - Adjust PSC cost/sea/shore rotation weight as appropriate
    - Adjust Navy versus command relevant weight as appropriate
    - Adjust scoring values as appropriate

APPENDIX C: SAS ANOVA RESULTS

ANOVA FOR EXERCISE 1 (MATCHES EXCEL RESULTS)

The ANOVA Procedure

Class Level Information

Class	Levels	Values
exp	4	1 2 3 4

Number of observations 91

The ANOVA Procedure

Dependent Variable: exercise1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	4.10760378	1.36920126	1.65	0.1834
Error	87	72.12117864	0.82897906		
Corrected Total	90	76.22878242			

R-Square	Coeff Var	Root MSE	exercise1 Mean
0.053885	20.63713	0.910483	4.411868

Source	DF	Anova SS	Mean Square	F Value	Pr > F
exp	3	4.10760378	1.36920126	1.65	0.1834

ANOVA FOR EXERCISE 2 (MATCHES EXCEL RESULTS)

The ANOVA Procedure

Class Level Information

Class	Levels	Values
exp	4	1 2 3 4

Number of observations 81

The ANOVA Procedure

Dependent Variable: exercise2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	66.1074406	22.0358135	2.99	0.0359
Error	77	566.5437594	7.3577112		
Corrected Total	80	632.6512000			

R-Square	Coeff Var	Root MSE	exercise2 Mean
0.104493	50.11823	2.712510	5.412222

Source	DF	Anova SS	Mean Square	F Value	Pr > F
exp	3	66.10744060	22.03581353	2.99	0.0359

ANOVA – 2 FACTOR – BALANCED (MATCHES EXCEL RESULTS)

The ANOVA Procedure

Class Level Information

Class	Levels	Values
exp_grp	4	1 2 3 4
Exercise_num	2	1 2

Number of observations 64

The ANOVA Procedure

Dependent Variable: Score

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	77.0376938	11.0053848	2.83	0.0134
Error	56	217.7372000	3.8881643		
Corrected Total	63	294.7748938			

R-Square	Coeff Var	Root MSE	Score Mean
0.261344	39.97907	1.971843	4.932188

Source	DF	Anova SS	Mean Square	F Value	Pr > F
exp_grp	3	23.36923125	7.78974375	2.00	0.1239
Exercise_num	1	22.70522500	22.70522500	5.84	0.0190
exp_grp*Exercise_num	3	30.96323750	10.32107917	2.65	0.0573

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APPENDIX D: SAS *T*-TEST RESULTS

EXERCISE 1 multiple comparison model: t-tests

```
The GLM Procedure

    Class Level Information

Class          Levels    Values

Exp_grp             4    1 2 3 4


Number of observations    91
 The GLM Procedure

Dependent Variable: score

                                        Sum of
Source                      DF         Squares     Mean Square    F Value
Pr > F

Model                        3      4.10760378      1.36920126       1.65
0.1834

Error                       87     72.12117864      0.82897906

Corrected Total             90     76.22878242


R-Square     Coeff Var      Root MSE    score Mean

0.053885      20.63713      0.910483      4.411868


Source                      DF       Type I SS     Mean Square    F Value
Pr > F

Exp_grp                      3      4.10760378      1.36920126       1.65
0.1834


Source                      DF     Type III SS     Mean Square    F Value
Pr > F

Exp_grp                      3      4.10760378      1.36920126       1.65
0.1834

The GLM Procedure
```

t Tests (LSD) for score

```
NOTE: This test controls the Type I comparisonwise error rate, not the
experimentwise error
rate.
```

Alpha	0.05
Error Degrees of Freedom	87
Error Mean Square	0.828979
Critical Value of t	1.98761

Comparisons significant at the 0.05 level are indicated by ***.

Exp_grp Comparison	Difference Between Means	95% Confidence Limits		
1 - 4	0.0044	-0.7110	0.7197	
1 - 2	0.0113	-0.6212	0.6438	
1 - 3	0.4311	0.0019	0.8603	***
4 - 1	-0.0044	-0.7197	0.7110	
4 - 2	0.0069	-0.8340	0.8478	
4 - 3	0.4268	-0.2741	1.1276	
2 - 1	-0.0113	-0.6438	0.6212	
2 - 4	-0.0069	-0.8478	0.8340	
2 - 3	0.4198	-0.1963	1.0359	
3 - 1	-0.4311	-0.8603	-0.0019	***
3 - 4	-0.4268	-1.1276	0.2741	
3 - 2	-0.4198	-1.0359	0.1963	

The GLM Procedure

Bonferroni (Dunn) t Tests for score

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher
Type II error rate than Tukey's for all pairwise comparisons.

Alpha	0.05
Error Degrees of Freedom	87
Error Mean Square	0.828979
Critical Value of t	2.69992

Comparisons significant at the 0.05 level are indicated by ***.

Exp_grp Comparison	Difference Between Means	Simultaneous 95% Confidence Limits	
1 - 4	0.0044	-0.9673	0.9761
1 - 2	0.0113	-0.8479	0.8705
1 - 3	0.4311	-0.1519	1.0141
4 - 1	-0.0044	-0.9761	0.9673
4 - 2	0.0069	-1.1353	1.1492
4 - 3	0.4268	-0.5253	1.3788

2	- 1	-0.0113	-0.8705	0.8479
2	- 4	-0.0069	-1.1492	1.1353
2	- 3	0.4198	-0.4171	1.2567
3	- 1	-0.4311	-1.0141	0.1519
3	- 4	-0.4268	-1.3788	0.5253
3	- 2	-0.4198	-1.2567	0.4171

Tukey's Studentized Range (HSD) Test for score

NOTE: This test controls the Type I experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	87
Error Mean Square	0.828979
Critical Value of Studentized Range	3.70438

Comparisons significant at the 0.05 level are indicated by ***.

Exp_grp Comparison		Difference Between Means	Simultaneous 95% Confidence Limits	
1	- 4	0.0044	-0.9383	0.9471
1	- 2	0.0113	-0.8222	0.8449
1	- 3	0.4311	-0.1345	0.9968
4	- 1	-0.0044	-0.9471	0.9383
4	- 2	0.0069	-1.1012	1.1151
4	- 3	0.4268	-0.4969	1.3504
2	- 1	-0.0113	-0.8449	0.8222
2	- 4	-0.0069	-1.1151	1.1012
2	- 3	0.4198	-0.3921	1.2318
3	- 1	-0.4311	-0.9968	0.1345
3	- 4	-0.4268	-1.3504	0.4969
3	- 2	-0.4198	-1.2318	0.3921

EXERCISE 2 multiple comparison model: t-tests

The GLM Procedure

Class Level Information

Class	Levels	Values
Exp_grp	4	1 2 3 4

Number of observations 81

The GLM Procedure

Dependent Variable: score

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	66.1074406	22.0358135	2.99	0.0359
Error	77	566.5437594	7.3577112		
Corrected Total	80	632.6512000			

R-Square	Coeff Var	Root MSE	score Mean
0.104493	50.11823	2.712510	5.412222

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Exp_grp	3	66.10744060	22.03581353	2.99	0.0359

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Exp_grp	3	66.10744060	22.03581353	2.99	0.0359

The GLM Procedure

t Tests (LSD) for score

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	77
Error Mean Square	7.357711
Critical Value of t	1.99125

Comparisons significant at the 0.05 level are indicated by ***.

Exp_grp Comparison	Difference Between Means	95% Confidence Limits	
4 - 3	1.4511	-0.4796	3.3819

4	- 1	1.5619	-0.4479	3.5718	
4	- 2	3.7033	1.2216	6.1851	***
3	- 4	-1.4511	-3.3819	0.4796	
3	- 1	0.1108	-1.2793	1.5009	
3	- 2	2.2522	0.2393	4.2652	***
1	- 4	-1.5619	-3.5718	0.4479	
1	- 3	-0.1108	-1.5009	1.2793	
1	- 2	2.1414	0.0525	4.2303	***
2	- 4	-3.7033	-6.1851	-1.2216	***
2	- 3	-2.2522	-4.2652	-0.2393	***
2	- 1	-2.1414	-4.2303	-0.0525	***

The GLM Procedure

Bonferroni (Dunn) t Tests for score

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher
Type II error rate than Tukey's for all pairwise comparisons.

Alpha	0.05
Error Degrees of Freedom	77
Error Mean Square	7.357711
Critical Value of t	2.70813

Comparisons significant at the 0.05 level are indicated by ***.

Exp_grp Comparison		Difference Between Means	Simultaneous 95% Confidence Limits		
4	- 3	1.4511	-1.1747	4.0770	
4	- 1	1.5619	-1.1715	4.2953	
4	- 2	3.7033	0.3282	7.0785	***
3	- 4	-1.4511	-4.0770	1.1747	
3	- 1	0.1108	-1.7798	2.0014	
3	- 2	2.2522	-0.4854	4.9898	
1	- 4	-1.5619	-4.2953	1.1715	
1	- 3	-0.1108	-2.0014	1.7798	
1	- 2	2.1414	-0.6996	4.9824	
2	- 4	-3.7033	-7.0785	-0.3282	***
2	- 3	-2.2522	-4.9898	0.4854	
2	- 1	-2.1414	-4.9824	0.6996	

The GLM Procedure

Tukey's Studentized Range (HSD) Test for score

NOTE: This test controls the Type I experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	77
Error Mean Square	7.357711
Critical Value of Studentized Range	3.71378

Comparisons significant at the 0.05 level are indicated by ***.

Exp_grp Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
4 - 3	1.4511	-1.0951	3.9974	
4 - 1	1.5619	-1.0886	4.2125	
4 - 2	3.7033	0.4305	6.9762	***
3 - 4	-1.4511	-3.9974	1.0951	
3 - 1	0.1108	-1.7225	1.9441	
3 - 2	2.2522	-0.4024	4.9069	
1 - 4	-1.5619	-4.2125	1.0886	
1 - 3	-0.1108	-1.9441	1.7225	
1 - 2	2.1414	-0.6134	4.8963	
2 - 4	-3.7033	-6.9762	-0.4305	***
2 - 3	-2.2522	-4.9069	0.4024	
2 - 1	-2.1414	-4.8963	0.6134	

APPENDIX E: EXCEL ANOVA RESULTS

Anova: Two-Factor With Replication

SUMMARY	Exercise 1	Exercise 2	Total
2nd Experimental Run			
Count	8	8	16
Sum	36.53333	26.8	63.33333
Average	4.566667	3.35	3.958333
Variance	0.963175	1.078095	1.347333
4th Experimental Run			
Count	8	8	16
Sum	36.8	53.1	89.9
Average	4.6	6.6375	5.61875
Variance	0.460635	8.948393	5.497921
3rd Experimnetal Run (MIIS Students)			
Count	8	8	16
Sum	33.03333	48.56667	81.6
Average	4.129167	6.070833	5.1
Variance	0.122996	10.64585	6.030815
1st Experimental Run (NPS Students)			
Count	8	8	16
Sum	32.4	48.43333	80.83333
Average	4.05	6.054167	5.052083
Variance	0.423175	8.444742	5.209477
Total			
Count	32	32	
Sum	138.7667	176.9	
Average	4.336458	5.528125	
Variance	0.5087	8.264166	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	23.39674	3	7.798912	2.006986	0.123406	2.769433
Columns	22.72111	1	22.72111	5.847091	0.018881	4.012975
Interaction	30.95264	3	10.31755	2.655136	0.057232	2.769433
Within	217.6094	56	3.885883			
Total	294.6799	63				

Same Run as Above w/o 2nd Experimenatal Run

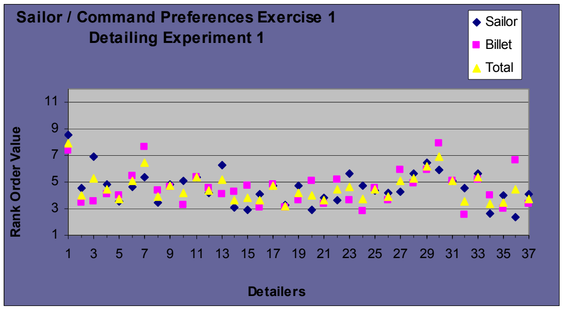
Anova: Two-Factor With Replication

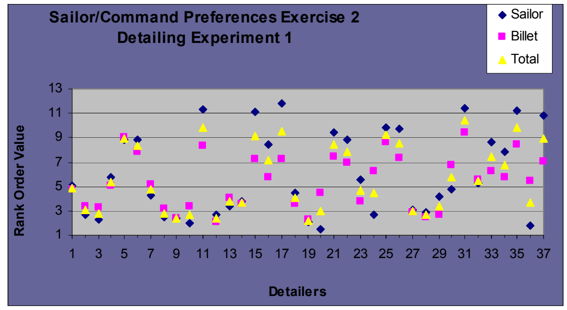
SUMMARY	Exercise 1	Exercise 2	Total
4th Experimental Run			
Count	8	8	16
Sum	36.8	53.1	89.9
Average	4.6	6.6375	5.61875
Variance	0.460635	8.948393	5.497921
3rd Experimnetal Run (MIIS Students)			
Count	8	8	16
Sum	33.03333	48.56667	81.6
Average	4.129167	6.070833	5.1
Variance	0.122996	10.64585	6.030815
1st Experimental Run (NPS Students)			
Count	8	8	16
Sum	32.4	48.43333	80.83333
Average	4.05	6.054167	5.052083
Variance	0.423175	8.444742	5.209477
Total			
Count	24	24	
Sum	102.2333	150.1	
Average	4.259722	6.254167	
Variance	0.367921	8.61032	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	3.160046	2	1.580023	0.326386	0.72334	3.219938
Columns	47.7337	1	47.7337	9.860368	0.003089	4.07266
Interaction	0.018935	2	0.009468	0.001956	0.998046	3.219938
Within	203.3206	42	4.840966			
Total	254.2332	47				

APPENDIX F: DETAILING EXPERIMENTS 1, 2, 3 AND 4 RESULTS

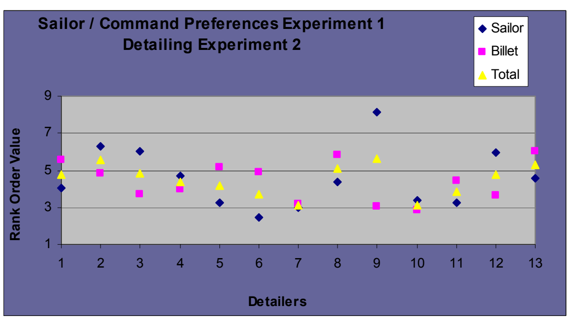


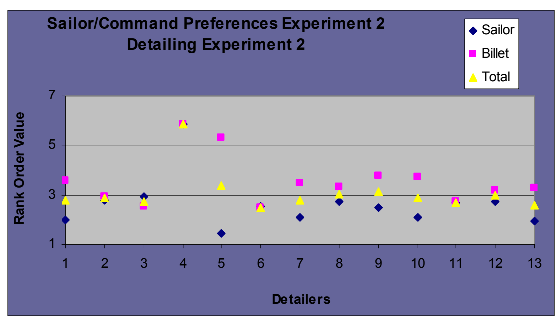


Detailing Experiment 1

Exercise 1	
Sailor Avg	4.61
Command Avg	4.55
Assignment Avg	4.58
Std Dev	1.048
Variance	1.099

Exercise 2	
Sailor Avg	6.03
Command Avg	5.39
Assignment Avg	5.71
Std Dev	2.717
Variance	7.382

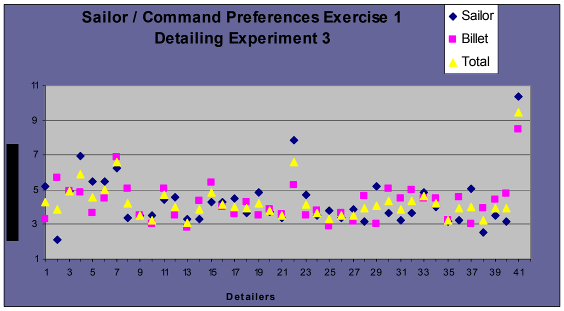


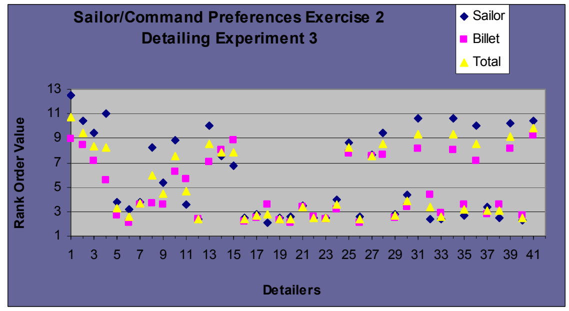


Detailing Experiment 2

Exercise 1	
Sailor Avg	4.58
Command Avg	4.41
Assignment Avg	4.49
Std Dev	0.848
Variance	0.72

Exercise 2	
Sailor Avg	2.64
Command Avg	3.56
Assignment Avg	3.10
Std Dev	0.8645
Variance	0.7473

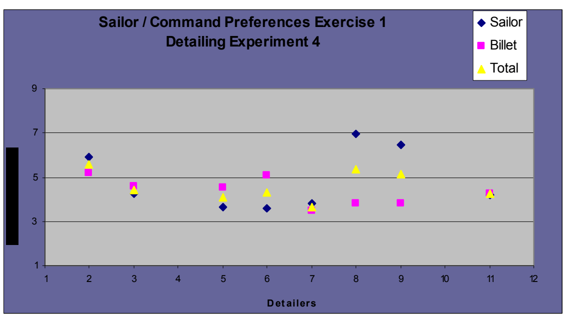




Detailing Experiment 3

Exercise 1	
Sailor Avg	4.33
Command Avg	4.28
Assignment Avg	4.30
Std Dev	1.119
Variance	1.253

Exercise 2	
Sailor Avg	5.74
Command Avg	4.87
Assignment Avg	5.30
Std Dev	2.881
Variance	8.302



Detailing Experiment 4

Experiment 1	
Sailor Avg	4.86
Command Avg	4.34
Assignment Avg	4.60
Std Dev	0.679
Variance	0.461

Experiment 2	
Sailor Avg	3.27
Command Avg	6.27
Assignment Avg	6.65
Std Dev	2.845
Variance	8.092

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