NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

ESTIMATING INTER-DEPLOYMENT TRAINING CYCLE PERFORMANCES

by

Levent Eriskin

December 2003

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REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** December 2003	**3. REPORT TYPE AND DATES COVERED** Master's Thesis	
4. TITLE AND SUBTITLE: Estimating Inter-Deployment Training Cycle Performances			**5. FUNDING NUMBERS**
6. AUTHOR(S) Eriskin, Levent			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES)			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200 words)

The objective of this thesis is to estimate Inter-Deployment Training Cycle (IDTC) performances of the US Pacific Fleet surface ships, which are evaluated at the end of the Basic Training Phase, by using Command Metrics Tool (COMET) metrics. The basic objective was primarily to decide whether the COMET database can be used to estimate performances of ships, and to build regression models to estimate Final Evaluation Problem (FEP) performances of ships.

This study develops multivariate logit regression models to examine and explore the structure of the data sets. Most of the models developed according to statistical criteria include only the intercept, indicating that there is no real relationship between the COMET metrics and IDTC performances. The assessments made at the end of FEP are not good Measure of Performances (MOPs) by which to assess ships' IDTC performances.

14. SUBJECT TERMS Inter-Deployment Training Cycle, Final Evaluation Problem, the Command Metrics Tool (COMET), Logistic Regression			**15. NUMBER OF PAGES** 69
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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ESTIMATING INTER-DEPLOYMENT TRAINING CYCLE PERFORMANCES

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Submitted in partial fulfillment of the
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MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

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The objective of this thesis is to estimate Inter-Deployment Training Cycle (IDTC) performances of US Pacific Fleet surface ships, which are evaluated at the end of the Basic Training Phase, by using Command Metrics Tool (COMET) metrics. The objective was primarily to decide whether the COMET database can be used to estimate the performances of ships, and to build regression models to estimate Final Evaluation Problem (FEP) performances of ships.

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LIST OF ACRONYMS

2M	Miniature/Microminiature
AFT	Afloat Training Group
AIC	Akaike Information Criterion
CART	Command Assessment of Readiness and Training
CHOP	Change of Command
CINC	Commander in Chief
CNSF	Commander Naval Surface Forces
COB	Current On Board
COMET	Command Metrics
COMPUTEX	Composite Unit Training Exercise
CSMP	Consolidated Ships Maintenance Project
CWC	Composite Warfare Commander
DLR	Depot Level Repairable
DUI	Driving Under the Influence
ESWS	Enlisted Surface Warfare Specialist
FEP	Final Evaluation Problem
FPFT	Force Protection Fundamentals Training
FY	Fiscal Year
GENDET	General Detail Sailor
IBFT	Integrated Battle Force Training
IDTC	Inter-deployment Training Cycle
IMA	Intermediate Maintenance Activity
ISIC	Immediate Superior In Command
JFTEX	Joint Task Force Exercise
LTC	Leadership Training Course
MEFEX	Marine Expeditionary Force Exercise
MOP	Measure Of Performance
NCPACE	Navy College Program for Afloat College Education
NJP	Non-Judicial Punishment

SGCP	Shipboard Gage Calibration Program
SSEW	Shipboard Security Engagement Weapons
SWO	Surface Warfare Officer
TSTA	Tailored Ship’s Training Assessment
TYCOM	Type Commander
UD	Underway Demonstration
VLS	Vertical Launching System

EXECUTIVE SUMMARY

It is important for the US Navy to make its ships ready for battle and deployment in a short period of time. After finishing their deployment, ships undergo an Inter-Deployment Training Cycle (IDTC), the aim of which is to make ships ready for their next deployment.

If areas that might make the ship fail the Final Evaluation Problem (FEP) in the Basic Training Phase could be determined before the FEP takes place, the ship would concentrate on these areas before encountering problems. As a result, this would increase a ship’s probability of passing the FEP.

The Command Metrics Tools (COMET) is a new database that holds ships’ measured effectiveness in various fields. Data collection started for all Pacific Fleet ships on 01 September 2001 and for all Atlantic Fleet ships on 01 May 2002. Metrics in the COMET database are updated periodically. In the study, the COMET metrics are used as independent variables.

At the end of the Basic Training Phase, ships are assessed during FEP according to mission areas defined in COMNAVSURFORINST 3502.1A (2003). Each mission area has certifications to be met. In the study, the proportion of certifications met for each warfare and mission area, representing the performance of a ship at FEP, was defined to be the response variable.

A total of 21 response variables (mission areas defined in COMNAVSURFORINST 3502.1A (2003)) and 44

independent variables (COMET metrics tracked in COMET) were used to build regression models. There were 51 ships in the data.

A logistic regression model was utilized to explain and explore the effect of the predictor variables on each FEP performance measurement. At the end of the study, it was seen that most of the response variables were modeled only by the intercept, indicating that the predictor variables are generally not very helpful for predicting the response variables.

I. INTRODUCTION

A. BACKGROUND

Aircraft carriers and cruisers deploy overseas for six-month periods. A typical battle group consists of one carrier, two assigned Aegis cruisers, a destroyer squadron (four destroyers and frigates), two submarines and an oiler/replenishment ship.

Each operating battle group typically completes a recurring cycle of events that culminates each time in deployment to the Fifth, Sixth or Seventh Fleet. After deployment, the Inter-Deployment Training Cycle (IDTC) normally begins when the ship is transiting to its homeport from overseas deployment. After a leave and upkeep period followed by local at-sea operations, the ship undergoes a planned depot-level maintenance availability, during which the majority of inter-deployment repairs and equipment upgrades occur. Upon returning to sea the ship works up for its next deployment by completing a series of training exercises and events which increase steadily in complexity as the crew’s operating proficiency increases.

The pre-deployment aspects of the IDTC are divided into three principal phases: basic, intermediate and advanced. COMNAVSURFORINST 3502.1A (2003) describes these phases as follows:

1. Basic Training Phase

The Type Commanders (TYCOMs) are responsible for the conduct of Basic Phase Training. The focus is on unit-level training emphasizing basic command and control, weapons employment, mobility (navigation, seamanship, damage control, engineering, and flight operations) and warfare specialty following overhaul or major maintenance availability and before Change of Command (CHOP) to the fleet commander. The basic training consists of Command Assessment of Readiness and Training II (CART II), the Tailored Ship’s Training Assessment (TSTA), Underway Demonstration (UD), and the Final Evaluation Problem (FEP).

2. Intermediate Training Phase

The Numbered Fleet Commanders are responsible for the conduct of intermediate phase training. The focus in this phase is on warfare team training and initial and multi-unit operations under the traditional Composite Warfare Commander (CWC) concept or a modified concept of joint operations. During this phase, ships begin to develop warfare skills in coordination with other units while continuing to maintain unit proficiency. The intermediate training phase consists of Marine Expeditionary Force Exercise (MEFEX) and Composite Unit Training Exercise (COMPUTEX).

3. Advanced Training Phase

The focus of the advanced training, also under the numbered fleet commander, is to continue to develop and refine integrated group warfare skills and command and control procedures needed to meet the supported Commander In Chief’s (CINC) specific mission requirements. The advanced training phase consists of the Joint Task Force Exercise (JTFEX).

The FEP is the third command assessment conducted by the Immediate Superior in Command (ISIC) and assisted by the Afloat Training Group (AFT) that determines a unit’s readiness to proceed to the intermediate and advanced phases of the IDTC. The FEP is conducted subsequent to the TSTA and is intended to demonstrate the ship's availability to conduct multiple simultaneous combat missions and support functions and to survive complex casualty control situations under stressful conditions, as well as demonstrate a capability to deploy. Table 1 is a pictorial representation of pre-deployment phases of the IDTC (COMNAVSURFORINST 3502.1A, 2003).

BASIC	**INTERMEDIATE**	**ADVANCED**
CART II TSTA UD FEP	MEFEX COMPUTEX	JFTEX

Table 1. Pre-Deployment Phases of The IDTC

By the completion of FEP, a ship needs to show that she is "surge ready," meaning that she is ready to move to intermediate and advanced training phases. This also means that she is immediately deployable as a unit for single operations or under the command of a numbered fleet commander.

COMNAVSURFORINST 3502.1A (2003) defines 21 different warfare and mission areas and their standards upon which the assessments of ISIC and AFT will be based. Each warfare and mission area has criteria that must be met by ships to be qualified in that specific area. Some areas do not apply to some classes of ships depending on the ships' mission. Table 2 provides the list of the required certifications listed by ship class (COMNAVSURFORINST 3502.1A, 2003).

REQUIRED BASIC PHASE CERTIFICATIONS	SHIP CLASS																
	AGF	AOE1	AOE6	ARS50	CG47	DD963	DDG51	FFG7	LCC	LHA	LHD	LPD4	LPD17	LSD36	LSD41/49	MCM	MHC51
AVIATION	X	X	X	X	X	X	X	X	X	X	X	X		X	X		
AMPHIBIOUS WARFARE										X	X	X		X	X		
AT/FP	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
AIR WARFARE	X	X	X		X	X	X	X	X	X	X	X		X	X		
COMMUNICATIONS	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
CRYPTOLOGY[1]	X				X	X	X	X		X	X						
ELECTRONIC WARFARE	X	X	X		X	X	X	X	X	X	X	X		X	X		
MEDICAL	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
DIVING AND SALVAGE				X													
INTELLIGENCE	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
COMBAT LOGISTICS		X	X							X	X						
MINE WARFARE																X	X
DAMAGE CONTROL	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
ENGINEERING	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
NAVIGATION	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
SEAMANSHIP	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
STRIKE WARFARE[2]					X	X	X										
SURFACE WARFARE	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
UNDERSEA WARFARE					X	X	X	X									
VBSS					X	X	X	X				X		X	X		
3M	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X

Table 2. Required Certifications Listed By Ship Class

[1] Not applicable to Flight (FL) I DDGs

[2] Vertical Launching System (VLS) ships only

The number of certifications met for each warfare and mission area at FEP, according to the criteria defined in the COMNAVSURFORINST 3502.1A (2003), represents the ship’s performance in that specific area. The average number of certifications met at FEP provides an assessment of the ship’s overall performance at FEP.

B. OBJECTIVES

The purpose of this thesis is to find estimators of performance of surface ships at Final Evaluation Problem (FEP). If areas that might make the ship fail the FEP in the Basic Training Phase could be determined before the FEP takes place, the ship could concentrate on those areas before encountering problems. As a result, this could increase a ship’s probability of passing the FEP.

The COMET metrics were intended to be used for estimation. The COMET is a snapshot of a ship’s measured effectiveness in various fields. Therefore, the main question became: “Can we find estimators among the COMET metrics to predict IDTC performances of ships?”

C. SCOPE, LIMITATIONS AND ASSUMPTIONS

The COMET originally was implemented on Pacific Fleet surface ships on 01 September 2001 and implemented on Atlantic Fleet surface ships on 01 May 2002. Being a new database, it has many missing values in it. Because of these missing values, some metrics could not be included in the analysis as predictors.

The metrics in the COMET database are updated periodically (http://extra.cnsp.navy.mil). Therefore, among those values which were taken prior to the FEP, the values taken closest to the FEP dates were used in this analysis. The database of the FEP dates of the ships includes only 51 ships. With this number the analysis is possible; however, more data points would give results with smaller variability.

As mentioned before, some warfare and mission areas apply to only specific classes of ships. Therefore, this analysis could not be performed for some mission and warfare areas in which too few ships underwent FEP of that type.

D. COURSE OF THE STUDY

This thesis is comprised of four chapters. Chapter II describes the data set and variable selection. The statistical models and techniques used in the analysis are also explained in this chapter. Chapter III focuses on the logit regression analysis. Chapter IV summarizes the conclusions of the analysis and presents recommendations for further study.

II. DATA AND METHODOLOGY

A. VARIABLE SELECTION

1. Dependent Variables

In this study, the dependent variables are the FEP performances of ships. At the end of the Basic Training Phase, ships are assessed during FEP according to warfare and mission areas listed in Table 2 and defined in COMNAVSURFORINST 3502.1A (2003). Each warfare and mission area has certifications to be met. In the analysis, the proportion of certifications met for each mission area was used as the response variable, representing the performance of a ship in that specific area at FEP. The total performance of a ship was defined to be the proportion of certifications met for all areas at FEP. The AFT, which assists ISIC to conduct the FEP assessment, keeps track of these data. The data used in the analysis were provided by AFT Pacific and consist of 51 assessments made between 15 March 2002 and 15 July 2003.

The Diving and Salvage Mission Area could not be modeled because this area was added to the new version of the Training Manual (COMNAVSURFORINST 3502.1A, 2003), and data for this area were not available.

There were only two ships to which the Mine Warfare Mission Area applied. Due to the lack of data for this area, this variable could not be modeled.

2. Independent Variables

In the study, the COMET metrics were used to represent independent variables. The COMET is a new database that keeps ships' measured effectiveness in various fields, which was implemented on Pacific Fleet surface ships on 01 September 2001 and for Atlantic Fleet surface ships on 01 May 2002. Metrics in the COMET database can be reached from Commander Naval Surface Force, Pacific Fleet web page (http://extra.cnsp.navy.mil), and are updated online periodically at the ship level. Each metric has different periodicity. Areas currently tracked in the COMET database are:

a. Personnel

b. Legal

c. Dental

d. Medical

e. Safety

f. Supply

g. Maintenance and engineering

h. Information resources and combat systems

i. Training and readiness

j. Warfare readiness

k. Miscellaneous (Ship-gathered data) (http://extra.cnsp.navy.mil).

Some of the metrics were excluded because they were considered to be irrelevant to the analysis. Some metrics were also excluded because they had many missing values. The independent variables and their descriptions are listed in Appendix A.

B. METHODOLOGY

1. Logit Regression

The goal of any regression analysis is to find the best fitting and most parsimonious and reasonable model by which to describe the relationship between an outcome (dependent or response) variable and a set of explanatory (independent or predictor) variables (Hamilton, 1992). Linear regression models are appropriate for measurement response variables. However, many research questions, especially in social and medical science, involve trying to predict whether something will happen. These kinds of questions involve two-category (dichotomous) variables, which describe whether something will happen or will not happen. What distinguishes logistic regression models from linear regression model is that logistic regression handles dichotomous response variables.

In order to define the relationship between two measurement variables *X* and *Y*, we use mathematical models. One simple relationship can be expressed as linear relationship: $Y = \beta_0 + \beta_1 X$. In this equation β_0 represents the *Y* intercept and β_1 represents the slope. According to this equation *X* is the predictor of *Y*. However, more realistically in data analysis, we should only claim that the expected value of *Y* given *X* changes linearly with *X*, which can be expressed as follows : $E[Y \mid X] = \beta_0 + \beta_1 X$. In this case, β_0 equals the mean of *Y* when *X* = *0*. Since all models are constructed over some assumptions, there is an error embedded in them. This error is the difference between the expected value and the observed value:

$$\varepsilon = Y - \beta_0 - \beta_1 X$$
$$= Y - E[Y \mid X] \tag{2.1}$$

Therefore, the actual Y can be expressed as the sum of the expected value and error term:

$$Y = E[Y \mid X] + \varepsilon$$
$$= \beta_0 + \beta_1 X + \varepsilon \tag{2.2}$$

In logistic regression models, the response variable is bounded inside (0, 1). In order to model an outcome with this property, the logit function is utilized:

$$l(x) = log_e\left(\frac{P(x)}{1 - P(x)}\right) \tag{2.3}$$

In this equation, logits range from $-\infty$ to $+\infty$ while $P(x)$ ranges from 0 to 1.

Logit regression models can be expressed as follows:

$$l(X_i) = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + ... + \beta_{n-1} X_{i,n-1} \tag{2.4}$$

In this model, $l(x)$ is a continuous linear function of predictor variables $(\boldsymbol{X})$, while $P(x)$ is a continuous nonlinear function with an S-shape. $P(x)$ approaches, but never reaches, the boundaries of 0 and 1.

Predicted probabilities can be computed by inverting the logit function:

$$\hat{P} = \frac{1}{1 + e^{-l(x)}} \tag{2.5}$$

Logit regression models have many of the desirable properties of linear regression models. The most important one is the linear relationship between the logits $(l(x))$ and the predictor variables $(\boldsymbol{X})$.

Although estimation strategies differ, logit regression requires some of the same assumptions as linear regression models. Hamilton (1992) enumerates these assumptions as follows:

> 1. The model is specified correctly. For logit regression this means that true conditional probabilities are a logistic function (or, logits are a linear function) of the *X* variables. No important variables are omitted, and no extraneous variables are included. *X* variables are measured without error.
>
> 2. The cases are independent.
>
> 3. None of the *X* variables are linear functions of the others. Perfect multicollinearity makes estimation impossible; strong multicollinearity makes estimates imprecise. (Hamilton, 1992, p.225)

These assumptions must be checked in order to validate the model. According to Hamilton (1992), if these conditions are met, maximum likelihood estimates of the logit parameters should theoretically have the desirable properties of approximate unbiasedness, efficiency, and normality, in sufficiently large samples.

In this study, response variables are the proportions of certifications met for each warfare area. Since the response variables are restricted to [0,1], logit regression was utilized, enabling prediction of the response variables without violating the boundaries.

2. Stepwise Regression and Akaike Information Criterion (AIC)

One of the biggest challenges in multiple regression analysis is to decide which predictors are strong predictors of the response variable. Especially after including the interactions among predictors into the model, the set of predictors can become huge, and therefore, the challenge is harder to meet.

Stepwise search helps to overcome this challenge. “Stepwise regression” is a way of performing an automated stepwise search procedure. There are two techniques used in this procedure (Hamilton, 1992, p.83):

a. Forward Inclusion

The model starts with no predictors in it. At each step, the predictor whose addition improves the model most with respect to the criterion is added to the model.

b. Backward Elimination

The model starts with all predictors included in it. The predictor whose deletion improves the model with respect to the criterion is removed at each step.

The Akaike Information Criterion (AIC) is a stepwise search criterion developed to be utilized in stepwise regression. The AIC can be expressed as follows (Venables & Ripley, 2002, p.174):

$$AIC = -2 . l(\boldsymbol{\beta}, \boldsymbol{X}) + 2 . p \tag{2.6}$$

where $l(\boldsymbol{\beta}, \boldsymbol{X})$ represents the maximized log likelihood function and p represents the number of parameters in the model. $\boldsymbol{\beta}$ is the $p \times 1$ regression parameter vector and $\boldsymbol{X}$ is the $n \times p$ design matrix.

In stepwise regression, the predictors whose addition will decrease the AIC most, and the predictor whose deletion will decrease the AIC most, are found, and the step producing the largest decrease is taken. If no step can decrease the AIC, the procedure halts. As can be seen from Equation 2.6, the AIC criterion looks for a good fit, while imposing a penalty on the number of variables in the model. This enables the stepwise search technique to find a good-fitting and parsimonious model which, while not necessarily optimal, describes the relationship between the predictor variables and response variable.

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III. ANALYSIS

A. PRELIMINARY DATA ANALYSIS

One of the assumptions of logit regression models is that none of the predictors is a linear combination of the others. Collinearity refers to a linear relationship between two predictor variables while a linear relationship among three or more predictors is defined as multicollinearity. In the presence of perfect collinearity or multicollinearity it is not possible to determine the effect of a predictor on the response variable. Excluding one of these variables will entail no loss because a perfect relationship implies perfect redundancy (Hamilton, 1992).

In order to detect the linear relationships among predictors, correlations among predictors and a scatter plot matrix were examined. A relationship was defined as significant when a correlation coefficient was observed to be greater than 0.6 or less than -0.6 ($\rho_{X_1X_2}$ > 0.6 and $\rho_{X_1X_2}$ < -0.6). Significant linear relationships among predictors for sample size of 51 are as follows:

Predictor Pair	**Correlation Coefficient**
weig.main.met – Op.factor	0.847
main.metric - backlog	-0.623
repairs.2M – cost.avo.2M	0.699

Table 3. Significant Linear Relationships Among Predictors

Figure 1 is a scatter plot of **Weighted Maintenance Metric** versus **Operational Factor**. The scatter plot figure indicates a positive linear relationship between these two predictors which is also quantified by the correlation coefficient ($\rho_{X_1X_2}$=0.847). This positive linear relationship can be explained by the fact that **Weighted Maintenance Metric** is calculated as the product of **Operational Factor** and **Maintenance Metric**. Therefore big **Weighted Maintenance Metric** values occur with big **Operational Factor** values.

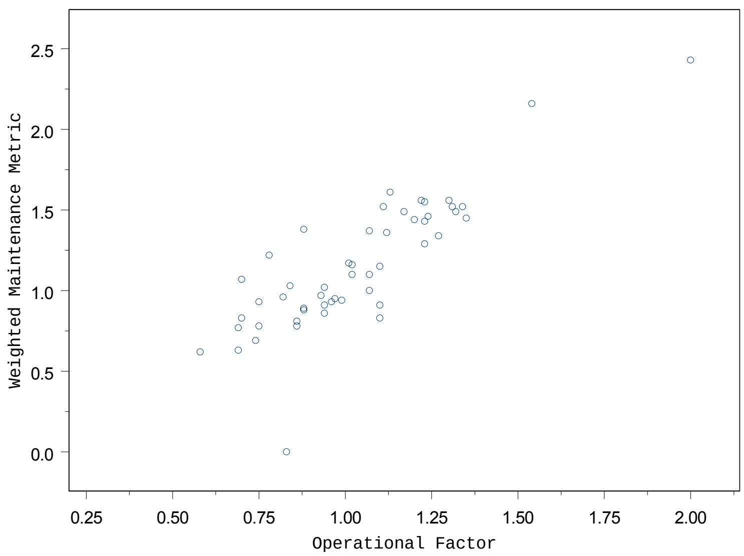

Figure 1. Scatter Plot of **Operational Factor** vs. **Weighted Maintenance Metric**

Figure 2 is a scatter plot of **Backlog** versus **Maintenance Metric**. **Maintenance Metric** is calculated as follows:

$$Maintenance\ Metric = \frac{1}{2}(X+Y+Z+W+Q) \tag{2.7}$$

where X is the **Backlog Ratio**, Y is the **Self Sufficiency Ratio**, Z is the **T/A 4 Jobs Older Than Three Months Ratio**, W

is the **Ship's Force and AIMD Costs Ratio**, and Q is the **Mean Total Time to Correct Ratio**.

Calculation of **Backlog Ratio** varies depending on whether the **Backlog** is above the **Backlog** average for the ship's class or below it. If the **Backlog** is above the class average, then

$$Backlog\ Ratio = \frac{Backlog}{Class\ Backlog\ Average} \tag{2.8}$$

If not, then

$$Backlog\ Ratio = \left(\left(\frac{Class\ Backlog\ Average}{Backlog}\right)(-1) + 2\right) \tag{2.9}$$

Both of these equations yield positive **Backlog Ratios** and they both decrease when **Backlog** increases. **Backlog Ratio** is one of the additive terms in **Maintenance Metric** formula, for which, a small **Backlog Ratio** is associated with a small **Maintenance Metric** value.

The correlation coefficient suggests a negative linear relationship between these two variables ($\rho_{X_1X_2}$=-0.623). However, the scatter plot suggests that this relationship is nonlinear.

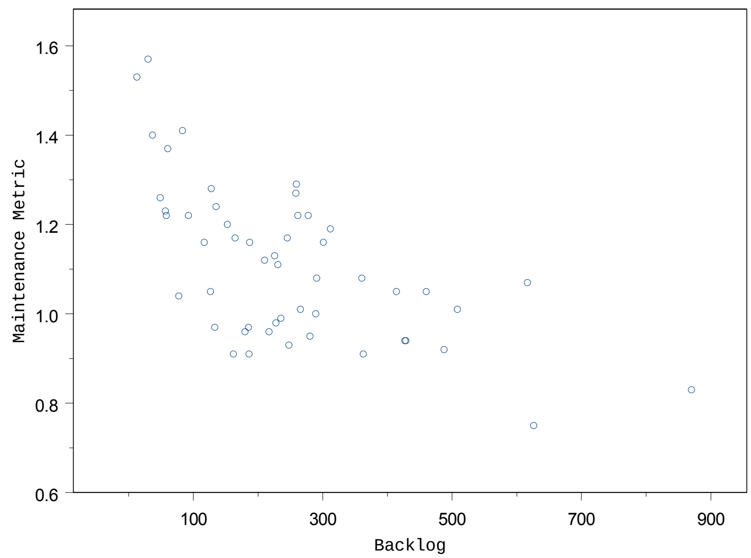

Figure 2. Scatter Plot of **Backlog** vs. **Maintenance Metric**

Figure 3 represents the scatter plot of **Number of 2M Repairs** vs. **Cost Avoidance 2M.** The plot suggests a positive linear relationship between these two predictors ($\rho_{X_1X_2}$=0.699). A 2M part is a Miniature/Microminiature part such as a transistor, diode and a resistor which is used onboard most surface ships. This relationship can be explained by the fact that a 2M cost is avoided by repairing a 2M part onboard a ship. Therefore, when more parts are repaired onboard a ship, more 2M cost is avoided.

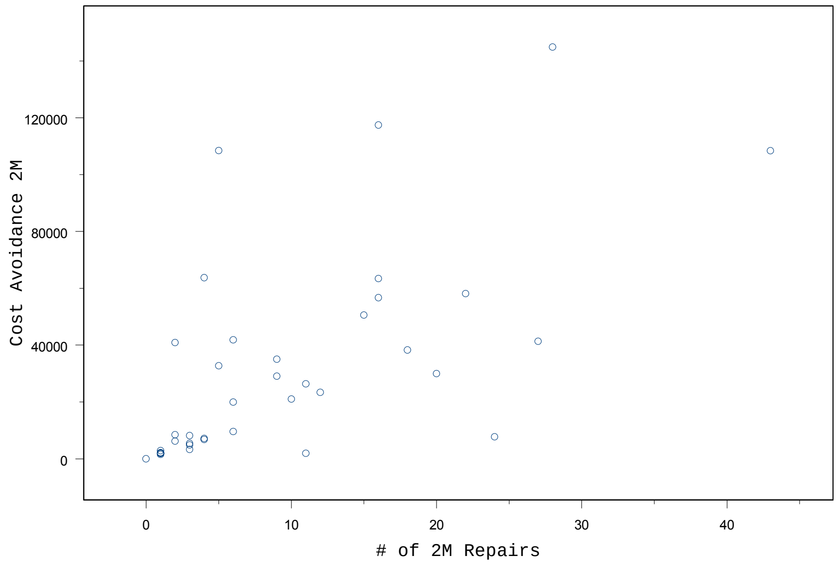

Figure 3. Scatter Plot of # **of 2M Repairs** vs. **Cost Avoidance 2M**

The multicollinearity analysis showed that there are only three significant multicollinearities among the predictor variables. Therefore, it can be expected that estimation should not be affected by multicollinearity.

B. MULTIVARIATE ANALYSIS

Multivariate modeling analyzes the effects of individual independent variables on the response variable while holding the effects of other variables constant. Response variables in the analysis were the proportions of certifications met for all warfare and mission areas and the total proportion of certifications met for all warfare and mission areas. Since the response variables had values between [0, 1], multivariate logistic regression techniques were used in the analysis.

The software package S-Plus® 6.1 was used to build logistic regression models. A stepwise model selection procedure with the AIC criterion was used to determine which predictor variables and two-way interactions were significant in estimating the response variables. Because we sought parsimonious models, the forward inclusion technique was used in stepwise regression. After developing the models, diagnostics were checked and influence analysis was performed. Table 5 summarizes the regression models built to estimate response variables.

RESPONSE VARIABLE	COEFFICIENT	VALUE	STD. ERROR	t VALUE	RESID. DEV.
Aviation	intercept	18.249	13.691	1.332	2.670
	E4.adv	-0.184	0.163	-1.131	
Amph. Warf.	intercept	1.677	0.792	2.116	2.800
Anti-terror. Force Protections	intercept	35.611	15.859	2.245	10.993
	TA4.3	-0.048	0.024	-1.692	
	MTTT	-0.020	0.009	-2.101	
	E4.adv	-0.054	0.033	-1.650	
	net.effect	-0.073	0.046	-1.589	
Air Warfare	intercept	2.365	0.504	4.685	7.747
Comms.	intercept	3.725	0.923	4.032	4.297
Crypt.	intercept	3.244	1.097	2.957	3.488
EW	intercept	3.038	0.670	4.532	8.256
Medical	intercept	69.909	80.661	0.866	0.052
	dental.health	-1.017	1.199	-0.848	
Intelligence	intercept	9.071	4.534	2.000	7.209
	gross.effect	-0.087	0.061	-1.427	
Combat Logis.	intercept	3.178	2.282	1.392	0.678
Damage Control	intercept	2.968	0.655	4.525	7.149
Engineering	intercept	4.274	1.203	3.551	4.219
Navigation	intercept	3.337	0.769	4.338	7.332

Seamanship	intercept	3.122	0.696	4.482	6.852
Strike Warfare	intercept	1.596	1.065	1.499	2.121
	repairs.2M	0.507	0.571	0.888	
Surface Warf.	intercept	2.760	0.592	4.663	6.794
Undersea Warfare	intercept	1.612	0.701	2.298	7.767
	DUI	3.126	2.845	1.098	
Visit, Board, Search and Seizure	intercept	6.774	4.030	1.680	6.305
	SSEW	0.082	0.041	1.975	
	E5.adv	-0.196	0.107	-1.827	
	FPFT	0.095	0.058	1.623	
	ZoneB.reen	-0.061	0.041	-1.480	
Force Maintenance and Material Management	intercept	-235.29	455.251	-0.516	0.003
	drug.test	4.381	9.289	0.471	
	gross.effect	2.163	4.829	0.448	
Total	Intercept	0.593	0.412	1.440	9.501
	DUI	1.009	0.782	1.290	

Table 4. Logit Regression Results for the Response Variables

Residual deviance is the measure of fit used in logit regression, which gets smaller as the model fits better to the data.

Eleven out of 20 models built by using logit regression included only the intercept in the predictor set, which indicates that, in those cases, the COMET predictions were not helpful for estimating the response variables. The means of those response variables (the proportions of positive responses) which had only the intercept in the model were the best predictors by which to estimate those variables (β_0 equals the mean of Y when X = 0). Since the proportions were transformed by the logit function, the means of these response variables are estimated by:

$$\overline{y} = \frac{1}{\left(1+e^{-intercept}\right)} \tag{2.10}$$

The reasons that the COMET predictions were not helpful for estimating the response variables are the lack of data on a large number of ships and apparent unrelatedness of COMET metrics to FEP assessments. The criteria assessed at FEP are very specific, which as a result may not reflect ships' performances on these mission and warfare areas. Most of the assessments vary between 0.7 and 1.0. Additionally, there are some mission and warfare areas for which all of the certifications were met by all ships. Without having variation in the assessments, it is impossible to build models to estimate ships' performances for these mission and warfare areas.

The effects of the predictors on the response variables can be best examined by looking at conditional effect plots. Conditional effect plots are built by plotting one predictor versus response variable while holding the other predictors at their mean values. These plots show how a change in the value of a predictor affects the response variable. A linear relationship between predictors and logits $l(x)$ implies a curvilinear relationship between predictors and response variables (proportion of certifications met).

Figure 4 is the conditional effect plot of **Percentage of Eligible E-4 Advancements** versus **Proportion of Certifications Met for Aviation Mission Area**.

According to the conditional effect plot, the more eligible E-4 advancements a ship has, the smaller is the expected proportion of certifications met for the aviation mission area.

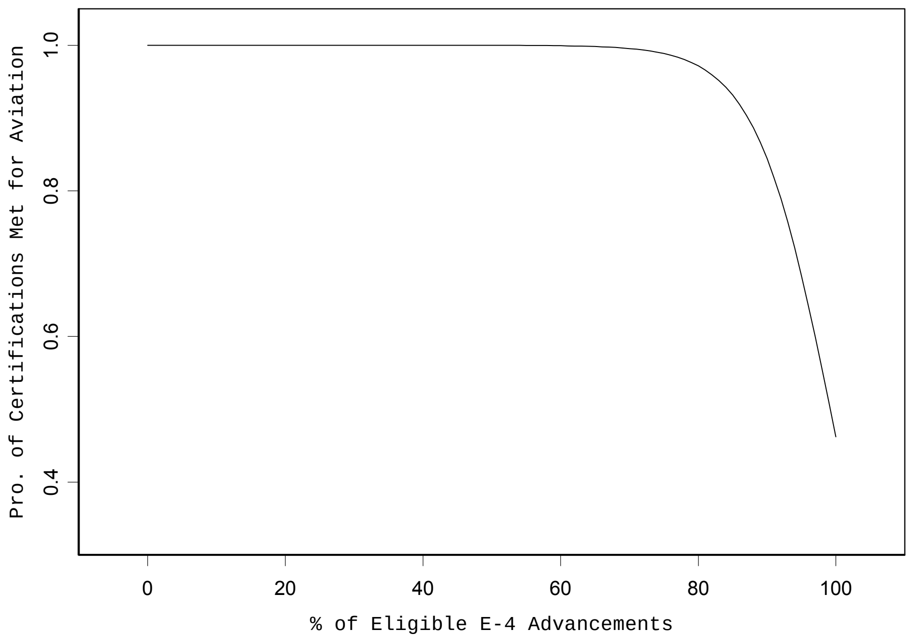

Figure 4. Conditional Effect Plot of **% Eligible E-4 Advancements** vs. **Proportion of Certifications Met for Aviation Mission Area**

The Proportion Met For the Aviation Mission Area goes down most steeply when percentage of advancements varies between 70 and 100. However, having eligible E-4 advancements means having more qualified E-3 personnel. Common intuition says that, this would have a positive effect on the Aviation mission area, which as a result, would increase the certifications met for this area.

The Anti-Terrorism/Force Protection Mission Area was modeled by **% of Open 2Ks Older than 3 Months with Type Availability 4**, **Mean Total Time to Correct**, **% of Eligible**

E-4 Advancements and **Net Effectiveness**. Figures 5, 6, 7, 8 and 9 are the conditional effect plots of these predictor variables versus **the Proportion of Certifications Met For the Anti-Terrorism/Force Protection Mission Area**.

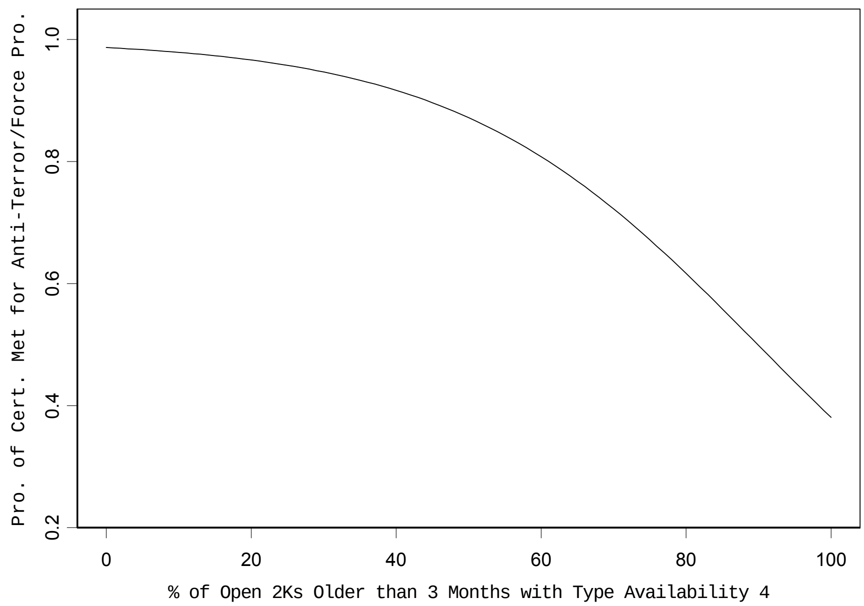

Figure 5. Conditional Effect Plot of **% of Open 2Ks Older than 3 Months with Type Availability 4** vs. **Proportion of Certifications Met for Anti-Terror/Force Protection Mission Area**

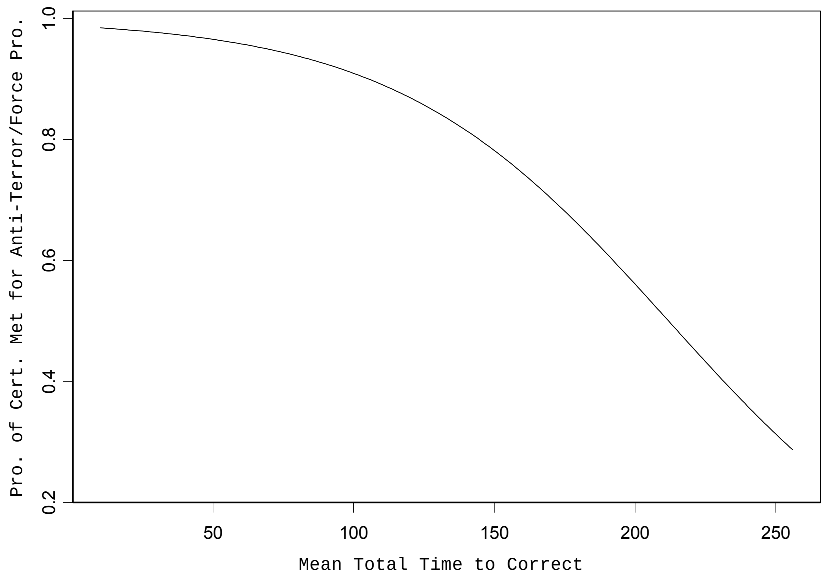

Figure 6. Conditional Effect Plot of **Mean Total Time to Correct** vs. **Proportion of Certifications Met for Anti-Terror/Force Protection Mission Area**

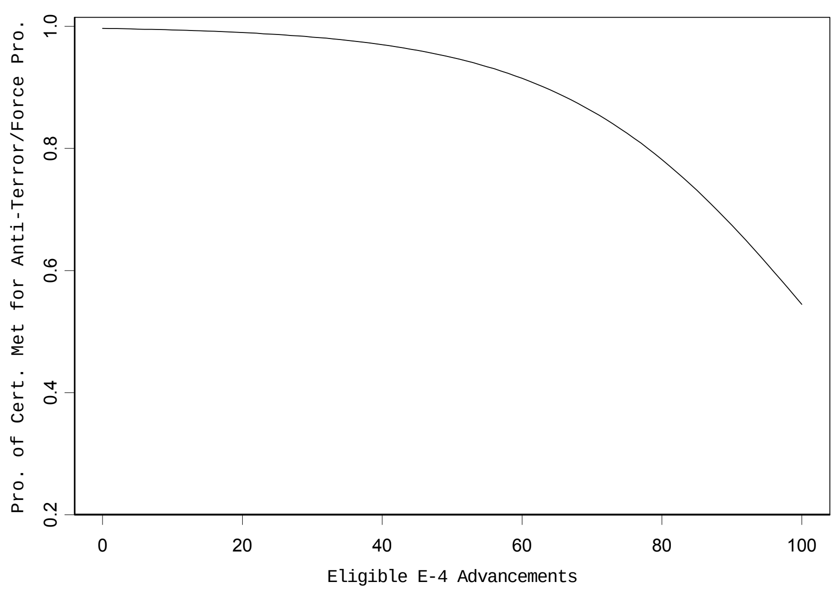

Figure 7. Conditional Effect Plot of **% of Eligible E-4 Advancements** vs. **Proportion of Certifications Met for Anti-Terror/Force Protection Mission Area**

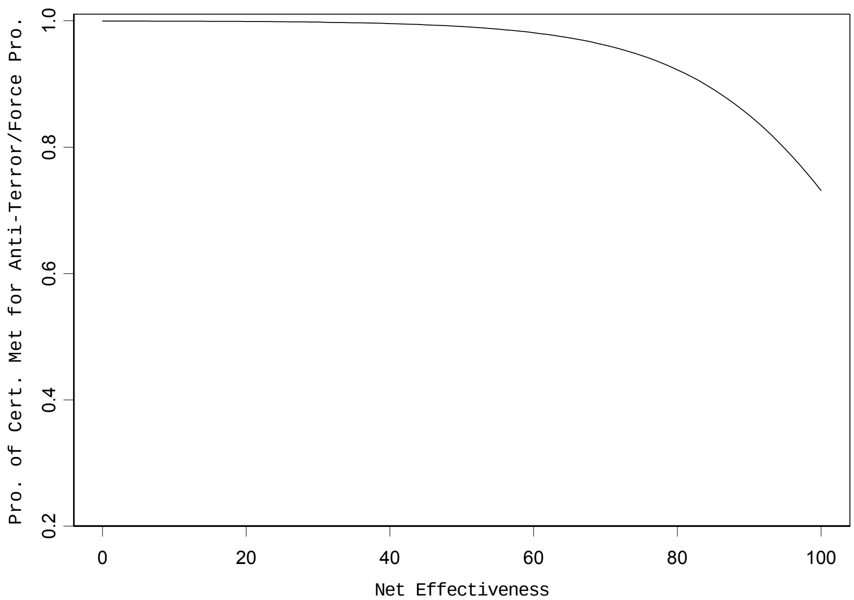

Figure 8. Conditional Effect Plot of **Net Effectiveness** vs. **Proportion of Certifications Met for Anti-Terror/Force Protection Mission Area**

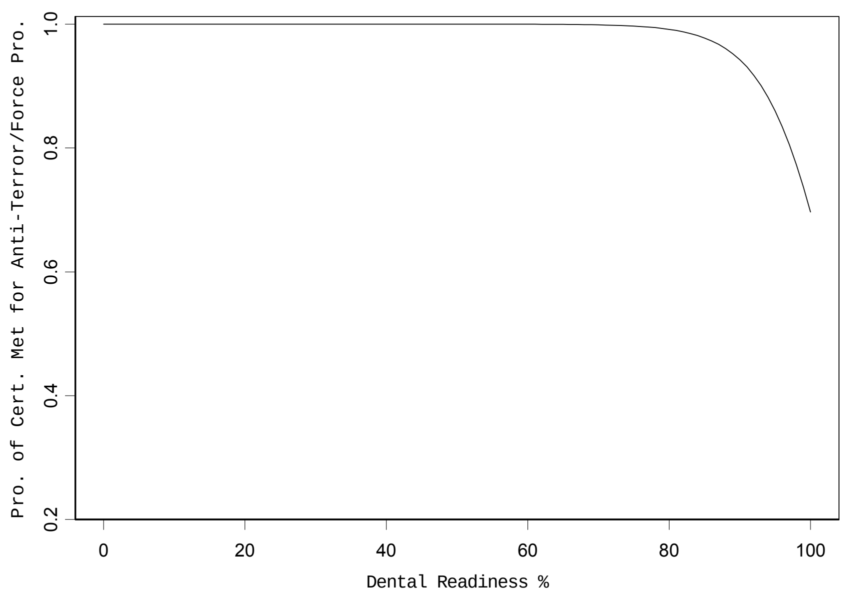

Figure 9. Conditional Effect Plot of **Dental Readiness %** vs. **Proportion of Certifications Met for Anti-Terror/Force Protection Mission Area**

The coefficients of these predictors are negative, meaning that high values of these predictors are associated with low values of the response variable, meaning that, the more **% of Open 2Ks Older than 3 Months with Type Availability 4**, **Mean Total Time to Correct**, **% of Eligible E-4 Advancements** and **Net Effectiveness** a ship has, the smaller the proportion of certifications expected to be met for Anti/Terror Force Protection Mission Area. s

The conditional effect plot of **Dental Readiness %** is steeper within the range (80,100). This means small increases in this predictor variable within these ranges are associated with big changes in the **Proportion Met For Anti-Terror/Force Protection Mission Area.**

Medical certification criterion was modeled by the **Dental Health %.** Figure 10 is the conditional effect plot of **Dental Health %** versus **Proportion of Certifications Met For Medical Mission Area.**

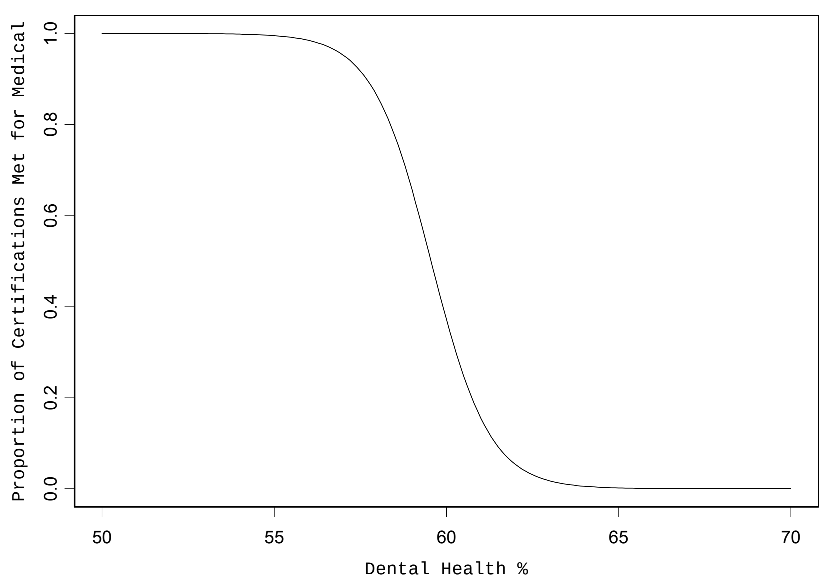

Figure 10. Conditional Effect Plot of **Dental Health %** vs. **Proportion of Certifications Met for Medical Mission Area**

The coefficient of this predictor is -1.017, which means high **Dental Health %** values are associated with a low proportion value for the Medical mission area. This model is a good example of how the predictor set and response variables are not related. According to COMNAVSURFORINST 3502.1A (2003) there are no requirements in the Medical mission area regarding the **Dental Health %**. Therefore, a relationship between Medical Mission Area and **Dental Health %** is not reasonable.

Figure 11 is the conditional effect plot of **Gross Effectiveness %** versus **Proportion of Certifications Met For Intelligence Mission Area**.

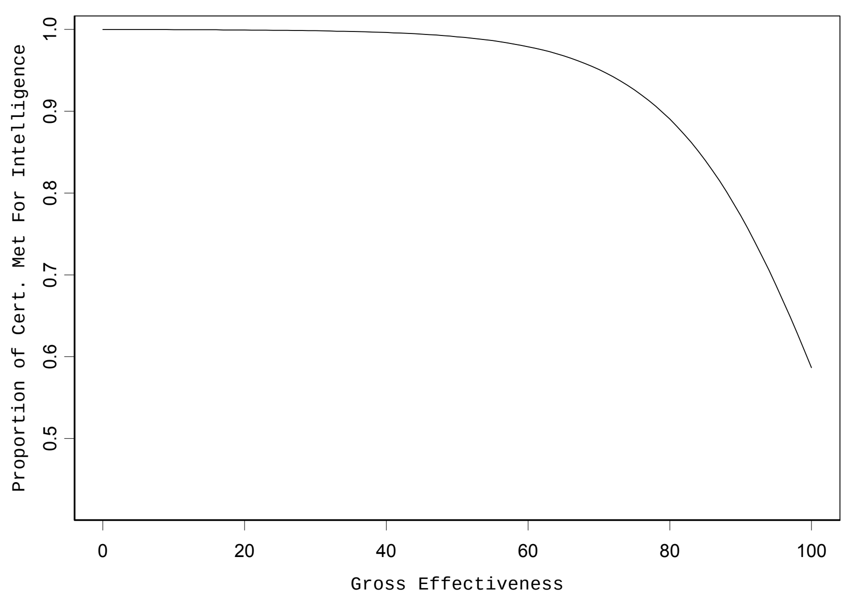

Figure 11. Conditional Effect Plot of **Gross Effectiveness** vs. **Proportion of Certifications Met for Intelligence Mission Area**

This conditional plot suggests that the better the gross effectiveness a ship has, the smaller the number of Intelligence certifications expected to be met.

The Strike Warfare certification criterion was modeled by **Number of Repairs 2M**. Figure 12 is the conditional effect plot of **Number of Repairs 2M** versus **Proportion of Certifications Met For the Strike Warfare Area**.

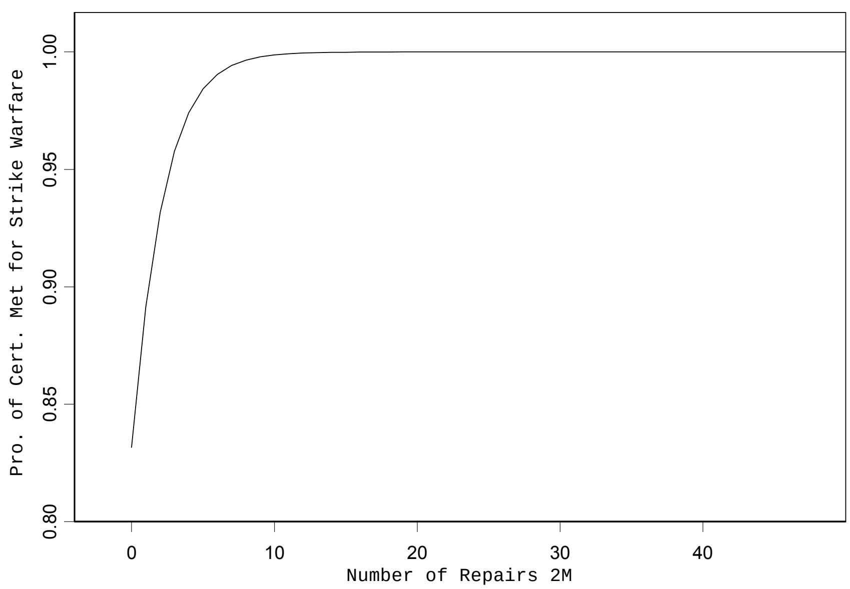

Figure 12. Conditional Effect Plot of **Number of Repairs 2M** vs. **Proportion of Certifications Met for Strike Warfare Certification Criteria**

Number of Repairs 2M had a positive coefficient in the model. The conditional effect plot also reveals that a high values of the **Number of Repairs 2M** are associated with a high proportion for the Strike warfare area. This relationship appears to be more strong within the range of (0, 10) repairs. After having made 10 repairs, more repairs made will not have a big effect on the proportion.

Undersea warfare area model was modeled by the **DUI**. Figure 13 is the conditional effect plot of **DUI** versus **Proportion of Certifications Met For Undersea Warfare Area**.

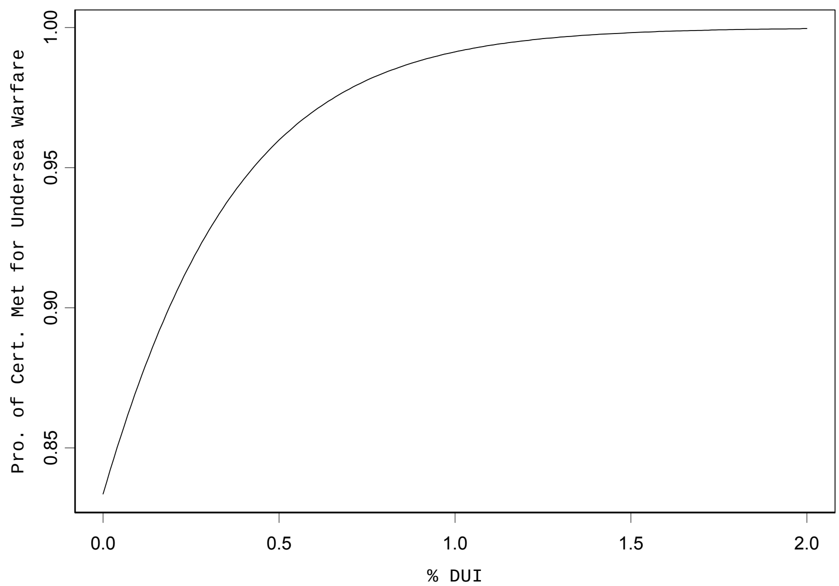

Figure 13. Conditional Effect Plot of **% DUI** vs. **Proportion of Certifications Met for Undersea Warfare Certification Criteria**

Conditional effect plot suggests that high values of the % of DUI are associated with a high proportion for Undersea warfare area. However, estimating Undersea warfare performance with % of **DUI** is not a reasonable approach because there is no requirement in the Undersea warfare area regarding the % of **DUI** (COMNAVSURFORINST 3502.1A, 2003, p. 2-4-S-1).

Visit, Board, Search and Seizure mission area was modeled by **% of SSEW Billets Complete**, **% of Eligible E-5 Advancements**, **% FPFT Billets Complete and Reenlistment % Zone B**. Figures 14, 15, 16 and 17 are conditional effect plots of these predictor variables.

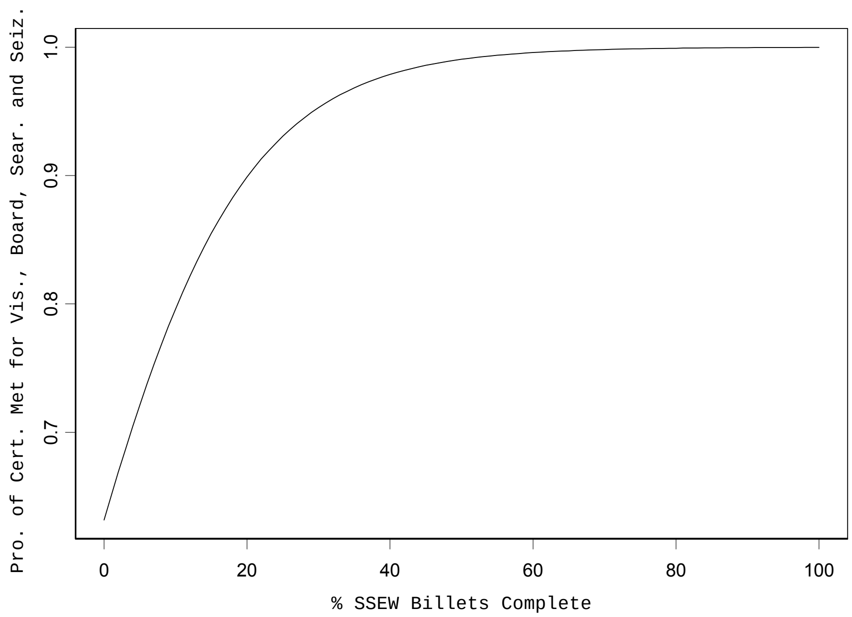

Figure 14. Conditional Effect Plot of **% SSEW Billets Complete** vs. **Proportion of Certifications Met for Visit, Board, Search and Seizure Mission Area**

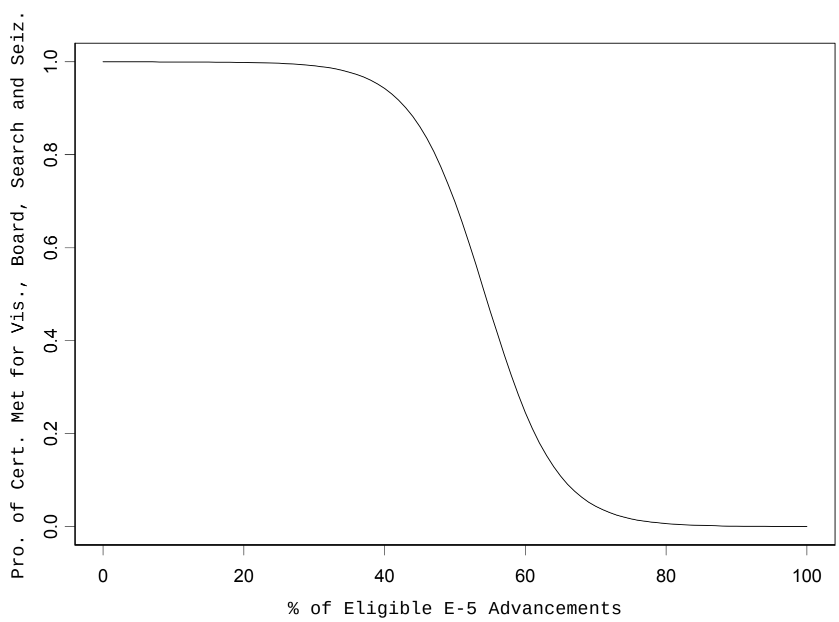

Figure 15. Conditional Effect Plot of **% of Eligible E-5 Advancements** vs. **Proportion of Certifications Met for Visit, Board, Search and Seizure Mission Area**

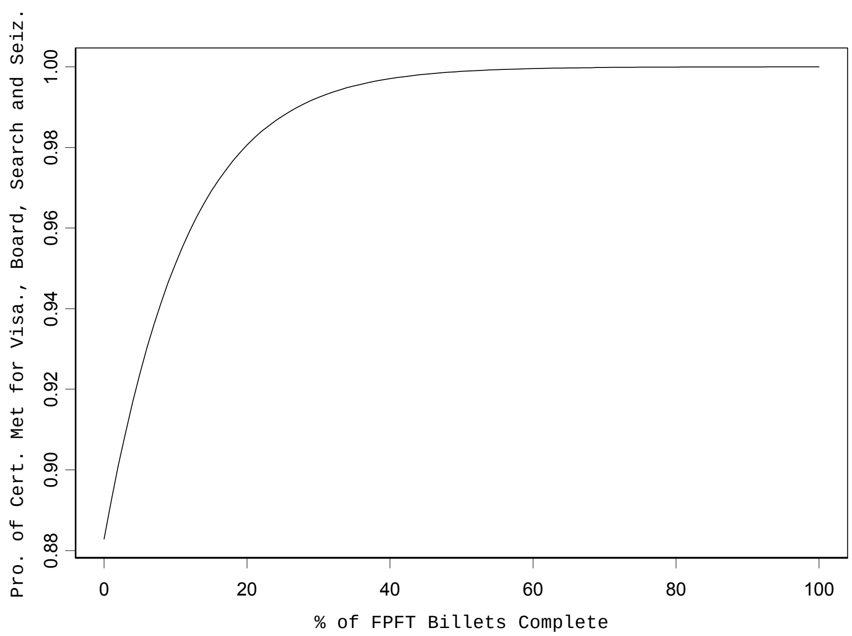

Figure 16. Conditional Effect Plot of **% of FPFT Billets Complete** vs. **Proportion of Certifications Met for Visit, Board, Search and Seizure Mission Area**

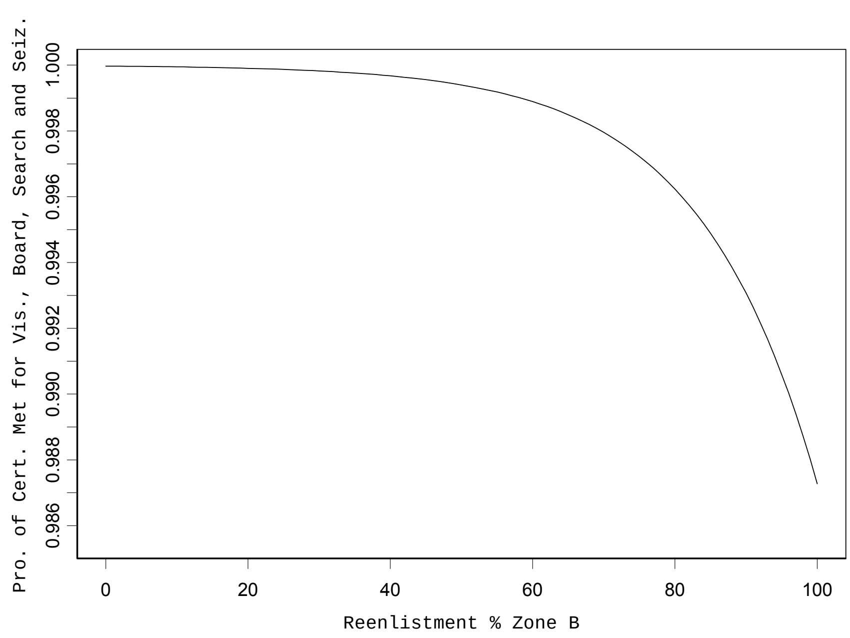

Figure 17. Conditional Effect Plot of **Reenlistment % Zone B** vs. **Proportion of Certifications Met for Visit, Board, Search and Seizure Mission Area**

Among the predictors, **% of Eligible E-5 Advancements** and **Reenlistment % Zone B** have negative coefficients while **% of SSEW Billets Complete** and **% FPFT Billets Complete** have positive coefficients. Therefore, high values of the **% of Eligible E-5 Advancements** or **the Reenlistment % Zone B** are associated with a low proportion for Visit, Board, Search and Seizure mission area, while high proportion for Visit, Board, Search and Seizure mission area is associated with high values of the latter two.

The conditional effect curves of **% SSEW Billets Complete**, **% FPFT Billets Complete** and **Reenlistment % Zone B** are not steep, which suggest that big increases in the values of **% SSEW Billets Complete**, **% FPFT Billets Complete** and **Reenlistment % Zone B** change are associated with small decreases in the proportion met for Visit, Board, Search and Seizure Mission Area. However, the conditional effect curve of **% Eligible E-5 Advancements** is much steeper, especially within the ranges (40,80). Therefore, a small decrease in the **% Eligible E-5 Advancements** within this range is associated with a big increase in the **Proportion Met for Visit, Board, Search and Seizure Mission Area**.

Force Maintenance and Material Management mission area was modeled by **Commander Naval Surface Forces (CNSF) Drug Testing Standard Unit Performance** and **Gross Effectiveness.** Conditional effect plots of these variables are as follows:

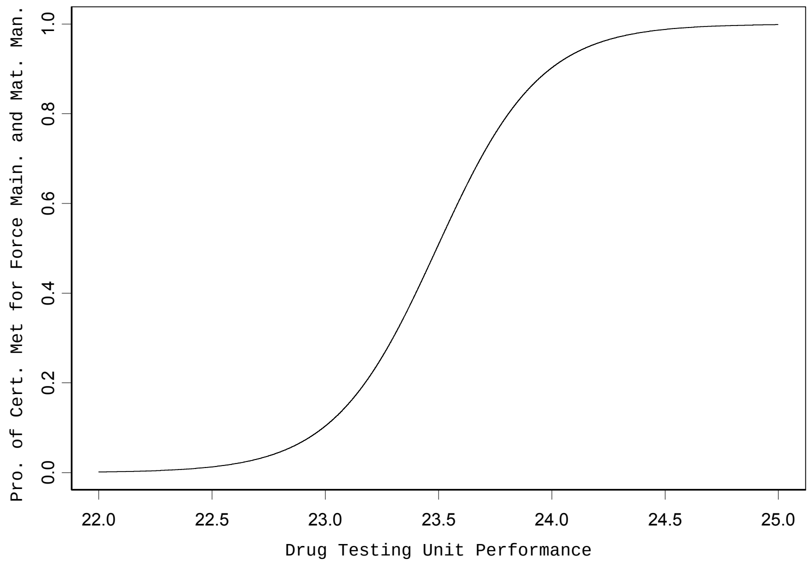

Figure 18. Conditional Effect Plot of **Drug Testing Unit Performance** vs. **Proportion of Certifications Met for Force Maintenance and Material Management Mission Area**

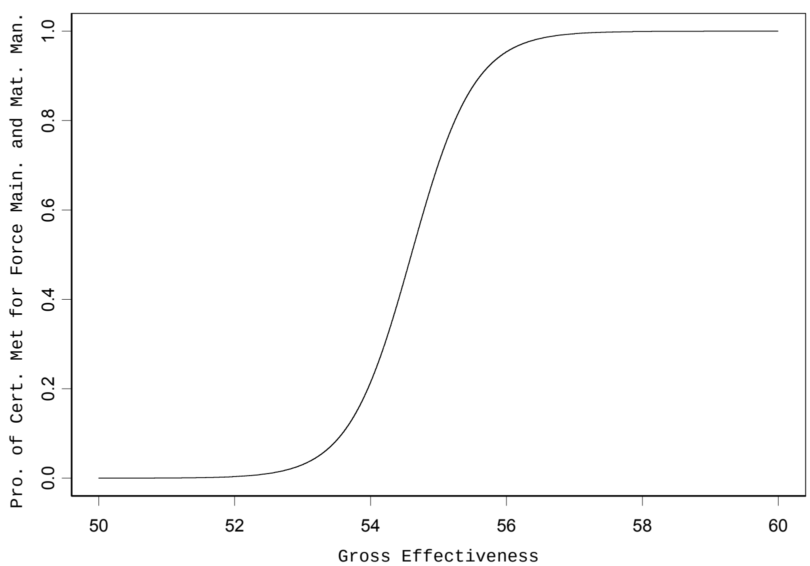

Figure 19. Conditional Effect Plot of **Gross Effectiveness** vs. Proportion of Certifications Met for Force Maintenance and Material Management Mission Area

Both of these variables have positive coefficients, which mean high values of these variables are associated with high proportion for Force Maintenance and Material Management mission area. The curves are much steeper within ranges (23,24) for **Drug Testing Unit Performance** and within ranges (53,57) for **Gross Effectiveness**, meaning that small increases within these ranges are associated with big increases in the **Proportion of Certifications Met For Force Maintenance and Material Management Mission Area.** On the other hand there are only 13 observations for this mission area; therefore, a small sample size like this may not yield reasonable inferences. Both conditional effect plots show a sigmoidal shape. The reason for this is that there are only two values in the response variable: 1.0 and 0.0.

The proportion of total number of certifications met for all warfare and mission areas represents ships' total performance at FEP. This response variable was modeled by **DUI**. Figure 29 is the conditional effect plot of **% of DUI** versus **Proportion of Total Number of Certifications Met.**

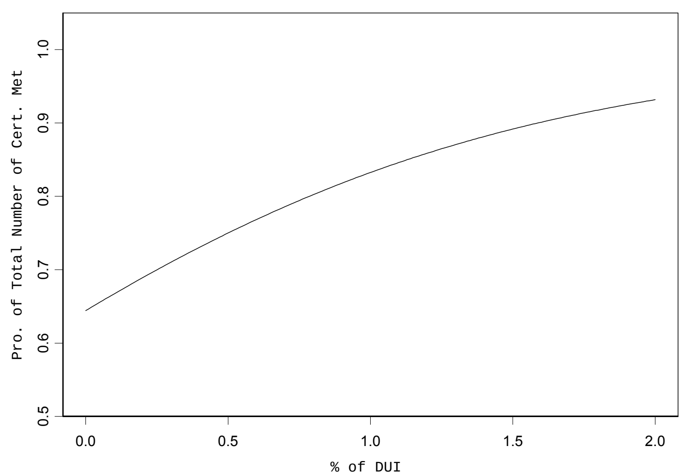

Figure 20. Conditional Effect Plot of **% of DUI** vs. **Proportion of Total Number of Certifications Met**

The fact that **Proportion of Total Number of Certifications Met** was modeled by **DUI** only is also a good indication of anomalies in the data. None of the mission areas includes a criterion regarding the **DUI** (COMNAVSURFORINST, 2003, pp. 2-4-A-1 – 2-4-U-4). Additionally, **% DUI** varies between (0,2), which is a very small interval indicating that variation in this metric is very small. This model, like some other models, does not provide a reasonable estimating technique.

C. INFLUENCE ANALYSIS

A case is influential if its deletion substantially changes the regression results. Influential cases are not necessarily outliers, influence results from a particular combination of values on all variables in the regression. In order to find the influential cases, the ΔB statistic which measures the standardized change in estimated parameters (b_k) that result from deleting all cases with the jth X pattern was considered. ΔB_j can be expressed as follows:

$$\Delta B_j = \frac{{r_j}^2 h_j}{(1-h_j)^2} \tag{2.11}$$

where h_j is the leverage of the jth case and r_j is the Pearson residual. A large value of ΔB_j indicates that the jth pattern exerts substantial influence. According to Hamilton (1992, p.236), case j is influential if $\Delta B_j \geq 1$.

Plots of ΔB of mission and warfare areas were examined to detect influential cases. Two models with highly influential cases were found in the data. Having a ΔB value of 5.52, USS PEARL HARBOR was the most influential case in the Medical mission area model. A graph of ΔB is shown in Figure 21.

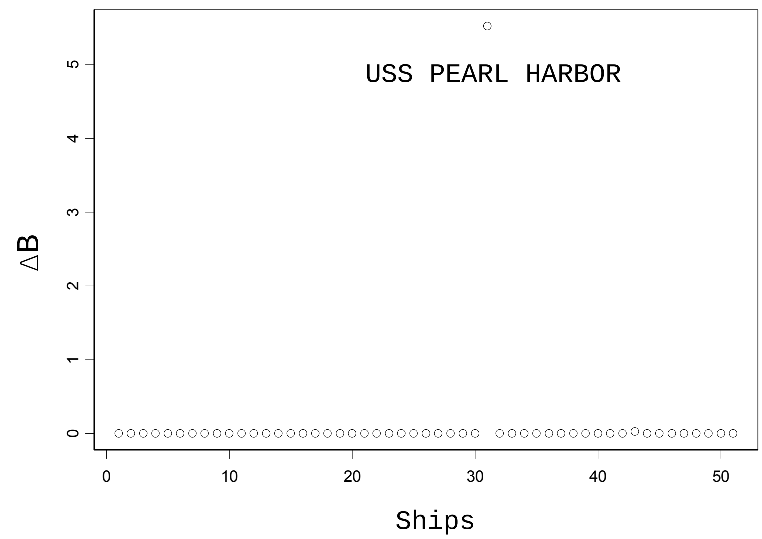

Figure 21. Influence Statistic ΔB vs. Ships for Medical Mission Area

The USS PEARL HARBOR was the most influential case in the Medical mission area because she is the only ship having a proportion other than 1.0 (her value is 0.67). The rest of the ships have a medical proportion of 1.0. Therefore, deleting her from the model makes the model invalid and making predictions impossible because in that case all of the proportions for this mission area would be 1.0.

The other influential case was the USS LAKE ERIE in the Force Maintenance and Material Management mission area model. It had a ΔB statistic of 6.574. Figure 22 represents the influence diagnostic graph for the Force Maintenance and Material Management mission area.

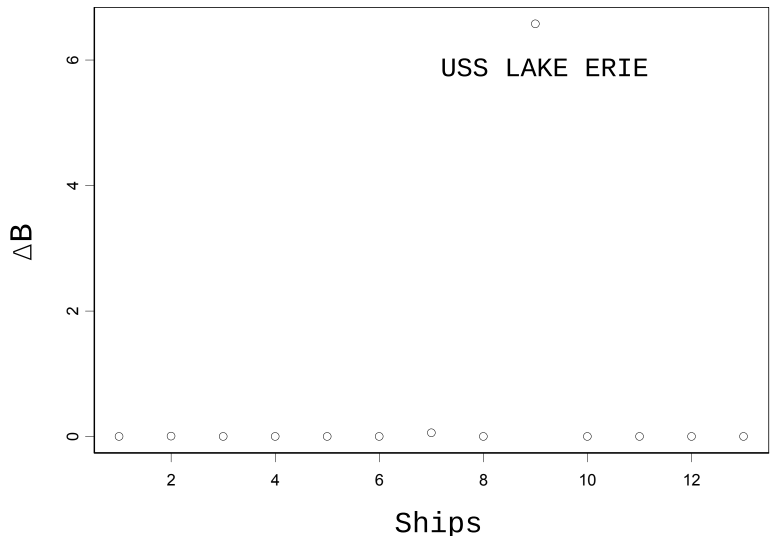

Figure 22. Influence Statistic ΔB vs. Ships for Force Maintenance and Material Management Mission Area

There are 13 observations for this mission area and two proportions are achieved by ships: 0.0 and 1.0. Plot of these values on two predictor axes is as follows:

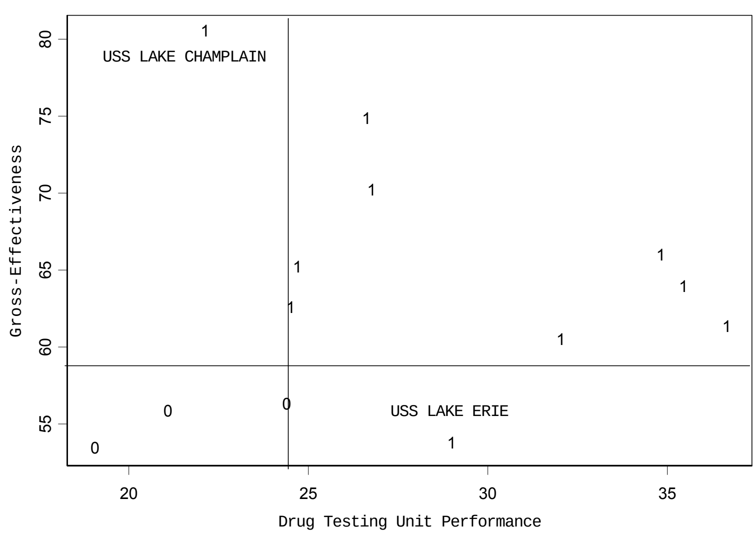

Figure 23. Force Maintenance and Material Management Values on Predictor Axis

This diagnostic graph suggests that Force Maintenance and Material Management mission area could have been modeled with **Gross Effectiveness** only if the data had not included the USS LAKE ERIE in this mission area. Then it would have been possible to suggest that a ship whose **Gross Effectiveness** value is more than 59 is likely to achieve 1.0 effectiveness proportion for Force Maintenance and Material Management mission area at FEP.

Similarly, without having the USS LAKE CHAMPLAIN in data, it would have been possible to model Force Maintenance and Material Management mission area only with **Drug Testing Unit Performance**. This would have yielded a conclusion that a ship whose **Drug Testing Unit Performance** is greater than 24.5 is likely to achieve a 1.0 proportion for the Force Maintenance and Material Management mission area at FEP.

There are two reasons for having these influential cases. One of them is that there are not enough data points to make strong inferences about the models and cases. When the number of data points increases, the influential cases tend to have less influence on the model due to variation. The other reason is that proportions met for most of the mission and warfare areas tend to be close to 1.0. As a result, a ship having a smaller proportion for a mission and warfare area compared to other ships makes a substantial influence on the model.

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IV. SUMMARY, LIMITATIONS AND RECOMMENDATIONS

The purpose of this thesis was to estimate IDTC performances of the US Pacific Fleet surface ships, which are evaluated at the end of the Basic Training Phase, by using the COMET metrics. Proportions of certifications met for each mission and warfare area were used as indicators of performances of ships at FEP. Therefore, in the analysis, these were the response variables which were intended to be modeled by using regression models. The metrics in the COMET data base were used as independent variables by which to estimate the response variables. Since the response variables are bounded in [0,1], logistic regression was used to build models. In order to determine which predictor variables were strong estimators of the response variables, stepwise regression techniques were utilized. The AIC was used to determine independent variables and two-way interactions to be added and deleted. Having developed the models, influence analysis was performed and diagnostics were checked.

Eleven out of 20 models built by using multivariate logistic regression model included only the intercept in the predictor set. The other nine models included at most four independent variables as predictors for the response variables. Considering that the data set included 44 independent variables, it can be concluded that, in general, COMET metrics are not helpful to estimate FEP performances of ships.

The data consist of 44 metrics from the COMET data base and 22 assessments from the FEP (21 for mission and warfare areas, one for proportion of total number of certifications met for all mission and warfare areas) for 51 ships. The number of ships in the data was sufficient enough to perform the analysis; however, data for more ships might yield more reasonable answers.

Each warfare and mission area has criteria that must be met by ships in order to be qualified in that area. Some areas do not apply to all classes of ships based on mission. The Diving and Salvage mission area could not be modeled because this area was added to the new version of the Training Manual (COMNAVSURFORINST 3502.1A, 2003) which was effective on 07 April 2003, and data for this area was not available due to the lack of ARS type of ships having undergone FEP up to the time of the analysis. Additionally, there were only two ships to which the Mine Warfare mission area applied. Due to the lack of data for this area, this area could not be modeled as well.

According to COMNAVSURFORINST 3502.1A (2003), almost all of the mission and warfare areas have, as a certification requirement, that all relevant personnel complete (or have a plan for completion of) schooling required for that area. However, none of the models included FPFT (% Force Protection Fundamentals Training Billets Complete) and IBFT (Integrated Battle Force Training % Complete) as predictors. Normally, these metrics would be expected to be in the predictor sets of most of the models.

Even if some of the predictor variables seem to be irrelevant for a mission and warfare area or the mission and warfare area does not have a requirement regarding these kinds of predictors, some of the areas were modeled by these irrelevant predictor variables. The reason for this is that the requirements for mission and warfare areas are very specific, which as a result may not reflect a ship’s performance for that area.

Most of the assessments for mission and warfare areas tend to range from 0.7 to 1.0. Additionally, there are some mission and warfare areas for which all of the certifications are met by all ships. Therefore, most of the response variables’ means are very high; some are even 1.0. Without having variation in the assessments, it is impossible to build models to estimate ships’ performances for these mission and warfare areas.

In the future, this kind of an analysis can be performed by using the COMET database and using some other MOP (Measure Of Performance). Also including US Atlantic Fleet Surface ships will increase the size of the data, which would help the analysis. The biggest challenge in this analysis is to find the best MOP by which to represent ships’ IDTC performances. The assessments based on grades in those mission and warfare areas would be the best MOP to estimate and to build models.

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APPENDIX A. INDEPENDENT VARIABLES

VARIABLE NAME	**VARIABLE**	**DESCRIPTION**
DLR.oblig	Current FY DLR % Obligation	The percentage that Depot Level Repairable (DLR) carcass charges (the charge for not returning the broken unit to the repair facility) comprise of the total DLR obligations (money spent) for a given Fiscal Year (FY).
DUI	% DUI’s	Average percentage of ship’s crew that were adjudged a Driving Under Influence (DUI) over the last four quarters.
E4.adv	% of Eligible E-4 Advancements	The percentage of rank E-3 crew eligible to advance to rank E-4.
E5.LTC.comp	E-5 LTC Completion	The percentage of rank E-5 crew completed Leadership Training Course.
E5.adv	% of Eligible E-5 Advancements	The percentage of rank E-4 crew eligible to advance to rank E-5.
E6.LTC.comp	E-6 LTC Completion	The percentage of rank E-6 crew completed Leadership Training Course.
E6.adv	% of Eligible E-6 Advancements	The percentage of rank E-5 crew eligible to advance to rank E-6.
E7.LTC.comp	E-7 LTC Completion	The percentage of rank E-7 crew completed Leadership Training Course.
E7.adv	% of Eligible E-7 Advancements	The percentage of rank E-6 crew eligible to advance to rank E-7.
ESWS	% ESWS Qualified Sailors	The percentage of Enlisted Surface Warfare Specialist (ESWS) recipients among all the sailors that are required to be qualified.
FPFT	% FPFT Billets Complete	The percentage of all Force Protection Fundamentals Training (FPFT) requirements completed. Each ship class has different requirement for this training.
IBFT	IBFT % Complete	The percentage of all Integrated Battle Force Training (IBFT) requirements completed.
OP.factor	Op Factor	Operational Factor. Represents a ship’s operation tempo or underway time. Big values of Operational Factor are associated with long underway times.

SSEW	% SSEW Billets Complete	The percentage of all Shipboard Security Engagement Weapons (SSEW) Training requirements completed. Each ship class has different requirement for this training.
TA.4.3	T/A 4>3 Months	The percentage of open 2Ks older than 3 months with type availability 4. 2K is a maintenance form generated when a discrepancy is observed onboard a ship. Type availability 4 refers to the maintenance performed by the ship's crew.
Uri.sweep	# of Urinalysis Sweep	Unit sweeps include drug testing of all personnel assigned to the command. The urinalysis data is a rolling 12-month window for the period June 2002-May 2003. This is the total samples divided by the Current On Board (COB). For each multiple of 70% the ship gets credit for 1 unit sweep.
ZoneA.att	Attrition % Zone A	The percentage of attrition in Zone A. Zone A refers to sailors with 0 to 6 years of active service.
ZoneA.reen	Reenlistment % Zone A	The percentage of reenlistment in Zone A. Zone A refers to sailors with 0 to 6 years of active service.
ZoneB.reen	Reenlistment % Zone B	The percentage of reenlistment in Zone B. Zone B refers to sailors with 7 to 10 years of active service.
ZoneC.reen	Reenlistment % Zone C	The percentage of reenlistment in Zone C. Zone C refers to sailors with 11 to 14 years of active service.
Backlog	Backlog	The number of deferred failures in a ship's Consolidated Ships Maintenance Project (CSMP).
form.cour.req	# of Unfilled Formal Course Requirements	Number of unfilled school quotas required by the Surface Training Manual.
com.cal.read	Combat Calibration Readiness	The percentage of shipboard general/special purpose electronic test equipment current in regards to their calibration periodicity.
com.pack	# of Commissioning Packages	The number of commissioning packages submitted during the current fiscal year.
comp.col.cour	% of Crew Completing College Courses	Total number of college courses completed in fiscal year 2003.

cost.avo.2M	2M Cost Avoidance	Total cost avoided by repairing 2M (Miniature/ Microminiature) parts onboard the ship in a quarter.
dental.health	Dental Health %	The percentage of the crew having Class 1 dental status. Personnel with a dental status of either Class 1 or 2 have minimal dental disease conditions and are considered ready for deployments where dental support may not be available.
dental.read	Dental Readiness %	The percentage of the crew with a Class 1 or 2 dental status. Personnel with a dental status of either Class 1 or 2 have minimal dental disease conditions and are considered ready for deployments where dental support may not be available.
drug.test	Commander Naval Surface Forces (CNSF) Drug Testing Standard Unit Performance	Total number of urinalysis sweeps divided by the COB for each month. This is totaled and divided by 12 to determine the rolling 12 month average for the period June 2002-May 2003.
eng.cal.read	Engineering Calibration Readiness	The percentage of shipboard engineering gages, meters, and associated Shipboard Gage Calibration Program (SGCP) equipment current regards to their calibration periodicity.
fail.col.cour	% of Crew Failing College Courses	The total number of college course failures for all the Navy College Program for Afloat College Education (NCPACE) offered courses on the ship in fiscal year 2003.
for.IMA.cost	Ship Force and IMA Costs	18 month average of the total Intermediate Maintenance Activity (IMA) man-hours times the IMA labor rate plus the Total Replacement Cost of all repair parts ordered. IMA is a military organization specializes in the repair of certain pieces of equipment.
gendets	# General Detail Sailors (GENDETS) to A-School	The number of undesignated permanent ship's crew sent to an A-School. A-School Core courses include general knowledge and skills training for the particular rating, while A-School Strand courses focus on the more specialized training requirements for that rating and a specific aircraft or equipment, based on the student's fleet activity destination.
gross.effect	Gross Effectiveness %	Issue percentage of repair parts from stock base on total demands. The low-gross effectiveness means that the range of stock is insufficient.

Comp.col.cour	% of Crew Completing College Courses	Total number of NCPACE delivered college courses completed in fiscal year 2003.
maint.metric	Maintenance Metric	This metric is calculated by summing Self Sufficiency Ratio, Mean Total Time to Correct Ratio, Ships Force and IMA Costs Ratio, Backlog Ratio, and T/A 4>6 Months metric and then dividing this value by 5. Number is scaled between 0 and 2. High values of this metric are desired.
mast.cases	% Mast Cases	Average percentage of the ship's crew that received Non-Judicial Punishment (NJP) over the last four quarters.
net.effect	Net Effectiveness %	Issue percentage of repair parts from stock. The low-net effectiveness means the depth of stock is insufficient.
random.comp	Monthly Random Compliance	Urinalysis Sweep of randomly selected personnel on board. This is the total number of samples divided by COB for the most recent month. If this is greater than CNSF standard of 20%, then the ship is in compliance.
repairs.2M	# of Repairs 2M	Total number of 2M parts repaired onboard the ship in a quarter.
self.suff	Self Sufficiency	18 month average of Status 2 and 3 failures corrected by ship's force divided by the total number of Status 2 and 3 failures corrected by ship's force. Status 2 failure is one that results in the equipment being inoperable. Status 3 failure is one that results in the degradation of the equipments capability.
SWO	% SWO Qualified Officers	The percentage of Surface Warfare Officer (SWO) qualified officers among all the officers required to be SWO qualified.
MTTT	Mean Total Time to Correct	18 month average of calendar days between discovery of the failure and the completion of the 2K. 2K is a maintenance form generated when a discrepancy is observed onboard a ship.
weig.main.met	Weighted Maintenance Metric	Maintenance metric multiplied by the Op Factor.

Table 5. Independent Variables and Descriptions

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