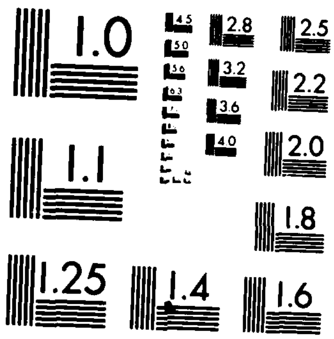
AD-A170 904 MODELING AND INTERPRETING CONSTRUCTION PRODUCTION DATA: 1/1
A REGRESSION APPROACH(U) AIR FORCE INST OF TECH
WRIGHT-PATTERSON AFB OH C B BOHNE 1986
UNCLASSIFIED AFIT/CI/NR-86-104T F/G 13/13 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD-A170 904

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFIT/CI/NR 86-104T	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Modeling and Interpreting Construction Production Data: A Regression Approach		5. TYPE OF REPORT & PERIOD COVERED THESIS/~~DISSERTATION~~/
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Christopher Bryan Bohne		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS AFIT STUDENT AT: The Ohio State University		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS AFIT/NR WPAFB OH 45433-6583		12. REPORT DATE 1986
		13. NUMBER OF PAGES 81
14. MONITORING AGENCY NAME & ADDRESS(If different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLAS
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

DTIC ELECTE AUG 1 3 1986 S D E

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

APPROVED FOR PUBLIC RELEASE: IAW AFR 190-1

Lynn Wolaver 6 Aug 86
LYNN E. WOLAVER
Dean for Research and Professional Development
AFIT/NR

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

ATTACHED.

DTIC FILE COPY

86 8 12 040

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

MODELING AND INTERPRETING CONSTRUCTION PRODUCTION DATA:

A REGRESSION APPROACH

A Thesis

Presented in Partial Fulfillment of the Requirements for

the degree Masters of Science in the

Graduate School of the Ohio State University

by

Christopher Bryan Bohne, BSCE

* * * * *

The Ohio State University

1986

Master's Examination Committee:

Richard E. Larew

Paul A. Thompson

Fabian C. Hadipriono

Approved by

Adviser

Department of Civil Engineering

THESIS ABSTRACT

THE OHIO STATE UNIVERSITY
GRADUATE SCHOOL

NAME: Bohne, Christopher Bryan QUARTER/YEAR: WI/1986

DEPARTMENT: Civil Engineering DEGREE: Master of Science

ADVISER'S NAME: Larew, Richard E.

TITLE OF THESIS: Modeling and Interpreting Construction Production Data: A Regression Approach

This thesis examines elevated concrete slab production data from a high-rise building. The importance of collecting pertinent information during construction is discussed.

A nine step approach is presented as a methodology for analyzing construction data by linear regression.

Examples are given to show how analysis results may be used in the evaluation of alternative construction methods and in deciding the number of workers to be assigned to a crew.

Adviser's Signature

ACKNOWLEDGEMENTS

This author would like to thank Dr. Paul Thompson and Dr. Fabian Hadipriono for their help in the preparation of this thesis. A special thanks to Dr. Larew for his support and guidance throughout the author's masters program. Dr. Larew combines a unique blend of knowledge and genuine concern for the construction industry and his students.

The United States Air Force deserves credit for seeing the value of an educated, quality force. Without the support of the Air Force, a masters degree would have remained a dream of this author's for a long time.

The value of a good education was instilled in this author by his parents to whom much appreciation and love is passed.

This thesis is dedicated to Mary, Sarah, and Laura for whom, when all is said and done, the long hours away from home are really for.

TABLE OF CONTENTS

CHAPTER		PAGE
	ACKNOWLEDGEMENTS	ii
	LIST OF TABLES	v
	LIST OF FIGURES	vii
	LIST OF SYMBOLS	viii
1.	INTRODUCTION	1
	1.1 Introduction	1
	1.2 Two Types of Response Variables	2
	1.3 Goals of Study	3
2.	DATA COLLECTION	4
	2.1 Introduction	4
	2.2 Data Used in This Study	6
	2.3 Summary	8
3.	MODEL FORMULATION	9
	3.1 Introduction	9
	3.2 Three Predictor Variable Groups	9
	3.3 Standardization	9
	3.4 Draft Model Formulation	10
	3.5 Example Model Formulation	12
	3.6 Summary	15
4.	MODEL TESTING	16
	4.1 Introduction	16
	4.2 Traditional Approach	16
	4.8 Testing LABORWH	17
	4.9 Testing FINISWH	21
	4.10 Testing FIXEDOH	22
	4.11 Summary	22
5.	INTERPRETATION OF RESULTS	24
	5.1 Introduction	24
	5.2 Interpretation of LABORWH	25
	5.3 Summary	28

CHAPTER		PAGE

6. SUMMARY AND CONCLUSIONS 30
   6.1 Summary 30
   6.2 Major Conclusions of Confusion Areas 30
   6.3 Satisfaction of Goals of This Study 32
   6.4 Recommendations for Future Research 32

REFERENCES CITED 34

A. DATA USED IN STUDY 35

B. VARIABLE LABELS 39

C. TRADITIONAL TEST OF LABORWH 41
   C.1 Intrduction 41
   C.2 Hypothesis 41
   C.3 Testing the Model 41
   C.4 Interpretation of Results 42
   C.5 Summary 42

D. LABORWH COMPUTER OUTPUT 48

E. FINISWH COMPUTER OUTPUT 67

F. FIXEDOH COMPUTER OUTPUT 75

LIST OF TABLES

TABLE		PAGE
2.1	Sample Observation	7
3.1	Chosen Variables for the Prediction of LABORWH	13
4.1	Summary of Tests on LABORWH	18
4.2	Collinearity Diagnostics of LABORWH Model	20
4.3	Summary of Tests on FINISWH	23
4.4	Summary of Tests on FIXEDOH	23
5.1	Descriptive Statistics of LABORWH Model	27
A.1	List of Data	36
B.1	Variable Labels	40
C.1	Traditional Approach Regression Run 1	43
C.2	Traditional Approach Regression Run 2	44
C.3	Traditional Approach Regression Run 3	45
C.4	Traditional Approach Regression Run 4	46
C.5	Traditional Approach Regression Run 5	47
D.1	Last Step of Stepwise Regression Run	49
D.2	Regression Run 1	50
D.3	Regression Run 2	51
D.4	Regression Run 3	52
D.5	Regression Run 4	53
D.6	Regression Run 5	54

TABLE		PAGE
D.7	Influence Diagnostics	65
E.1	Regression Run 1	68
E.2	Regression Run 2	69
E.3	Regression Run 3	70
E.4	Regression Run 4	71
E.5	Regression Run 5	72
E.6	Regression Run 6	73
E.7	Regression Run 7	74
F.1	Last Step of Stepwise Regression Run	76
F.2	Regression Run 1	77
F.3	Regression Run 2	78
F.4	Regression Run 3	79
F.5	Regression Run 4	80
F.6	Regression Run 5	81

LIST OF FIGURES

FIGURE		PAGE
2.1	Air Force Labor Accounting Form	5
D.1	Plot of Residuals Versus KOD	56
D.2	Plot of Residuals Versus TEMP	57
D.3	Plot of Residuals Versus VOLGROSS	58
D.4	Plot of Residuals Versus VOLKOD	59
D.5	Plot of Residuals Versus VOLDAY	60
D.6	Plot of Residuals Versus VOLTRUCK	61
D.7	Plot of Residuals Versus ASSLEN	62
D.8	Plot of Residuals Versus ELASSLEN	63
D.9	Plot of Residuals Versus TASSLEN	64
D.10	Plot of Residuals Versus TVOLGROS	65
D.11	Plot of Residuals Versus DAY	66

LIST OF SYMBOLS

SYMBOL	MEANING
k	NUMBER OF VARIABLES IN THE EQUATION.
n	NUMBER OF OBSERVATIONS.
$\bar{X}$	ARITHMETIC AVERAGE OF X, EQUAL TO THE SUM OF X'S DIVIDED BY THE NUMBER OF X'S.
X(S)	STANDARDIZED X IN ACCORDANCE TO EQ. 3.1.
Σ	SUMMATION FROM 1 TO i.
Δ	BINARY VARIABLES WITH VALUE 0 OR 1.
df	DEGREES OF FREEDOM.
MSE	MEAN SQUARE ERROR.
SSE	SUM OF SQUARES OF ERRORS.
SSR	SUM OF SQUARES REGRESSION.
*	MULTIPLY TIMES

CHAPTER 1

INTRODUCTION

1.1 Introduction

In today's construction industry where approximately 15% of all contractors are failing (4:59)[#], and where litigation and arbitration are increasingly used as avenues of restoration (3:391), new management tools and methods are required to increase survivability. Analytical procedures can be used to improve planning of a forthcoming construction job. Trouble-shooting during the course of construction can be accomplished using analytical procedures. Additionally, if claims cannot be avoided on a job, analytical procedures could be used to compare what actually happened, to what should have happened.

However, analytical procedures tailored to the needs of the construction manager are scarce. It is therefore the objective of this thesis to tailor one analytical method for use by the construction industry. The technique chosen for research is the modeling and interpretation of construction data using regression analysis.

Linear regression is a tool which has been available to the construction industry for a long time, yet has not been utilized for a

---

\# The first number gives reference number in the REFERENCES CITED section. The second number is the page number.

variety of reasons. Based on this writer's experience and the courses taken during masters studies at The Ohio State University, four areas of confusion exist:

1) Data acquisition: The data necessary for linear regression is not usually collected. Chapter 2 of this thesis will present some of the reasons and possible cures.

2) Model formulation: A methodology for the formulation of possible models is lacking in the construction industry. A proposed methodology is the subject of Chapter 3.

3) Model testing: Several techniques are available for the development of the "best" model. A few of these will be reviewed and utilized in Chapter 4.

4) Interpretation of results: The utility of the exercise depends on the interpretation of the regression results. Chapter 5 will present the interpretation of the results derived from the data analyzed.

1.2 Two Types of Response Variables

Construction studies generally involve labor and material quantities. Two circumstances exist in such studies:

1) The quantity of work in a given period is fixed and the labor required (input) is a random variable; and

2) The labor available to do the work is fixed and the quantity (output) is a random variable.

In this study, the data was obtained from a project in which the first condition held. In particular, this study will concern concrete work in which the quantitiy to be placed varied from day to day. The quantity for each day was known and fixed prior to starting the day's work. The question to be examined may be stated as "How many men (manhours) are required to complete a given day's pour? Hence the dependent variable is manhours.

1.3 Goals of Study

The goals of this study are threefold:

1) To present a methodology or approach to developing a regression model;

2) To show how one may predict and call important information from a final model in order to make decisions on process selection; and

3) To show how one may select a crew size which is sufficient to complete the work without excess idle time using said model and associated descriptive statistics.

CHAPTER 2

DATA COLLECTION

2.1 Introduction

Initial analysis is generally done on whatever data is available. Upon completion of this analysis, the analyst might suggest collection of additional types of data. This may require changes in collection techniques such as additional field forms or proper completion of present forms. In order to effectively use regression analysis, a data set including all possibly relevant variables is required. An incomplete data set will yield a large random error term which consists of unexplained error, and error due to excluded variables. "The ordinary least squares estimates of the parameters are unbiased only when all theoretically specified variables are included in the regression."(8:82). A complete data set will result in a more meaningful model to the analyst. In general, the construction industry does not keep the right records from which a complete data set can be extracted. A typical construction accounting form is shown in Figure 2.1. This form is used by The United States Air Force to account for manhours expended on in-house construction.

Through examination of the form in Figure 2.1, it is noted that items of interest to the construction manager are missing. Other potentially interesting variables include crew size, temperature, floor (elevation), method of construction, material type, area, and volume.

BASE CIVIL ENGINEER WEEKLY WORK SCHEDULE (PART I)				WEEK ENDING				COST CENTER				APPROVED					
LINE NO	DESCRIPTION A	LABOR UTIL CODE (LUC) B	MANHOUR ALLOCATIONS														
			MAN HRS C	MON		TUES		WED		THU		FRI		SAT		SUN	
				SCHED	ACT	SCHED	ACT	SCHED	ACT	SCHED	ACT	SCHED	ACT	SCHED	ACT	SCHED	ACT
1	ASSIGNED																
2	BORROWED																
3	OVERTIME	38															
4	TOTAL AVAILABLE (total of items 1 2 and 3)																
5	SUPERVISION	31															
6	TRAINING	32															
7	LEAVE	33															
8	ALL OTHER	34															
9	LOANED LABOR	39															
10	TOTAL INDIRECT (total of items 5 through 9)																
11	AVAILABLE FOR WORK (items 4 minus item 10)																

Figure 2.1 Air Force Labor Accounting Form (10)

An iterative process consisting of collecting data, analyzing the data, then collecting more data, often exists. Variables found important in previous analysis along with new variables to be tested, are collected in subsequent studies. This iteration continues until it becomes uneconomical to do so, or until the analyst chooses to halt. It is noted that it is always less expensive to collect the data as the process is going on rather than to hire a consultant to piece the information together at a later date.

2.2 Data Used in This Study

A complete data set made available to this writer will be analyzed and reviewed in this thesis. The data was extracted from work account records of a concrete contractor's performance on elevated concrete slab pours of a 45 story building. The data is listed in Appendix A. Labels and definitions of the variables are given in Appendix B. These data are very complete and provide an example of a good data collection system in construction.

In order to avoid confusion, a description of data from one workday will be presented. In particular, observation one in Table 2.1 will be explained.

DATE is given in month/day/year format. For this work day, the date is November 22, 1983. DAY refers to the day of the contract. Day one of the contract is March 8, 1983. The elevation above ground level (EL) is zero feet for this observation, and the area of the pour (AREA) is 17,300 square feet. The gross volume (VOLGROSS) of concrete poured is 345 cubic yards. The minimum temperature (MINTEMP) is 55 degrees

Table 2.1 Sample Observation

DATE	DAY	EL	AREA	VOLGROSS	MINTEMP	PRECIP	PLACBUGY	TRUKPUMP	FLOTFIN	KOD	ATR	ASSLEN	FIXEDOH	LABORWH	FINISWH
112283	260	0	17300	345	55	0	0	1	1	0	0	75	1483	100.5	51

Fahrenheit with no precipitation (PRECIP). The method of placement is truck pumping (TRUKPUMP = 1, PLACBUGY = 0). The slab is float finished (FLOTFIN = 1) by the cement finishers, and the fixed overhead (FIXEDOH), which consists of supervisor costs and an occasional police officer, is $1,483. The pour is not made in the Kodiak (KOD = 0) area of the building, nor was it part of the atrium (ATR = 0). Workers had to assemble 75 feet of pipe (ASSLEN) to facilitate the pumping operations. This particular pour required 100.5 manhours of concrete laborers (LABORWH) and 51 manhours of cement finishers (FINISWH).

The population of this study consists of all elevated concrete slab pours constructed in this project. Due to the size and nature of the data, all the data was utilized. No random sampling was done. This particular project ran for more than nine months and involved over $10 million worth of concrete work.

After some preliminary work with graphics and descriptive statistics, a change in modus operandi (5), or change in methods, was identified. Upon inquiry of the data source, it was discovered that a truck pump was used in addition to the stationary pump which was the standard method of placement. This additional information was added to the data set. Another class of work, slab on grade (as opposed to elevated slab) was included in the original data set. The slab on grade pours were removed. Outliers were identified and investigated, and all errors in data entry were corrected.

2.3 Summary

Construction data historically has not been examined by linear regression. Field data has generally been limited to that which was required by accountants. Reluctance of field personnel to record data and failure by management to request indepth data have contributed to the problems in availability of data. One data set will be examined in this study to illustrate the methods proposed in this thesis.

CHAPTER 3

MODEL FORMULATION

3.1 Introduction

The purpose of this chapter is to introduce a standardized approach for the formulation of a model. Any approach should provide for useful interpretation of the intercept term and predictor variables. This project includes variables at the ratio, interval, and binary levels. Each type of variable requires a different type of analysis.

3.2 Three Predictor Variable Groups

Ratio-level variables have an absolute minimum value of zero. They are typically real, positive variables which are objective in nature such as area and volume.

Interval-level variables have arbitrarily chosen zero points. These variables have values relative to an arbitrary point, and include variables like temperature and elevation.

Binary-level variables have values of either zero or one. These variables have a value of 0 for an observation at standard condition such as "concrete pumped" (as opposed to "direct chute" or "crane and bucket"), and a value of 1 when conditions are other than standard.

3.3 Standardization

Often the construction manager is interested in the effect deviation from the standard condition has on a process. This is some standard was caused by an external force. In the analysis of the data presented in this thesis, deviation from the average condition of the interval-level variables will be examined. The standardization equation which will be used is:

$$X(S) = (X-\bar{X}), \tag{3.1}$$

where X(S) is denoted as X-standardized;

X is the interval-level variable; and

$\bar{X}$ is the arithmetic mean, or some standard value of X.

By definition, an interval-level variable has an arbitrary zero point, thus standardization will change the intercept and not the slope.

3.4 Draft Model Formulation

Independent variables can be chosen and combined into a draft model. The first consideration is to search for intercept combinations. The intercept term is confounded and comprised of mobilization, demobilization, and a contingency buffer. Interpretation of the intercept term is further complicated because ratio-level variables, when equal to zero, are in most cases outside the data range. The intercept term is a defined constant when all ratio-level variables are zero, i.e., no concrete has yet been poured. Interval-level variables must be adjusted when standard conditions do not exist. This is most easily done by standardizing the variables; hence all interval-level variables will be standardized using Equation 3.1.

Adjustments to the intercept term are accomplished by adding all binary and interval-level variables thought to affect the intercept. The generic formula is:

$$A=A_0+\Sigma B_i\Delta_i+\Sigma C_j(X-\bar{X}), \tag{3.2}$$

where A is the adjusted intercept term;

A_o is the defined constant;

$B_i \Delta_i$ are the products of the binary-level variable and its coefficients; and

$C_j (X - \bar{X})$ are the products of the interval-level variable and its coefficients.

This equation can be transformed into the form:

$$A = A_o [1 + b_i \Delta_i + c_j (X - \bar{X})]. \tag{3.3}$$

The coefficients of Equation 3.3 are not the same as the coefficients in Equation 3.2.

Development of the independent variables is similar to the approach used in developing the intercept form. Ratio-level variables are combined with binary and interval-level variables in the form:

$$D = \Sigma (E_l * Z_m [\Sigma F_n * \Delta_n + \Sigma G_p (X - \bar{X})] + E_l Z_m), \tag{3.4}$$

where D is the adjusted coefficient;

E_l is the coefficient of Z_m;

Z_m is the ratio-level variable being developed;

$F_n \Delta_n$ are the binary-level variables affecting Z_m; and

$G_p (X - \bar{X})$ are the interval-level variables affecting Z_m.

Transformation is accomplished by dividing Equation 3.4 by each E_l Z_m. It should be emphasized that the binary-level and interval-level variables used in Equation 3.4 are variables which are considered by the analyst to affect each ratio-level variable chosen. This does not preclude the use of other variables by themselves.

The final draft model combines Equations 3.3 and 3.4 and other chosen variables to take the form of:

$$Y = A_o + \Sigma B_i \Delta_i + \Sigma C_j (X - \bar{X}) + Z_m E_l + \Sigma(F_n \Delta_n * Z_m) + \Sigma[G_p (X - \bar{X}) * Z_m]. \qquad (3.5)$$

This equation requires transformation in order to ease interpretation. The transformed equation is:

$$Y = A_o [1 + \Sigma b_i \Delta_i + \Sigma c_j (X - \bar{X})] + E_l * Z_m [1 + \Sigma f_n \Delta_n + \Sigma g_p (X - \bar{X})]. \qquad (3.6)$$

Summarizing the alternate approach, the analyst must choose from available data the variables which may be helpful in explaining or predicting a particular construction process. All interval-level variables are then standardized using Equation 3.1. Under standard conditions, all binary-level variables are set at zero. The intercept is developed using interval and binary-level variables which intuitively influence the mobilization, demobilization, and contingency buffer. Equation 3.2 is used to develop the intercept term. After the independent variables are chosen, they are combined with any influencing variables in accordance with Equation 3.4. The draft model is then transformed to facilitate interpretation.

3.5 Example Model Formulation

Three independent variables are of concern to the construction manager of this project. The laborer workhours, cement finisher workhours, and fixed overhead models will be developed to demonstrate the concepts introduced in this chapter.

Table 3.1 illustrates the variables chosen to be formulated for the prediction of LABORWH. These variables were chosen from this writer's experience and knowledge of concrete operations. DAY is chosen because "learning affect" is often discussed in the literature. The elevation may be significant because the laborers must construct and disassemble the pumping pipe, EL and ASSLEN are thus included in

Table 3.1 Chosen Variables for the Prediction of LABORWH

VARIABLE	TYPE	CONTRIBUTES TO	LABEL
NEWDAY	INTERVAL	INTERCEPT	STANDARDIZED TIME
ELSTAND	INTERVAL	INTERCEPT	STANDARDIZED ELEVATION
TEMP	INTERVAL	INTERCEPT	STANDARDIZED TEMPERATURE
PRECIP	BINARY	INTERCEPT	PRECIPITATION
KOD	BINARY	INTERCEPT	KODIAK POUR
ATR	BINARY	INTERCEPT	ATRIUM
PLACBUGY	BINARY	INTERCEPT	BUGGY PLACEMENT
TRUKPUMP	BINARY	INTERCEPT	TRUCK PUMP USED
VOLGROSS	RATIO	WORK DONE	GROSS VOLUME
VOLKOD	PRODUCT	WORK DONE	VOLGROSS TIMES KOD
VOLATR	PRODUCT	WORK DONE	VOLGROSS TIMES ATR
VOLDAY	PRODUCT	WORK DONE	VOLGROSS TIMES NEWDAY
TVOLGROS	PRODUCT	WORK DONE	TEMP TIMES VOLGROSS
PVOLGROS	PRODUCT	WORK DONE	PRECIP TIMES VOLGROSS
VOLBUGY	PRODUCT	WORK DONE	PLACBUGY TIMES VOLGROSS
VOLTRUCK	PRODUCT	WORK DONE	TRUKPUMP TIMES VOLGROSS
ASSLEN	RATIO	WORK DONE	PIPE ASSEMBLY LENGTH
ELASSLEN	PRODUCT	WORK DONE	ASSLEN TIMES ELSTAND
TASSLEN	PRODUCT	WORK DONE	ASSLEN TIMES TEMP
PASSLEN	PRODUCT	WORK DONE	ASSLEN TIMES PRECIP
AREAVOL	PRODUCT	WORK DONE	AREA TIMES VOLGROSS

the draft model. MINTEMP and PRECIP were chosen because weather is often the cause for delay. The binary-level variables were chosen to test the affect of abnormal conditions. Since the laborers work with volume, VOLGROSS is imput into the initial model.

The interval-level variables DAY, EL, and MINTEMP have been standardized and appear as NEWDAY, ELSTAND, and TEMP respectively. The draft model form of the intercept term is LABORWH = INTERCEPT +NEWDAY +ELSTAND +TEMP +PRECIP +KOD +ATR +PLACBUGY +TRUKPUMP. Each of the variables in this equation (excluding the intercept) have a coefficient associated with them. These variables are thought to have an effect on mobilization, demobilization and the contingency buffer. This draft form can be transformed to read: INTERCEPT *(1+NEWDAY +ELSTAND +TEMP +PRECIP +KOD +ATR +PLACBUGY +TRUKPUMP). The transformed variables have a transformed coefficient equal to the draft coefficient divided by the intercept value. The transformed coefficients represent a rate of intercept change. The transformation is done to facilitate interpretation.

The two ratio-level variables when combined with contributing factors take the form of (VOLGROSS +VOLKOD +VOLATR +VOLDAY +TVOLGROS +PVOLGROS +VOLCRAN +VOLBUGY +VOLTRUCK) +(ASSLEN +ELASSLEN +TASSLEN +PASSLEN) +AREAVOL. The variable combination forms are defined in Appendix B. AREAVOL was included above and beyond the intercept and ratio-level forms because it was thought it may contribute to the prediction of labor workhours. These variables are then transformed by dividing all VOLGROSS interactions by the coefficient of VOLGROSS. ASSLEN is treated similarily. AREAVOL is then added to the transformations to form the complete transformation. The total transformation form is accomplished by adding the intercept and ratio-level transformations to other predictor (AREAVOL in this case) variables which may effect the response variable. The complete model including the transformation form is included in Appendix D. The response variables FINISWH and FIXEDOH are developed and transformed in similar fashion. The complete models are included in Appendices E and F respectively.

3.6 Summary

The recommended approach to formulating regression models accomplishes two things: 1. It proposes a standardized method of model formulation; and 2. The proposed formulation method eases the interpretation of the regression results. The predictor variables can be broken into three groups necessary to accomplish the proposed model formulations. The independent variable LABORWH was developed as an example. Similar procedures were used, though not illustrated, for the development of FINISWH, and FIXEDOH.

CHAPTER 4

MODEL TESTING

4.1 Introduction

Once the models have been formulated, the deadwood or useless variables should be removed. The goal of regression analysis is to build a simple yet meaningful model. Model testing is used to accomplish this goal. Some model testing methods and statistics which are in common use: stepwise regression; t-test; F-test; R^2 ; R^2_{ADJ} ; Mallow's Cp statistic; collinearity diagnostics; and influence diagnostics. Important information can also be extracted from residual plots. Ludolph (6:31) discusses the use of residual plots in his MS thesis. All of the above tests and statistics are indicators of lack of fit of a model. It is important to note that lack of fit is a relative concept. Standard software packages exist which will perform the tests necessary to run a regression analysis. SAS (1) will be used throughout this study.

4.2 Traditional Approach

Traditional hypothesis testing procedures proposed by statisticians involve selecting variables and their forms (exponential, logrithmic, etc.) through experience, or upon suggestion. This entails: 1. Choosing independent and dependent variables; 2. Selecting "in-place" values (observations with values of x and y) versus selecting random assignment (find a value of y from an assigned x value); 3. Choosing a number of observations to use; and 4. Formulating a hypothesis. Parameters are then estimated and the hypothesis is tested.

A hypothesis formulated before analysis, based on theoretical ideas is refered to as an a priori hypothesis. After testing an a priori hypothesis through regression, the regression results can be used to formulate a new hypothesis, or an a posteriori hypothesis (9). A new data set is required to test the a posteriori. This procedure is repeated until the "best" model is formed. There may not be a best model. The traditional approach requires much data to satisfy the assumptions of regression.

A hypothesis formed by the traditional approach on this data set is illustrated in Appendix C of this thesis. The dependent variable being tested is LABORWH.

4.3 Testing LABORWH

The computer output for the analysis of LABORWH is attached in Appendix D. The thought process used in developing the final model will be discussed in this section; a tableau of test results is provided in Table 4.1. The subsequent response variables will be briefly presented with inclusion of a tableau similar to Table 4.1.

Due to the large number of variables formulated in the draft model for predicting labor workhours, the data was screened using stepwise regression. An α level of 0.25 was chosen. Thirteen variables met the 0.25 significance level and were input into a regression run. The initial regression run yielded a R^2_{ADJ} of 0.6732, and a mean square error of 148.874. The predictor variable PASSLEN is the least

Table 4.1 Summary of Tests on LABORWH

REGRESSION RUN	VARIABLE REMOVED	MSE	R^2	R^2_{ADJ}
1	-	148.874	0.7049	0.6732
2	PASSLEN	149.443	0.7013	0.6719
3	AREAVOL	149.927	0.6979	0.6708
*4	ELSTAND	150.293	0.6947	0.6700
5	KOD	155.003	0.6825	0.6597

* INDICATES "BEST" MODEL

significant in the t-test, and is thus removed in the second regression run. Run two shows a slight drop in the R^2_{ADJ} and a small rise in the MSE. By the t-test criteria, AREAVOL is removed and the regression is run again. The R^2_{ADJ} and MSE again experiences a slight drop and rise respectively. These changes have been slight thus far which indicates an insignificance of the removed variables. ELSTAND is removed and a fourth regression is run. The results of this run are similar to previous runs. The fifth run with KOD removed results in significant changes in the indicators used to this point; the model chosen is thus that tested in regression run four.

The collinearity diagnostics indicate the degree of multicollinearity present in the model. Table 4.2 illustrates the results of collinearity diagnostics on the final model for the prediction of LABORWH. Of particular interest is the conditional index. When the conditional index is large, estimates of the response variable may have considerable amounts of numerical error. It has been suggested that a bottom line conditional index less than 30 indicates an acceptable model (9). The conditional index of 16.432 in Table 4.2 indicates the final LABORWH model is fair.

The influence diagnostics provide a measure of the influence each observation has on the parameter estimates of the model. Appendix D contains the influence diagnostics for LABORWH. The important diagnostics are provided by examining the DFBETAS. This statistic indicates the effect the removal of a particular observation has on each of the parameter estimates, scaled by the standard error. A value for a DFBETA of 0.5 or more is cause for some concern.

Table 4.2 Collinearity Diagnostics of LABORWH Model

COLLINEARITY DIAGNOSTICS VARIANCE PROPORTIONS

NUMBER	EIGENVALUE	CONDITION INDEX	PORTION INTERCEP	PORTION TEMP	PORTION KOD	PORTION VOLGROSS
1	4.600	1.000	0.0006	0.0031	0.0005	0.0009
2	2.873	1.265	0.0042	0.0032	0.0013	0.0050
3	1.802	1.598	0.0003	0.0000	0.0309	0.0020
4	0.942879	2.209	0.0000	0.0096	0.0008	0.0010
5	0.272347	4.110	0.0193	0.0773	0.0000	0.0056
6	0.217178	4.602	0.0087	0.0119	0.0034	0.0047
7	0.102940	6.684	0.0391	0.0202	0.2113	0.1268
8	0.072460	7.967	0.0570	0.5359	0.0107	0.0037
9	0.057462	8.947	0.0183	0.1726	0.6422	0.0464
10	0.043434	10.291	0.2071	0.0128	0.0720	0.6217
11	0.017034	16.432	0.6454	0.1534	0.0268	0.1822

NUMBER	PORTION VOLKOD	PORTION VOLDAY	PORTION TVOLGROS	PORTION VOLTRUCK	PORTION ASSLEN	PORTION ELASSLEN	PORTION TASSLEN
1	0.0005	0.0063	0.0027	0.0000	0.0007	0.0039	0.0030
2	0.0014	0.0070	0.0025	0.0124	0.0012	0.0000	0.0008
3	0.0353	0.0001	0.0002	0.0052	0.0001	0.0004	0.0001
4	0.0006	0.0149	0.0077	0.1875	0.0023	0.0056	0.0038
5	0.0020	0.0005	0.0055	0.1156	0.0015	0.2105	0.0031
6	0.0031	0.7804	0.0079	0.1501	0.0006	0.0232	0.0128
7	0.3635	0.0005	0.1700	0.0006	0.0017	0.0020	0.0644
8	0.0130	0.0034	0.0609	0.1336	0.0143	0.0906	0.4026
9	0.5536	0.0355	0.3953	0.0026	0.0000	0.0059	0.0792
10	0.0216	0.1506	0.3472	0.0005	0.0317	0.0801	0.2503
11	0.0054	0.0008	0.0002	0.3920	0.9459	0.5776	0.1599

Several steps may be taken when a point with large values is encountered. The first step in dealing with these data points is to check data entry for accuracy. Next, the observations should be examined to ensure that they are part of the population of the study. Observation 25, 97, and 102 were scrutinized in this manner due to large values of "DFBETAS". No data entry error was noted, and the observations belong to the population outlined in Section 2.2. There is a possibility that the data was recorded incorrectly at the job sight. The fate of highly influential observations lies in the hands of the analyst; they should not be dropped without much thought and good reason. In the present case, the observations were retained.

The final test of the model chosen as the "best" model is the Extra Sums of Squares Test. An alpha level of 0.05 is chosen for this test. The full model consists of the variables singled out in the final stepwise regression step. The reduced model consists of the variables present in the "best" model. The removed variables are being tested for significance. The removed variables are PASSLEN, KOD, AREAVOL. With v_1=13-10 or three, and v_2=135-13-1 which equals 121, the F_C=2.68. The observed F, F_O is:

F_O=(43021.12-42398.63)*121/[18013.8*(13-10)]=1.39. Because $F_C > F_O$, none of the removed variables contribute anything above and beyond those in the "best" model. Thus the ten variables tested in regression run three make up the final or "best" model.

4.4 Testing FINISWH

The variables thought to have an impact on the cement finishers workhours are ELSTAND, TEMP, KOD, VOLGROSS, VOLKOD, VOLDAY, TVOLGROS,

VOLTRUCK, ASSLEN, ELASSLEN, TASSLEN, PASSLEN, and AREAVOL. Due to the relatively low number of variables, a stepwise regression is not run. Applying the various lack of fit tests results in the sixth regression run on Table 4.3 being chosen as the "best" model. Removal of AREAVOL may also be considered. The small changes in the MSE, R^2, and adjusted R^2 indicate that the variables removed are insignificant. An overall R^2 of 0.7826 is very good for this type of data. Over 78% of the variability in FINISWH is explained by these five variables.

4.5 TESTING FIXEDOH

Stepwise regression resulted in 13 variables meeting the significance level of entry of 0.25. The model with NEWDAY and FINISWH removed had an R^2_{ADJ} of 0.6614. The removal of PASSLEN resulted in a drop of over one-tenth in the adjusted R^2. PASSLEN is thus left in the model, and no further regressions are run. Eleven variables remain in the model. It is desireable to have less than eleven variables in the final model, but significant changes occur in the three tests in Table 4.4 with the removal of the next viable variables, PASSLEN then KOD. The regression runs are included in Appendix F of this thesis.

4.6 Summary

The model testing tools reviewed in this chapter provide indicators to the lack of fit of the model being tested; however no one test is conclusive in itself. By combined use of the tests a "best" model can be chosen. This may not be the best model, indeed there may not be a best model (2:85). If blessed with an abundant amount of data, the analyst is urged to use accepted means of hypothesis testing. This is rarely the case in the construction industry.

Table 4.3 Summary of Tests on FINISWH

REGRESSION RUN	VARIABLE REMOVED	MSE	R^2	R^2_{ADJ}
1	-	125.290	0.8063	0.7907
2	PRECIP	124.308	0.8063	0.7924
3	TEMPAREA	123.343	0.8063	0.7940
4	PRECAREA	123.242	0.8049	0.7941
5	FLOTAREA	124.954	0.8006	0.7913
*6	NEWDAY	127.364	0.7952	0.7873
7	AREAVOL	130.127	0.7891	0.7826

Table 4.4 Summary of Tests of FIXEDOH

REGRESSION RUN	VARIABLE REMOVED	MSE	R^2	R^2_{ADJ}
1	-	15586.113	0.6980	0.6656
2	NEWDAY	15664.113	0.6940	0.6639
*3	FINISWH	15781.347	0.6892	0.6614
4	PASSLEN	16423.050	0.6739	0.6476

* INDICATES "BEST" MODEL

CHAPTER 5

INTERPRETATION OF RESULTS

5.1 Introduction

In a simple, first-order model (no higher order or interaction terms), a one unit change in an independent variable with coefficient B will result in a mean change in the dependent variable by B, all other variables held constant. Productivity is defined as output/input (quantity/manhours). When the dependent variable is manhours, the coefficient of independent variables with units of quantity of work (cubic yards poured, square feet painted, etc.) is the inverse of productivity. It is suggests these be labeled "unit time" when manhours is the response variable, and "unit cost" when cost is the response variable (5).

Multicollinearity can cause very confusing results. If multicollinearity exists between two independent variables, each variable may seem insignificant based on individual t-tests, but when the F-test is used at least one of the two variables may be significant.

When an interaction is present in the model, keeping one variable constant, both the slope and the intercept change as the second variable in the interaction changes. The slope of a variable depends on the other interaction variable. For example, given the model Y=A +B*X+C*Z+D*X*Z, the slope of Z equals C +D*X at a given X (7:199).

The coefficients of the transformed models represent rates of change. By transforming the model equations, it is possible to identify the effects certain variables have on the intercept and ratio-level variables. The intercept cannot be broken down into its three components (mobilization, demobilization, and contingency buffer) using the techniques proposed.

An interpretation of the results of the LABORWH will be discussed in this chapter. Then the goals of the study as addressed in Section 1.3 will be completed. The chapter will close with some applications of the results.

5.2 Interpretation of LABORWH

The "best" model as identified in Chapter 4, can be transformed to ease interpretation. The intercept term has the transformed form of 28.23*(1 -0.02*TEMP -0.96*KOD). Both ratio-level variables are also transformed. VOLGROSS takes the form 0.222*VOLGROSS*(1 +2.64*KOD +0.0038*DAY -0.018*TEMP +0.74*TRUKPUMP). Likewise, ASSLEN is transformed as 0.061*ASSLEN*(1 -0.004*EL +0.039*TEMP).

The coefficients of the "best" model for the prediction of LABORWH identify interesting implications of the pouring operations. The intercept term indicates over 28 hours of work are required when no work is done and operations are at standard conditions. A proportional increase to the intercept is caused by temperatures below the average. This indicates more manhours are required for mobilization, demobilization and contingencies when the temperature is low. Kodiak pours cause a proportional decrease in the intercept. This is most likely due to the fact that Kodiak pours are smaller in volume than the norm. They consist of areas which were blocked out (not poured when rest of slab was pou ed) to accomodate the tiebacks which supported a crane system.

The Kodiak pours cause a proportional increase in the overall manhours of the pour. The Kodiak pours are small, but somewhat specialized due to their location. The day of work and fact that truck pumps are being used have the same effect. Work tends to slow down as the job nears conclusion. Correcting punchlist items combined with the fact that the workers will be out of work when the job is done may explain this. Since concrete sets faster in warmer weather, it is expected that manhours and temperature have a negative relation, which is reflected in the regression results. The proportional effects of elevation and temperature on the assembly length are confusing. At lower elevations it tends to require more work to assemble the pipe. Equally confusing is the fact that at higher temperatures the manhours used to assemble the pipe increase.

Based on the results of the regression runs, managers have more insight into the construction process. Providing protection from the environment is something which should be examined. The cost of the protection may outweigh the savings in labor costs. Avoiding the use of the truckpump is another item which could save money. Other items such as the effects of time and Kodiak pours are important for planning purposes. Schedules can be made reflecting these effects.

Plots of the regression residuals versus each of the independent variables of the final model for LABORWH appear in Appendix D. The plots appear to be homoscedastic. There are no strong trends. The

Table 5.1 Descriptive Statistics of LABORWH Model

VARIABLE=RESID RESIDUALS

MOMENTS

N	135	SUM WGTS	135
MEAN	-1.179E-14	SUM	-1.592E-12
STD DEV	11.7931	VARIANCE	139.077
SKEWNESS	0.546949	KURTOSIS	0.309896
USS	18636.3	CSS	18636.3
CV	-1.000E+17	STD MEAN	1.01499
T:MEAN=0	-1.162E-14	PROB>|T|	1
SGN RANK	-280	PROB>|S|	0.539311
NUM ¬= 0	135		

QUANTILES(DEF=4)

100% MAX	34.5541	99%	33.0548
75% Q3	6.51257	95%	23.4307
50% MED	-0.287526	90%	16.5639
25% Q1	-7.93424	10%	-14.2713
0% MIN	-24.2865	5%	-19.259
		1%	-23.5976
RANGE	58.8406		
Q3-Q1	14.4468		
MODE	-24.2865		

EXTREMES

LOWEST	HIGHEST
-24.2865	28.4747
-22.373	29.0173
-21.9575	29.3252
-19.7387	30.3895
-19.6507	34.5541

plot of the residuals versus VOLGROSS hints that less variability in manhours appears with larger pours (greater than 200 cubic yards). Descriptive statistics of the residuals make it possible to choose a crew size for average conditions. By replacing the variable names with the desired (proper) numerical values, the mean labor workhours required can be predicted. Being the mean, roughly 50% (assuming a nearly symmetrical distribution) of the time more labor than is predicted will be required. Table 5.1 contains the descriptive statistics for the residuals of the "best" model for prediction of LABORWH. The descriptive statistics indicate 16.56 manhours should be added to the mean prediction in order to reach a 90% confidence level of completing the job in the predicted time. The job of the manager is to choose the confidence level. The additional manhours required to be added to the mean can then be derived. The crew size can be chosen using the simple analysis described above.

5.3 Summary

There are two major concerns of interpretation of the results. The first is one of validity. Are the results useful? If not, all is not lost. Important insights into the operations can be gained through analysis. The deficiency of a single, precise lack of fit test is the second concern.

Having found the results valid, the construction manager has many uses for them. Manhours can be predicted, decisions on methods of construction can be made, and crew size can be chosen. By multiplying the manhours for both laborers and finishers by their respective rates of pay, and adding the cost of the fixed overhead, a cost estimate can be derived. Regression analysis can also be used in claims cases. Costs can be calculated for the way a project should have been. This can be compared to the way it actually was. The claim can then be based on this difference.

CHAPTER 6

SUMMARY AND CONCLUSIONS

6.1 Summary

In Chapter 1 of this thesis, four areas of confusion were discussed, and the three major goals of the study were given. The data set for this research was described in Chapter 2. Chapter 3 dealt with the formulation of regression models. The models were tested in Chapter 4, and interpreted in Chapter 5. The major conclusions of this study and recommendations for future research are given hereafter.

6.2 Major Conclusions of Confusion Areas

The major conclusions based on the four confusion areas presented in Section 1.1 of this thesis are:

1) Data aquisition in the construction industry needs improvement in order to facilitate various analytical techniques. Construction managers and accounting personnel need to develop data forms together to satisfy both of their needs. It is less expensive, and more accurate, to collect the right data as the job is in progress than to try to extract it from records after the job is complete.

2) The thrust of this study is in the methodology proposed. A nine step approach to the analysis of construction data has been introduced: 1. Data

collection; 2. Choose response variables; 3. Break independent variables into ratio, interval, and binary-levels; 4. Develop initial regression model(s); 5. Model coding; 6. Identify independent variables in coded form and calculate transforms; 7. Run regression, find parameters, and select best model; 8. Decode best model; and 9. Interpret decoded model. This nine step approach provides a standard methodology in lieu of a capricious approach. The regression results achieved by this method on the data set used in this study are within the region of results one would expect to find in the industry.

3) Many of the assumptions of regression are violated in these, and most construction data. Because construction data are few and far between, random sampling is often not done. This is the case in this study. Additionally, the random error associated with any one dependent variable is not always independent of the error associated with any other point. The question to be resolved by the analyst is one of validity; "Is regression analysis useful for a particular construction process?" The violations of assumptions tend not to loom as big if the methodology is valid (useful).

4) The value of regression analysis lies in the interpretation of the results. Improvements to a

process, and/or identifications of problem areas in the process can be achieved through proper interpretation of the regression results. This interpretation can aid in decision making. Descriptive statistics of the residuals of a model provide for such things as the selection of crew size.

6.3 Satisfaction of Goals of This Study

The three goals of this study presented in Section 1.3 have been satisfied:

1) A Methodology was developed in this thesis and is summarized by the nine step approach presented in the second section of this chapter;

2) Examples of how one can use the parameter estimates to make such decisions as whether to use weather protection or not is presented in Section 5.2; and

3) A demonstration of how a manager can use the descriptive statistics of the model residuals to choose a crew size, based on a percentile dictated by management, is included in Section 5.2 of this thesis.

6.4 Recommendations for Future Research

Four areas offer potential for future research. The first is to continue applying the techniques discussed in this study to to other data sets. An opportunity to analize data, then use the results to predict an actual job, would provide for an interesting study. Analysis of data from various contractors with similar specialties may identify aspects common to all the data. Modification of the methodology may improve the results and validity of them.

Deconfounding the intercept term provides the second area of future research. It may only be possible to accomplish this through time-lapse study. The time-lapse equipment is available at The Ohio State University.

The third area for future research is to test and further develop the nine step approach introduced in this thesis.

The final suggested research subject is to evaluate the benefits and desirability of using a confidence interval approach to sizing of crews given daily point estimates of manhour requirements.

REFERENCES CITED

1. Allen, Alice. SAS User's Guide: Statistics, 1982 Edition. Cary, NC: SAS Institute Inc., 1982.

2. Daniel, Cuthbert and Wood, Fred S. Fitting Equations to Data. New York: Wiley-Interscience, 1971.

3. Diekmann, James E. and Kruppenbacher, Timothy A. "Claims Analysis and Computer Reasoning," Jounal of Construction Engineering and Management, Dec. 1984.

4. "ENR Market Trends," Engineering News Record, 27 June 1985.

5. Larew, Richard E. Discussions and conferences, The Ohio State University, 1985.

6. Ludolph, Douglas Edward. "Unit Cost Estimating." Master's thesis, The Ohio State University, 1979.

7. Mendenhall, William and McClave, James T. A Second Course in Business Statistics: Regression analysis. San Francisco: Dellen Publishing Co., 1981.

8. Rao, Potluri and Miller, Roger LeRoy. Applied Econometrics. Belmont, CA: Wadsworth Publishing Co., 1971.

9. Thompson, Paul. Class notes from Business Management 801.05, Regression Analysis, The Ohio State University, 1985.

10. United States Air Force. AF FORM 561, May 1978.

APPENDIX A

DATA USED IN STUDY

This section contains the data used in this study. Some variables made available to this writer are not included in the following list because they were not used in this study. Additionally, no transformed values such as AREAVOL are listed in these pages.

Table A.1 List of Data

OBS	DATE	DAY	EL	AREA	VOLGROSS	MINTEMF	PRECIP	PLACBUGY	TRUKPUMP	FLOTFIN	KOD	ATR	ASSLEN	FIXEDOH	LABORWH	FINISWH	POURCOST
1	112283	260	0	17300	345	55	0	0	1	1	0	0	75	1483	100.5	51.0	4.36
2	112883	266	0	7214	135	45	1	0	1	1	0	0	85	776	64.0	51.0	2.94
3	121383	281	36	7600	158	43	0	0	1	0	0	0	96	1009	106.0	78.5	4.05
4	121583	283	36	2587	50	40	0	0	1	1	0	0	96	587	57.5	5.5	1.72
5	121683	284	18	10200	150	27	0	0	1	1	0	0	138	837	111.0	42.5	3.63
6	122183	289	18	7480	150	13	1	0	1	1	0	0	78	1004	138.0	56.0	4.89
7	122283	290	18	6350	100	19	1	0	1	1	0	0	88	673	65.5	32.0	2.48
8	10384	302	36	7200	104	32	0	0	1	0	0	0	121	882	81.5	65.5	3.76
9	10484	303	36	8600	160	34	0	0	1	0	0	0	131	1095	104.0	64.5	4.38
10	10684	305	67	4800	60	32	1	0	1	0	0	0	102	1104	70.0	51.0	3.69
11	11084	309	67	5800	138	10	0	0	1	0	0	0	152	1070	108.0	83.5	5.09
12	11184	310	67	7620	140	8	0	0	1	0	0	0	142	905	93.5	86.5	4.78
13	11284	311	67	5590	80	7	0	0	1	0	0	0	97	625	76.0	59.5	3.17
14	11784	316	54	8700	130	21	0	0	1	0	0	0	109	942	96.0	75.0	4.36
15	11884	317	54	8500	144	13	1	0	1	0	0	0	164	841	96.5	77.0	4.35
16	12384	322	54	6525	111	13	0	0	1	0	0	0	134	765	116.0	65.5	4.15
17	12584	324	93	10370	160	34	0	0	1	0	0	0	243	938	107.5	93.0	5.17
18	12684	325	0	2400	45	30	0	1	0	1	0	0	0	66	30.0	19.0	1.01
19	12684	325	93	7200	110	30	0	0	1	0	0	0	253	893	121.0	66.5	4.58
20	12784	326	93	8000	100	22	0	0	0	0	0	0	263	431	62.0	64.0	2.73
21	13084	329	0	5235	90	28	1	0	0	0	0	0	145	683	84.0	57.5	3.61
22	13184	330	80	10370	160	12	0	0	0	0	0	0	180	749	111.0	102.5	5.25
23	20184	331	80	8630	130	9	0	0	0	0	0	0	355	635	99.0	85.5	4.30
24	20284	332	80	7300	100	23	0	0	0	0	0	0	225	477	83.0	63.5	3.17
25	20284	332	0	2300	60	23	0	1	0	1	0	0	0	277	30.0	14.0	1.18
26	20384	333	0	3000	60	30	1	0	0	1	0	0	0	601	44.0	23.0	1.79
27	20784	337	107	11130	230	13	1	0	0	1	0	0	287	739	103.0	56.0	3.60
28	20684	336	107	15300	280	14	1	0	0	1	0	0	402	862	133.5	67.5	4.79
29	21084	340	140	11130	240	30	0	0	0	1	0	0	320	657	102.5	68.0	3.81
30	21484	344	140	15300	259	40	0	0	0	1	0	0	435	714	102.5	51.0	3.52
31	21784	347	54	2376	44	41	1	1	0	0	0	0	249	836	85.0	46.0	3.44
32	22084	350	153	13950	207	34	0	0	0	0	0	0	448	815	104.0	85.5	4.70
33	22184	351	153	9750	160	34	0	0	0	0	0	0	333	754	94.5	74.0	4.01
34	22384	353	166	5915	100	35	0	0	0	0	0	0	541	660	75.5	63.0	3.15
35	22484	354	166	7800	139	30	0	0	0	0	0	0	356	630	67.0	58.5	3.01
36	22784	357	166	8290	178	28	1	0	0	0	0	0	356	1081	117.0	85.5	5.34
37	30184	360	178	9984	206	12	0	0	0	0	0	0	343	1013	118.0	100.0	5.76
38	30684	365	192	12280	180	25	0	0	0	0	0	0	382	835	104.0	90.0	4.74
39	30784	366	192	3600	66	14	0	0	0	0	0	0	352	498	63.0	34.0	2.21
40	30884	367	205	14820	216	9	1	0	0	0	0	0	500	910	98.0	91.5	4.97
41	30984	368	205	9430	170	9	0	0	0	0	0	0	395	755	103.0	88.0	4.57
42	31384	372	218	10250	170	29	0	0	0	0	0	0	533	774	95.5	72.0	3.99
43	31484	373	218	9515	160	29	0	0	0	0	0	0	413	717	91.5	79.0	4.01
44	31584	374	218	7205	95	28	1	0	0	0	0	0	353	541	64.0	54.5	2.75
45	31684	375	107	12190	150	32	1	0	0	0	0	0	352	968	101.5	108.0	5.53
46	32084	379	107	10395	110	30	0	0	0	0	0	0	282	735	81.5	73.5	3.74
47	32284	381	231	10250	169	30	1	0	0	0	0	0	566	795	84.5	83.0	4.11
48	32384	382	231	16800	237	30	0	0	0	0	0	0	396	821	102.0	106.0	5.29

Table A.1 List of Data
(cont'd)

OBS	DATE	DAY	EL	AREA	VOLGROSS	MINTEMP	PRECIP	PLACBUGY	TRUKPUMP	FLOTFIN	KOD	ATR	ASSLEN	FIXEDOH	LABORWH	FINISWH	POURCOST
49	32684	385	244	14900	230	24	0	0	0	0	0	0	489	815	95.5	92.0	4.65
50	32764	386	244	12300	169	23	0	0	0	0	0	0	419	795	91.0	82.5	4.18
51	40264	392	257	13660	216	34	0	0	0	0	0	0	502	835	98.0	82.0	4.52
52	40364	393	257	11260	167	30	0	0	0	0	0	0	432	661	89.5	76.5	3.80
53	40984	399	270	15305	230	34	0	0	0	0	0	0	515	821	100.0	94.0	4.79
54	41064	400	270	12715	180	34	0	0	0	0	0	0	445	774	102.0	84.5	4.40
55	41154	401	283	15365	236	31	0	0	0	0	0	0	528	861	94.0	91.5	4.65
56	41284	402	263	12715	179	38	0	0	0	0	0	0	458	601	90.0	86.5	4.35
57	41364	403	140	14750	210	44	0	0	0	0	0	0	315	801	103.5	94.5	4.87
58	41684	406	140	11980	175	35	0	0	0	0	0	0	385	914	103.0	91.0	4.98
59	41764	407	296	6315	161	32	1	0	0	0	0	0	631	727	86.5	76.0	3.73
60	41964	410	296	14865	188	32	0	0	0	0	0	0	491	801	87.0	84.5	4.23
61	42064	410	296	4915	65	40	0	0	0	0	0	0	521	596	60.0	43.0	2.45
62	42384	413	309	9490	160	37	0	0	0	0	0	0	644	764	72.0	72.5	3.51
63	42564	415	309	13780	211	44	0	0	0	0	0	0	474	827	99.0	104.0	5.18
64	42684	416	322	15740	230	52	0	0	0	0	0	0	567	821	98.0	91.5	4.81
65	42784	417	322	11480	178	63	1	0	0	0	0	0	497	710	76.0	81.0	3.94
66	50284	422	328	15915	230	44	0	0	0	0	0	0	573	947	99.0	102.5	5.53
67	50384	423	348	11365	190	41	0	0	0	0	0	0	523	862	97.5	90.5	4.92
68	50784	427	335	15915	234	46	0	0	0	0	0	0	580	934	95.0	115.0	5.77
69	50884	428	335	6565	100	46	1	0	0	0	0	0	555	960	62.0	77.0	4.05
70	50964	429	257	3900	58	41	0	1	0	0	1	0	452	1037	90.5	81.5	4.61
71	51084	430	309	2400	39	37	0	1	0	0	1	0	449	592	61.0	48.0	3.09
72	51064	430	335	4800	71	37	0	0	0	0	0	0	475	525	60.0	42.0	2.74
73	51184	431	361	14875	220	50	0	0	0	0	0	0	606	897	91.0	91.0	4.87
74	51484	434	18	10480	154	37	0	0	1	1	0	1	113	1012	99.0	40.5	3.82
75	51464	434	361	9599	140	37	0	0	0	0	0	0	536	1105	76.5	62.5	4.07
76	51584	435	93	4880	86	38	0	1	0	0	1	0	363	1105	107.0	50.0	4.34
77	51564	435	18	8409	120	38	0	0	1	1	0	1	98	1025	107.0	48.0	4.31
78	51664	436	36	8363	156	37	0	0	1	0	0	1	121	1339	102.0	64.0	5.19
79	51684	436	361	14635	225	37	0	0	0	0	0	0	606	1147	108.5	98.5	5.98
80	51764	437	36	6899	130	38	0	0	1	0	0	1	111	968	78.5	46.0	3.46
81	51784	437	361	11615	160	38	0	0	0	0	0	0	536	993	75.0	71.5	4.10
82	51884	438	80	1575	30	52	0	0	0	0	0	0	160	620	37.0	8.5	1.43
83	52184	441	54	7133	169	51	0	0	1	0	0	1	129	1177	95.0	64.5	4.71
84	52284	442	367	17300	256	64	0	0	0	0	0	0	632	1104	110.0	77.0	5.23
85	52284	442	54	7288	108	64	0	0	1	0	0	1	129	986	77.0	48.5	3.55
86	52484	444	67	7212	106	57	0	0	1	0	0	1	142	844	55.5	43.0	2.81
87	52484	444	387	11500	170	57	0	0	0	0	0	0	582	858	75.5	55.0	3.48
88	52584	445	374	1145	35	61	0	0	0	0	1	0	569	798	46.5	25.5	2.21
89	52584	445	67	7212	100	61	0	0	1	0	0	1	142	1044	74.0	50.5	3.66
90	53084	450	80	6789	100	44	1	0	1	0	0	1	145	1105	70.0	36.0	3.33
91	53184	451	400	16780	246	43	0	0	0	0	0	0	645	1388	111.0	90.5	5.94
92	60164	452	80	6789	97	59	0	0	1	0	0	1	145	923	67.5	45.5	3.16
93	60164	452	400	12110	178	59	0	0	0	0	0	0	575	1038	103.0	60.5	4.51
94	60464	455	93	14000	194	54	0	0	0	0	0	1	343	1252	106.5	69.0	4.96
95	60584	456	426	14825	234	59	0	0	0	0	0	0	671	1198	96.5	101.5	5.53
96	60684	457	426	11805	160	66	0	0	0	0	0	0	601	976	81.5	89.0	4.45

Table A.1 List of Data
(cont'd)

OBS	DATE	DAY	EL	AREA	VOLGROSS	MINTEMP	PRECIP	PLACBUGY	THUKPUMP	FLOTFIN	KOD	ATR	ASSLEN	FIXEDOH	LABORWH	FINISHWH	POURCOST
97	60784	458	67	2800	40	66	0	0	1	1	0	1	67	886	68.5	22.0	2.82
98	60884	459	452	11890	160	72	0	0	0	0	0	0	627	978	76.0	87.5	4.52
99	61184	462	452	14815	236	63	0	0	0	0	0	0	697	1090	100.5	106.5	5.70
100	61364	464	439	11040	160	73	0	0	0	0	0	0	614	898	77.0	76.5	3.92
101	61464	465	439	17935	260	75	0	0	0	0	0	0	684	1208	103.5	101.5	5.64
102	61584	466	80	1224	16	68	0	0	1	1	0	1	120	174	18.5	6.0	0.62
103	61584	466	107	8600	148	68	0	0	0	0	0	1	342	1010	107.5	36.5	3.84
104	61964	470	465	15125	220	66	0	0	0	0	0	0	710	871	82.0	107.5	5.05
105	62064	471	465	10500	154	66	0	0	0	0	0	0	640	877	57.0	73.0	3.43
106	62164	472	205	2800	40	66	0	0	0	0	1	0	380	948	49.0	33.5	2.68
107	62684	477	478	11550	170	53	0	0	0	0	0	0	653	675	74.5	64.0	3.50
108	62684	477	18	5660	80	53	0	0	1	0	0	1	118	946	66.5	41.0	3.28
109	62784	478	478	17440	251	64	0	0	0	0	0	0	723	1115	92.5	95.5	5.38
110	62884	479	54	4972	60	64	0	0	1	0	0	1	144	391	52.5	49.5	2.65
111	62864	479	426	2270	30	64	0	0	0	0	1	0	616	721	50.0	32.0	2.34
112	62964	460	80	3554	45	60	0	0	1	0	0	1	170	745	60.5	34.5	2.66
113	70264	484	413	12955	159	63	0	0	0	0	0	0	588	1109	98.5	92.5	5.26
114	70364	485	413	15935	261	65	0	0	0	0	0	0	658	1109	96.5	71.0	4.43
115	71064	492	517	12905	179	70	0	0	0	0	0	0	722	757	92.0	70.5	4.08
116	71184	493	517	17105	242	73	0	0	0	0	0	0	792	846	108.0	99.5	5.34
117	71284	494	122	5000	69	63	0	0	0	1	0	1	357	767	113.5	42.5	3.90
118	71764	499	557	16930	260	60	0	0	0	0	0	0	792	846	103.0	97.0	5.07
119	72064	502	361	3950	65	60	0	1	0	0	1	0	536	664	82.5	34.0	3.14
120	72384	505	461	1246	23	68	0	1	0	0	0	0	686	580	57.0	25.5	2.19
121	72684	508	452	5620	100	53	1	1	0	0	1	0	642	798	92.0	54.0	3.71
122	72784	509	543	8335	130	58	0	0	0	0	0	0	818	761	70.5	65.0	3.36
123	73084	512	543	14975	200	61	0	0	0	0	0	0	758	786	104.0	89.0	4.76
124	73164	513	530	9590	145	62	0	0	0	0	0	0	745	754	70.0	91.0	4.23
125	80184	514	530	14635	206	64	0	0	0	0	0	0	805	841	107.5	84.0	4.92
126	80264	515	491	16780	258	74	0	0	0	0	0	0	736	833	104.5	96.0	5.18
127	80684	519	491	11925	176	70	0	0	0	0	0	0	666	740	81.0	77.5	4.08
128	80784	520	504	15340	220	74	0	0	0	0	0	0	779	828	97.0	80.5	4.66
129	80884	521	504	10230	160	70	0	0	0	0	0	0	709	653	70.0	67.0	3.37
130	80984	522	573	14320	260	70	0	0	0	1	0	0	793	758	103.0	59.5	4.02
131	81484	527	93	8185	111	71	0	0	1	0	0	1	378	1174	116.0	59.5	4.60
132	81584	528	93	6907	60	67	0	0	0	0	0	1	413	1005	96.0	56.0	3.96
133	81764	530	599	13450	188	67	0	0	0	0	0	0	804	850	109.0	66.0	4.42
134	82084	533	122	4482	45	61	0	0	0	0	0	1	322	597	73.0	33.5	2.60
135	82184	534	107	5328	63	49	0	0	0	0	0	1	337	705	75.0	46.5	3.09

APPENDIX B

VARIABLE LABLES

This section labels or defines the variables used in this study. Due to field length limitations in SAS, the labels are short and concise.

Table B.1 Variable Labels

```
LABEL AREA=AREA FINISHED BY CEMENT FINISHERS
      ATR=ATRIUM VECTOR
      KOD=KODIAK VECTOR
      POURCOST=COST OF THE POUR IN THOUSANDS
      DAY=DAY OF WORK WITH MARCH 8,1983 AS DAY 1
      EL=ELEVATION OF POUR ABOVE GROUND
      VOLGROSS=GROSS VOLUME OF CONCRETE POUR
      MINTEMP=THE DAILY MINIMUM TEMPERATURE
      ASSLEN=ASSEMBLY LENGTH OF PIPE
      PUMPTRUK=TRUCK PUMPVECTOR TIMES AREA
      TRUKPUMP=TRUCK PUMP VECTOR
      PRECIP=PRECIPITATION VECTOR
      PLACBUGY=BUGGY VECTOR
      FLOTFIN=FLOAT FINISH VECTOR
      FIXEDOH=COST OF SUPERVISION,POLICE,OPERATORS
      LABORWH=LABORERS WORK HOURS
      FINISWH=CEMENT FINISHERS WORK HOURS
      NEWDAY=STANDARDIZED DAYS
      ELSTAND=STANDARDIZED ELEVATION
      TEMP=STANDARDIZED MINIMUM TEMPERATURE
      VOLKOD=VOLGROSS TIMES KODIAK VECTOR
      VOLCRAN=VOLGROSS TIMES CRANE VECTOR
      VOLTRUCK=VOLGROSS TIMES TRUCKPUMP VECTOR
      VOLATR=VOLGROSS TIMES THE ATRIUM VECTOR
      TVOLGROS=VOLGROSS TIMES THE STANDARDIZED TEMP
      PVOLGROS=VOLGROSS TIMES THE PRECIP VECTOR
      VOLBUGY=VOLGROSS TIMES THE BUGGY VECTOR
      PASSLEN=ASSEMBLY LENGTH OF PIPE TIMES PRECIP
      PRECAREA=AREA TIMES THE PRECIPITATION VECTOR
      TEMPAREA=TEMPERATURE TIMES THE AREA
      FLOTAREA=AREA TIMES THE FLOAT VECTOR
      ELASSLEN=EL TIMES ASSLEN
      TASSLEN=TEMP TIMES ASSLEN
      AREAVOL=AREA TIMES VOLGROSS
```

APPENDIX C

TRADITIONAL TEST OF LABORWH

C.1 Introduction

A traditional approach to formulating and testing the LABORWH model is presented in this section. The testing of the model is similar to the testing of the models discussed in Chapter 4 of this thesis; the formulation of the models is much different than the approach proposed in this study.

C.2 Hypothesis

It is thought that MINTEMP, VOLGROSS, EL, AREAVOL, ASSLEN, PRECIP, KOD, ATR, PLACBUGY, AND TRUKPUMP contribute something to the prediction of LABORWH. The null hypothesis, $H_0 : B_0 = B_1 = \ldots B_N = 0$, indicates no variables contribute to LABORWH. The alternate hypothesis, $H_A : B_0 \neq B_1 \neq \ldots B_N \neq 0$, indicates at least one B is not equal to zero.

C.3 Testing the Model

The first regression run with all considered variables included has an $R^2_{ADJ} = 0.5854$ and MSE of 188.836. Removal of PRECIP results in a slight rise in the R^2_{ADJ} (0.5867) and a slight decrease in the MSE (188.274). The R^2_{ADJ} lowers to 0.5829 and the MSE rises to 189.961 when PLACBUGY is removed. These adjustments are small enough to be considered insignificant however. After removing the variable ATR, the R^2_{ADJ} decreases a bit more, and MSE shows a larger increase. Hence, the model with ATR included is considered the best.

The last test to be used in qualifying this model is the F-test on the excluded variables. An alpha value of 0.05 results in an F_C of 3.07. F_O =(37619.231 -37099.812) *124 divided by 2*23415.384. Hence, F_O equals 1.37. Since $F_C > F_O$, it is 95% certain that none of the removed variables contribute significantly to the prediction of LABORWH. The final model is a good model.

C.4 Interpretation of Results

The mobilization/demobilization/contingency buffer (intercept) is 33.4 hours. Labor workhours decreases 0.22 hours for every degree increase in temperature. Maintaining a constant area of pour, the manhours required increases with volume. Elevation remains confusing. The manhours tends to decrease as the elevation increases. Thinner slabs at the higher elevations may be an answer. Kodiak pours tend to require 15 more hours to complete, and atrium pours nearly eight more. Using a truck pump increases the time by 12 1/2 hours on the average.

C.5 Summary

Many testing techniques are covered in the literature. The testing methods used in the body of this study was used in this appendix. The "best" model should be tested again with a new set of data, an additional variables perhaps added.

Table C.1 Traditional Approach Regression Run 1

DEP VARIABLE: LABORWH LABORERS WORK HOURS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	10	37619.231	3761.923	19.922	0.0001
ERROR	124	23415.684	188.836		
C TOTAL	134	61034.915			

ROOT MSE	13.741767	R-SQUARE	0.6164
DEP MEAN	87.162963	ADJ R-SQ	0.5854
C.V.	15.7656		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	30.418670	7.898800	3.851	0.0002
MINTEMP	1	-0.224088	0.113161	-1.980	0.0499
VOLGROSS	1	0.426547	0.077590	5.497	0.0001
EL	1	-0.104731	0.027931	-3.750	0.0003
AREAVOL	1	-0.010533	0.003884258	-2.712	0.0076
ASSLEN	1	0.096547	0.022621	4.268	0.0001
PRECIP	1	-2.835702	3.579561	-0.792	0.4298
KOD	1	10.538317	6.502690	1.621	0.1076
ATR	1	7.905382	5.105032	1.549	0.1240
PLACBUGY	1	9.171701	6.149443	1.491	0.1384
TRUKPUMP	1	13.814883	4.561132	3.029	0.0030

Table C.2 Traditional Approach Regression Run 2

DEP VARIABLE: LABORWH LABORERS WORK HOURS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	9	37500.723	4166.747	22.131	0.0001
ERROR	125	23534.192	188.274		
C TOTAL	134	61034.915			

ROOT MSE	13.721280	R-SQUARE	0.6144
DEP MEAN	87.162963	ADJ R-SQ	0.5867
C.V.	15.7421		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	30.009374	7.870134	3.813	0.0002
MINTEMP	1	-0.221645	0.112950	-1.962	0.0519
VOLGROSS	1	0.419433	0.076953	5.450	0.0001
EL	1	-0.102024	0.027680	-3.686	0.0003
AREAVOL	1	-0.010083	0.003836791	-2.628	0.0097
ASSLEN	1	0.095222	0.022525	4.227	0.0001
KOD	1	10.730969	6.488454	1.654	0.1007
ATR	1	8.494203	5.043103	1.684	0.0946
PLACBUGY	1	8.950987	6.133970	1.459	0.1470
TRUKPUMP	1	13.785563	4.554183	3.027	0.0030

Table C.3 Traditional Approach Regression Run 3

DEP VARIABLE: LABORWH LABORERS WORK HOURS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	8	37099.812	4637.477	24.413	0.0001
ERROR	126	23935.102	189.961		
C TOTAL	134	61034.915			

ROOT MSE	13.782639	R-SQUARE	0.6078
DEP MEAN	87.162963	ADJ R-SQ	0.5829
C.V.	15.81249		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	33.383081	7.556533	4.418	0.0001
MINTEMP	1	-0.219402	0.113445	-1.934	0.0554
VOLGROSS	1	0.403430	0.076509	5.273	0.0001
EL	1	-0.099719	0.027758	-3.592	0.0005
AREAVOL	1	-0.00957786	0.00383821	-2.495	0.0139
ASSLEN	1	0.091067	0.022444	4.057	0.0001
KOD	1	14.995486	5.818968	2.577	0.0111
ATR	1	7.778109	5.041615	1.543	0.1254
TRUKPUMP	1	12.482777	4.485787	2.783	0.0062

Table C.4 Traditional Approach Regression Run 4

DEP VARIABLE: LABORWH LABORERS WORK HOURS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	7	36647.672	5235.382	27.264	0.0001
ERROR	127	24387.243	192.026		
C TOTAL	134	61034.915			

ROOT MSE	13.857328	R-SQUARE	0.6004
DEP MEAN	87.162963	ADJ R-SQ	0.5784
C.V.	15.89818		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	31.704606	7.518326	4.217	0.0001
MINTEMP	1	-0.114789	0.091442	-1.255	0.2117
VOLGROSS	1	0.402371	0.076920	5.231	0.0001
EL	1	-0.117769	0.025309	-4.653	0.0001
AREAVOL	1	-0.00993253	0.003852081	-2.578	0.0111
ASSLEN	1	0.098388	0.022056	4.461	0.0001
KOD	1	13.242173	5.737838	2.308	0.0226
TRUKPUMP	1	14.056211	4.391985	3.200	0.0017

Table C.5 Traditional Approach Regression Run 5

DEP VARIABLE: LABORWH LABORERS WORK HOURS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	6	36345.074	6057.512	31.404	0.0001
ERROR	128	24689.841	192.889		
C TOTAL	134	61034.915			

ROOT MSE	13.888462	R-SQUARE	0.5955
DEP MEAN	87.162963	ADJ R-SQ	0.5765
C.V.	15.9339		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	26.677331	6.377231	4.183	0.0001
VOLGROSS	1	0.445315	0.069049	6.449	0.0001
EL	1	-0.123217	0.024990	-4.931	0.0001
AREAVOL	1	-0.011842	0.003546966	-3.339	0.0011
ASSLEN	1	0.094936	0.021933	4.328	0.0001
KOD	1	13.651740	5.741425	2.378	0.0189
TRUKPUMP	1	12.093022	4.113335	2.940	0.0039

APPENDIX D

LABORWH COMPUTER OUTPUT

The regression runs used to formulate the model for the prediction of LABORWH are included in this section. The final step of the stepwise regression run is presented first, followed by the individual runs. Residual plots are included to complete the output. The draft model is: LABORWH= INTERCEPT +NEWDAY +ELSTAND +TEMP +PRECIP +KOD +ATR +PLACBUGY +TRUKPUMP +VOLGROSS +VOLKOD +VOLDAY +TVOLGROS +PVOLGROS +VOLCRAN +VOLBUGY +VOLTRUCK +ASSLEN +ELASSLEN +TASSLEN +PASSLEN +AREAVOL. This model transforms to : LABORWH= INTERCEPT (1+NEWDAY +ELSTAND +TEMP +PRECIP +KOD +ATR +PLACBUGY +TRUKPUMP) +VOLGROSS*(1+VOLKOD +VOLDAY +TVOLGROS +PVOLGROS +VOLCRAN +VOLBUGY +VOLTRUCK) +ASSLEN*(1+ELASSLEN +TASSLEN +PASSLEN) +AREAVOL.

Table D.1 Last Step of Stepwise Regression Run

FORWARD SELECTION PROCEDURE FOR DEPENDENT VARIABLE LABORWH

STEP 13 VARIABLE PASSLEN ENTERED R SQUARE = 0.70486082
C(P) = 14.73851490

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	13	43021.11993471	3309.316918	22.23	0.0001
ERROR	121	18013.79488011	148.874338		
TOTAL	134	61034.91481481			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	13.2024019				
ELSTAND	-0.0572784	0.0409380	291.439843	1.96	0.1643
TEMP	-0.4818725	0.1776665	1095.148185	7.36	0.0077
KOD	-23.0242712	13.1872712	453.818034	3.05	0.0834
VOLGROSS	0.3123299	0.0744921	2617.135534	17.58	0.0001
VOLKOD	0.5609147	0.1990404	1182.309441	7.94	0.0056
VOLDAY	0.0007798	0.0001890	2535.695002	17.03	0.0001
TVOLGROS	-0.0037349	0.0011441	158[illegible].520904	10.66	0.0014
VOLTRUCK	0.1446653	0.0315690	3126.278796	21.00	0.0001
ASSLEN	0.0826540	0.0210563	2293.943334	15.41	0.0001
ELASSLEN	-0.0001741	0.0000568	1397.057954	9.38	0.0027
TASSLEN	0.0020747	0.0004448	3239.052544	21.76	0.0001
PASSLEN	-0.0106572	0.0088031	218.191863	1.47	0.2284
AREAVOL	-0.0048542	0.0036444	264.121999	1.77	0.1854

NO OTHER VARIABLES MET THE 0.2500 SIGNIFICANCE LEVEL FOR ENTRY

Table D.2 Regression Run 1

DEP VARIABLE: LABORWH LABORERS WORK HOURS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	13	43021.120	3309.317	22.229	0.0001
ERROR	121	18013.795	148.874		
C TOTAL	134	61034.915			

ROOT MSE	12.201407	R-SQUARE	0.7049
DEP MEAN	87.162963	ADJ R-SQ	0.6732
C.V.	13.99839		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	13.202402	9.790834	1.348	0.1800
ELSTAND	1	-0.057278	0.040938	-1.399	0.1643
TEMP	1	-0.481872	0.177667	-2.712	0.0077
KOD	1	-23.024271	13.187271	-1.746	0.0834
VOLGROSS	1	0.312330	0.074492	4.193	0.0001
VOLKOD	1	0.560915	0.199040	2.818	0.0056
VOLDAY	1	0.000779808	0.0001889509	4.127	0.0001
TVOLGROS	1	-0.00373495	0.001144121	-3.264	0.0014
VOLTRUCK	1	0.144665	0.031569	4.583	0.0001
ASSLEN	1	0.082654	0.021056	3.925	0.0001
ELASSLEN	1	-0.000174055	0.0000568184	-3.063	0.0027
TASSLEN	1	0.002074695	0.0004447902	4.664	0.0001
PASSLEN	1	-0.010657	0.008803051	-1.211	0.2284
AREAVOL	1	-0.00485425	0.00364443	-1.332	0.1854

Table D.3 Regression Run 2

DEP VARIABLE: LABORWH LABORERS WORK HOURS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	12	42802.928	3566.911	23.868	0.0001
ERROR	122	18231.987	149.443		
C TOTAL	134	61034.915			

ROOT MSE	12.224668	R-SQUARE	0.7013
DEP MEAN	87.162963	ADJ R-SQ	0.6719
C.V.	14.02507		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	14.922151	9.705701	1.537	0.1268
ELSTAND	1	-0.051115	0.040698	-1.256	0.2115
TEMP	1	-0.502144	0.177213	-2.834	0.0054
KOD	1	-19.913814	12.959218	-1.537	0.1270
VOLGROSS	1	0.304310	0.074338	4.094	0.0001
VOLKOD	1	0.501834	0.193333	2.596	0.0106
VOLDAY	1	0.0008100036	0.0001876545	4.316	0.0001
TVOLGROS	1	-0.00365652	0.001144463	-3.195	0.0018
VOLTRUCK	1	0.146800	0.031580	4.649	0.0001
ASSLEN	1	0.077957	0.020735	3.760	0.0003
ELASSLEN	1	-0.000180747	.00005665671	-3.190	0.0018
TASSLEN	1	0.002123283	0.0004438202	4.784	0.0001
AREAVOL	1	-0.00428185	0.003620519	-1.183	0.2392

Table D.4 Regression Run 3

DEP VARIABLE: LABORWH LABORERS WORK HOURS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	11	42593.904	3872.173	25.827	0.0001
ERROR	123	18441.011	149.927		
C TOTAL	134	61034.915			

ROOT MSE	12.244465	R-SQUARE	0.6979
DEP MEAN	87.162963	ADJ R-SQ	0.6708
C.V.	14.04778		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	19.570741	8.888542	2.202	0.0295
ELSTAND	1	-0.046287	0.040558	-1.141	0.2560
TEMP	1	-0.534852	0.175325	-3.051	0.0028
KOD	1	-24.286076	12.440814	-1.952	0.0532
VOLGROSS	1	0.221036	0.023877	9.257	0.0001
VOLKOD	1	0.556734	0.187981	2.962	0.0037
VOLDAY	1	0.0008233475	0.0001876184	4.388	0.0001
TVOLGROS	1	-0.00392455	0.001123614	-3.493	0.0007
VOLTRUCK	1	0.157938	0.030192	5.231	0.0001
ASSLEN	1	0.078745	0.020758	3.793	0.0002
ELASSLEN	1	-0.000190577	.00005613438	-3.395	0.0009
TASSLEN	1	0.002214997	0.0004377003	5.061	0.0001

Table D.5 Regression Run 4

DEP VARIABLE: LABORWH LABORERS WORK HOURS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	10	42398.629	4239.863	28.211	0.0001
ERROR	124	18636.286	150.293		
C TOTAL	134	61034.915			

ROOT MSE	12.259389	R-SQUARE	0.6947
DEP MEAN	87.162963	ADJ R-SQ	0.6700
C.V.	14.06491		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	28.230037	4.635538	6.090	0.0001
TEMP	1	-0.571671	0.172541	-3.313	0.0012
KOD	1	-27.082274	12.212032	-2.218	0.0284
VOLGROSS	1	0.221924	0.023894	9.288	0.0001
VOLKOD	1	0.585369	0.186526	3.138	0.0021
VOLDAY	1	0.0008387919	0.0001873578	4.477	0.0001
TVOLGROS	1	-0.00394214	0.001124878	-3.505	0.0006
VOLTRUCK	1	0.164595	0.029659	5.550	0.0001
ASSLEN	1	0.060727	0.013494	4.500	0.0001
ELASSLEN	1	-0.000241269	0.0000343661	-7.021	0.0001
TASSLEN	1	0.002341039	0.0004240542	5.521	0.0001

Table D.6 Regression Run 5

DEP VARIABLE: LABORWH LABORERS WORK HOURS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	9	41659.480	4628.831	29.863	0.0001
ERROR	125	19375.435	155.003		
C TOTAL	134	61034.915			

ROOT MSE	12.450039	R-SQUARE	0.6826
DEP MEAN	87.162963	ADJ R-SQ	0.6597
C.V.	14.28363		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	27.823380	4.703942	5.915	0.0001
TEMP	1	-0.606071	0.174515	-3.473	0.0007
VOLGROSS	1	0.237551	0.023186	10.245	0.0001
VOLKOD	1	0.211387	0.080947	2.611	0.0101
VOLDAY	1	0.0009184566	0.0001867414	4.918	0.0001
TVOLGROS	1	-0.00361091	0.001132256	-3.189	0.0018
VOLTRUCK	1	0.163036	0.030112	5.414	0.0001
ASSLEN	1	0.055435	0.013488	4.110	0.0001
ELASSLEN	1	-0.000237762	.00003486358	-6.820	0.0001
TASSLEN	1	0.002222851	0.0004272343	5.203	0.0001

Table D.7 Influence Diagnostics

OBS	DFBETAS INTERCEP	DFBETAS TEMP	DFBETAS KOD	DFBETAS VOLGROSS	DFBETAS VOLKOD	DFBETAS VOLDAY	DFBETAS TVOLGROS	DFBETAS ELASSLEN	DFBETAS TASSLEN
1	0.1140	-0.1603	-0.0279	-0.0979	-0.0161	0.6096	-0.3455	-0.2004	0.2916
25	-0.7104	0.3008	-0.0388	-0.0459	0.0167	0.1146	-0.2081	-0.3251	-0.1013
97	0.8405	0.8414	-0.0782	0.0387	0.0484	-0.0788	-0.2112	0.6325	-0.5437
102	-0.5007	-0.5655	0.1296	0.0744	-0.0777	0.1279	0.2513	-0.3113	0.2072

OBS	DFBETAS VOLTRUCK	DFBETAS ASSLEN
1	-0.2015	-0.0128
25	0.5866	0.5929
97	-0.3667	-0.6841
102	0.2516	0.3322

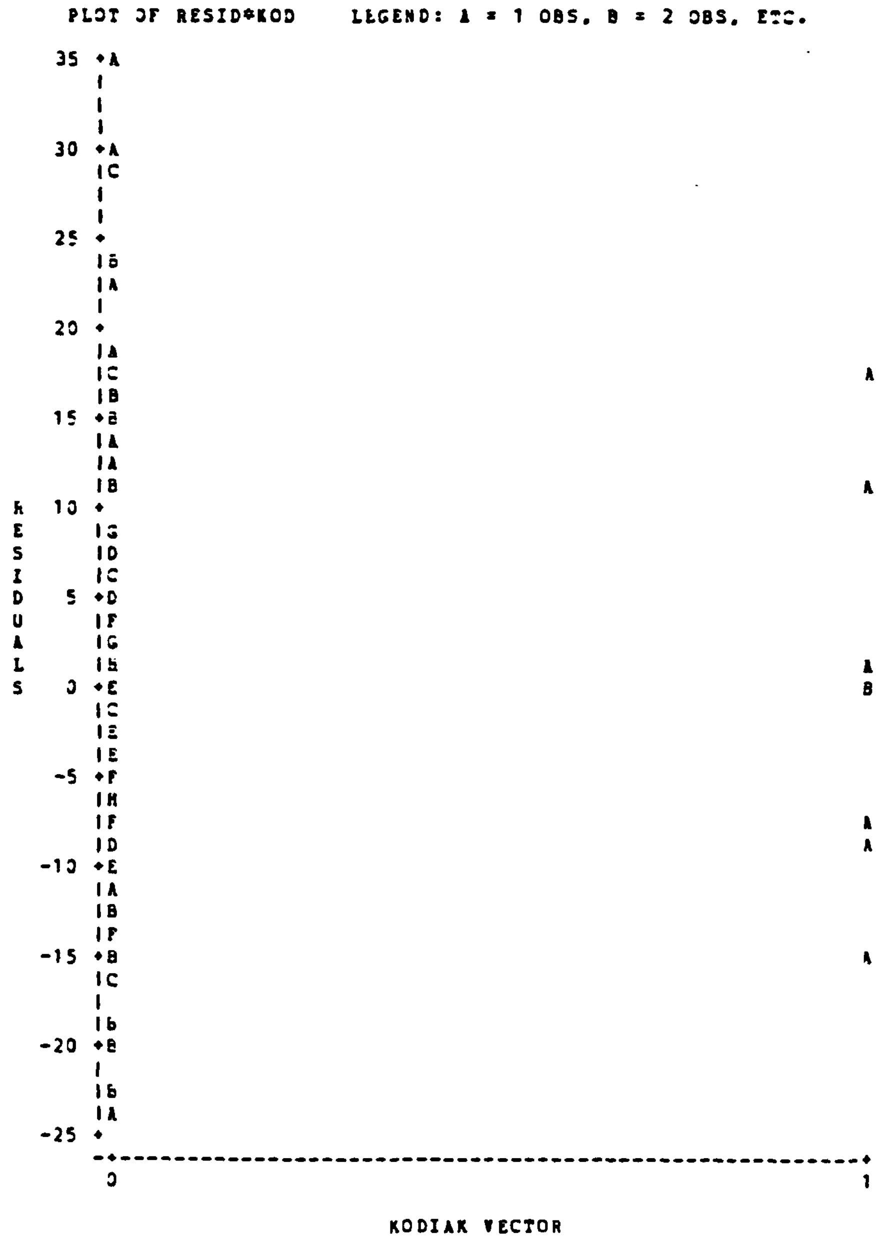


Figure D.1 Plot of Residuals Versus KOD

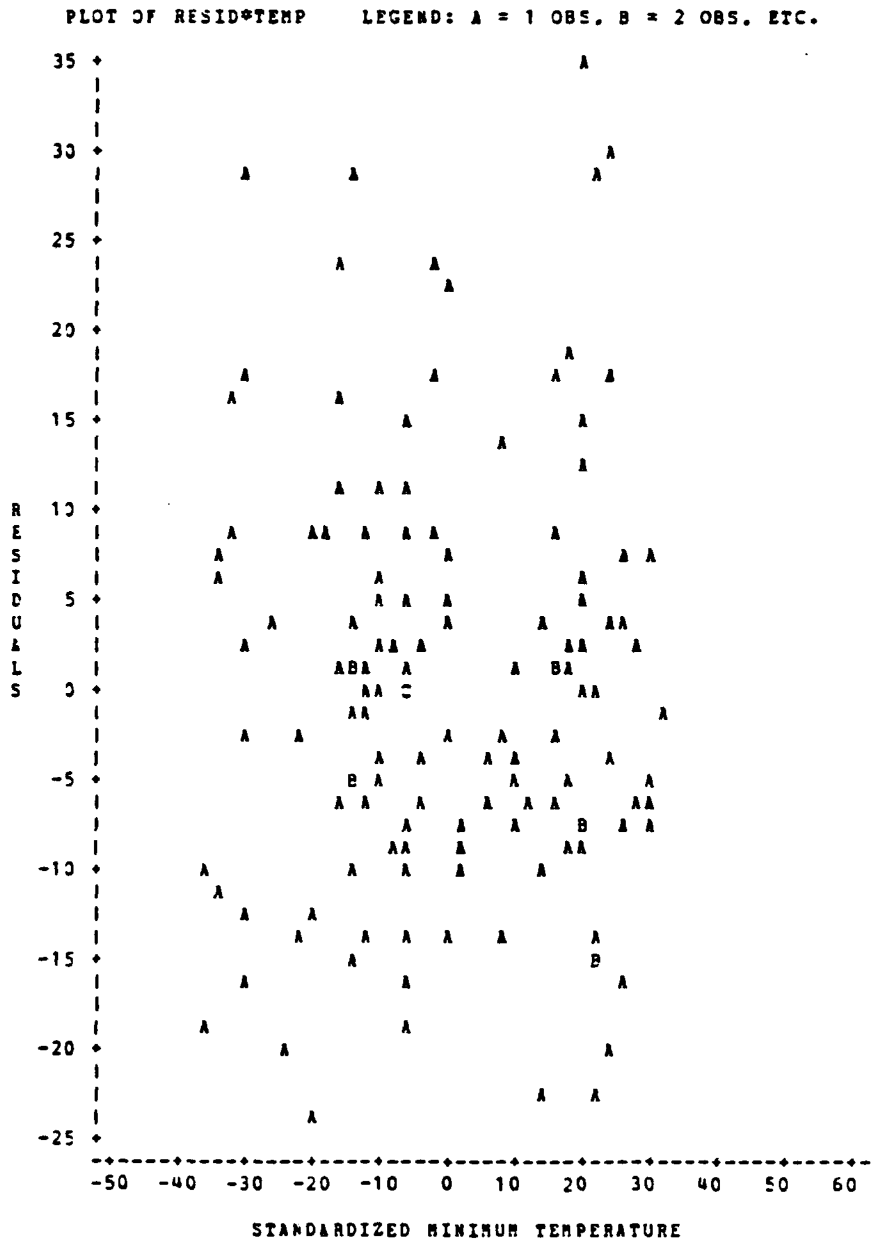


Figure D.2 Plot of Residuals Versus TEMP

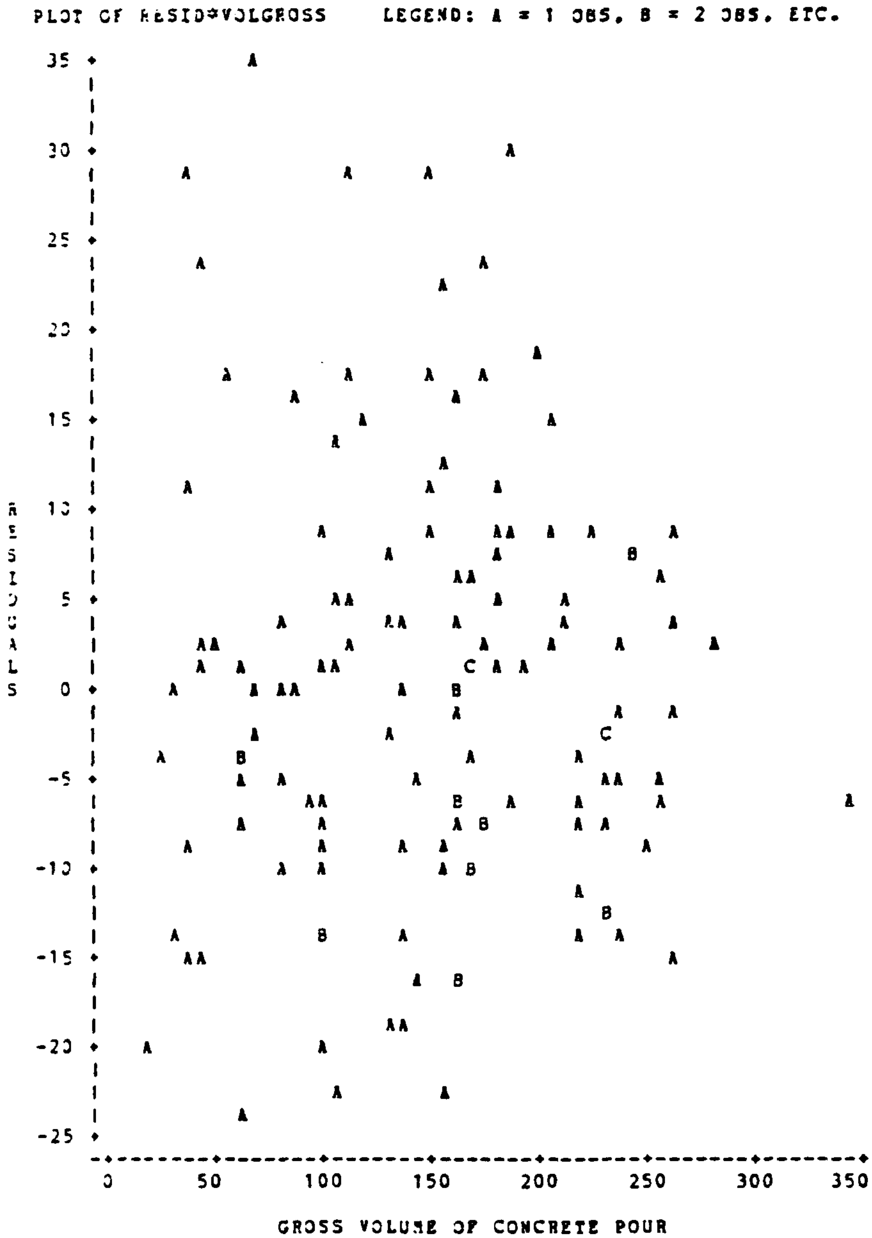


Figure D.3 Plot of Residuals Versus VOLGROSS

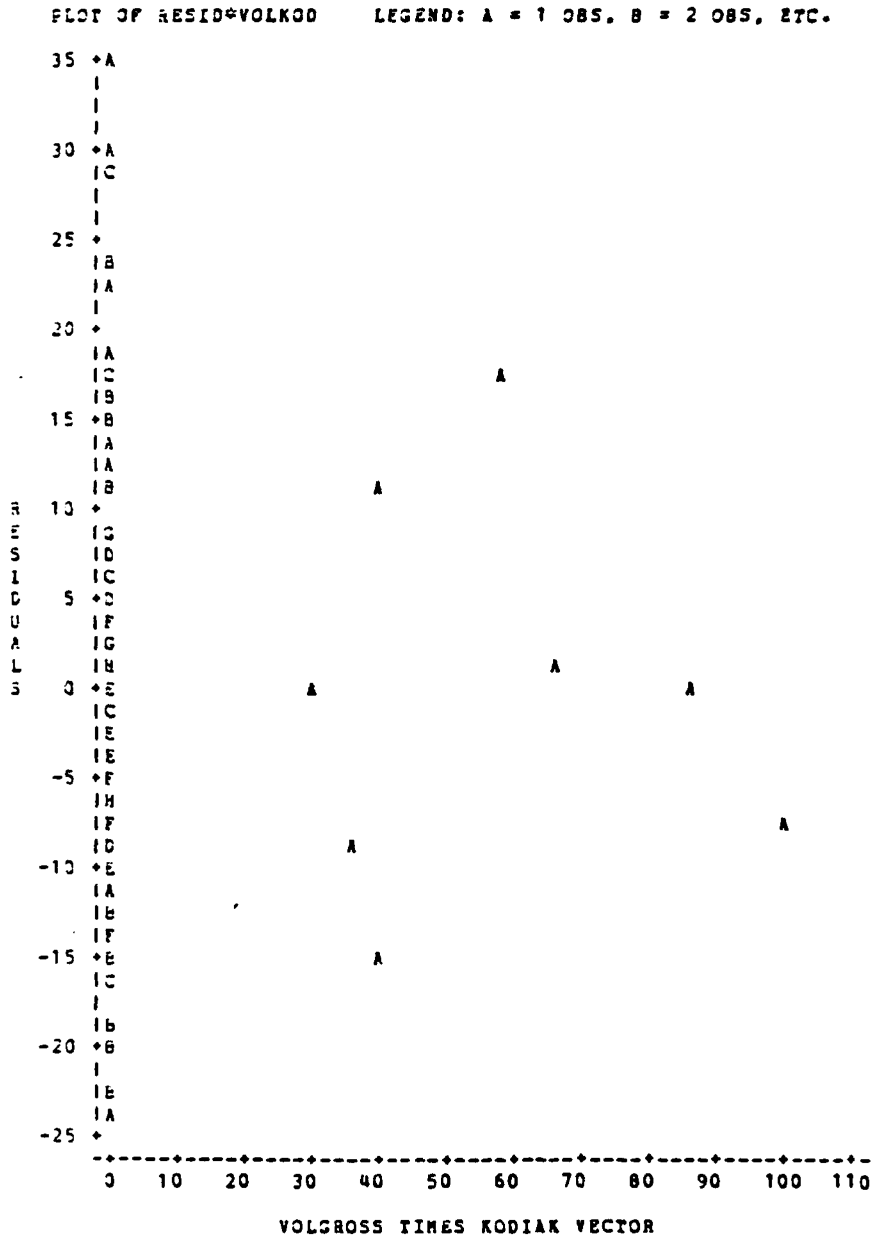


Figure D.4 Plot of Residuals Versus VOLKOD

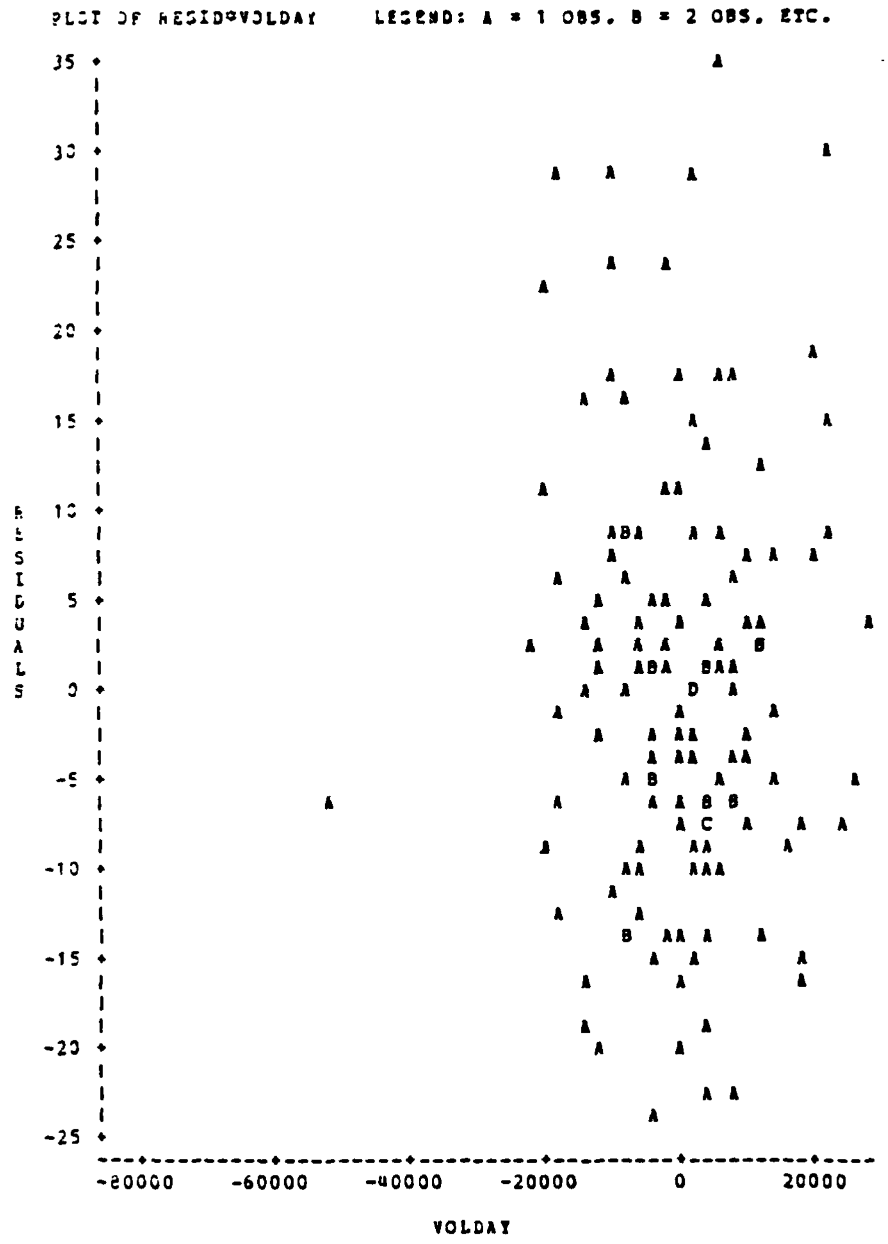


Figure D.5 Plot of Residuals Versus VOLDAY

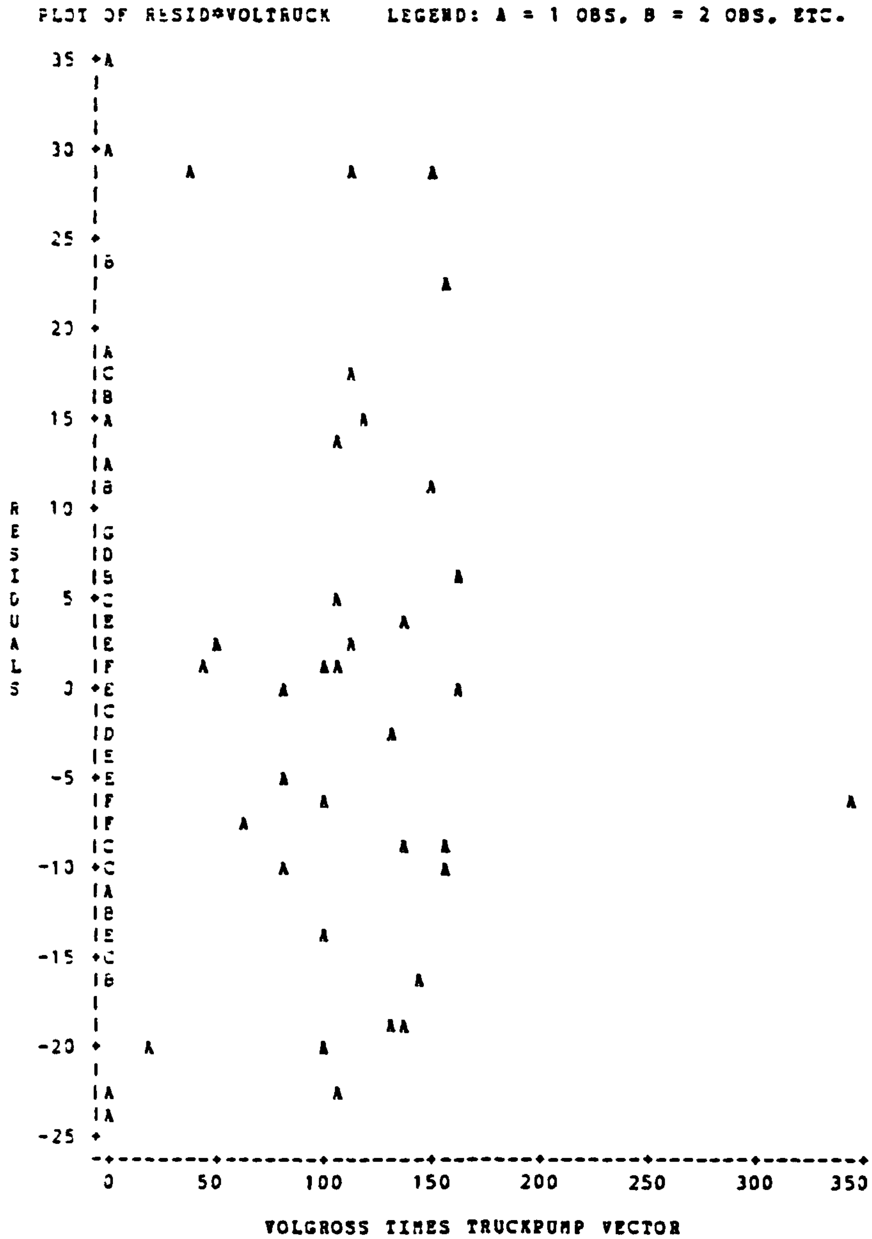


Figure D.6 Plot of Residuals Versus VOLTRUCK

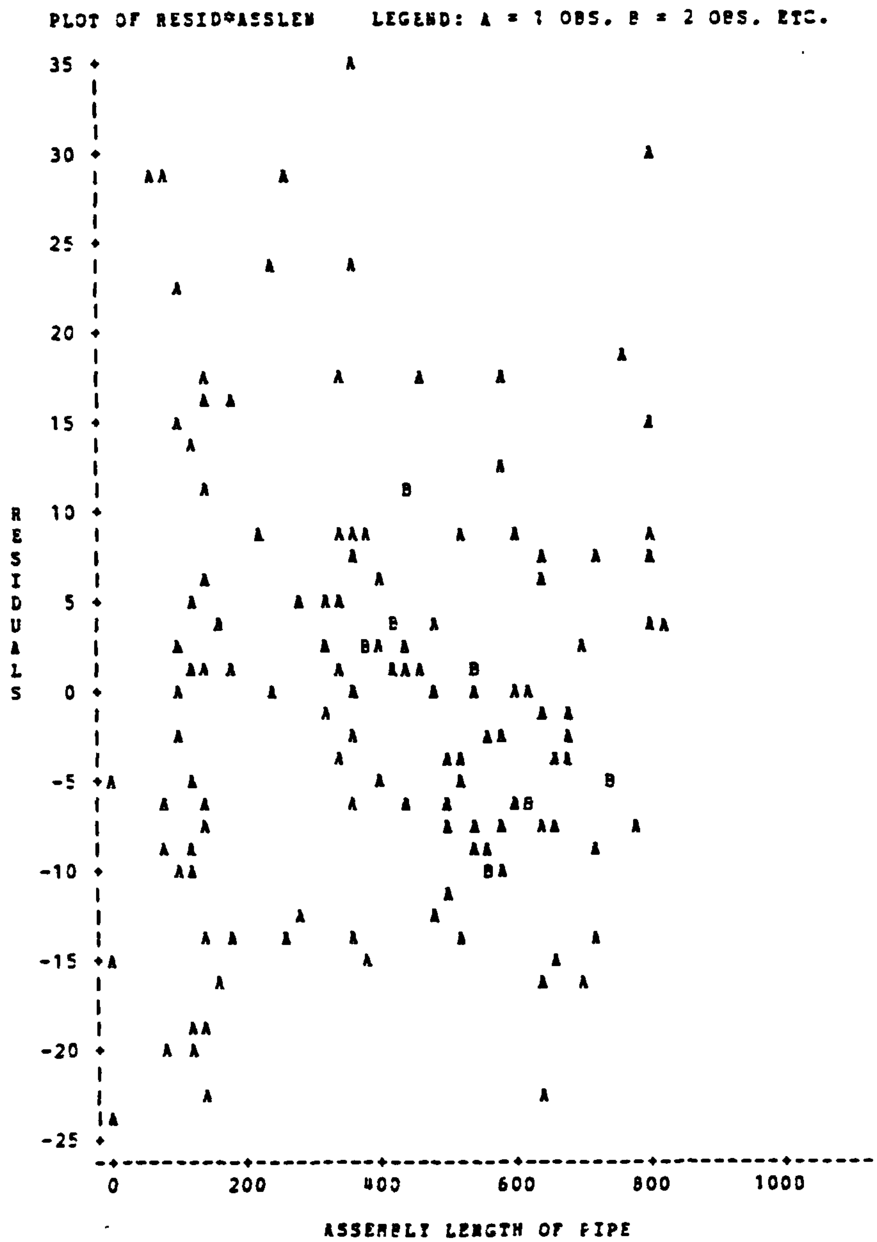


Figure D.7 Plot of Residuals Versus ASSLEN

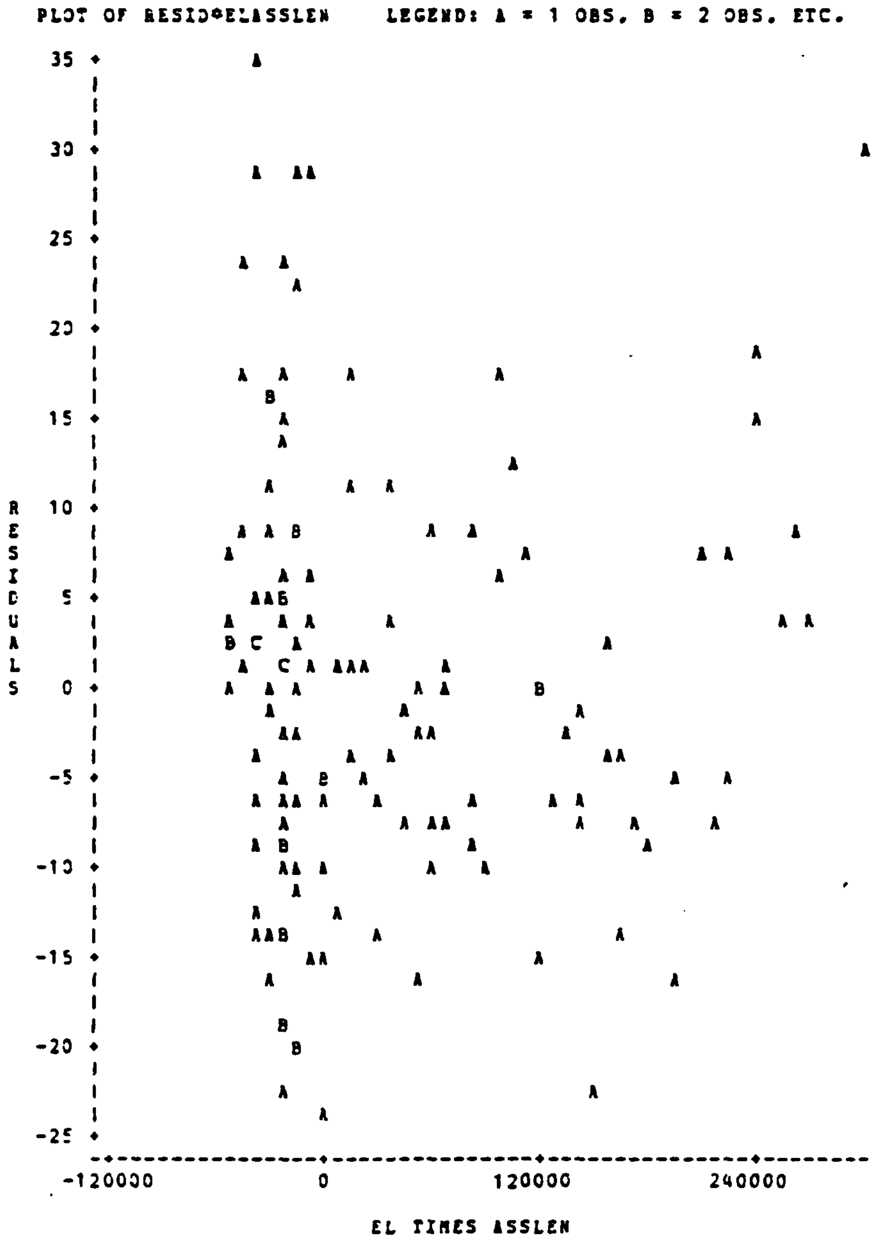


Figure D.3 Plot of Residuals Versus ELASSLEN

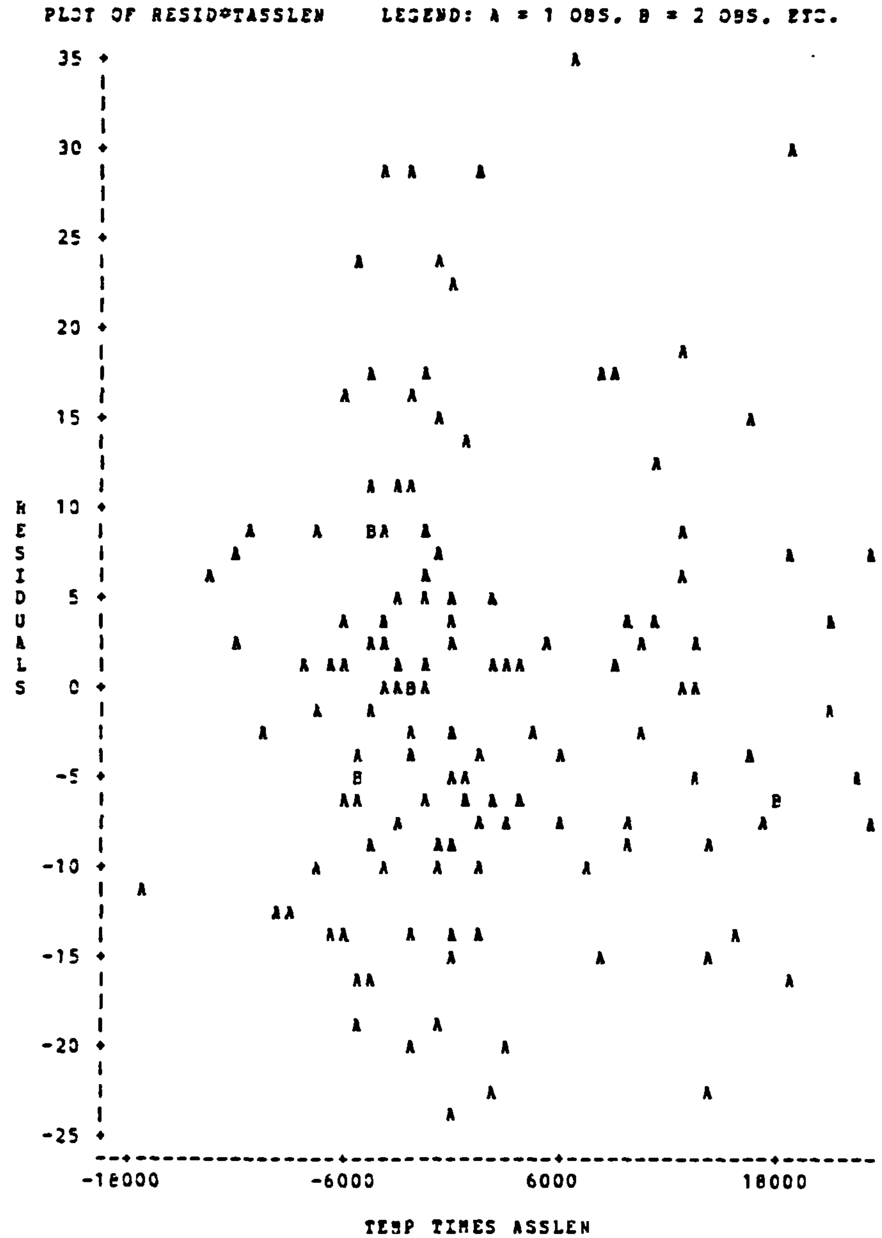


Figure D.9 Plot of Residuals Versus TASSLEN

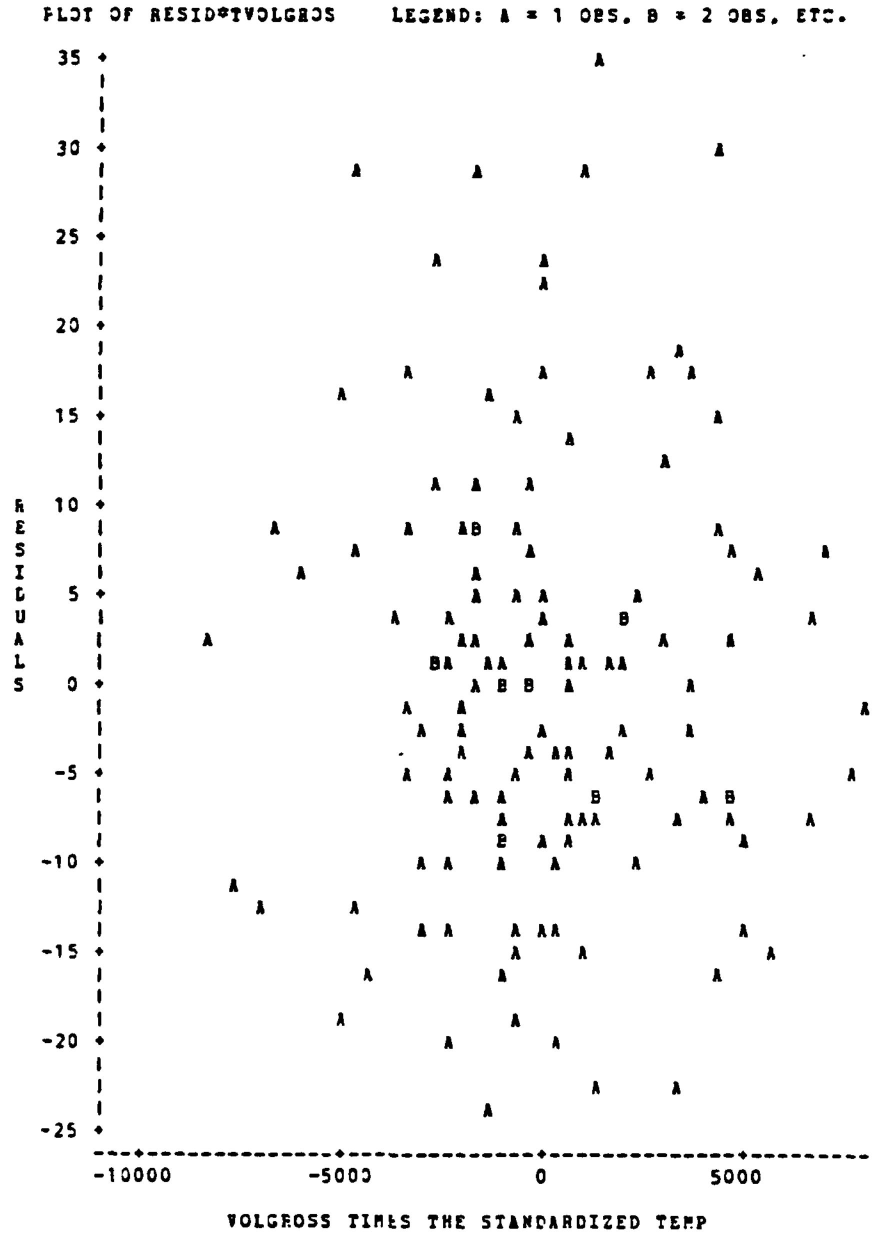


Figure D.10 Plot of Residuals Versus TVOLGROS

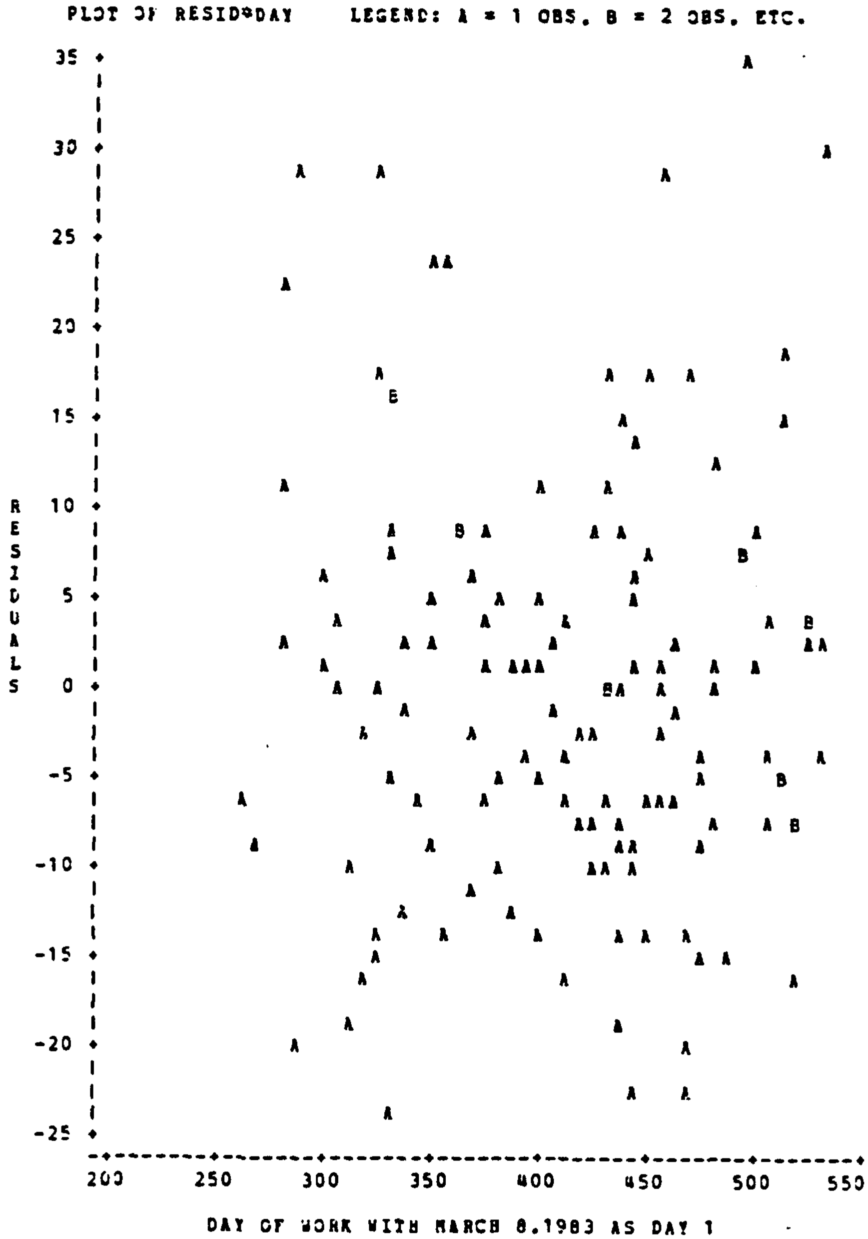


Figure D.11 Plot of Residuals Versus DAY

APPENDIX E

FINISWH COMPUTER OUTPUT

The regression runs used to formulate the model for the prediction of FINISWH are included in this section.

Table E.1 Regression Run 1

DEP VARIABLE: FINISWH CEMENT FINISHERS WORK HOURS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	10	64688.086	6468.809	51.631	0.0001
ERROR	124	15535.914	125.290		
C TOTAL	134	80224.000			

ROOT MSE	11.193285	R-SQUARE	0.8063
DEP MEAN	67.500000	ADJ R-SQ	0.7907
C.V.	16.58264		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	25.414528	4.287637	5.927	0.0001
NEWDAY	1	-0.049386	0.028547	-1.730	0.0861
TEMP	1	-0.207352	0.173046	-1.198	0.2331
AREA	1	0.005598014	0.0008650635	6.471	0.0001
ELSTAND	1	0.021635	0.009400167	2.302	0.0230
PRECIP	1	1.080380	7.582052	0.142	0.8869
FLOTFIN	1	-15.357549	5.703035	-2.693	0.0081
AREAVOL	1	-0.00530838	0.002948828	-1.800	0.0743
TEMPAREA	1	-.0000026418	0.0000142148	-0.186	0.8529
PRECAREA	1	0.0001866267	0.0008586422	0.217	0.8283
FLOTAREA	1	-0.00105633	0.0006039871	-1.749	0.0828

Table E.2 Regression Run 2

DEP VARIABLE: FINISWH CEMENT FINISHERS WORK HOURS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	9	64685.542	7187.282	57.818	0.0001
ERROR	125	15538.458	124.308		
C TOTAL	134	80224.000			

ROOT MSE	11.149335	R-SQUARE	0.8063
DEP MEAN	67.500000	ADJ R-SQ	0.7924
C.V.	16.51753		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR HO: PARAMETER=0	PROB > |T|
INTERCEP	1	25.564269	4.140538	6.174	0.0001
NEWDAY	1	-0.049993	0.028116	-1.778	0.0778
TEMP	1	-0.211473	0.169943	-1.244	0.2157
AREA	1	0.005586176	0.0008576841	6.513	0.0001
ELSTAND	1	0.021670	0.009360076	2.315	0.0222
FLOTFIN	1	-15.310027	5.670920	-2.700	0.0079
AREAVOL	1	-0.00531735	0.00293658	-1.811	0.0726
TEMPAREA	1	-.0000020239	.00001348411	-0.150	0.8809
PRECAREA	1	0.0002995416	0.000329337	0.910	0.3648
FLOTAREA	1	-0.00106401	0.0005992159	-1.776	0.0782

Table E.3 Regression Run 3

DEP VARIABLE: FINISWH CEMENT FINISHERS WORK HOURS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	8	64682.742	8085.343	65.552	0.0001
ERROR	126	15541.258	123.343		
C TOTAL	134	80224.000			

ROOT MSE	11.106004	R-SQUARE	0.8063
DEP MEAN	67.500000	ADJ R-SQ	0.7940
C.V.	16.45334		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	25.624145	4.105260	6.242	0.0001
NEWDAY	1	-0.048793	0.026851	-1.817	0.0716
TEMP	1	-0.232843	0.092429	-2.519	0.0130
AREA	1	0.005575753	0.0008515462	6.548	0.0001
ELSTAND	1	0.021336	0.009056745	2.356	0.0200
FLOTFIN	1	-15.399236	5.617771	-2.741	0.0070
AREAVOL	1	-0.00531096	0.002924859	-1.816	0.0718
PRECAREA	1	0.0003069892	0.0003243124	0.947	0.3457
FLOTAREA	1	-0.00105356	0.0005928416	-1.777	0.0780

Table E.4 Regression Run 4

DEP VARIABLE: FINISWH CEMENT FINISHERS WORK HOURS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	7	64572.223	9224.603	74.849	0.0001
ERROR	127	15651.777	123.242		
C TOTAL	134	80224.000			

ROOT MSE	11.101457	R-SQUARE	0.8049
DEP MEAN	67.500000	ADJ R-SQ	0.7941
C.V.	16.4466		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	25.853691	4.096414	6.311	0.0001
NEWDAY	1	-0.049134	0.026837	-1.831	0.0695
TEMP	1	-0.248873	0.090828	-2.740	0.0070
AREA	1	0.005610228	0.0008504186	6.597	0.0001
ELSTAND	1	0.021841	0.009037294	2.417	0.0171
FLOTFIN	1	-15.482392	5.614784	-2.757	0.0067
AREAVOL	1	-0.00546407	0.002919188	-1.872	0.0635
FLOTAREA	1	-0.000978925	0.0005873351	-1.667	0.0980

Table E.5 Regression Run 5

DEP VARIABLE: FINISWH CEMENT FINISHERS WORK HOURS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	6	64229.860	10704.977	85.671	0.0001
ERROR	128	15994.140	124.954		
C TOTAL	134	80224.000			

ROOT MSE	11.178292	R-SQUARE	0.8006
DEP MEAN	67.500000	ADJ R-SQ	0.7913
C.V.	16.56043		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	26.542491	4.103722	6.468	0.0001
NEWDAY	1	-0.050445	0.027011	-1.868	0.0641
TEMP	1	-0.239527	0.091282	-2.624	0.0097
AREA	1	0.005736147	0.0008529189	6.725	0.0001
ELSTAND	1	0.023243	0.009060339	2.565	0.0115
FLOTFIN	1	-23.093638	3.289417	-7.021	0.0001
AREAVOL	1	-0.0065859	0.002860192	-2.303	0.0229

Table E.6 Regression Run 6

DEP VARIABLE: FINISWH CEMENT FINISHERS WORK HOURS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	5	63794.058	12758.812	100.176	0.0001
ERROR	129	16429.942	127.364		
C TOTAL	134	80224.000			

ROOT MSE	11.285561	R-SQUARE	0.7952
DEP MEAN	67.500000	ADJ R-SQ	0.7873
C.V.	16.71935		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	26.609234	4.142945	6.423	0.0001
TEMP	1	-0.361500	0.064383	-5.615	0.0001
AREA	1	0.005528116	0.0008537281	6.475	0.0001
ELSTAND	1	0.016334	0.00834992	1.956	0.0526
FLOTFIN	1	-22.264153	3.290569	-6.766	0.0001
AREAVOL	1	-0.00553314	0.002830999	-1.954	0.0528

Table E.7 Regression Run 7

DEP VARIABLE: FINISWH CEMENT FINISHERS WORK HOURS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	4	63307.527	15826.882	121.627	0.0001
ERROR	130	16916.473	130.127		
C TOTAL	134	80224.000			

ROOT MSE	11.407310	R-SQUARE	0.7891
DEP MEAN	67.500000	ADJ R-SQ	0.7826
C.V.	16.89972		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	32.778303	2.712479	12.084	0.0001
TEMP	1	-0.370179	0.064923	-5.702	0.0001
AREA	1	0.003936442	0.0002589915	15.199	0.0001
ELSTAND	1	0.014805	0.008402869	1.762	0.0804
FLOTFIN	1	-24.868434	3.041176	-8.177	0.0001

APPENDIX F

FIXEDOH COMPUTER OUTPUT

The regression runs used to formulate the model for the prediction of FIXEDOH are included in this section. The final step of the stepwise regression run is presented first, followed by the individual runs. Initial model tested in the stepwise procedure is: FIXEDOH= NEWDAY +ELSTAND +TEMP +PRECIP +KOD +ATR +FLOTFIN +LABORWH +FINISWH +PLACBUGY +TRUKPUMP +VOLGROSS +VOLKOD +VOLATR +VOLDAY +TVOLGROS +PVOLGROS +VOLBUGY +VOLTRUCK +ASSLEN +ELASSLEN +TASSLEN +PASSLEN +AREAVOL.

Table F.1 Last Step of Stepwise Regression Run

FORWARD SELECTION PROCEDURE FOR DEPENDENT VARIABLE FIXEDOH

STEP 13 VARIABLE NEWDAY ENTERED R SQUARE = 0.69799713
C(P) = 7.65228210

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	13	4358788.227196	335291.4021	21.51	0.0001
ERROR	121	1885919.698730	15586.1132		
TOTAL	134	6244707.925926			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	336.414339				
NEWDAY	0.527056	0.415309	25102.0634	1.61	0.2069
TEMP	8.505632	1.927107	303626.2994	19.48	0.0001
PRECIP	230.992568	61.886367	217142.0142	13.93	0.0003
KOD	137.256211	57.099670	90060.5591	5.78	0.0177
ATR	-295.326912	101.872996	130986.2517	8.40	0.0044
FLOTFIN	-103.358294	47.262379	74541.3637	4.78	0.0307
LABORWH	4.035807	0.787518	409333.5781	26.26	0.0001
FINISWH	1.350122	0.948186	31600.7289	2.03	0.1570
VOLATR	2.799844	0.704534	246150.9777	15.79	0.0001
VOLTRUCK	1.709574	0.287416	551431.0178	35.38	0.0001
TASSLEN	-0.013671	0.003941	187584.8820	12.04	0.0007
PASSLEN	-0.448450	0.160371	121875.2006	7.82	0.0060
AREAVOL	0.022955	0.015726	33207.9512	2.13	0.1470

NO OTHER VARIABLES MET THE 0.2500 SIGNIFICANCE LEVEL FOR ENTRY

Table F.2 Regression Run 1

DEP VARIABLE: FIXEDOH COST OF SUPERVISION,POLICE,OPERATORS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	13	4358788	335291	21.512	0.0001
ERROR	121	1885920	15586.113		
C TOTAL	134	6244708			

ROOT MSE	124.844	R-SQUARE	0.6980
DEP MEAN	845.741	ADJ R-SQ	0.6656
C.V.	14.76154		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	336.414	60.274954	5.581	0.0001
NEWDAY	1	0.527056	0.415309	1.269	0.2069
TEMP	1	8.505632	1.927107	4.414	0.0001
PRECIP	1	230.993	61.886367	3.733	0.0003
KOD	1	137.256	57.099670	2.404	0.0177
ATR	1	-295.327	101.873	-2.899	0.0044
FLOTFIN	1	-103.358	47.262379	-2.187	0.0307
LABORWH	1	4.035807	0.787518	5.125	0.0001
FINISWH	1	1.350122	0.948186	1.424	0.1570
VOLATR	1	2.799844	0.704534	3.974	0.0001
VOLTRUCK	1	1.709574	0.287416	5.948	0.0001
TASSLEN	1	-0.013671	0.00394065	-3.469	0.0007
PASSLEN	1	-0.448450	0.160371	-2.796	0.0060
AREAVOL	1	0.022955	0.015726	1.460	0.1470

Table F.3 Regression Run 2

DEP VARIABLE: FIXEDOH COST OF SUPERVISION,POLICE,OPERATORS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	12	4333686	361141	23.055	0.0001
ERROR	122	1911022	15664.113		
C TOTAL	134	6244708			

ROOT MSE	125.156	R-SQUARE	0.6940
DEP MEAN	845.741	ADJ R-SQ	0.6639
C.V.	14.79843		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	324.653	59.707024	5.437	0.0001
TEMP	1	8.607385	1.930250	4.459	0.0001
PRECIP	1	212.989	60.389051	3.527	0.0006
KOD	1	159.800	54.401803	2.937	0.0040
ATR	1	-232.670	89.331922	-2.605	0.0103
FLOTFIN	1	-121.940	45.049534	-2.707	0.0078
LABORWH	1	4.073924	0.788912	5.164	0.0001
FINISWH	1	1.316818	0.950191	1.386	0.1683
VOLATR	1	2.670394	0.698853	3.821	0.0002
VOLTRUCK	1	1.475009	0.220653	6.685	0.0001
TASSLEN	1	-0.011448	0.003538588	-3.235	0.0016
PASSLEN	1	-0.400058	0.156161	-2.562	0.0116
AREAVOL	1	0.026806	0.015469	1.733	0.0856

Table F.4 Regression Run 3

DEP VARIABLE: FIXEDOH COST OF SUPERVISION,POLICE,OPERATORS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	11	4303602	391237	24.791	0.0001
ERROR	123	1941106	15781.347		
C TOTAL	134	6244708			

ROOT MSE	125.624	R-SQUARE	0.6892
DEP MEAN	845.741	ADJ R-SQ	0.6614
C.V.	14.8537		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR HO: PARAMETER=0	PROB > |T|
INTERCEP	1	363.916	52.753282	6.898	0.0001
TEMP	1	8.252836	1.920367	4.298	0.0001
PRECIP	1	209.958	60.574838	3.466	0.0007
KOD	1	145.370	53.595487	2.712	0.0076
ATR	1	-230.875	89.656172	-2.575	0.0112
FLOTFIN	1	-161.456	35.007038	-4.612	0.0001
LABORWH	1	4.520017	0.722945	6.252	0.0001
VOLATR	1	2.547024	0.695749	3.661	0.0004
VOLTRUCK	1	1.442951	0.220257	6.551	0.0001
TASSLEN	1	-0.011093	0.003542487	-3.131	0.0022
PASSLEN	1	-0.384260	0.156326	-2.458	0.0154
AREAVOL	1	0.037566	0.013429	2.797	0.0060

Table F.5 Regression Run 4

DEP VARIABLE: FIXEDOH COST OF SUPERVISION,POLICE,OPERATORS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	10	4208250	420825	25.624	0.0001
ERROR	124	2036458	16423.050		
C TOTAL	134	6244708			

ROOT MSE	128.152	R-SQUARE	0.6739
DEP MEAN	845.741	ADJ R-SQ	0.6476
C.V.	15.15269		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	372.722	53.690899	6.942	0.0001
TEMP	1	7.256570	1.914892	3.790	0.0002
PRECIP	1	84.785609	33.465022	2.534	0.0125
KOD	1	131.268	54.360150	2.415	0.0172
ATR	1	-223.433	91.408651	-2.444	0.0159
FLOTFIN	1	-146.166	35.143363	-4.159	0.0001
LABORWH	1	4.366004	0.734722	5.942	0.0001
VOLATR	1	2.521160	0.709672	3.553	0.0005
VOLTRUCK	1	1.524414	0.222132	6.863	0.0001
TASSLEN	1	-0.00896581	0.003504353	-2.558	0.0117
AREAVOL	1	0.035709	0.013678	2.611	0.0101

Table F.6 Regression Run 5

DEP VARIABLE: FIXEDOH COST OF SUPERVISION,POLICE,OPERATORS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	9	4112484	456943	26.788	0.0001
ERROR	125	2132224	17057.790		
C TOTAL	134	6244708			

ROOT MSE	130.605	R-SQUARE	0.6586
DEP MEAN	845.741	ADJ R-SQ	0.6340
C.V.	15.44273		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	393.085	54.039544	7.274	0.0001
TEMP	1	8.697966	1.854310	4.691	0.0001
PRECIP	1	80.536370	34.058409	2.365	0.0196
ATR	1	-291.996	88.550341	-3.298	0.0013
FLOTFIN	1	-142.380	35.780409	-3.979	0.0001
LABORWH	1	4.641789	0.739684	6.275	0.0001
VOLATR	1	2.788498	0.714401	3.903	0.0002
VOLTRUCK	1	1.497326	0.226095	6.623	0.0001
TASSLEN	1	-0.010830	0.003483664	-3.109	0.0023
AREAVOL	1	0.021347	0.012553	1.701	0.0915

END
DTIC
9—86