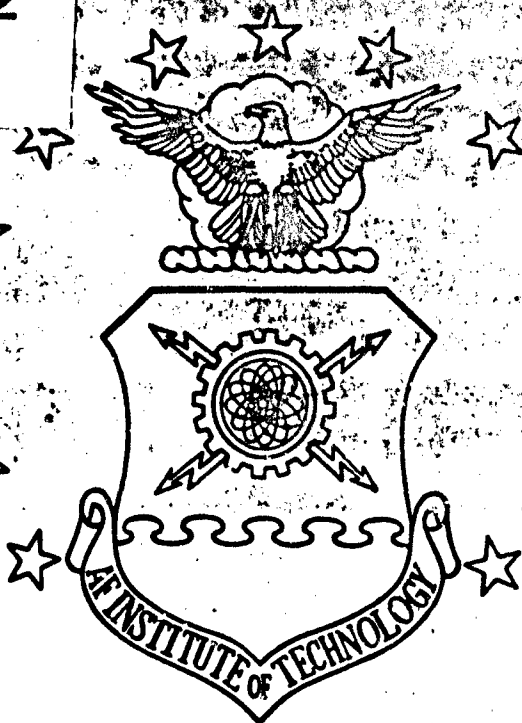


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A COMPARISON OF VARIABLE SE-
LECTION CRITERIA FOR MULTIPLE
LINEAR REGRESSION: A SECOND
SIMULATION STUDY

THESIS

David P. Woollard, Captain, USAF

AFIT/COB/ENG/ADM 22

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FOR MULTIPLE LINEAR REGRESSION: A SECOND SIMULATION STUDY**

THESIS

**Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology**

Air University

**In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Operations Research**

David P. Woollard, B.S., M.L.A.

Captain USAF

March, 1993

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David P. Woollard

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Abstract

The purpose of this thesis was to: (1) identify some promising least squares selection procedures discussed in the literature, (2) introduce, implement, and study a variable selection method proposed by Alan J. Miller, and, (3) make an extension of Ross J. Hansen's 1988 thesis research by comparing the methods he examined: Minimum MSE, Minimum S_p , and Minimum C_p with Miller's method.

To expedite a comparative analysis of Miller's method and the other methods, Response Surface methodology was employed with two performance measures. The first was the percentage of correct variables in a model. The second, the Theoretical Mean Squared Error of Prediction (TMSEP), measured the predictive error between the model selected and the theoretical model. Each technique was applied on generated data with known multicollinearities, variances, random predictors, and sample sizes. Both performance measures were computed for models selected under each technique. A full factorial design using each performance measure was set up to study the effectiveness of each variable selection technique with respect to the known data characteristics. Equations were generated which related these data characteristics to each combination of perfor-

mance measure and selection method. A graphical analysis of variance was performed to summarize each technique's performance.

Miller's method was shown to be the best overall technique for selecting models with the highest percentage of correct variables. Minimum MSE, followed closely by Minimum S_p , selected models with the least TMSEP.

A COMPARISON OF VARIABLE SELECTION CRITERIA
FOR MULTIPLE LINEAR REGRESSION: A SECOND SIMULATION STUDY

I. Introduction

Background

Linear regression is a statistical model-building tool that uses data to construct a mathematical expression capable of estimating the actual, but unknown, relationship between a set of independent or predictor variables and their corresponding response values. This mathematical expression or model can, with a certain degree of accuracy, predict the level of response of the associated phenomena, given a set of predictor values. The methodologies, processes and techniques employed to select which predictor variables to include in a model form a sub-topic of linear regression called subset selection. Unfortunately, it is often difficult to determine the "best" set of predictor variables to include in a linear regression model (Hansen, 1988:1). Alan J. Miller, an expert in the field of subset selection, assesses the situation on the back cover of his newest book, Subset Selection in Regression:

Most scientific computing packages contain facilities for stepwise regression, and often for "all subsets" and other techniques for finding "best-fitting" subsets of regression variables.

The application of standard theory can be very misleading in such cases when the model has not been chosen a priori, but from the data. There is widespread awareness that considerable overfitting occurs, and that prediction equations obtained after extensive "data dredging" often perform poorly when applied to new data. (Miller, 1990:cover)

Clearly, as A.J. Miller points out, automated subset selection processes are not foolproof. Over-fitting is likely when one blindly applies an automated subset selection method, such as Stepwise Regression, to data containing both significant and insignificant (random) predictors. The automated software selects predictors on the basis of some preset criteria and will probably find the "best fit" when a large number of these predictors are included in the model, including any random ones. At first, it may seem that predictors that are theoretically independent of the response would not be selected because they contribute nothing to the response. Freedman, however, demonstrated that this is not necessarily the case. His research indicates a good fit could result even when a model is constructed from only random noise predictors (Freedman, 1983:153). Furthermore, when automatic algorithms compare models containing only significant predictors and those containing the same significant predictors augmented with random predictors, one of the models containing randomness is often selected. This occurs because the largest sample correlation among the random predictors can become significant and, in turn, cause

the automated algorithm to favor a model composed of both significant and random predictors.

The problem of over-fitting emphasizes that when the subset selection process is blindly turned over to automated algorithms implemented by computer software packages, the resulting mathematical equation may be useless. It may model the data and the noise in the data very well while failing to achieve the real goal of modeling the underlying process or phenomena. As a result, when one uses an over-fitted model to predict future response levels, it generally performs poorly because the presence of the random predictors effectively mask whatever predictive insight the significant predictors have to offer (Cafarella, 1979:14).

Sometimes human judgement, tempered by years of experience, can recognize when over-fitting has occurred, can discontinue the automatic algorithm, and can select a more parsimonious model. Which criteria to use, however, in selecting a more parsimonious model that will indeed adequately represent the underlying process or phenomena may not be readily known. Obviously, research is needed to determine which subset selection criteria perform best under a given set of circumstances.

Problem Statement

This research effort collected and analyzed data on certain subset selection techniques to better understand why they perform as they do. The objectives of this research were: (1) identify some promising least squares selection procedures discussed in the literature, (2) introduce, implement, and study a variable selection method proposed by Alan J. Miller, and, (3) make an extension of Ross Hansen's 1988 thesis research by comparing the methods he examined: Minimum MSE, Minimum S_p , and Minimum C_p with Miller's method.

Assumptions

Miller's technique requires certain assumptions prior to its application. First, the collected data must be a random sample from the population. Next the error terms of the least squares linear regression must be independent and identically distributed, be from a normal distribution, and have a mean of zero and constant variance. Finally, when the Stepwise regression is run, only Forward Selection is used with a threshold F-value low enough to allow the selection of at least one known random predictor.

Scope

This study is an extension of Ross Hansen's research in which he examines three subset selection criteria (Minimum

MSE, Minimum Sp, and Minimum Cp) under varying amounts of multicollinearity, variable variation, number of variables, and sample size. Additionally, this study examined the performance of yet a fourth subset selection criteria, previously described and referred to as Miller's method, under the same conditions. The performance of Miller's method is compared to the performance of the three other criteria Hansen studied. Contrasts and comparisons are made and conclusions are drawn.

II. Concept Overview

Least Squares Regression

Assumptions. Certain key assumptions must be made prior to constructing a least squares linear regression. One must first assume the collected data represents the population from which it came. That is, the data reflects the normal case of the variable. Secondly, the error terms are assumed to be independent and identically distributed, from a normal distribution with a mean of zero and variance σ^2 .

Notation. The aim of linear regression is to calculate what proportion of the independent variables should be added or subtracted to best predict the dependent variable. In general, the linear least squares regression equation is written:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k + e \quad (1)$$

where:

Y is the observed value of the independent variable

β_0 is the constant term

$\beta_1, \beta_2, \dots, \beta_k$ are constant proportional multipliers of the dependent variables $X_1, X_2, \dots, X_k$

k is the number of independent variables

e is the error term.

If there are n observations, or data points, the above equation may be written as:

$$\sum_{i=1}^n Y_i = \sum_{i=1}^n (\beta_{0i} + \beta_{1i}X_{1i} + \beta_{2i}X_{2i} + \dots + \beta_{ki}X_{ki} + e_i) \quad (2)$$

For convenience, the above equation can be written in matrix notation.

$$Y = X\beta + e \quad (3)$$

where Y is an $n \times 1$ column vector:

$$Y = \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix} \quad (4)$$

and X is a $\{n \times (k+1)\}$ matrix.

$$X = \begin{bmatrix} 1 & X_{11} & X_{12} & \dots & X_{1k} \\ 1 & X_{21} & X_{22} & \dots & X_{2k} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & X_{n1} & X_{n2} & \dots & X_{nk} \end{bmatrix} \quad (5)$$

The first column contains all ones for the constant terms.
 The remaining columns contain the X_{ij} independent variables.
 The X matrix is commonly referred to as the design matrix.
B is a $k \times 1$ column vector of regression coefficient:

$$B = \begin{bmatrix} B_0 \\ B_1 \\ \cdot \\ \cdot \\ \cdot \\ B_k \end{bmatrix} \quad (6)$$

and e is a $n \times 1$ column vector of error terms:

$$e = \begin{bmatrix} e_1 \\ e_2 \\ \cdot \\ \cdot \\ \cdot \\ e_n \end{bmatrix} \quad (7)$$

In least squares regression, each subset of regression variables generates a surface which minimizes the squared distance (error) between the observed values for the dependent variables, Y , and the predicted values for the dependent variable,

$$\min \sum_{i=1}^n (e_i)^2 = \min \sum_{i=1}^n (\bar{Y}_i - Y_i)^2 \quad (8)$$

The goal is to find the subset of variables which minimizes the squared distances between the actual values observed and the fitted surface. The sum of the squared-error values is commonly referred to as the sum-of-squares error (SSE). Graphically, a regression resembles the following:

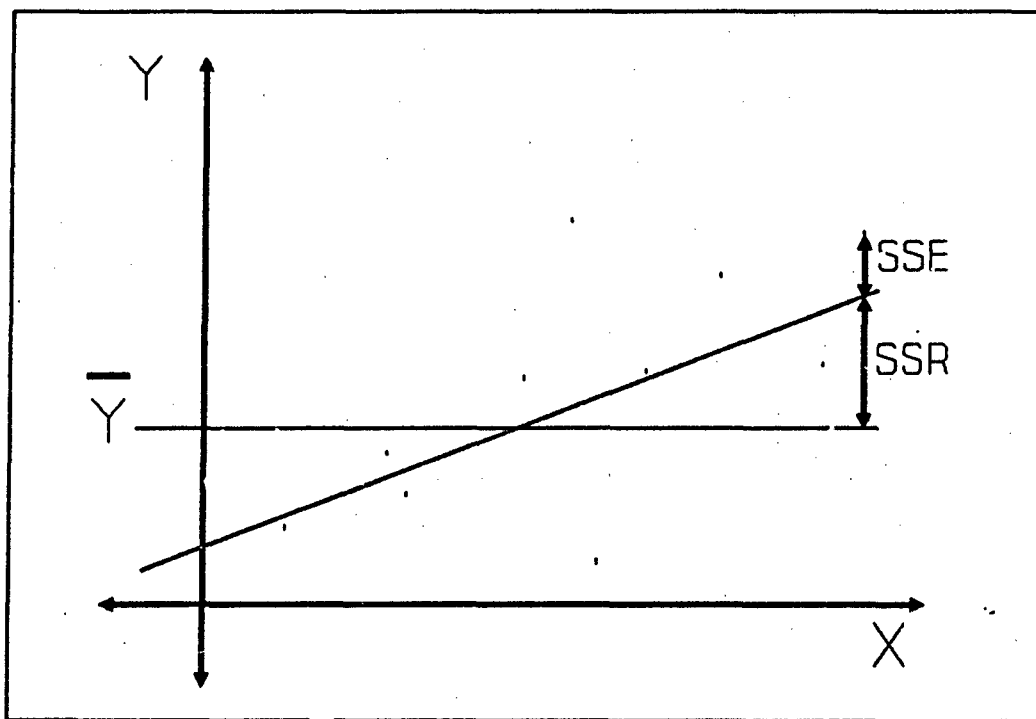


Figure 1. Two-dimensional Representation of Linear Least Squares Regression

SSR is the sum of the squared distances from the mean to the regression line, called Regression Sum of Squares. SSE is the sum of the squared distances from the point to the regression line, called Sum of Squares Error. SST is called Sum of Squares Total and is calculated by:

$$SST = SSR + SSE \quad (9)$$

III. Summary of Current Knowledge

Regression

Regression Analysis, as a branch of statistical mathematics, began in the late 1800's when Sir Francis Galton first attempted to use practical mathematical techniques to investigate the dependence between two variables: the height of the parents (he used the average of the parents heights) and the heights of their adult children. Having randomly collected (sampled) many pairs of parent/child height measurements (data), Galton observed that for a given parent-height average, the conditional mean of the heights of children with that given average parent height "regressed" toward the mean height of all children. Thus, the term regression analysis was born (Neter and others, 1990:26). Regression techniques have since been developed that can construct an equation or mathematical model based on past historical data and then use this model to predict future responses (Neter and others, 1990:27).

Subset Selection

Subset selection is an area of regression analysis concerned with choosing the "best" variables, or predictors, to include in the regression model (Hocking, 1983:220). The simple parent/child height model yielded only two choices:

one could accept the model or reject it. Accepting the model meant that if one specified the parent-height, an estimate of the adult child-height was automatically generated. Consider, however, the complexity that occurs if one not only possesses the heights of the parents but also their right arm lengths. Then one would have to decide whether to use a model to predict adult child-height based on the height of the parents, or the right arm length of the parents, or both, or neither. The methodologies of subset selection can help suggest which predictors to use. Unfortunately, and as previously addressed, applying these methodologies, without discretion, has a tendency to produce over-fitted models that have little predictive capability (Miller, 1990:12-13).

In spite of these difficulties, however, subset selection does play an important role in regression analysis. While other areas of regression analysis detect and correct problems in the data prior to model creation or verify the adequacy of the model after creation, subset selection techniques actually select the variables or predictors that go into the model. These techniques are subdivided into two major groupings:

- (1)Least Squares regression techniques

- (2)Biased regression techniques

For this literature review, only the Least Squares regression techniques will be addressed. Selection techniques for

least squares have an advantage over bias regression techniques in that the estimators are the best linear unbiased estimators (BLUE).

All-subsets regression. All-subsets regression does just that--it forms a regression model for each predictor or combination of predictors. Miller claims that only by an exhaustive search of all $2^k - 1$ combinations or subsets can one be guaranteed to find the best-fitting model (Miller, 1984:391). Once generated, various criteria may be employed in searching all $2^k - 1$ models for the one that best fits the data. The all-subsets variable selection criteria addressed in this literature review are:

- (1) Near-Optimal-Model for Mean Square Absolute Errors (MSAE),
- (2) Mallows Cp,
- (3) Coefficient of Determination or R^2 ,
- (4) Maximum Adjusted R^2 or Minimum MSE,
- (5) PRESS_p(Prediction Sum of Squares) or S_p .

Although exhaustive and guaranteed to find the "best" model ("best" being defined by the criteria used), the All-Subsets method has two drawbacks, regardless of the criteria involved. First, it can only be used for a moderately small number

of predictors because the number of possible subsets of predictors almost doubles with each additional predictor considered (e.g. 1 for 1 predictor, 3 for 2, 7 for 3, 524287

for 19, 1048576 for 20, 33.5 million for 25, etc.)(Miller, 1990:56). Consequently, when considering a realistic number of predictors (15 to 25) one is forced to use a less exhaustive, but more efficient, subset selection technique such as Stepwise regression. Secondly, All-Subsets regression is only guaranteed to find the "best" model if all significant predictors are considered (Narula, 1983:160). If the group of predictors under consideration does not contain all the significant predictors, then the All-Subsets approach can not find the "best" overall model, but will produce the "best" model for the predictors considered (Berk, 1978:3).

Mallows C_p . Mallows C_p is a statistic used to determine the best model when the independent variables are fixed. C_p is an approximation of the Mean Squared Error of Prediction (MSEP).

$$C_p = \frac{SSR}{S^2} + 2p - n \quad (10)$$

where

SSR is the Regression Sum of Squares

S^2 is the estimate for the variance

p is the number of parameters

n is the number of data points

Theoretically the value of C_p is p. Therefore, when C_p is approximately equal to p, the model is good. Draper and Smith suggest using this criterion in conjunction with

stepwise regression to obtain the best subset (Draper, 1981:341). It should be noted, however, as the variance approaches zero, the C_p statistic can not be calculated. Therefore this method has limitations especially when the fit is perfect.

Barr pointed out a weakness of Mallows C_p . Since S^2 in the C_p statistic is estimated from the original variable pool, it could be biased and larger than the true variance (Barr:5). If this is the case, the C_p statistic will be deflated causing the wrong model to be selected.

A limitation of C_p , as well as many other statistics, is that it "depend[s] on the observed data only through sufficient statistics, so they model average behavior of the fit of a model to the data" (Weisberg, 1981:27). Weisberg developed a procedure which allocates the C_p statistic to individual cases. The advantage of Weisberg's procedure is if the model under consideration is biased, it provides a means to determine the bias of using a subset model instead of the entire model (Weisberg, 1981:28).

Another application of the C_p statistic is to choose the model which has the smallest C_p value. (Judge, 1985:863) By choosing the model with the minimum C_p , it is believed that one is choosing the model with the minimum prediction error. This is appealing, especially when it is difficult to determine the optimal subset using the C_p close to p crite-

rion. Since the Min C_p criterion is based on minimum prediction error it is based on a sound principle. However, like the C_p -close-to-p criterion, Min C_p is derived under the assumption that the independent variables are fixed. Since this rarely happens in practice, there is some question to the usefulness of the Min C_p criterion. Judge, Griffiths, Carter, Lutkepohl, and Lee recommend that the Min C_p procedure not be used in any applied work (Judge, 1985: 864)

Coefficient of Determination. The coefficient of determination, R^2 , is a statistic which gives an estimation of the amount of variation about the mean which is explained by the model.

$$R^2 = \frac{\sum_j (\hat{Y}_j - \bar{Y})^2}{\sum_j (Y_j - \bar{Y})^2} \quad (11)$$

where

$\hat{Y}_j$ is the predicted value of Y_j .

Y_j is the actual value of Y_j

$\bar{Y}$ is the mean of Y .

At first one might believe that it is desirable to find the model which has the maximum R^2 , since it explains the most

variation about the mean. However, this is not necessarily the best. Certainly when we look at the R^2 value we would like to see a large value, but it should not be used as the only measure for subset selection. Maximum R^2 receives little praise as far as its usefulness in determining a good fit. The major pitfall of using R^2 is that whenever a variable is added, it will increase R^2 . R^2 will increase regardless of whether the variable has anything to do with the dependent variable. According to Healy 1986, "In particular, the multiple correlation coefficient is not really a regression-related concept at all. It is basically defined to be the largest possible correlation between the y-variate and any linear function of the x's and this only makes sense when y and x's have a joint probability distribution" (Healy, 1984:608). If maximum R^2 is used as the selection criterion, the model containing all variables will always be selected.

Maximum Adjusted R^2 or Minimum MSE. For simplicity only Maximum Adjusted R^2 will be discussed. However, Maximum Adjusted R^2 and Minimum MSE test exactly the same thing. Adjusted R^2 is related to R^2 , but an adjustment has been made for the degrees of freedom. The following equation shows the relationship between R^2 and Adjusted R^2 .

$$\text{Adjusted } R^2 = 1 - \frac{(1-R^2)(n-1)}{(n-p)} \quad (14)$$

According to Draper and Smith, the adjusted R^2 statistic can be used not only to compare models for the same data set (the same variable selection discussed in all other sections of this literature review), but also to compare models taken from two entirely different data sets (Draper, 1981:92). However, they do not recommend using the Adjusted R^2 statistic in the latter role. The Adjusted R^2 statistic (or the minimum MSE criterion) is still widely used in practice.

PRESS_p or S_p. The S_p criterion, originally proposed by Hocking in 1976 (Hocking, 1976:20), has considerable appeal and consequently receives praise in recent years. The S_p statistic is an approximation of the MSEP based solely on the data and number of variables. As is the case with MSEP, the goal of this criterion is to find the minimum value.

$$S_p = \frac{SSE}{(n-p)(n-p-2)} \quad (15)$$

Breiman and Freedman point out that the S_p statistic does not necessary provide an accurate approximation of MSE, but works nonetheless (Breiman, 1983:132).

The advantages of this method are numerous. Looking at the S_p equation gives the reader an idea of the relative ease with which S_p is calculated. What makes S_p even more appealing is it is based on MSE. As Thompson points out, "This method [S_p] is based on a sound criterion -- that of minimizing the expected squared distance between the true and predicted values of the dependent variable, Y " (Thompson, 1978:6). Since S_p is an approximation of MSE, it can be used like MSE to determine the optimal number of regressors to include in the model (Breiman, 1983:132).

S_p is not without its disadvantages. It must be calculated for all $2^k - 1$ possible subsets (Thompson, 1978:6). Even though it requires relatively little computational effort, it does require that many regressions be run. Through counter examples Breiman and Freedman show that when true variance due to prediction equals zero, the S_p criterion fails to pick the optimal number of variables to include in the model (Breiman, 1983:132).

Stepwise Regression. A more efficient technique, called Stepwise regression, does not consider all the possible combinations of predictors, but selects only the significant predictors and brings them into the model one at a

time. Stepwise regression exists in three versions: 1) Forward Selection, 2) Backward Elimination, or 3) a combination of 1) and 2). Forward Selection starts with no predictors in the model. It then adds significant predictors to the model one at a time. At each iteration, every predictor not yet in the model is tested for significance with respect to the current model, adding the most significant one to the model. The process continues until all predictors improving the fit of the model are included in the model (Thompson, 1987:10). At no point are variables ever taken out of the model. Backward Elimination, the reverse of Forward Selection, starts with every known predictor already in the model. At each iteration, all the insignificant predictors are identified with respect to the current model, and the least significant predictor is eliminated. This process continues until tests indicate that all insignificant predictors, with respect to the current model, have been eliminated. At no point are variables added back into the model (Thompson, 1987:10-11). The combination of both techniques proceeds like Forward Selection except that Backward Elimination is implemented at each step. Each predictor is tested for significance with respect to the current model, and the most significant predictor is added to the model. Each time a new predictor is brought in, every predictor in the new model is tested with respect to the new model to make sure that it is still significant after the addition of

the newest predictor. Predictors in the model are ranked by their significance and the least significant predictor is eliminated. This process continues until all significant predictors are included in the model and all insignificant predictors are eliminated (Thompson, 1987:11).

The overriding question, then, is how does one measure significance among predictors? The most common measure of significance, called the F-statistic, is a ratio that shows how much explanatory power a predictor brings to the model under consideration. To use an F-statistic in Forward Selection stepwise regression, however, one must decide what numerical threshold of the F-statistic is appropriate. Selecting a small threshold F-value may inadvertently admit random predictors into the model while choosing a large F-statistic may cause significant predictors to be omitted.

Miller's Method. Dr. Alan J. Miller suggests an alternate subset selection method -- one which he theorizes could guard against bringing random predictors into the model. He proposes augmenting the set of predictors with an equal number of "dummy" predictors whose values are random numbers. The method then applies Forward Selection stepwise regression and proceeds, according to Miller, until the first known random predictor is selected for inclusion in the model. One then stops the Forward Selection stepwise regression and discards the current model which includes this known random predictor and uses the previous model

(Miller, 1984:395). Any predictors not selected must, therefore, have less significance than the random predictor that Forward Selection attempted to select. Thus, all predictors not selected should be discarded as insignificant (Hocking, 1983:220). Just how well this subset selection method performs on data plagued with collinearity and other problems is one of the questions which inspired this research effort.

IV. Methodology and Model Development

Objective

The goal of this thesis is to gain a better understanding of the Minimum MSE, Minimum S_p , and Minimum C_p variable selection criteria as well as introducing and studying yet a fourth selection criteria: Miller's method. The four techniques will be compared.

Justification

In this research effort, four variable selection techniques were examined: Minimum MSE, Minimum S_p , Minimum C_p , and Miller's method. These methods were chosen for the following reasons:

(1) Ross Hansen's 1988 thesis research had already studied and compared minimum MSE, minimum S_p , and minimum C_p variable selection techniques. The methodology and systematic approach he developed defined and guided this research effort. However, due to recently discovered computer errors in his data sets and analysis programs, much of Hansen's original computations have been re-worked.

(2) Each of these techniques lend themselves to computer implementation, allowing the researcher to conduct useful experiments and gain credible results with a reason-

able amount of computational effort. This is possible because each of these techniques involve absolute criterion. In other words, all four methods can be executed by a series of predetermined decisions. For the first three methods, the MSE, S_p , and C_p statistics for each data set of variables can be calculated by the SAS (SAS, 1985:956) all-subsets regression procedure, R-Squared. The model selected by the Minimum MSE, Minimum S_p , or Minimum C_p methods is simply the one with the smallest value of MSE, S_p , or C_p , respectively. Similarly, for Miller's method, a model for each data set, augmented with the appropriate number of random predictors, can be automatically selected using the SAS Stepwise procedure with the forward selection option. Miller's model is the largest subset of predictors from the associated SAS model such that each predictor is added in the order of significance determined by the associated SAS model and no random predictors are admitted. Upon encountering the first random predictor, the selection process terminates and the current model becomes the model for that data set.

(3) The first three techniques are very powerful, as Hansen points out:

The first three techniques appear in the last decade's literature. The Minimum MSE procedure used to be one of the most widely used methods. Its appeal over techniques such as Max R^2 stems from its adjustment for degrees of freedom. More recently, S_p seems to have become the most popular technique. Its appeal is based on the principal

of minimizing mean square errors of prediction (MSEP). The C_p criterion is also based on MSEP, and some authors praise this criterion. (Hansen, 1988:31)

(4) A formal study of the fourth technique, Miller's method, has not been reported in statistical literature to date. Comparing this virtually unknown subset selection technique with the three well-understood techniques, Minimum MSE, Minimum S_p , and Minimum C_p methods, yielded valuable insight into all four methods.

Limitations

Since this thesis extensively employs least squares regression, the results and conclusions are valid only if certain assumptions can be made about the data. As outlined in Chapter 2, the data must be assumed to be representative of the population. Likewise, the error terms must be assumed to be independent and identically distributed from a normal population with an expected value of zero and a constant variance σ^2 . Finally, each predictor must be assumed related to the response (Hansen, 1988:32).

Overview

The methodology and approach exercised in this thesis will be similar in content to that used by Ross Hansen in his 1988 study. Only a slight expansion in methodology occurs with the additional implementation of Miller's subset

selection method. This research effort can be divided into roughly four areas of focus:

- (1) Data generation.
- (2) Model selection.
- (3) Generation and analysis of a performance measure for percentage of correct variables.
- (4) Generation and analysis of a performance measure for method accuracy.

The data used in this study is the same as that employed by Hansen, except that certain computer errors have been corrected. The data sets contain various known and verifiable statistical properties.

A model was selected from each data set using each of the four variable selection methods. To accomplish this, preliminary models were formed using SAS all-possible subsets and stepwise regression routines. FORTRAN routines then performed the final model selection process for each method on each data set.

Two different sets of performance measures were calculated. The first set, designated PM, was used to evaluate what effect the various statistical properties of the data have on the percentage of correct variables selected in a given model. Response Surface methodology (RSM) and Box and Whisker plots were applied to determine what impact specific statistical properties of the data and the subset selection technique used have on the percentage correct variables

selected for a given group of models (Hansen, 1988:32). The second set, designated TMSEP for Theoretical Minimum Mean Squared Error of Prediction, is used to compare the accuracy of one subset selection technique to another. This is accomplished by comparing models created under different selection techniques to the theoretical model from which the data was originally generated. Box and Whisker plots were also generated to analyze the impact of each factor on the accuracy of the models a method selects.

Data Generation

Since this study compares its results with the results of Hansen's study, part of the data used came directly from Hansen's study. The Hansen data, however, was augmented with an equal number of random predictors to accommodate Miller's method.

The data for this study was generated from the following equation:

$$Y_i = X_{1i} + X_{2i} + X_{3i} + X_{4i} + \epsilon_i \quad (16)$$

where Y_i is the response variable.

$X_{1i}, \dots, X_{4i}$ are randomly generated predictors.

ϵ_i is a noise term to create variance in the model.

Most simulation studies investigate subset selection techniques with all significant predictors plus some unknown random variables included among the group of predictors from

which the model is created. This study attempted to find what happens when one of the significant predictors is deleted entirely from consideration. After the data is created by equation (1), the X_4 predictor is dropped from consideration. This simulated the situation which arises when a significant predictor is unknown and not considered. Additionally, either one or three noise variables were included in the predictor pool to simulate data collected on predictors thought to be significant but, in reality, extraneous (Hansen, 1988:34-35). Furthermore, when Miller's variable selection method was implemented, the predictor pool (consisting of both significant and extraneous predictors) was doubled in size by the addition of an equal number of known random predictors. The number of random predictors added always equaled the number variables already in the predictor pool. In practice, however, the actual data sets were not permanently expanded. SAS allowed each data set to be temporary expanded while running a stepwise analysis and implementing Miller's method on each data set.

Factors. To understand how the various statistical properties of the data effect each of the four techniques studied, six potentially significant statistical properties or factors were chosen a priori and the data sets were generated based on these six factors. RSM was used to construct an equation made up of significant factors and factor interactions which adequately predicts the usefulness

of each method (Hansen, 1988:35-36). The six factors considered in this study were:

(1) The number of extraneous variables in the original group of predictors. These variables model predictors which are believed significant, but are actually random, extraneous predictors (denoted by EX_1 , EX_2 , EX_3). Because these variables are noise, they are theoretically independent of the dependent variable. In this study, at the low setting the number of extraneous variables is 1 and at the high setting, 3.

(2) The amount of correlation among the predictors which are not extraneous, random variables (denoted by X_1 , X_2 , X_3 , X_4). At the low setting the variables are orthogonal, or have zero correlation, while at the high setting they are highly correlated with a correlation of 0.9.

(3) The variance of the extraneous predictors. The low setting for the variance is 1, and the high setting is 100.

(4) The variance of the significant predictors. The low setting for the variance is 1, and the high setting is 100.

(5) The sample size. The low setting for sample size is 10, while the high setting is 20. The low setting was set by Ross Hansen in his study of the S_p criteria -- any smaller and S_p could not be calculated. Hansen's bounds on sample size were adopted to facilitate method comparison (Hansen, 1988:35-36).

(6) The variance of the error term. The low setting for the variance of the error term is 0.0625, and the high setting is 0.25.

Data Sets. Sixty data sets were generated for each of the 64 high/low combinations of the six factor settings. In the literature, each combination of factor settings is typically referred to as a design point in the experiment. In this case, the experiment was to determine what effect each of the six factors has on PM. Hansen wrote automated routines which created each group of the sixty data sets at

each of the sixty-four design points and put them in a file related to the design point. For this thesis effort these files were renamed 01.dat, 02.dat, ..., 64.dat). In all, 3840 data sets were generated. Appendix H contains FORTRAN code which was used to verify that the data sets do indeed possess appropriate statistical properties. A close examination of Hansen's data revealed that he used the "natural order" for generating all-possible combinations of the factor settings. To accomplish this, he first established a permanent factor order for future reference.

Table 1.
Factor Order for Data Generation

Order	Factor Description	Values		Factor Symbol
		Low	High	
1	# of extraneous predictors	1.0	3.0	A
2	Correlation among indep. predictors	0.0	0.9	B
3	Variance of ext. predictors	1.0	100.0	C
4	Variance of indep. predictors	1.0	100.00	D
5	Sample Size	10.0	20.0	E
6	Variance of the error term	0.0625	0.25	F

The factors were then varied according to the "natural order". Factor A is varied most rapidly from its low to high

setting, followed by Factor B, C, D, E, and F. The following table gives an example of factor combinations at several design points. For the sake of brevity, "A" means factor A at its high setting and "a" means factor A at its low setting and so forth.

Table 2.
Mapping of Design Points to Factor Settings

Design Point	Data File	Factor Settings
1	01.dat	a b c d e f
2	02.dat	A b c d e f
3	03.dat	a B c d e f
4	04.dat	A B c d e f
5	05.dat	a b C d e f
6	06.dat	A b C d e f
7	07.dat	a B C d e f
8	08.dat	A B C d e f
9	09.dat	a b c D e f
.	.	.
.	.	.
.	.	.
64	64.dat	A B C D E F

Generating the data in this systematic fashion results in an equation relating the performance measure for each subset selection method to these six factors. Before the performance measures can be generated, however, models must be selected using each technique on each data set.

Model Selection

Generally speaking, the variable selection process for all four methods involved employing SAS routines to develop a set of models and then filtering through those models with FORTRAN programs, selecting a model by each method. The implementation of this methodology was similar for the Minimum MSE, Minimum S_p , and Minimum C_p variable selection techniques, but differed for Miller's method. Appendices A and B clearly outline these techniques and reveals these differences.

The reader should keep in mind that the best model at each design point consist of only three predictors: X_1 , X_2 , X_3 because X_4 had been discarded after data generation. Extraneous predictors, EX_1 , or EX_1 , EX_2 , and EX_3 , were added to create the experiment. Although the experimenter knew these were extraneous variables and that they should not be selected for inclusion in the model, the three significant predictors and the extraneous predictor(s) were presented nevertheless to the selection process as legitimate predictors.

Minimum MSE, Minimum S_p , and Minimum C_p Methods. Separate processing was performed for data sets possessing one extraneous predictor and those with three extraneous predictors (see Appendix A). The all-possible subsets SAS routine, RSquared, was used to generate the models. Fifteen models were generated for design points with 4 variables in

the pool and 63 models for design points with 6 variables in the pool and the MSE, C_p , and S_p statistics calculated for each model. The two different quantities of models are due to the number of predictors (p) being considered and is equal to $2^p - 1$. FORTRAN programs then filtered through the models for each data set and selected three models for each data set: one with the smallest MSE statistic, one with the smallest C_p statistic, and one with the smallest S_p statistic.

Miller's Method. Again, it was necessary to handle the processing separately for data sets possessing one extraneous predictor and those with three extraneous predictors (see Appendix B). To employ Miller's method, the data sets were purposely augmented with an equal number of known random predictors. Depending on whether the number of extraneous variables in the data set is 1 or 3, either 4 or 6 random predictors, respectively, were added to the data set. Miller's method effectively doubled the number of predictors in the pool at each design point. The total number of predictors under consideration by Miller's selection process at each design point varied from 8 (3 unknown true predictors, 1 unknown random predictor, 4 known random predictors) to 12 (3 unknown true predictors, 3 unknown random predictors, 6 known random predictors).

Once augmented, the SAS Stepwise routine using Forward Selection processed each data set. One should note that the

F-to-enter threshold criteria was set to 1 to assure that at least one of the known random predictors would be admitted to the model. Once a model was generated for each data set, FORTRAN programs were used to generate a model for each data set via Miller's method.

Performance Measure (PM) for the Percentage of Correct Variables

Justification. How one rates the performance of a subset selection technique is a critical issue. Adopting a reasonable, logical rating system eventually led to the development of equations which related the success of a method to the statistical properties of the data to which it was applied. Hansen contends that there are no guaranteed methods to screen out extraneous variables (random noise terms which do not contribute at all to the model). Furthermore, he contends that once in the variable pool, there is no criterion which guarantees that no extraneous variables will be chosen for the model. Even the all-subset procedure, which A.J. Miller contends performs quite well, occasionally chooses extraneous variables (Hansen, 1988-:32-33).

Since there really are no "guaranteed methods" for capturing all the true variables, an excellent measure of performance is to rate the success of a subset selection

method by the percentage of variables chosen correctly.
This index, referred to as PM, is calculated as follows:

$$PM = \frac{\text{number of correct variables chosen}}{\text{number of variables chosen}} \quad (17)$$

This study used PM to examine the relative contributions of the six factors as they relate to the performance of each of the four subset selection methods studied. Furthermore, PM is a logical choice for two reasons. First, the best model may not include all the predictors it is generated from, but only the most significant. Even though a response value may have been generated from three predictors, the best model may only contain two of those predictors. Therefore, PM compensates by determining the percentage of correct variables chosen. Second, PM takes in to account the number of extraneous variables chosen. It is worse to select a model with only two predictors, one of which is extraneous, than it is to select a model containing five predictors, one of which is extraneous. PM adjusts accordingly (Hansen, 1988:33).

Calculation of PM. At each of the 64 design points, 60 models were generated. FORTRAN routines examined the 3840 (64 times 60) models produced and selected a model based on the criteria for each method studied. In this final stage of model selection the FORTRAN programs also collected the following statistics at each of the 64 design points:

- (1) The total number of predictors chosen in all 60 data sets.

- (2) The total number of correct predictors chosen among all 60 data sets (Hansen, 1988:39).

Using these statistics, PM was calculated for each method at each design point. With PM in hand, the experiment was set up and the relationships determined between the PM and the six factors.

Experiment. When using RSM it is convenient to work with coded factors (-1,1 variables) for the following reasons:

- (1) By coding the factors, the resulting predictors are of the same magnitude.
- (2) Calculations are simplified.
- (3) The resulting design matrix, Z, is orthogonal. Consequently, stepwise regression can be used to find the significant factors with confidence (4:36).

In general, translating a variable from uncoded space to coded space is as follows:

$$Z = \frac{X - \frac{HIGH + LOW}{2}}{\frac{HIGH}{2} - \frac{LOW}{2}} \quad (18)$$

where X is the variable in uncoded space
Z is the variable in coded space
HIGH is the upper bound on the uncoded variable
LOW is the lower bound on the uncoded variable

The following equations were necessary to code the variables:

$$z_1 = \frac{A-2}{1} \quad (19)$$

$$z_2 = \frac{B-0.45}{0.45} \quad (20)$$

$$z_3 = \frac{C-50.5}{49.5} \quad (21)$$

$$z_4 = \frac{D-50.5}{49.5} \quad (22)$$

$$z_5 = \frac{E-15}{5} \quad (23)$$

$$z_6 = \frac{F-0.15625}{0.09375} \quad (24)$$

where $z_1, \dots, z_6$ are the coded variables.

Table 3.
Variable Coding for Response Surface Methodology

Variable Description	Uncoded Variable Name	Non-Coded		Coded Variable Name	Coded	
		Low	High		Low	High
Number of ext. vars.	A	1.0	3.0	Z_1	-1	1
Correlation of ind. vars.	B	0.0	0.9	Z_2	-1	1
Variance of ext. vars.	C	1.0	100	Z_3	-1	1
Variance of ind. vars.	D	1.0	100	Z_4	-1	1
Sample Size	E	10.0	20.0	Z_5	-1	1
Variance of error term	F	0.0625	0.25	Z_6	-1	1

It seems reasonable to assume significance of individual factors as well as the significance of interactions between factors. To insure that estimates for both these main factors and their interactions can be accurately calculated, a full 2^6 factorial design is necessary. To construct the design matrix for a full factorial design, the coded factors are varied from their low to high settings with the first coded main factor being varied most rapidly, the second varied next most rapidly, and so forth. The interaction terms are simply the product of the corresponding coded main factors. An example of this process using full 2^3 factorial design is summarized in the table below.

Table 4.
Example of Coding Interaction Variables

C o d e d s e t t i n g s	z_1	z_2	z_3	z_1z_2	z_1z_3	z_2z_3	$z_1z_2z_3$
	-1	-1	-1	1	1	1	-1
	1	-1	-1	-1	-1	1	1
	-1	1	-1	-1	1	-1	1
	1	1	-1	1	-1	-1	-1
	-1	-1	1	1	-1	-1	1
	1	-1	1	-1	1	-1	-1
	-1	1	1	-1	-1	1	-1
	1	1	1	1	1	1	1

If a design with less than 2^6 runs is used, information on some of the high order interactions would be unobtainable (Hansen, 1988:38).

Results. The significant factors that contribute to the PM were selected using Stepwise regression with Forward Selection and Backward Elimination (since the design matrix for this experiment was orthogonal). The resulting equations indicate which factor or factor combinations were most significant in increasing the PM, the percentage of correct variables, for a particular method. These equations are not intended to predict the percentage of correct variables, given certain factor settings. The role of these equations, however, is restricted to determining which factors are significant and how they contribute to the percentage of correct variables in a model. On this basis, the four

subset selection methods can be compared. Three similar equations were discovered by Hansen, one for each of the three criteria he studied (Hansen, 1986:39). The analysis which follows is based on the assumption that the closer a PM value is to one, the better a method's performance. Factors which cause PM to become closer to one are desirable.

PM Equations. Using the statistical package STATISTIX version 4.0 a 2^6 full factorial design matrix was created and augmented with the PM vector (STATISTIX, 1992). This design matrix was then exported to the SAS system where a Stepwise regression procedure was run, generating the equations below, as outlined in appendix E (SAS, 1985). An equation was generated for each method studied and shows how that method's performance is related to the factors under which it was applied.

Minimum MSE.

$$PM_{MSE} = 0.78 - 0.10(A) + 0.0023(D) + 0.006(E) + 0.0062(F) \\ + 0.003(AE) + 0.003(AF) - 0.003(DF) - 0.006(EF) \\ - 0.003(AEF) \quad (25)$$

Minimum S_p .

$$PM_{Sp} = 0.85 - 0.07(A) + 0.002(D) + 0.007(E) + 0.007(F) \\ + 0.002(AD) + 0.006(AE) + 0.003(DE) + 0.007(AF) \\ - 0.002(DF) - 0.005(EF) - 0.002(ADF) - 0.006(AEF) \quad (26)$$

Minimum C_p .

$$\begin{aligned}
 PM_{CP} = & 0.84 - 0.07(A) + 0.003(D) + 0.007(E) + 0.008(F) \\
 & + 0.002(AD) + 0.006(AE) + 0.003(DE) + 0.008(AF) \quad (27) \\
 & - 0.003(DF) - 0.005(EF) - 0.002(ADF) - 0.006(AEF)
 \end{aligned}$$

Miller's Method.

$$\begin{aligned}
 PM_{MILLER} = & 0.88 - 0.04(A) + 0.01(B) + 0.02(E) \\
 & + 0.01(AB) + 0.008(AE) - 0.008(BE) \quad (28) \\
 & - 0.008(BCEF)
 \end{aligned}$$

Summary of Effects.

Table 5.
Main Factor Coefficients of Effects by Method for PM

METHOD→→→	Minimum MSE	Minimum S_p	Minimum C_p	Miller's Method
! FACTOR !				
A (ext. vars.)	- 0.1	- 0.07	- 0.07	- 0.04
B(ind. corr.)	0	0	0	+ 0.01
C (ext. σ^2)	0	0	0	0
D (ind. σ^2)	+ 0.0023	+ 0.002	+ 0.003	0
E (sam. size)	+ 0.006	+ 0.007	+ 0.007	+ 0.02
F (error σ^2)	+ 0.0062	+ 0.007	+ 0.008	0
Intercept (μ)	+ 0.78	+ 0.85	+0.84	+ 0.88

Table 6.
Main Factor Effects by Method and Rank Order of Significance
for PM

METHOD---	Minimum MSE	Minimum S_p	Minimum C_p	Miller's Method
FACTOR				
A (ext. vars.)	1st	1st	1st	1st
B (ind. corr.)	No effect	No effect	No effect	2nd
C (ext. σ^2)	No effect	No effect	No effect	No effect
D (ind. σ^2)	4th	4th	4th	No effect
E (sam. size)	3rd	2nd	2nd	3rd
F (error σ^2)	2nd	3rd	3rd	No effect

All Four Methods. The following results pertain to all methods:

- (1) The fewer the number of extraneous variables the better the performance.
- (2) Larger sample sizes also yielded better performance.
- (3) The variance of the independent variable had little effect on the performance of any method.

Minimum MSE, Minimum C_p , Minimum S_p Method.

The following additional results were observed for these methods:

- (1) Higher variances on the independent variable yielded better results.
- (2) Higher variances on the error term give better results.

(3) They were not affected by the correlation of the independent variables.

Miller's Method. The following additional results were observed for this method:

(1) The method did better when the independent variables are highly correlated.

(2) It was not affected by the fluctuating variance on any term (independent or extraneous variables or the error term).

Analysis.

To further assess the impact of each factor (A, B, C, D, E, F) on PM for a given method, STATISTIX version 4.0 was used to produce Box and Whisker plots by indicator grouping (STATISTIX, 1992:96). Each PM value was associated with one of eight values or indicators, dividing it into eight equal indicator groupings. To assign the indicator values, an integer "1" through "4" was assigned to PM values according to the method it measured: 1 for minimum MSE, 2 for minimum S_p , 3 for minimum C_p , and 4 for Miller's method. Next, each number was assigned either a plus or minus sign depending on the factor setting of the factor under consideration, plus for high values and minus for low values. A set of indicator values was developed for each of the six factors studied. The six resulting plots reveal much about the useful-

ness of the four subset selection techniques in choosing the correct variables.

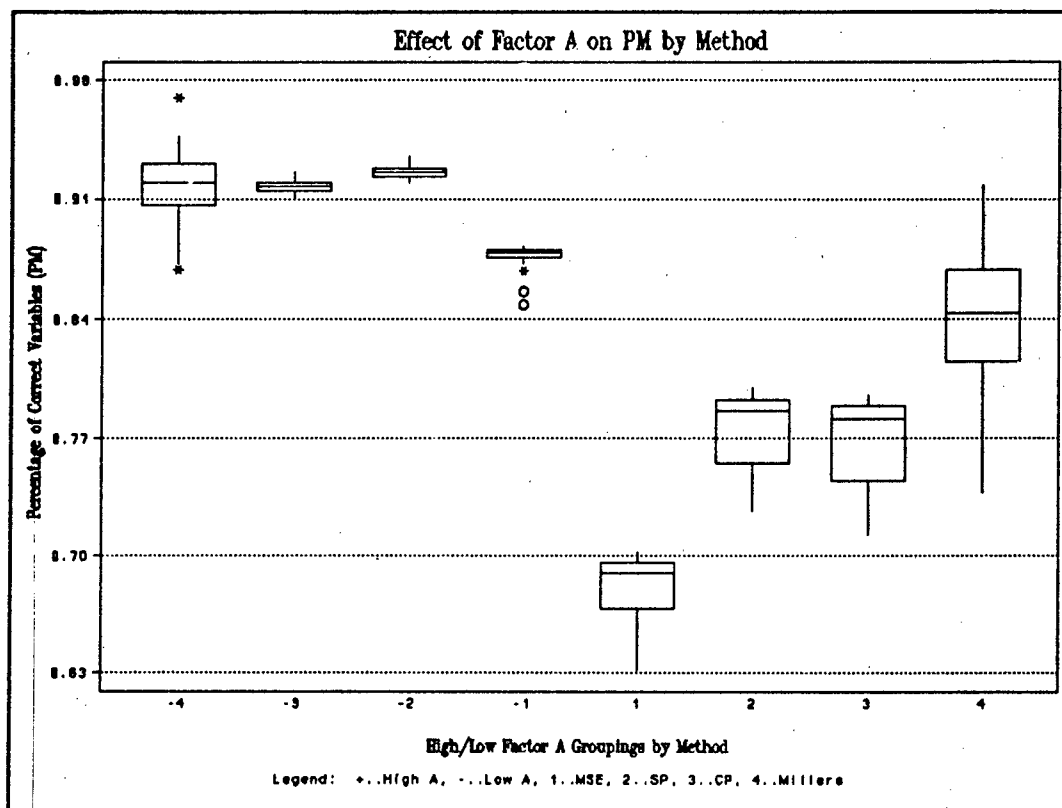


Figure 2. Box and Whisker Plots Showing the Effect of Factor A on PM by Method

Of the four methods applied in selecting correct variables, Minimum MSE is the most affected by the number of extraneous variables in the variable pool. Between the low and high settings, the Minimum MSE method degraded by 15 percent on the average.

On the other hand, Miller's method was a top performer at either setting. Miller's method, on average, outperformed the other three methods being least affected by the number of extraneous variables present. Since in practice, the number of extraneous variables present in a variable pool is not known (by definition), the consistency of Miller's method in dealing with an unknown number of extraneous variables is highly desirable.

When only one extraneous variable is present, the performance of Minimum S_p and Minimum C_p was constant and stable, choosing the correct variable at least 91 times out of 100. Under these circumstances, where few extraneous variables were in the pool, the performances of Minimum S_p and Minimum C_p were predictable and reliable, though not as good as Miller's method.

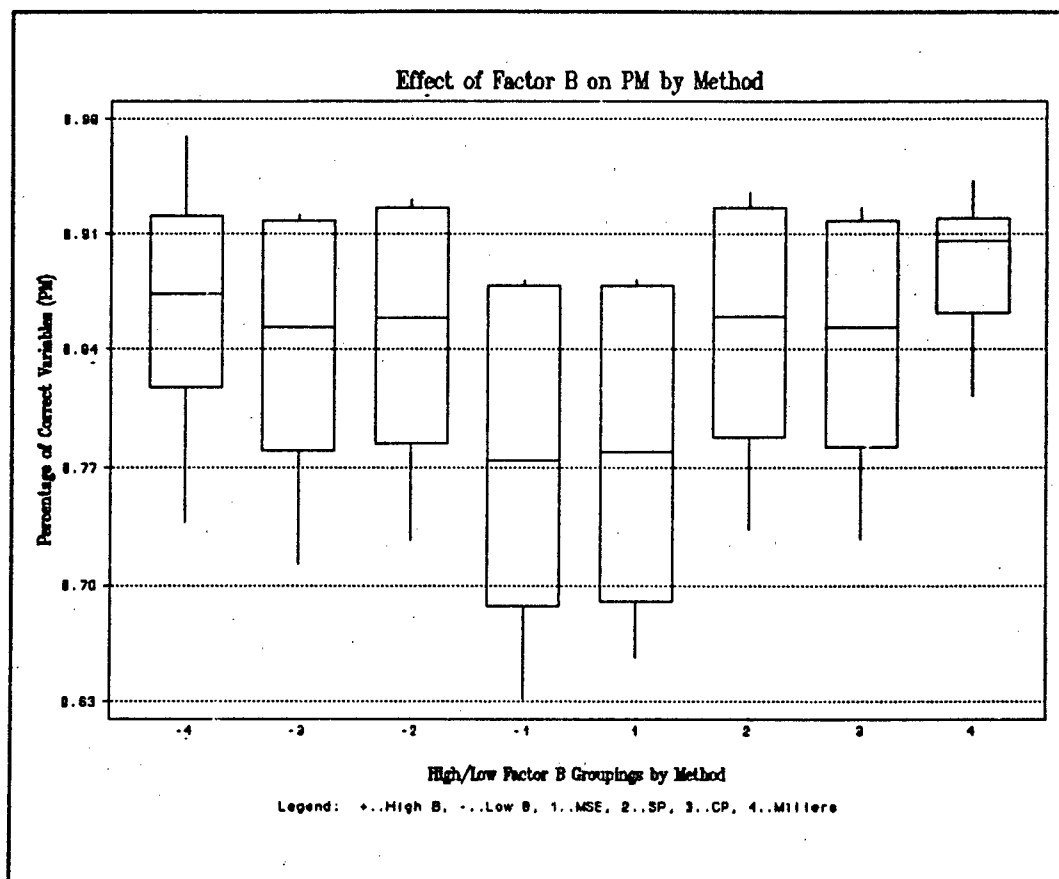


Figure 3. Box and Whisker Plots Showing the Effect of Factor B on PM by Method

Miller's method selects the highest percentage of correct variables at either level and is the only method significantly affected by an increase in correlation among the truly significant predictors. The ability of Miller's method to select correct variables actually increases as the correlation between the correct variables increases. This occurs because the increased correlation among the correct variables causes them to behave as one variable. If any one

correct variable is selected, it is equivalent to all the correct variables being selected.

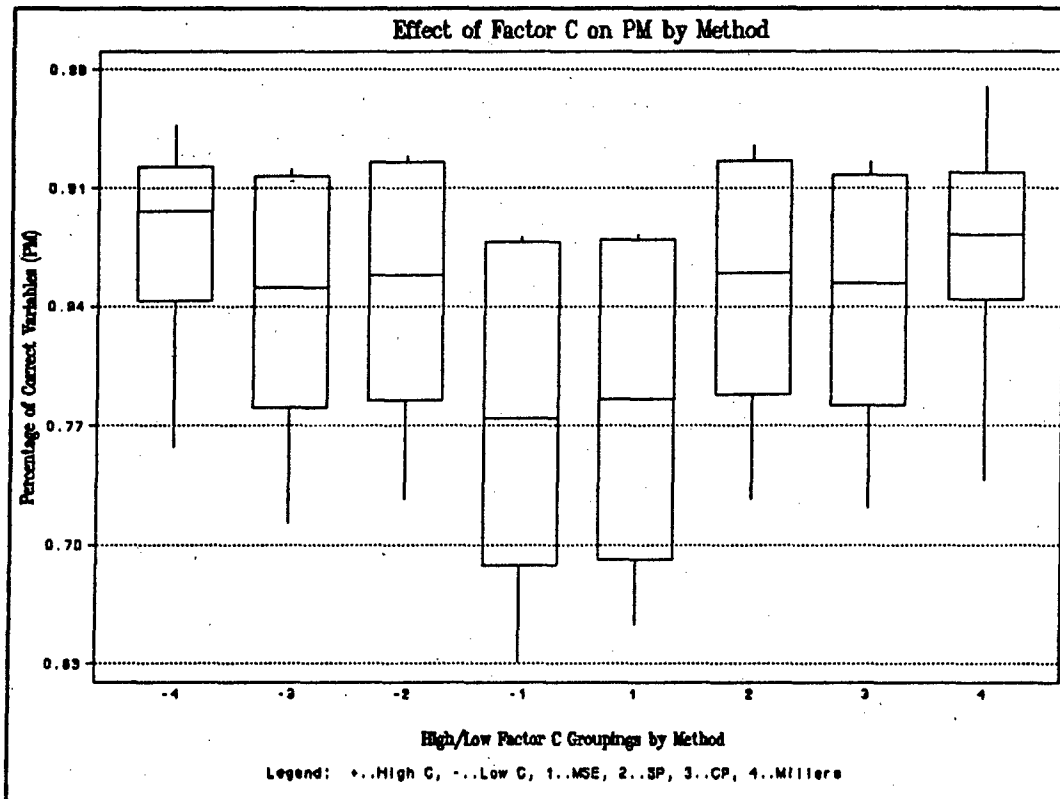


Figure 4. Box and Whisker Plots Showing the Effect of Factor C on PM by Method

Factor C, the variance of the extraneous variable, had little effect on any of the four methods. The median of the MSE method improved slightly with an increase in variance of the extraneous variables while the median of Miller's method decreased slightly.

The Minimum S_p , Minimum C_p , and Minimum MSE methods lag behind Miller's method and show a greater variability.

Clearly the Minimum MSE method selects the smallest percentage of correct variables.

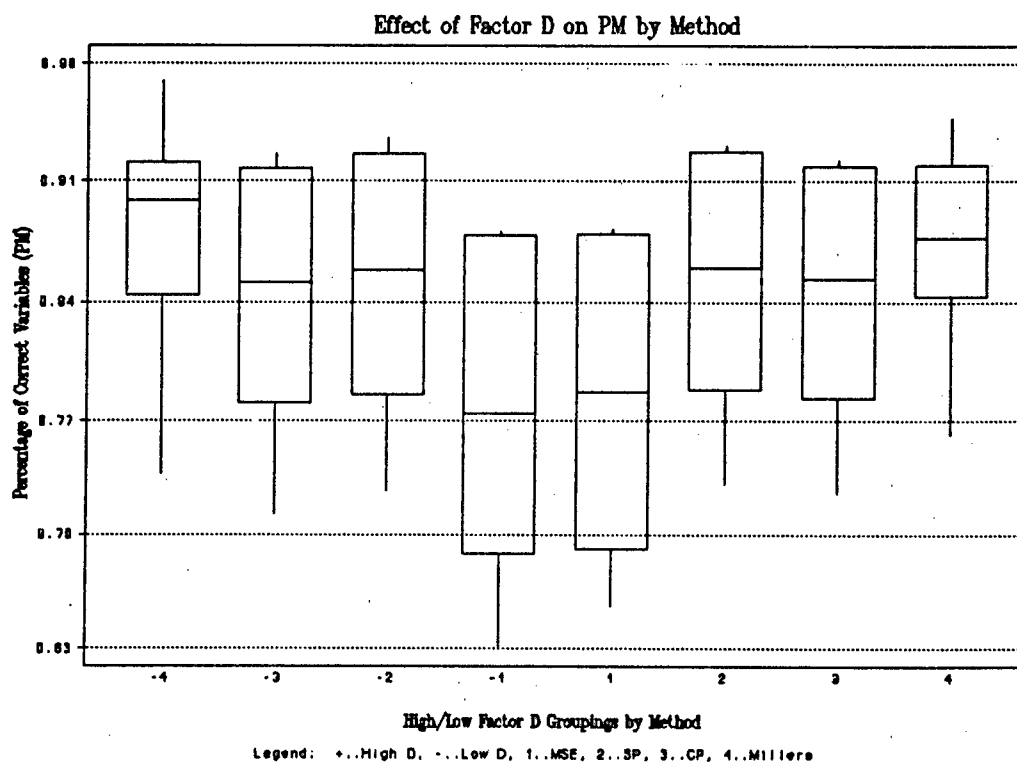


Figure 5. Box and Whisker Plots Showing the Effect of Factor D on PM by Method

Again, this plot for factor D, like that of factor C, shows that the variance of the correct variables has little effect on the percentage of correct variables chosen for any of the four methods.

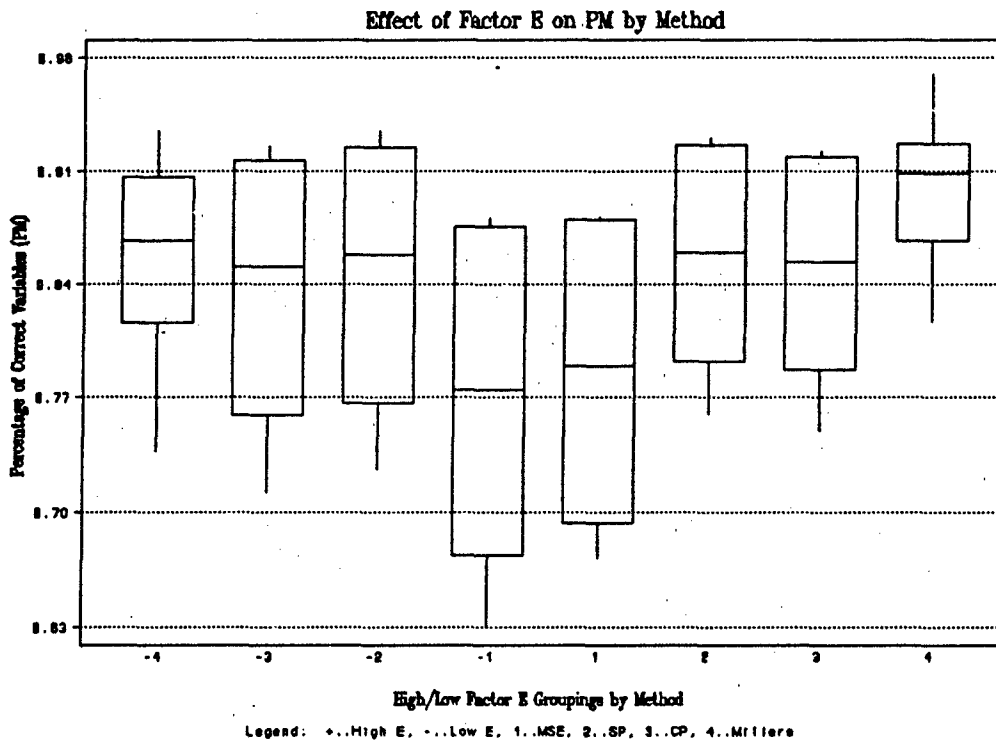


Figure 6. Box and Whisker Plots Showing the Effect of Factor E on PM by Method

Increasing the sample size, factor E, increases the median performance of Miller's method by 5 percent. The Minimum MSE method also improves slightly as sample size increases. The Minimum S_p and Minimum C_p method are not effected.

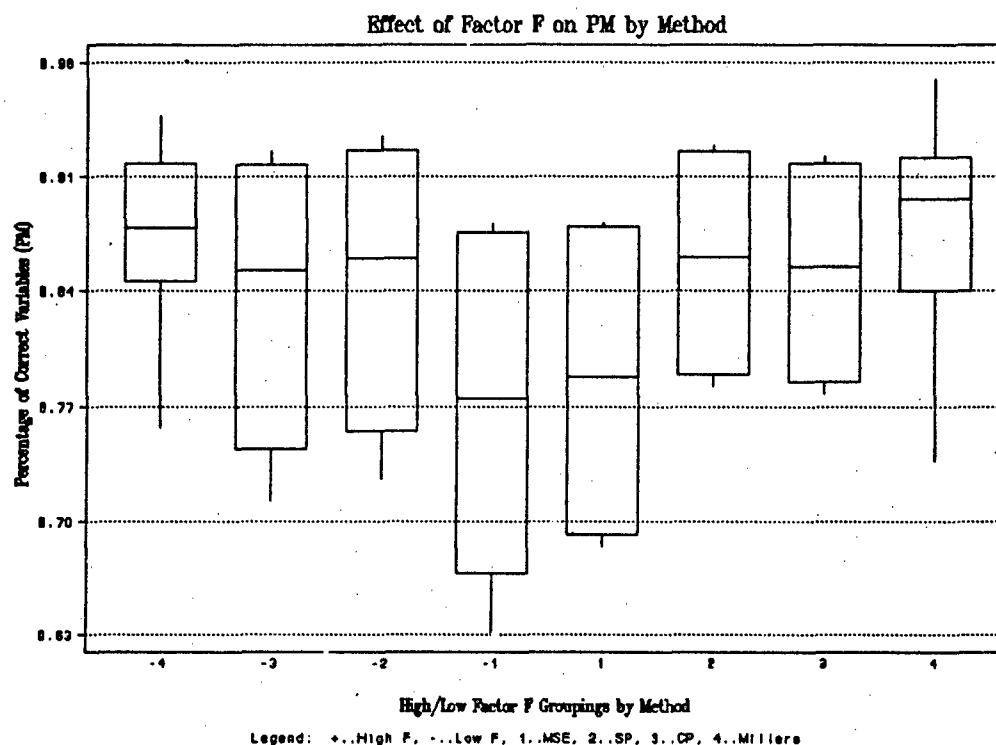


Figure 7. Box and Whisker Plots Showing the Effect of Factor F on PM by Method

Increasing the variance of the error term, factor F, has little effect on any of the four methods. The median performances of the Minimum MSE method and Miller's method is slightly increased at the higher factor levels.

Theoretical Mean Square Error of Prediction (TMSEP) as a Performance Measure of Model Accuracy

Justification. Thus far, analysis has been limited to studying the effects which varying factors have on a method's ability to select the correct variables. PM, however,

when employed as an index for comparing different selection methods, favored techniques which select models with the highest percentage of correct variables. Although models with a high percentage of correct predictors are desirable, methods which select such models may do so by selecting more variables overall. In such models, the ratio of extraneous variables to all the variables may be small, but the absolute number of extraneous variables may be larger than desired simply because of the sheer number of variables selected. Comparing techniques on the basis of PM may favor methods which create these larger models rather than those which create parsimonious models. Therefore, a different, more absolute performance measure was adopted to compare selection techniques in terms of how close the selected models response value is to the true response value. A comparison of how accurately each technique performs can be accomplished using another performance measure known as Theoretical Minimum Mean Square Error of Prediction (TMSEP) and defined by:

$$TMSEP_{k,M} = \frac{\sum_{t=1}^{n_k} (Y_t - \bar{Y}_{k,M})^2}{(n_k - p_{k,M})} \quad (29)$$

where

$TMSEP_{k,M}$ is the TMSEP for data set k using the subset selection technique M

Y_t is the theoretical conditional mean of Y calculated from the underlying data generation model (1) and the data set k .

$\bar{Y}_{kM}$ is the predicted value of Y using the model selected by applying method M to data set k

n_k is the sample size of data set k.

p_{kM} is the number of predictors in the model selected by applying method M to data set k

TMSEP is a good choice for an inter-technique comparison. It compares each method's model at a particular data set to the theoretical model which generated the original data. In theory, TMSEP directly measures how well the predicted model explains the variations in the original data. Furthermore, the TMSEP criterion is a variation of Mean Squared Error Prediction (MSEP), a statistic that has received much praise in the literature. TMSEP and MSEP both calculate the squared difference between the predicted value of Y and the actual value of Y and adjust the value for the degrees of freedom. TMSEP differs from MSEP, however, in its calculation. TMSEP is calculated by squaring the difference between the theoretical Y value (the response from the underlying data generation equation, excluding the error term) and the predicted Y value generated by the model constructed using variable selection procedure, M. The resulting value is the Theoretical MSEP or TMSEP. Since the TMSEP is based on MSEP which has received considerable praise in the literature during the past decade, the TMSEP

is also considered a most promising criterion (Hansen, 1988,43-45).

In defending the credibility of TMSEP, Hansen notes that at first glance, TMSEP appears to unfairly favor the Minimum C_p and Minimum S_p criteria because both are based in minimum MSE. Furthermore, one might falsely assume that since the S_p criterion and TMSEP are based on the regressors being randomly generated, the TMSEP would favor the Minimum S_p method. Hansen clearly shows this is not the case.

It is assumed when calculating the S_p and C_p statistics that all relevant variables are included in the variable pool. It is also assumed that the variable pool does not contain extraneous variables. In this study both of these assumptions are violated. Therefore, it is possible that either the MSE, C_p , or Miller] criterion could outperform the S_p criterion. (Hansen, 1988:46)

Calculating TMSEP. The equation presented thus far to calculate TMSEP does so one data set at a time. Recall that the generated data consists of 64 design points each of which is made up of 60 data sets. In order to compare each of the four variable selection techniques, the TMSEP must somehow be calculated for each technique at each design point. Although generating the TMSEP for each data set is a starting point, a slightly different TMSEP equation is necessary to generate the aggregate TMSEP at each design point.

Starting with the original equation from Hansen's thesis:

$$TMSEP_{k,M} = \frac{\sum_{t=1}^{n_k} (Y_t - \bar{Y}_{k,M})^2}{(n_k - p_{k,M})} \quad (31)$$

Then, applying algebra yields:

$$\frac{(n_k - p_{k,M}) TMSEP_{k,M}}{\sigma^2} = \frac{\sum_{t=1}^{n_k} (Y_t - \bar{Y}_{k,M})^2}{\sigma^2} \quad (32)$$

Hansen assumed a Chi Square distribution (Hansen, 1988:44)

$$\frac{\sum_{t=1}^{n_k} (Y_t - \bar{Y}_{k,M})^2}{\sigma^2} \sim \chi^2_{(n_k - p_{k,M})} \quad (33)$$

Then, it follows from equation 31 that:

$$\frac{(n_k - p_{k,M}) TMSEP_{k,M}}{\sigma^2} \sim \chi^2_{(n_k - p_{k,M})} \quad (34)$$

Based on the theorem that the sum of independent χ^2 variables is also χ^2 , we have:

$$\sum_{k=1}^{60} \left[\frac{(n_k - p_{k,M}) TMSEP_{k,M}}{\sigma^2} \right] \sim \chi^2_{(n_k - p_{k,M})} \quad \text{OR} \quad \chi^2_{\left[\sum_{k=1}^{60} n_k - \sum_{k=1}^{60} p_{k,M} \right]}$$

Now

$$\sum_{k=1}^{60} \left[\frac{(n_k - p_{k,M}) TMSEP_{k,M}}{\sigma^2} \right] = \sum_{k=1}^{60} \left[\frac{\sum_{t=1}^{n_k} (Y_t - \bar{Y}_{k,M})^2}{\sigma^2} \right] \quad (36)$$

$$\sum_{k=1}^{60} \left[\frac{(n_k - p_{k,M}) TMSEP_{k,M}}{\sigma^2} \right] = \frac{\sum_{k=1}^{60} \sum_{t=1}^{n_k} (Y_t - \bar{Y}_{k,M})^2}{\sigma^2} \quad (37)$$

So:

$$\frac{\sum_{k=1}^{60} \sum_{t=1}^{n_k} (Y_t - \bar{Y}_{k,M})^2}{\sigma^2} \sim \chi^2_{\left[\sum_{k=1}^{60} n_k - \sum_{k=1}^{60} p_{k,M} \right]} \quad (38)$$

Therefore, the formula for calculating TMSEP is:

$$TMSEP_{D,M} = \sum_{k=1}^{60} TMSEP_{k,M} = \frac{\sum_{k=1}^{60} \sum_{t=1}^{n_k} (Y_t - \bar{Y}_{k,M})^2}{\sum_{k=1}^{60} n_k - \sum_{k=1}^{60} D_{k,M}} \quad (39)$$

where $TMSEP_{D,M}$ is the TMSEP at design point D using method M

Minimum MSE, Minimum S_p , and Minimum C_p Methods.

Appendix C outlines the data processing to calculate TMSEP for each design point for the above three methods. The processing is similar to that performed at each design point during subset selection for each method. The processing differs in that for each model selected, the coefficients of regression are estimated by SAS. The FORTRAN program uses these coefficients and the original data to generate TMSEP for each design point and each method.

Miller's Method. Appendix D outlines the data processing to calculate TMSEP for each design point for Miller's method. A FORTRAN program creates a SAS program file to calculate the coefficients of regression for each model. This SAS program is executed and the output is filtered and formatted by yet another FORTRAN program. A third FORTRAN program processes this output along with the data sets and calculates the TMSEP for each method and design point.

Experiment. An experiment identical to the one run for PM was run to determine the significant factors for TMSEP. Basically, TMSEP was substituted for PM in the experimental design and then the experiment was run as before, using the SAS Stepwise procedure.

Results. The same comments that applied to PM apply to TMSEP, with one notable exception. Whereas with PM, values $\rightarrow 1^-$ were desirable, with TMSEP values $\rightarrow 0^+$ are the target.

TMSEP Equations. These equations were generated in exactly the same manner as the PM equations

Minimum MSE.

$$\begin{aligned}
 TMSEP_{MSE} = & 22.15 - 1.76(A) - 16.91(B) + 21.6(D) + 3.04(E) \\
 & + 1.4(AB) - 1.75(AD) + 0.74(AE) - 16.57(BD) \\
 & - 2.4(BE) + 3.03(DE) + 1.38(ABD) - 0.65(APE) \\
 & + 0.74(ADE) - 2.36(BDE) - 0.64(ABDE)
 \end{aligned}
 \tag{40}$$

Minimum Sp.

$$\begin{aligned}
 TMSEP_{sp} = & 23.22 - 1.54(A) - 17.76(B) + 22.65(D) + 2.29(E) \\
 & + 1.27(AB) - 1.52(AD) - 17.4(BD) - 1.8(BE) \\
 & + 2.3(DE) + 1.24(ABD) - 1.77(BDE)
 \end{aligned}
 \tag{41}$$

Minimum C_p .

$$\begin{aligned}
 TMSEP_{CP} = & 37.51 - 0.84(A) - 25.72(B) + 36.69(D) + 5.86(E) \\
 & + 0.79(AB) - 0.82(AD) - 25.19(BD) - 4.08(BE) \\
 & + 5.77(DE) + 0.77(ABD) - 4.0(BDE)
 \end{aligned}
 \quad (42)$$

Miller's Method.

$$\begin{aligned}
 TMSEP_{MILLER} = & 33.02 - 26.22(B) + 32.26(D) - 3.93(E) \\
 & - 25.69(BD) + 3.32(BE) - 3.84(DE) \\
 & + 3.27(BDE)
 \end{aligned}
 \quad (43)$$

Summary of Effects.

Table 7.
Main Factor Coefficients of Effects by Method for TMSEP

METHOD----	Minimum MSE	Minimum S_p	Minimum C_p	Miller's Method
! FACTOR !				
A (ext. vars.)	- 1.76	- 1.54	- 0.84	0
B(ind. corr.)	- 16.91	- 17.76	- 25.72	- 26.22
C (ext. σ^2)	0	0	0	0
D (ind. σ^2)	+ 21.6	+ 22.65	+ 36.69	+ 32.26
E (sam. size)	+ 3.04	+ 2.29	+ 5.86	- 3.93
F (error σ^2)	0	0	0	0
Intercept (μ)	+ 22.15	+ 23.22	+ 37.51	+ 33.02

Table 8.

**Main Factor Effects by Method and Rank Order of Significance
for TMSEP**

METHOD--- FACTOR	Minimum MSE	Minimum S _p	Minimum C _p	Miller's Method
A (ext. vars.)	4th	4th	4th	No effect
B (ind. corr.)	2nd	2nd	2nd	2nd
C (ext. σ^2)	No effect	No effect	No effect	No effect
D (ind. σ^2)	1st	1st	1st	1st
E (sam. size)	3rd	3rd	3rd	3rd
F (error σ^2)	No effect	No effect	No effect	No effect

All Four Methods. The following results
pertain to all methods:

(1) The higher the correlation among the independent or correct variables, the better the performance.

(2) Lower variances in the independent or correct variables yielded better performance.

Minimum MSE, Minimum C_p, Minimum S_p Method.

The following results were additionally observed for these methods:

(1) The higher the number of extraneous variables, the closer the response value is to its true theoretical value.

(2) Smaller sample sizes give better results.

Miller's Method. The following additional
results were observed for this method:

(1) Adding extraneous variables causes improvement of the TMSEP for a model.

(2) Better performance is obtained with larger sample sizes.

Analysis. As with PM, Box and Whisker plots were employed to further assess the impact of each factor (A, B, C, D, E, F) on TMSEP for a given method. STATISTIX 4.0 was also used to produce these Box and Whisker plots by forming the indicators in the same manner as before. A set of indicator values are created for each of the six factors studied. The six resulting plots revealed much about the ability of each subset selection technique to create a model close to the actual model.

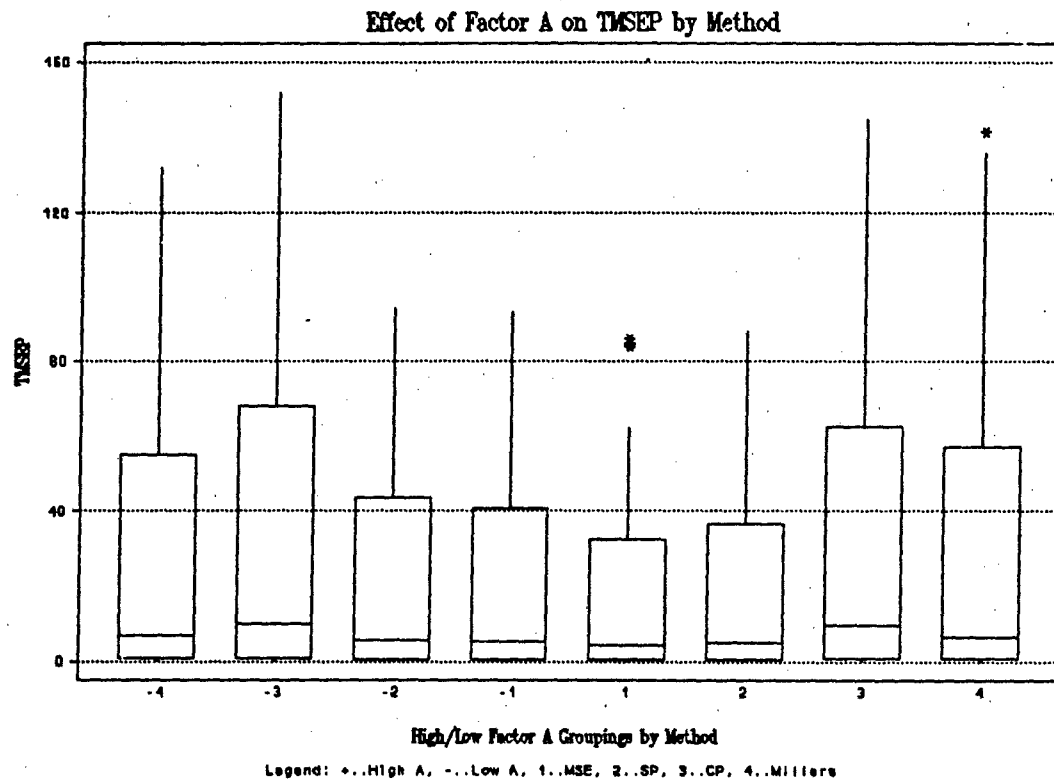


Figure 8. Box and Whisker Plots Showing the Effect of Factor A on TMSEP by Method

The number of extraneous variables involved had very little impact on how close a method came to selecting the absolutely correct model. Of the four methods studied, however, MSE appears to perform best.

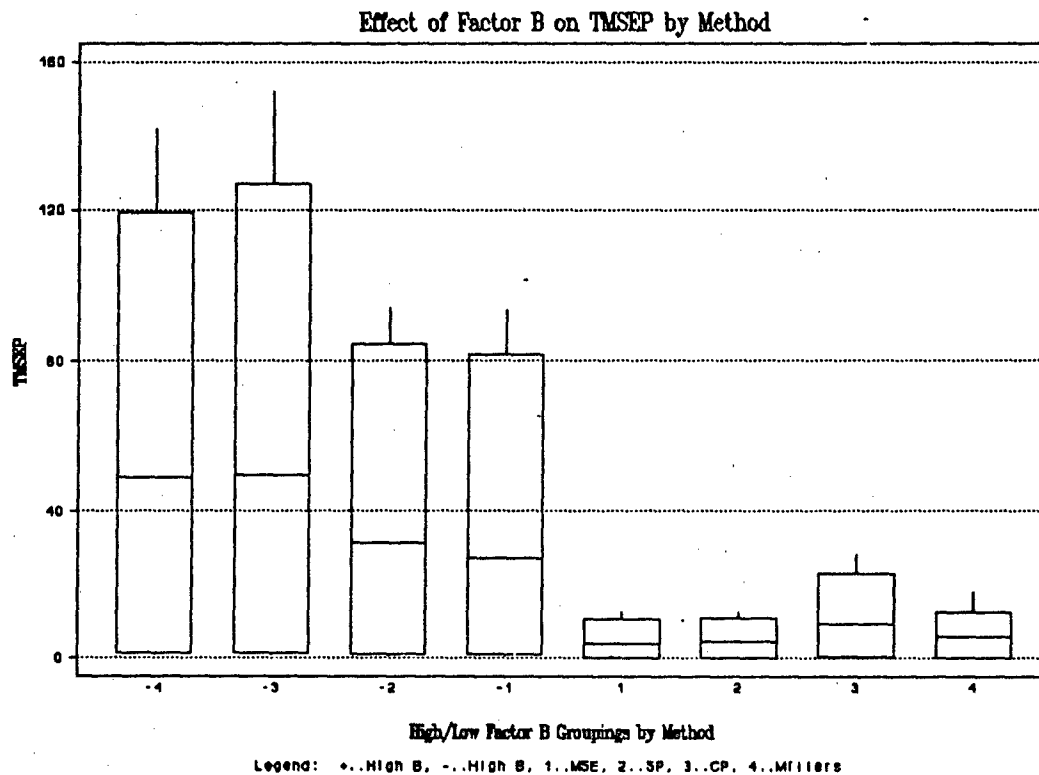


Figure 9. Box and Whisker Plots Showing the Effect of Factor B on TMSEP by Method

Clearly the amount of correlation between the correct variables has a great effect on model accuracy. When the correct variables are highly correlated, one contains almost all of the information contained in all four of them (including the one omitted from the pool).

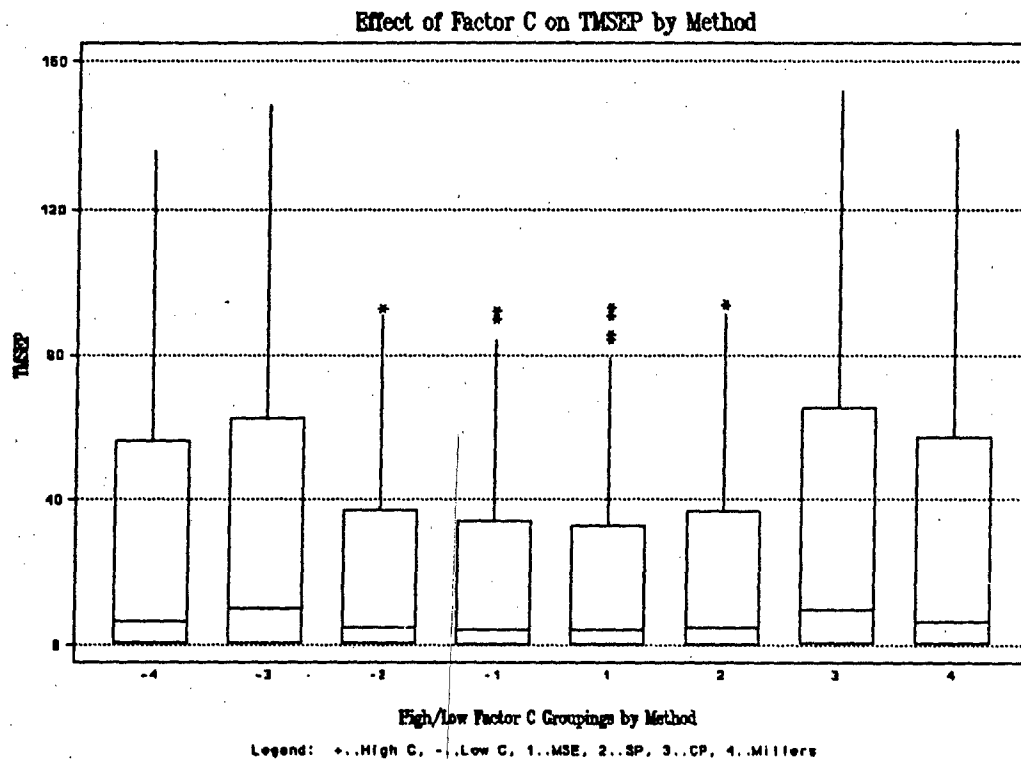


Figure 10. Box and Whisker Plots Showing the Effect of Factor C on TMSEP by Method

Factor C, the variance of the extraneous variables, has no effect on the accuracy of any method. If the focus was on selecting the correct variables, it follows that a change in the extraneous variables would have little effect.

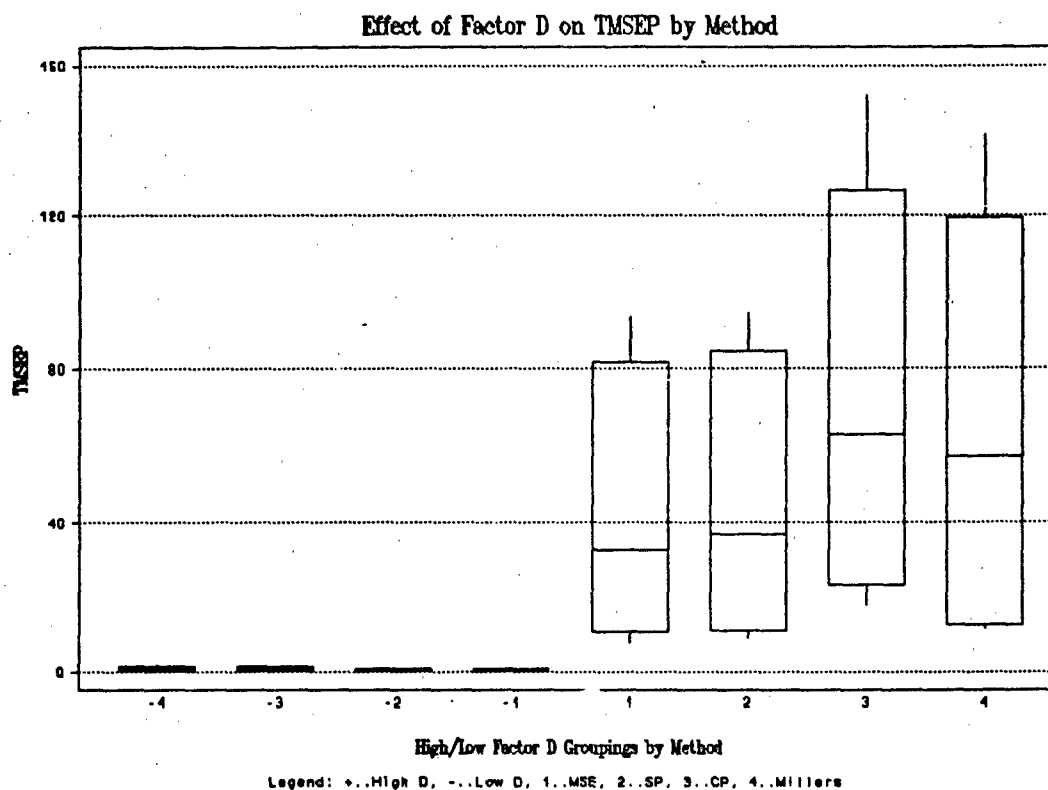


Figure 11. Box and Whisker Plots Showing the Effect of Factor D on TMSEP by Method

The variance of the extraneous variables, factor D, effects the performance of all four methods. Minimum MSE and Minimum S_p methods appear to be more affected than Minimum C_p and Miller's methods.

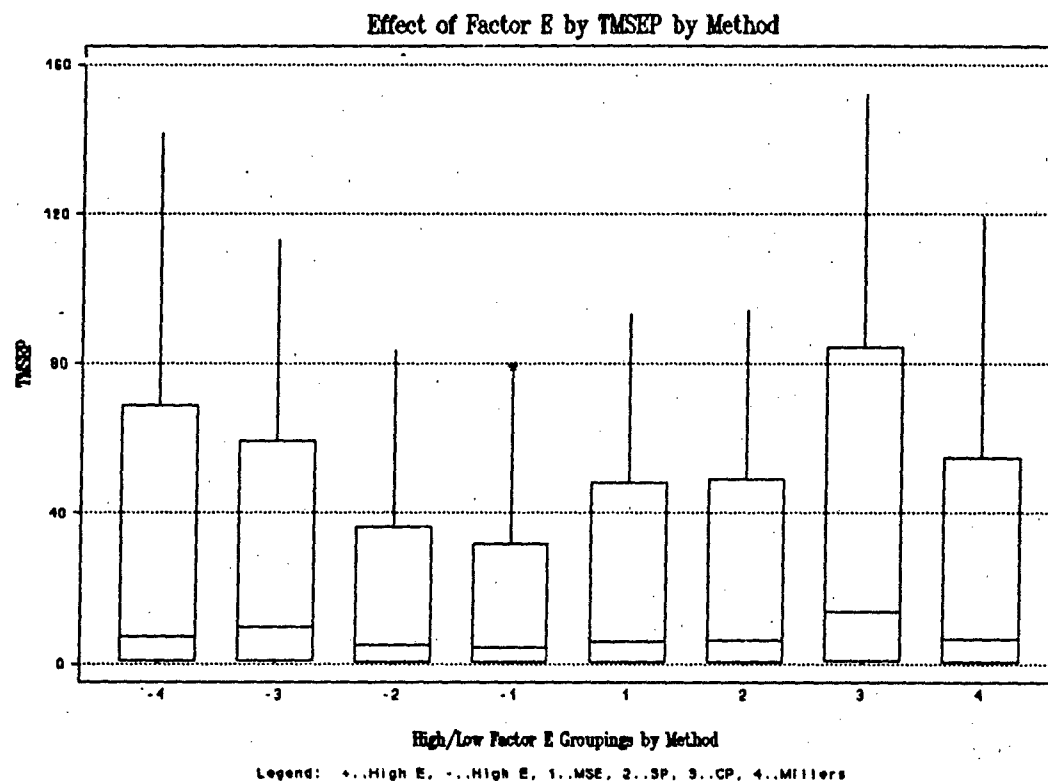


Figure 12. Box and Whisker Plots Showing the Effect of Factor E on TMSEP by Method

Increasing the sample size, factor E, tends to increase the variance in the Minimum MSE, Minimum S_p , and Minimum Cp methods. Miller's method, however, becomes slightly more consistent.

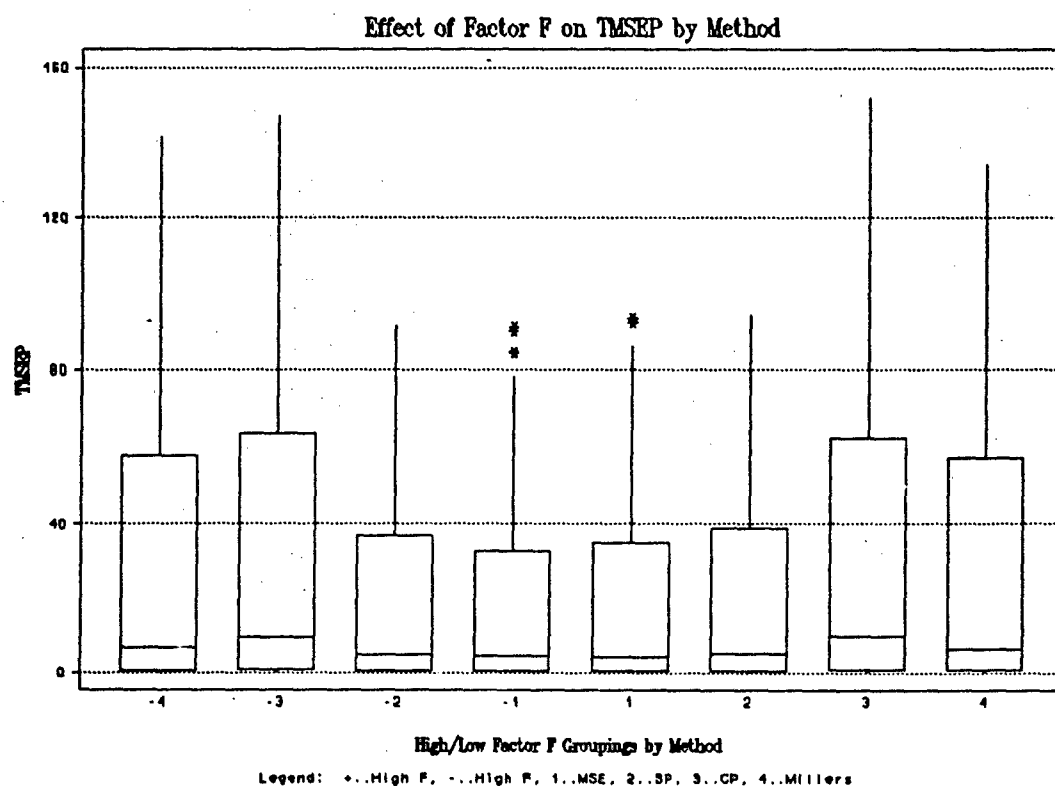


Figure 13. Box and Whisker Plots Showing the Effect of Factor F on TMSEP by Method

The variance of the error term, factor F, has no apparent effect on the accuracy of the four methods studied. All the method were able to filter out the white noise equally well.

V. Conclusions and Recommendations for Further Research

Conclusion

Objective. The objectives of this research were: (1) identify some promising least squares selection procedures discussed in the literature, (2) introduce, implement, and study a variable selection method proposed by Alan J. Miller, and (3) make an extension of Hansen's research by comparing the methods he examined: Minimum MSE, Minimum S_p , and Minimum C_p , with Miller's method.

Techniques Studied. The Minimum MSE, Minimum S_p , and Minimum C_p variable selection techniques have received much praise in the past 20 years. Due to the similarity to the Maximum R^2 criterion and its adjustment for degrees of freedom, Minimum MSE was considered the favored technique fifteen years ago. More recently Minimum S_p and Minimum C_p , both of which are based on MSEP, have received the majority of the praise. Of the two, Minimum S_p is the more practical selection method because it is designed for random regressors (Hansen, 1988:59).

Compared to the three well-known techniques mentioned above, Miller's method was obscure and untested. A literature search revealed only Miller's original reference to the procedure. This research has compared and contrasted Miller's method with the well-accepted techniques, Minimum

MSE, Minimum S_p , and Minimum C_p , and thereby defined its role among current variable screening techniques.

Methodology. To facilitate a comparative analysis of Miller's method and the other methods, Response Surface Methodology was employed with two performance measures. The first, designated PM, measured the percentage of correct variables in a model. The second, Theoretical Mean Squared Error of Prediction (TMSEP), measured the predictive error between the model selected and the theoretical model. A 2^6 full factorial design was setup, yielding the 64 high/low combinations, or design points, of the six factors being studied. Using Hansen's data, which had been generated with 60 replications at each design point, both PM and TMSEP were calculated for each subset selection method at each design point. The SAS Stepwise procedure was used to select significant factors or factor combinations at the $\alpha = 0.01$ level and to generate a linear equation for each combination of performance measure and selection method. Four of these eight equations revealed what each of the six factors and their combinations contributed toward improving the percentage of correct variables (maximizing PM) in a model and the other four examined how the same factors related to minimizing the error between the modeled response and the theoretical response (minimizing TMSEP). STATISTIX 4.0 was then used to produce Box and Whisker plots by performance measure and method. These plots revealed factor effects and provid-

ed a graphical analysis of variance on performance measures by method and factor settings.

Two-Stage Variable Selection Technique. The data used in this thesis attempted to simulate real world data. Extraneous variables were added and one of the significant predictors was totally dropped from consideration after generating the data. In light of these tough, inherent data problems, it was suspected from the beginning of this research effort that a single selection method may not be effective at both screening out the extraneous variables and selecting the final model. Therefore, two performance measures, PM and TMSEP, were examined because they rate selection methods from different vantage points. A selection technique which rated highly under PM would perform well as a screening method prior to final variable selection. During the screening process the objective is to select the greatest number of significant variables (or correct or true variables) while rejecting any extraneous ones. PM measured how well each method accomplished this. On the other hand, a selection technique which rated highly under TMSEP would perform the final variable selection process well. During the final selection process, a set of likely predictors is examined and the final subset selected. One hopes that this final subset of predictors has a response close to that of the theoretically correct set of predictors. TMSEP measured the performance of each method

in this regard. Note that PM and TMSEP were calculable only because the data for this research was generated by a known model. In practice, PM and TMSEP cannot be calculated. It was the intention of this research, therefore, to observe the performance of the four variable selection techniques in question under controlled conditions and to note the conditions under which they perform best.

In a screening situation where PM would apply, all four PM equations and a comparison of their regression factor coefficients indicated that the number of extraneous variables (factor A) was the most significant factor, sometimes by a difference as much as two magnitudes. Box plots of PM for factor A also revealed that Miller's method had the highest median PM value. The equation for $PM_{MILLERS}$ reveals why this occurred. $PM_{MILLERS}$ had the highest intercept value and the number of extraneous variables reduced the performance measure by less than half the amount the other PM equations did for the other methods. Obviously, when selecting the independent or correct variables from a variable pool containing extraneous variables, Miller's method was the method least affected by the presence of extraneous variables. Thus Miller's method is the best technique for screening.

Once screened, the variable pool is ready for final model selection. As stated previously, a method's performance during this final selection stage is best gauged by

TMSEP. TMSEP was primarily affected by two factors: the variance of the independent or correct variables (factor D) and the correlation among the same variables (factor B), as the all TMSEP equations reveal. The regression coefficients of factors B, D, and the BD interaction were a magnitude larger than any other coefficients. Closer examination of the TMSEP equations showed that when factor D (variance of the correct variable) was at its low setting, factor B (correlation of the correct variables) caused about the same improvement (decrease) of TMSEP at its high and low levels. When factor D is set high, however, the low setting of factor B worsens (increases) TMSEP and the high settings of factor B improves (decreases) TMSEP. The following analysis graphically depicts this BD interaction using $B+D+BD$ to calculate the weights in each quadrant. This explains the importance of the BD interaction.

Minimum MSE		Minimum S_p	
	B		B
(-1,1)	(1,1)	(-1,1)	(1,1)
-21.94	-11.88	-23.01	12.51
		D	D
(-1,-1)	(1,-1)	(-1,1)	(1,1)
-21.26	+55.08	-22.29	+57.81
Minimum C_p		Miller's	
	B		B
(-1,1)	(1,1)	(-1,1)	(1,1)
-37.22	-14.22	-32.79	-19.65
		D	D
(-1,-1)	(1,-1)	(-1,1)	(1,-1)
-36.16	+87.6	-31.73	+84.17

Figure 14. Graphical Analysis of the BD Interaction by Method

Box plots for factors B and D show that the Minimum MSE method had the best median TMSEP, followed closely by the Minimum S_p method. Furthermore, the following box plot for the BD interaction factor confirms that the Minimum MSE method would perform best as a final selection technique.

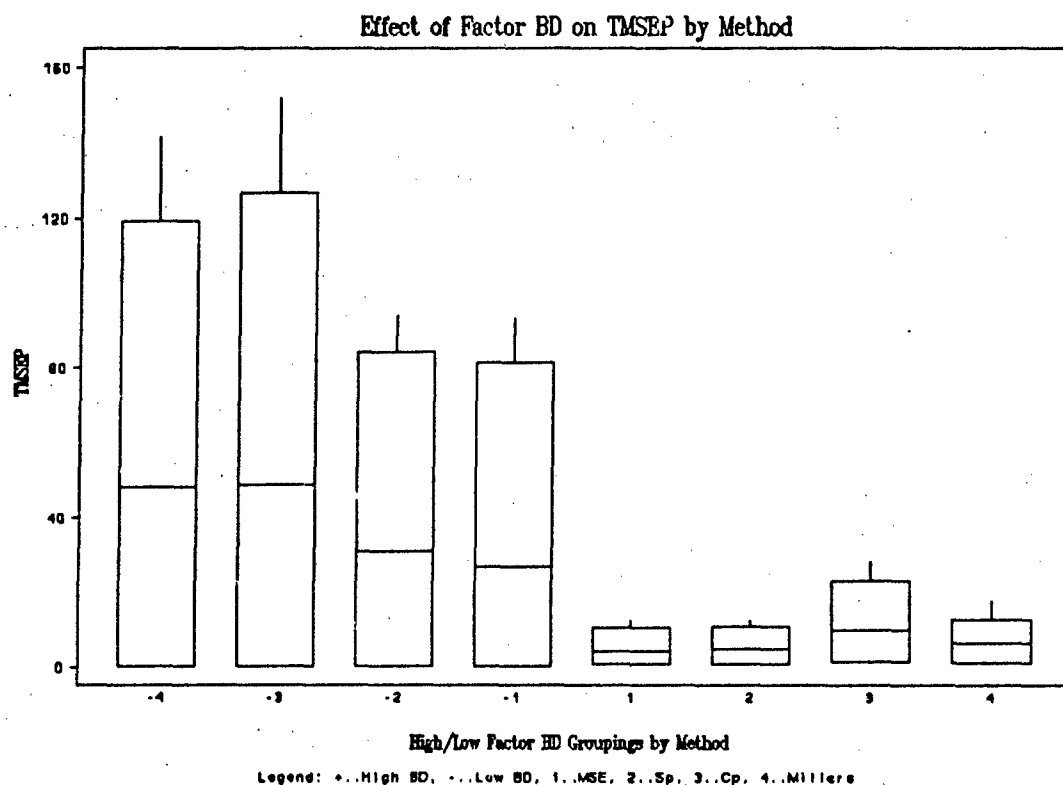


Figure 15. Box and Whisker Plots Showing the Effect of Factor BD on TMSEP by Method

This research proposes a two-stage variable selection technique. Miller's method is used to first screen the variable pool and reduce the number of extraneous variables. Next the Minimum MSE method is used to select the model from this reduced variable pool.

Factor C, the variance of the extraneous variables, had little or no effect on either PM or TMSEP. It was the only factor which had no impact throughout this research effort.

Neither did it appear in any of the PM or TMSEP equations. Based on these results, this factor could be dropped from further consideration.

Another useful result of this research is the comparison of the two MSE criteria: Minimum S_p and Minimum C_p . A great deal of praise has been given to the Minimum S_p criterion in the past 15 years. It was identified as one of the most promising methods when the regressors are random and one desires to minimize the mean square error of prediction. The minimum C_p criterion has also received praise for minimizing mean square error of prediction, but its usefulness is limited to cases where the regressors are fixed. Some have recommended that the Minimum C_p criterion not be used in practice.

The results of this thesis indicate that the Minimum S_p method outperformed the Minimum C_p method at every factor level, using both PM and TMSEP. No evidence was found to refute the assertion that the Minimum C_p criterion should not be used in practice. In fact, this research effort supports using Minimum S_p method instead of the Minimum C_p method, thereby improving the selection process.

Most other simulations have dealt with the number of correct variables chosen of those available. No provisions were made for circumstances in which a significant regressor is not included in the variable pool. Therefore, techniques

praised as good variable selection techniques may not be as appealing as originally thought. This appears to be the case with Minimum C_p . It should be noted, however, that Mallows C_p method (C_p -close-to-p) is not the same as the Minimum C_p method (C_p -close-to-zero). This Mallows C_p method, as originally proposed, was not studied in this thesis.

Recommendations for Further Research

This research effort lends itself to several follow-on studies. The methodology established by Hansen and the computer programming groundwork in this research project make embellishments and the use of more complex model a feasible task.

One area which leads to further research deals with expanding the number of factors under consideration. This research effort studied six factors, but many more could be added. The response surface region could be expanded to include negative correlation, larger sample sizes, and the spread of the variance on the independent or correct variables. The factors studied could also include an indicator variable to keep track of the effect of dropping a significant variable. That is, by including a variable to keep track of the difference between the full model and a model where a variable is dropped, one could quantify the effects of failing to collect data on all the significant variables. This research only collected information on the effects of

dropping a variable and it was assumed that if all the variables were present the techniques studied would perform better. However, to gain a better understanding of Miller's method, it would be worthwhile to quantify the effects of not including all significant variables in the variable pool. To implement this, factor C (the variance of the extraneous variables) which had no effect, could be replaced with the indicator variable described above. Thus, the information desired could be gained without increasing the size of the experimental design.

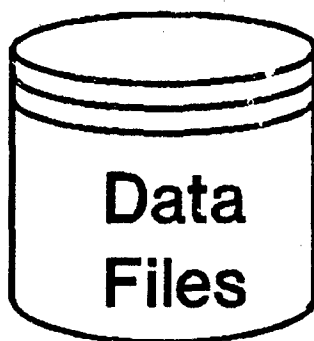
Further research could also be done to address the question of which screening and final selection method combinations work best together and under what circumstances. The four methods studied in this thesis could generate 16 screening and final selection method combinations. Some of these combinations may be eliminated a priori, but the rest could be studied either under the original six factors used in this thesis or under an expanded set of factors. The number of methods considered could also be increased. One method which could be added is Mallows C_p , as the method was originally set forth. This would allow a comparison between Miller's method and other variable selection techniques not studied in this thesis.

This thesis effort has implemented a promising new variable selection technique: Miller's method. Additionally, by comparing its performance with three well tested

methods, this research has served to suggest a possible role for Miller's method among the many selection techniques. The results of this research indicate that Miller's method may be most effective when used as a screening method prior to final variable selection.

Appendix A: Flow Chart for the Development of the MSE, S_p,
and C_p PMs

Legend of Flow Chart Symbols

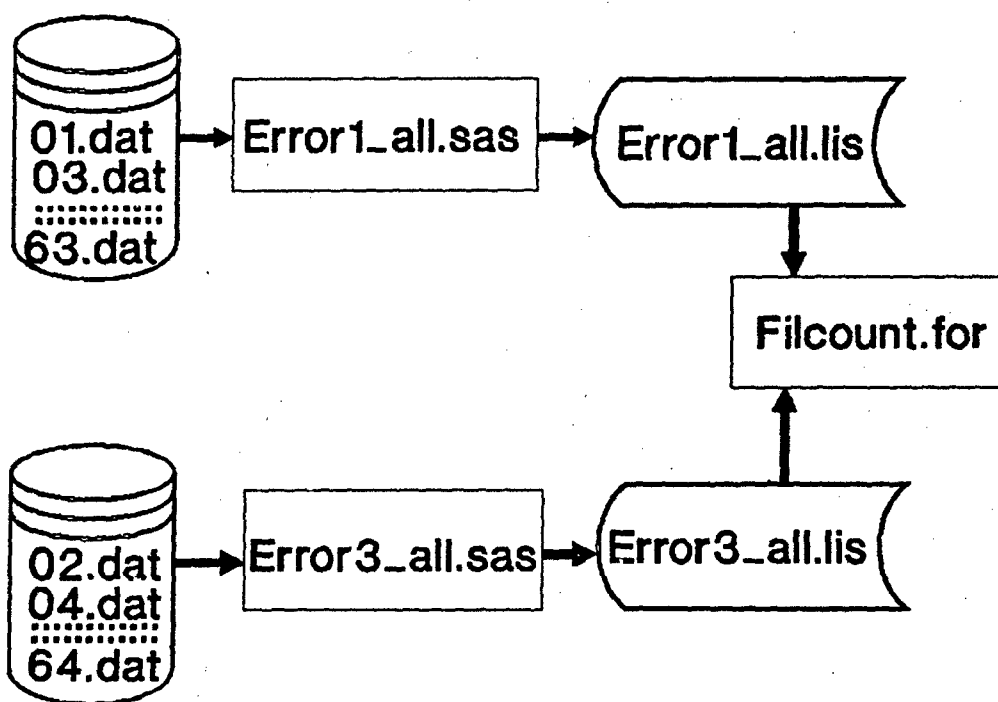


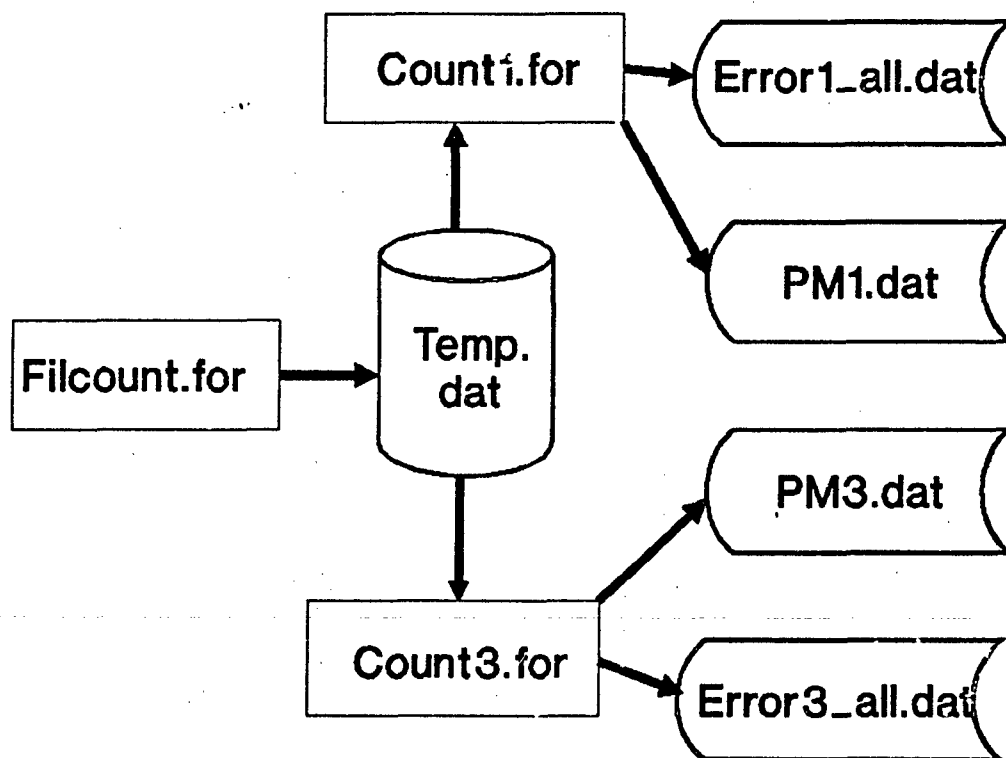
Flow of Data



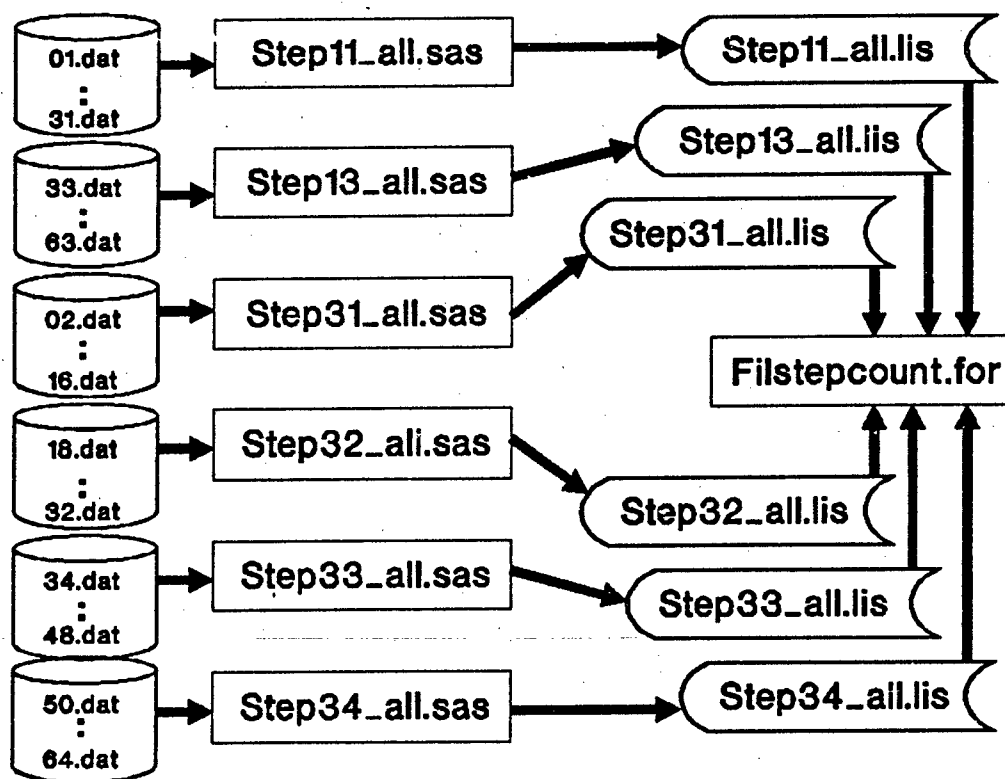
Programs

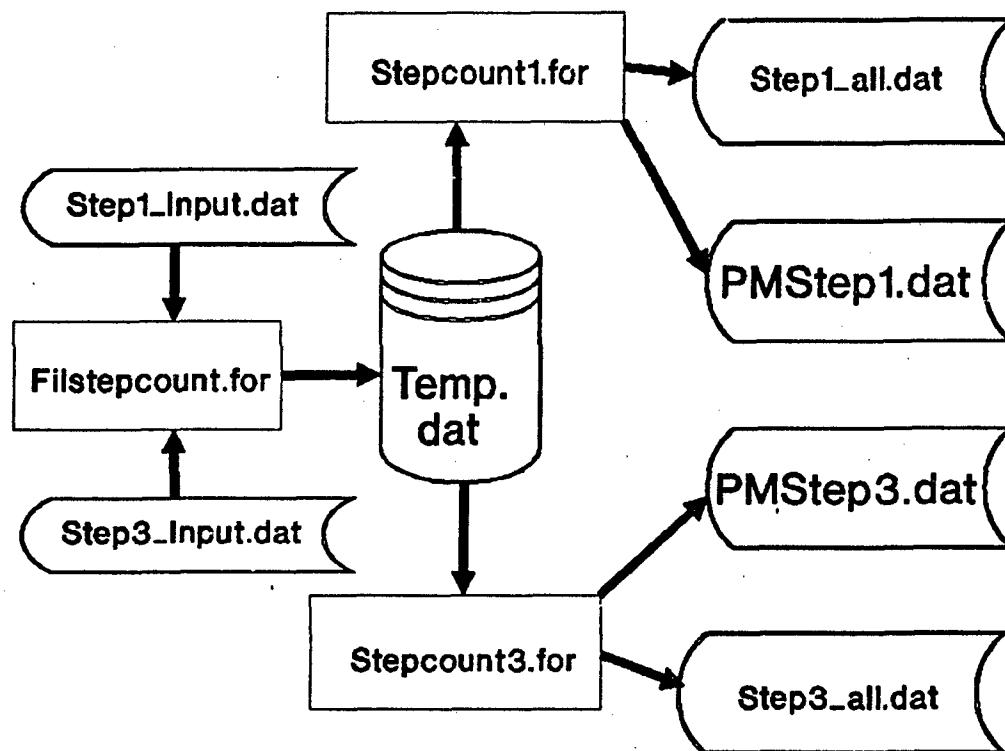
Listing or
Output Files



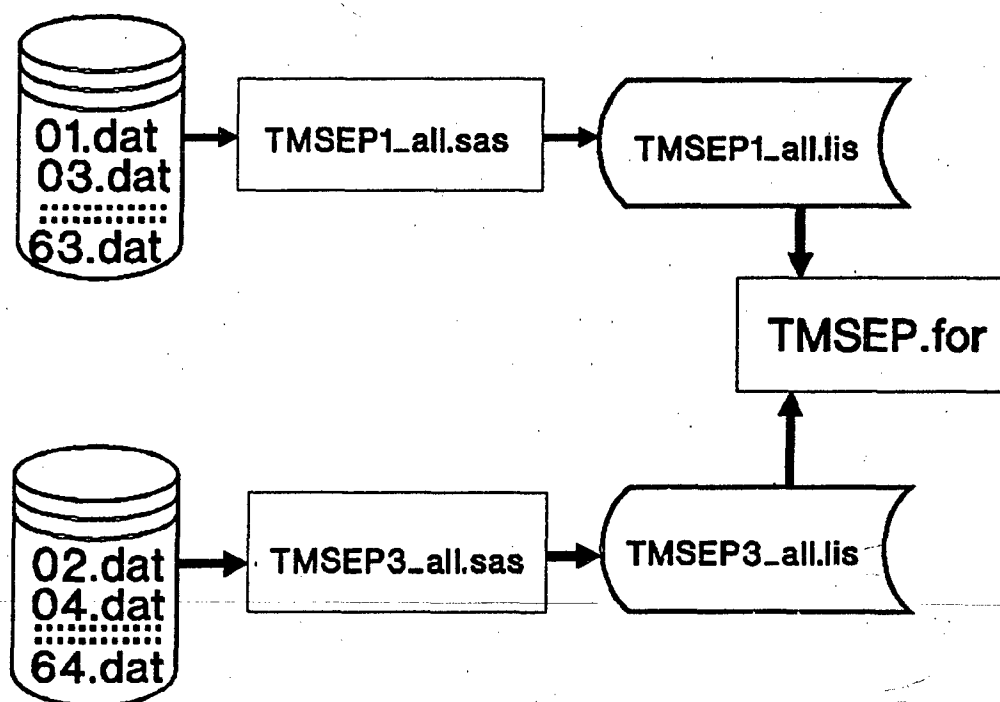


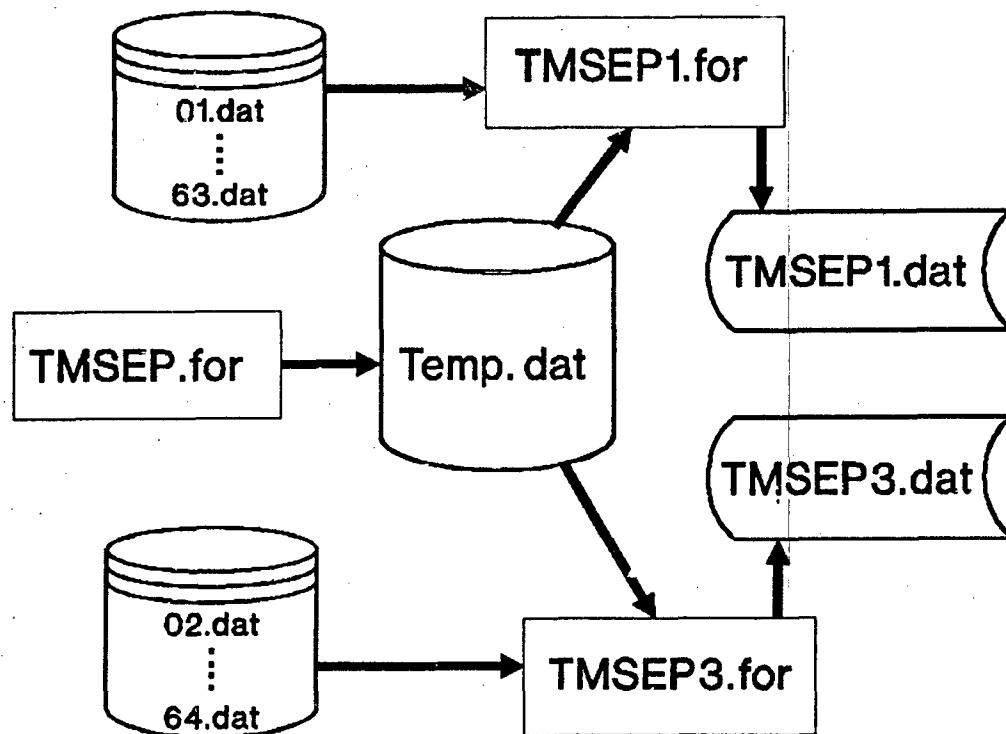
Appendix B: Flow Chart for the Development of the PM for
Miller's Method



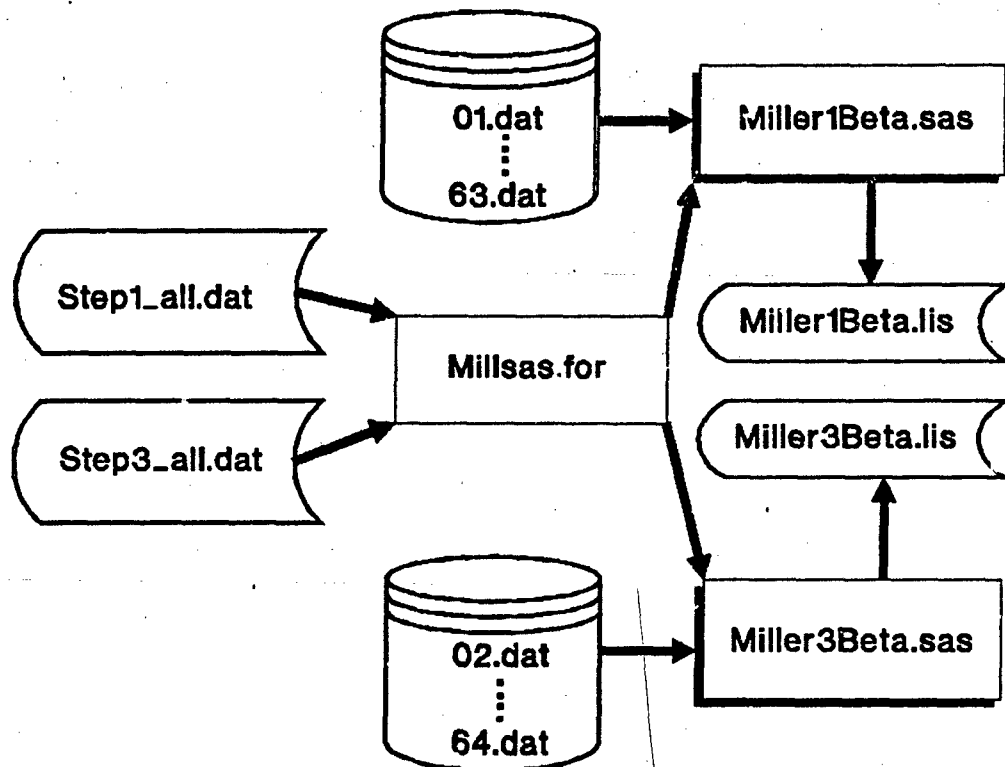


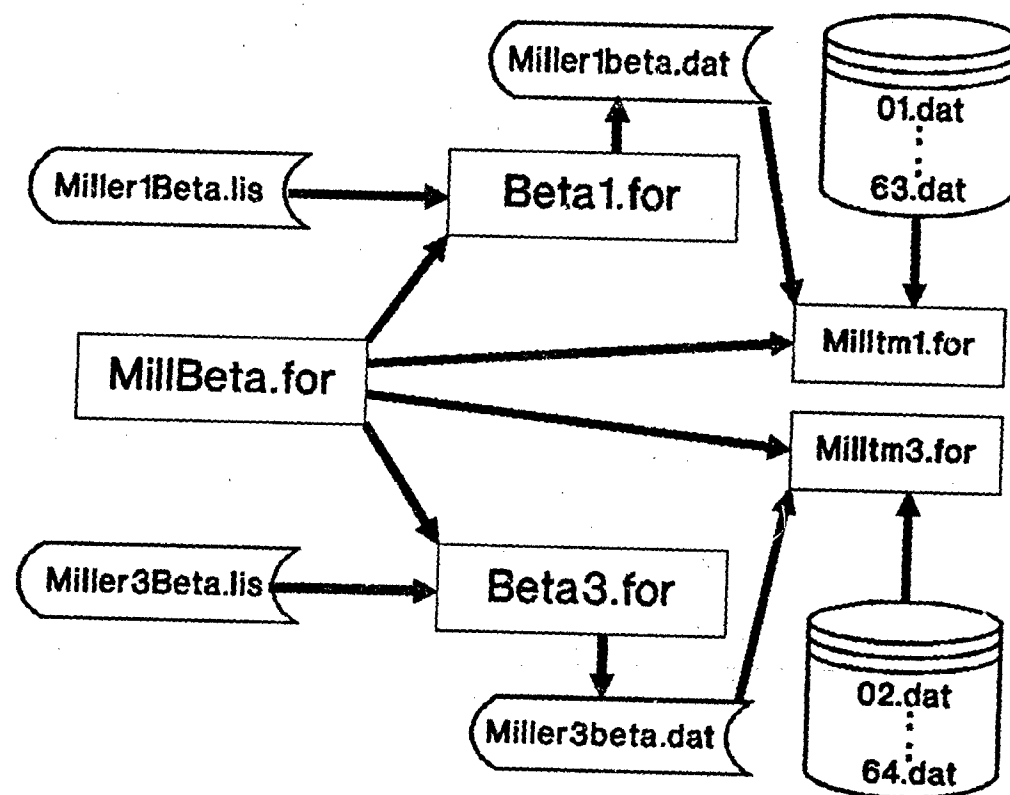
Appendix C: Flow Chart for the Development of the MSE, S_p , and C_p TMSEPs

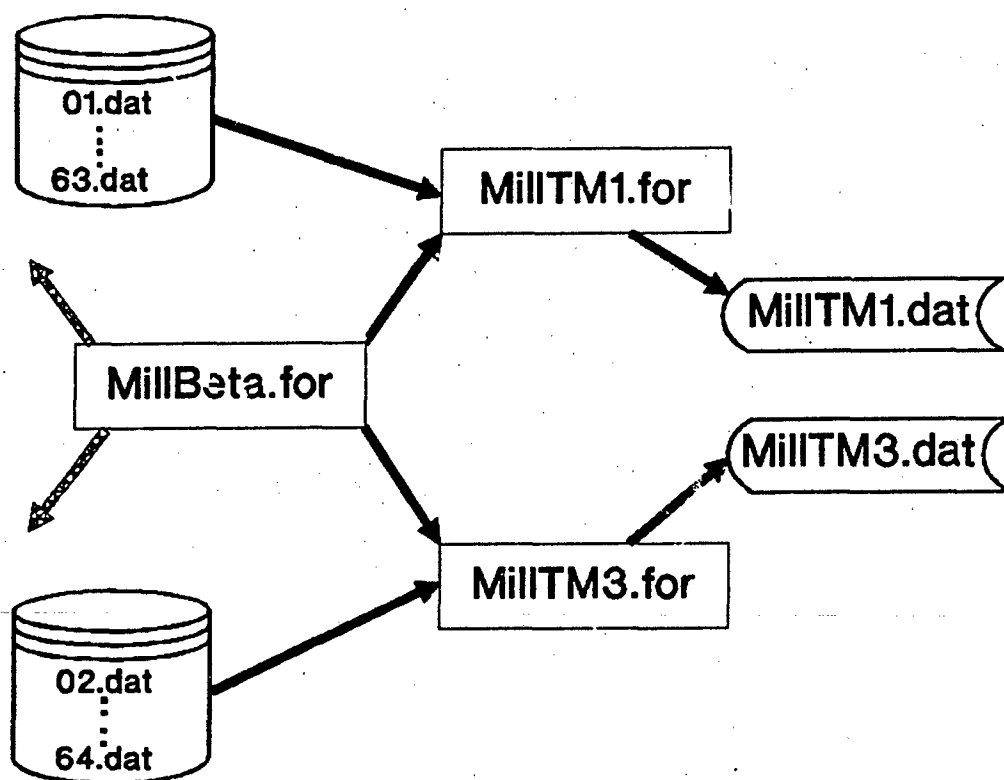




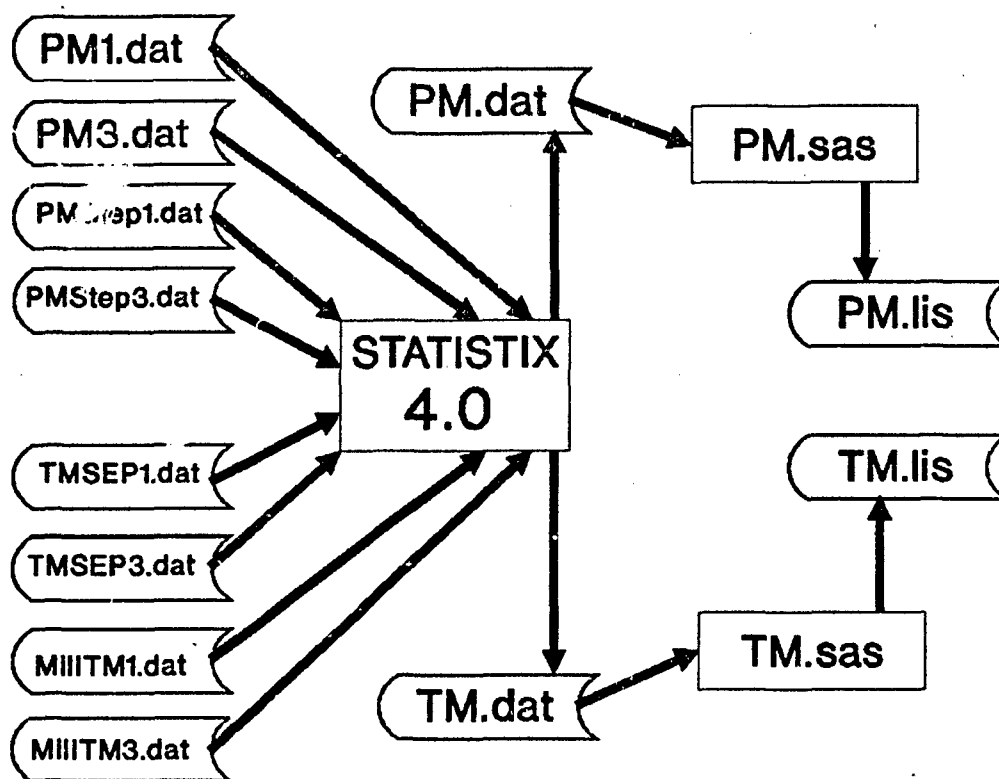
Appendix D: Flow Chart showing the Development of TMSEP for
Miller's Method







Appendix E: Flowchart Describing the Experiments Using PM
and TMSEP



Appendix F: A Glossary of Input/Output Data Files

Used Throughout All Sections

01.dat, 02.dat, ..., 64.dat

64 specifically generated data files, one file for each of the 64 permutations of the six-factors analysis

01.dat, 03.dat, ..., 63.dat

Of the 64 files, these are the ones with one extraneous variable

02.dat, 04.dat, ..., 64.dat

Of the 64 files, these are the ones with three extraneous variables

Temp.dat

Scratch file used to pass large amounts of data between FORTRAN main routines and their associated subroutines. Always contains temporary data generated by the most recently executed FORTRAN program.

Calculating PM for MSE, SP and CP methods

Error1_all.lis

Listing generated by SAS program Error1_all.sas. Contains output from the procedure RSquare (options MSE, SP, CP) run on 1920 data sets with one extraneous variable.

Error3_all.lis

Listing generated by SAS program Error1_all.sas. Contains output from the procedure RSquare (options MSE, SP, CP) run on 1920 data sets with three extraneous variables.

Error1_all.dat

Output from the FORTRAN subroutine Count1.for. Contains the selected model according to the MSE, SP, and CP methods for each of the 1920 data sets with one extraneous variable.

Error3_all.dat

Output from the FORTRAN subroutine Count3.for. Contains the selected model according to the MSE, SP, and CP methods for each of the 1920 data sets with three extraneous variables.

PM1.dat

Output from the FORTRAN subroutine Count1.for. Contains performance measures at each of the 32 odd design points

(1,3,...,63) for the MSE, SP, and CP methods of variable selection.

PM3.dat

Output from the FORTRAN subroutine Count3.for. Contains performance measures at each of the 32 even design points (2,4,...,64) for the MSE, SP, and CP methods of variable selection.

Calculating PM for Miller's method

Step11_all.lis

Listing generated by SAS program Step11_all.sas. Contains output from the procedure Stepwise(Forward Selection) run on 960 data sets (1,3,...,31) with one extraneous variable.

Step13_all.lis

Listing generated by SAS program Step11_all.sas. Contains output from the procedure Stepwise(Forward Selection) run on 960 data sets (33,35,...,63) with one extraneous variable.

Step31_all.lis

Listing generated by SAS program Step31_all.sas. Contains output from the procedure Stepwise(Forward Selection) run on 480 data sets (2,4,...,16) with three extraneous variables.

Step32_all.lis

Listing generated by SAS program Step32_all.sas. Contains output from the procedure Stepwise(Forward Selection) run on 480 data sets (18,20,...,32) with three extraneous variables.

Step33_all.lis

Listing generated by SAS program Step33_all.sas. Contains output from the procedure Stepwise(Forward Selection) run on 480 data sets (34,36,...,48) with three extraneous variables.

Step34_all.lis

Listing generated by SAS program Step34_all.sas. Contains output from the procedure Stepwise(Forward Selection) run on 480 data sets (50,52,...,64) with three extraneous variables.

Step1_Input.dat

Input data file for FilStepCount.for. Contains the names of the SAS listing files (from data sets with one extraneous variable) that FilCount.for is to process.

Step3_Input.dat

Input data file for FilStepCount.for. Contains the names of the SAS listing files (from data sets with three extraneous variables) that FilCount.for is to process.

Step1_all.dat

Generated by FORTRAN subroutine StepCount1.for. Contains the model selected via Miller's method for each of 1920 data sets with one extraneous variable.

Step3_all.dat

Generated by FORTRAN subroutine StepCount3.for. Contains the model selected via Miller's method for each of 1920 data sets with three extraneous variables.

PMStep1.dat

Output from the FORTRAN subroutine StepCount1.for. Contains performance measures at each of the 32 odd design points (1,3,...,63) for the Miller's method of variable selection.

PMStep3.dat

Output from the FORTRAN subroutine StepCount3.for. Contains performance measures at each of the 32 even design points (2,4,...,64) for the Miller's method of variable selection.

Stepwise Analysis using PM for each method

PM.dat

Output from the statistical analysis program STATISTIX 4.0. Contains the design point four columns of PMs (one for each method) augmented with a full 2^6 factorial design matrix. This file is then used as input to the SAS program PM.sas.

PM.lis

Listing file generated by the SAS program PM.sas. Contains the complete analysis from the procedure Stepwise. Attempts a best fit for each method's PM as a linear function of the six factors studied and their interactions.

Calculating TMSEP for MSE, SP and CP methods

TMSEP1_all.lis

Listing generated by SAS program TMSEP1_all.sas. Contains output from the procedure RSquare (options MSE, SP, CP, and B) run on 1920 data sets with one extraneous variable.

TMSEP3_all.lis

Listing generated by SAS program TMSEP3_all.sas. Contains output from the procedure RSquare (options MSE, SP, CP, and B) run on 1920 data sets with one extraneous variable.

TMSEP1.dat

Generated by FORTRAN subroutine TMSEP1.for. Contains the TMSEPs for the 32 odd design points (1,3,...,63) with one extraneous variable.

TMSEP3.dat

Generated by FORTRAN subroutine TMSEP3.for. Contains the TMSEPs for the 32 even design points (2,4,...,64) with three extraneous variables.

Calculating TMSEP for Miller's method

Miller1Beta.sas

Generated by FORTRAN program MillSAS.for. This is a SAS input program design to calculate the constant and the coefficients of regression for each of the 1920 models selected using Miller's method and data sets with one extraneous variable.

Miller3Beta.sas

Generated by FORTRAN program MillSAS.for. This is a SAS input program design to calculate the constant and the coefficients of regression for each of the 1920 models selected using Miller's method and data sets with three extraneous variables.

Miller1Beta.lis

Listing file generated by the SAS program Miller1Beta.sas. Contains the unformatted and unfiltered data on the constant and the coefficients of regression for each of the 1920 models selected using Miller's method and data sets with one extraneous variable.

Miller3Beta.lis

Listing file generated by the SAS program Miller3Beta.sas. Contains the unformatted and unfiltered data on the constant and the coefficients of regression for each of the 1920 models selected using Miller's method and data sets with three extraneous variables.

Miller1Beta.dat

Generated by the FORTRAN subroutine Beta1.sas. Contains the filtered and formatted data on the constant and the coefficients of regression for each of the 1920 models selected using Miller's method and data sets with one extraneous variable.

Miller3Beta.dat

Generated by the FORTRAN subroutine Beta3.sas. Contains the filtered and formatted data on the constant and the coefficients of regression for each of the 1920 models selected using Miller's method and data sets with three extraneous variables.

MillTM1.dat

Generated by the FORTRAN subroutine MillTM1.for. Contains the TMSEPs for the odd design points (1,3,...,63) with one extraneous variable.

MillTM3.dat

Generated by the FORTRAN subroutine MillTM3.for. Contains the TMSEPs for the odd design points (2,4,...,64) with three extraneous variables.

Stepwise Analysis using TMSEP for each method

TM.dat

Output from the statistical analysis program STATISTIX 4.0. Contains the design point four columns of TMSEPs (one for each method) augmented with a full 2^6 factorial design matrix. This file is then used as input to the SAS program TM.sas.

TM.lis

Listing file generated by the SAS program TM.sas. Contains the complete analysis from the procedure Stepwise. Attempts a best fit for each method's TMSEP as a linear function of the six factors studied and their interactions.

Appendix C: A Glossary of FORTRAN Program Files

Calculating PM for MSE, SP and CP methods

FileCount.for

PURPOSE: Filters the SAS RSquare listings and generates the formatted file Temp.dat of all the possible model combinations for each of the 3840 data set. Calls Count1 and Count3 to select the best model.

INPUT DATA FILES: Error1_all.lis, Error3_all.lis

OUTPUT DATA FILES: Temp.dat

SUBROUTINES CALLED: Count1.for, Count3.for

Count1.for

PURPOSE: Selects the best model for each of the 1920 data sets (one extraneous variable) from a file of all possible model combinations for each set. Uses the MSE, SP, and CP methods of variables selection. Calculates a performance measure for each of the three groups of 60 models selected at each of the odd design points (1,3,...,63).

INPUT DATA FILES: Temp.dat

OUTPUT DATA FILES: Error1_all.dat, PM1.dat

SUBROUTINES CALLED: None

Count3.for

PURPOSE: Selects the best model for each of the 1920 data sets (three extraneous variables) from a file of all possible model combinations for each set. Uses the MSE, SP, and CP methods of variables selection. Calculates a performance measure for each of the three groups of 60 models selected at each of the even design points (2,4,...,64).

INPUT DATA FILES: Temp.dat

OUTPUT DATA FILES: Error3_all.dat, PM3.dat

SUBROUTINES CALLED: None

Calculating PM for Miller's method

FilStepCount.for

PURPOSE: Filters the SAS Stepwise(Forward Selection) listings and generates the formatted file Temp.dat of the model selected for each of the 3840 data sets. Calls Stepcount1 and Stepcount3 to select the best models.

INPUT DATA FILES: Step11_all.lis, Step13_all.lis,
Step31_all.lis, Step32_all.lis,
Step33_all.lis, Step34_all.lis
Step1_Input.dat, Step3_Input.dat

OUTPUT DATA FILES: Temp.dat

SUBROUTINES CALLED: Stepcount1.for, Stepcount3.for

StepCount1.for

PURPOSE: Implements Miller's method for each of the 1920 models (from data sets with one extraneous variable). Calculates a performance measure for each group of 60 models selected at each odd design point (1,3,...,63).

INPUT DATA FILES: Temp.dat

OUTPUT DATA FILES: Step1_all.dat, PMStep1.dat

SUBROUTINES CALLED: None

StepCount3.for

PURPOSE: Implements Miller's method for each of the 1920 models (from data sets with three extraneous variables). Calculates a performance measure for each group of 60 models selected at each even design point (2,4,...,64).

INPUT DATA FILES: Temp.dat

OUTPUT DATA FILES: Step3_all.dat, PMStep3.dat

SUBROUTINES CALLED: None

Calculating P for MSE, SP and CP methods

TMSEP.for

PURPOSE: Filters the SAS RSquare listings and generates the formatted file Temp.dat of all the possible model combinations for each of the 3840 data set. Calls TMSEP1 and TMSEP3 to select the best model.

INPUT DATA FILES: TMSEP1_all.lis, TMSEP3_all.lis

OUTPUT DATA FILES: Temp.dat

SUBROUTINES CALLED: TMSEP1.dat, TMSEP3.dat

TMSEP1.for

PURPOSE: Selects the best model for each of the 1920 data sets (one extraneous variable) from a file of all possible model combinations for each set. Uses the MSE, SP, and CP methods of variables selection. Using each of the data sets with one extraneous variable, it calculates a TMSEP for each of the three groups of 60 models selected at each of the odd design points (1,3,...,63).

INPUT DATA FILES: 01.dat, 03.dat,...,63.dat, Temp.dat

OUTPUT DATA FILES: TMSEP1.dat

SUBROUTINES CALLED: None

TMSEP3.for

PURPOSE: Selects the best model for each of the 1920 data sets (three extraneous variables) from a file of all possible model combinations for each set. Uses the MSE, SP, and CP methods of variables selection. Using each of the data sets with three extraneous variables, it calculates a TMSEP for each of the three groups of 60 models selected at each of the even design points (2,4,...,64).

INPUT DATA FILES: 02.dat, 04.dat,...,64.dat, Temp.dat

OUTPUT DATA FILES: TMSEP3.dat

SUBROUTINES CALLED: None

Calculating TMSEP for Miller's method

MillSAS.for

PURPOSE: Reads the 3840 models (selected by Miller's method) and generates SAS code, specific to each model, to estimate the constant term and the coefficients of regression for that model.

INPUT DATA FILES: Step1_all.dat, Step3_all.dat

OUTPUT DATA FILES: Miller1Beta.sas, Miller3Beta.sas

SUBROUTINES CALLED: None

MillBeta.for

PURPOSE: Calls Beta1 and Beta3 and then calls MillTM1 and MillTM3.

INPUT DATA FILES: None

OUTPUT DATA FILES: None

SUBROUTINES CALLED: Beta1.for, Beta3.for,
MillTM1.for, MillTM3.for

Beta1.for

PURPOSE: Filters the unformatted SAS listing file produced by the SAS program Miller1Beta.sas (from data sets with one extraneous variable) and outputs the estimates of the model constant and regression coefficients in a sorted, formatted order.

INPUT DATA FILES: Miller1Beta.lis

OUTPUT DATA FILES: Miller1Beta.dat

SUBROUTINES CALLED: None

Beta3.for

PURPOSE: Filters the unformatted SAS listing file produced by the SAS program Miller3Beta.sas (from data sets with three extraneous variables) and outputs the estimates of the

model constant and regression coefficients in a sorted, formatted order.

INPUT DATA FILES: Miller3Beta.lis

OUTPUT DATA FILES: Miller3Beta.dat

SUBROUTINES CALLED: None

MillTM1.for

PURPOSE: At each of the 32 odd design points (1,3,...,63, the ones with only one extraneous variable) it examines each of the 60 model predicted and calculates a aggregated TMSEP for that design point.

INPUT DATA FILES: Miller1Beta.dat, 01.dat, ..., 63.dat

OUTPUT DATA FILES: MillTM1.dat

SUBROUTINES CALLED: None

MillTM3.for

PURPOSE: At each of the 32 even design points (2,4,...,64, the ones with only three extraneous variables) it examines each of the 60 model predicted and calculates a aggregated TMSEP for that design point.

INPUT DATA FILES: Miller3Beta.dat, 02.dat, 04.dat, ..., 64.dat

OUTPUT DATA FILES: MillTM3.dat

SUBROUTINES CALLED: None

BARR.FOR

PURPOSE: Written to read and correct most errors found in Hansen's data files. It was written by Dr. David Barr. It scans the data file after correction and outputs certain data characteristics for verification. Some errors had to be corrected by hand, but this program will allow the experimenter to be absolutely certain about the data's current characteristics.

Appendix H: A Glossary of SAS Program Files

Calculating PM for MSE, SP and CP methods

Error1 all.sas

Reads 01.dat,03.dat,...,63.dat by set and use the RSquared procedure to generate all-possible models for each set of 10 or 20. MSE, SP, and CP statistics are calculated for each model. The listing file Error1_all.lis is output.

Error3 all.sas

Reads 02.dat,04.dat,...,64.dat by set and use the RSquared procedure to generate all-possible models for each set of 10 or 20. MSE, SP, and CP statistics are calculated for each model. The listing file Error3_all.lis is output.

Calculating PM for Miller's method

Step11 all.sas

Reads 01.dat,03.dat,...,31.dat by set and augments each set with four known random predictors. The Stepwise procedure is then run and one model is chosen for each set. The listing Step11_all.lis is generated.

Step13 all.sas

Reads 33.dat,35.dat,...,63.dat by set and augments each set with four known random predictors. The Stepwise procedure is then run and one model is chosen for each set. The listing Step13_all.lis is generated.

Step31 all.sas

Reads 02.dat,04.dat,...,16.dat by set and augments each set with six known random predictors. The Stepwise procedure is then run and one model is chosen for each set. The listing Step31_all.lis is generated.

Step32 all.sas

Reads 18.dat,20.dat,...,32.dat by set and augments each set with six known random predictors. The Stepwise procedure is then run and one model is chosen for each set. The listing Step32_all.lis is generated.

Step33 all.sas

Reads 34.dat,36.dat,...,48.dat by set and augments each set with six known random predictors. The Stepwise procedure is then run and one model is chosen for each set. The listing Step33_all.lis is generated.

Step34_all.sas

Reads 50.dat, 52.dat, ..., 64.dat by set and augments each set with six known random predictors. The Stepwise procedure is then run and one model is chosen for each set. The listing Step34_all.lis is generated.

Stepwise analysis using PM for each method

PM.sas

Reads PM.dat and performs four separate Stepwise regressions. Each regression considers a different dependent variable but the uses the same independent variables. Generates listing file PM.lis.

Calculating TMSEP for MSE, SP and CP methods

TMSEP1_all.sas

Reads 01.dat, 03.dat, ..., 63.dat by set and use the RSquared procedure to generate all-possible models for each set of 10 or 20. MSE, SP, and CP statistics and the coefficients of regression are calculated for each model. The listing file TMSEP1_all.lis is output.

TMSEP3_all.sas

Reads 02.dat, 04.dat, ..., 64.dat by set and use the RSquared procedure to generate all-possible models for each set of 10 or 20. MSE, SP, and CP statistics and the coefficients of regression are calculated for each model. The listing file TMSEP3_all.lis is output.

Calculating TMSEP for Miller's method

Miller1Beta.sas

Reads 01.dat, 03.dat, ..., 63.dat by set and uses the RSquared procedure (with various switches) to calculate the coefficients of regression for only the model selected for each data set by Miller's method. The listing file Miller1Beta.lis is generated.

Miller3Beta.sas

Reads 02.dat, 04.dat, ..., 64.dat by set and uses the RSquared procedure (with various switches) to calculate the coefficients of regression for only the model selected for each data set by Miller's method. The listing file Miller3Beta.lis is generated.

Stepwise analysis using TMSEP for each method

TM.sas

Reads TM.dat and performs four separate Stepwise regressions. Each regression considers a different dependent variable but the uses the same independent variables. Generates listing file TM.lis.

Appendix I: FORTRAN Programs

List of FORTRAN Programs

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```

*****
*                                     BARR.FOR
*
* This program reads in Hansen's data files and scans them
* for certain data characteristics.  These are output for
* verification.
*****

```

```

      real x(4),ex(3)
      integer n,set,count,ind(6),inum,nex,ss,nexref(2)
      integer lecount,hecount,lxcount,hxcount
      double precision
+ errorsum,error2sum,lerrorsum,lerror2sum
      double precision exsum(3),ex2sum(3),xsum(4),x2sum(4)
      double precision herrorsum,herror2sum,lexsum,lex2sum
      double precision
+ hexsum,hex2sum,lxsum,lx2sum,hxsum,hx2sum
      double precision
+ xprod(4,4),lxsum,lx2sum,hxsum,hx2sum,
+ error
      character*6 nameoffile(64)

      nameoffile(1)='01.dat'
      nameoffile(2)='02.dat'
      nameoffile(3)='03.dat'
      nameoffile(4)='04.dat'
      nameoffile(5)='05.dat'
      nameoffile(6)='06.dat'
      nameoffile(7)='07.dat'
      nameoffile(8)='08.dat'
      nameoffile(9)='09.dat'
      nameoffile(10)='10.dat'
      nameoffile(11)='11.dat'
      nameoffile(12)='12.dat'
      nameoffile(13)='13.dat'
      nameoffile(14)='14.dat'
      nameoffile(15)='15.dat'
      nameoffile(16)='16.dat'
      nameoffile(17)='17.dat'
      nameoffile(18)='18.dat'
      nameoffile(19)='19.dat'
      nameoffile(20)='20.dat'
      nameoffile(21)='21.dat'
      nameoffile(22)='22.dat'
      nameoffile(23)='23.dat'
      nameoffile(24)='24.dat'
      nameoffile(25)='25.dat'
      nameoffile(26)='26.dat'
      nameoffile(27)='27.dat'
      nameoffile(28)='28.dat'
      nameoffile(29)='29.dat'
      nameoffile(30)='30.dat'

```

```

nameoffile(31)='31.dat'
nameoffile(32)='32.dat'
nameoffile(33)='33.dat'
nameoffile(34)='34.dat'
nameoffile(35)='35.dat'
nameoffile(36)='36.dat'
nameoffile(37)='37.dat'
nameoffile(38)='38.dat'
nameoffile(39)='39.dat'
nameoffile(40)='40.dat'
nameoffile(41)='41.dat'
nameoffile(42)='42.dat'
nameoffile(43)='43.dat'
nameoffile(44)='44.dat'
nameoffile(45)='45.dat'
nameoffile(46)='46.dat'
nameoffile(47)='47.dat'
nameoffile(48)='48.dat'
nameoffile(49)='49.dat'
nameoffile(50)='50.dat'
nameoffile(51)='51.dat'
nameoffile(52)='52.dat'
nameoffile(53)='53.dat'
nameoffile(54)='54.dat'
nameoffile(55)='55.dat'
nameoffile(56)='56.dat'
nameoffile(57)='57.dat'
nameoffile(58)='58.dat'
nameoffile(59)='59.dat'
nameoffile(60)='60.dat'
nameoffile(61)='61.dat'
nameoffile(62)='62.dat'
nameoffile(63)='63.dat'
nameoffile(64)='64.dat'
nexref(1)=1
nexref(2)=3

```

```

1000 format(5x,4(f15.5,1x))

```

```

open(unit=8,file='iv1.out',status='new')
open(unit=9,file='iv0.out',status='new')
open(unit=11,file='dbarr.out',status='new')
open(unit=12,file='dbarr.log',status='new')
k=64
ind(3)=0
ind(4)=0
ind(5)=0
ind(6)=0
count=0
lxcount=0
hxcount=0
lecount=0

```

```

hecount=0
lxsum=0
lx2sum=0
hxsum=0
hx2sum=0
lerrorsum=0
lerror2sum=0
herrorsum=0
herror2sum=0

```

```

do 10 inum=1,k

  errorsum=0
  error2sum=0

  do 11 i11=1,3
    exsum(i11)=0
    ex2sum(i11)=0
11  continue

  do 12 i12=1,4
    xsum(i12)=0
    x2sum(i12)=0
12  continue

  do 13 i13=1,4
    do 14 i14=1,4
      xprod(i13,i14)=0
14  continue
13  continue

  print *, nameoffile(inum)
  write(11,*) nameoffile(inum)
  write(12,*) nameoffile(inum)
  ind(1)=inum+1-2*((inum+1)/2)
  ind(2)=iabs(2*((inum+3)/4)-((inum+1)/2)-1)
  ind(3)=iabs(2*((inum+7)/8)-((inum+3)/4)-1)
  ind(4)=iabs(2*((inum+15)/16)-((inum+7)/8)-1)
  ind(5)=iabs(2*((inum+31)/32)-((inum+15)/16)-1)
  ind(6)=iabs(2*((inum+63)/64)-((inum+31)/32)-1)
  nex=nexref(ind(1)+1)

  open(unit=10,file=nameoffile(inum),status='old')

  if (ind(5).eq.0) then
    ss=10
  else
    ss=20
  endif

```

```

n=ss*60
do 50 h= 1,n
    read (10,*) set,y, (x(i),i=1,4), (ex(i),i=1,nex)

count=count+1
if(ind(6).eq.0) then
    lecount=lecount+1
else
    hecount=hecount+1
endif

if(nex.eq.1) then
    ex(2)=0
    ex(3)=0
endif

call errorcomp(x,y,error,errorsum,error2sum)
call extra(nex,ex,exsum,ex2sum)
call xi(x,xsum,x2sum,xprod)

    write(11,*) set,y,error,(x(i),i=1,4),(ex(i),i=1,3),
+ (ind(7-i),i=1,6)
50 continue

    call
+ endprint(n,ind,nex,ss,errorsum,error2sum,lerrorsum,
+ lerror2sum,exsum,ex2sum,xsum,x2sum,xprod,herrorsum,
+ herror2sum,
+ lxsum,lx2sum,hxsum,hx2sum,lxcount,
+ hxcount,nameoffile,inum)
10 continue

*****

print*, ' '
write(12,*) ' '
print *, 'number of observations = ',count
write(12,*) 'number of observations = ',count

print *, 'small independent variance = ',
+ lx2sum/(lxcount)-(lxsum/(lxcount))**2
print *, 'large independent variance = ',
+ hx2sum/(lxcount)-(hxsum/(lxcount))**2
write(12,*) 'small independent variance = ',
+ lx2sum/(lxcount)-(lxsum/(lxcount))**2
write(12,*) 'large independent variance = ',
+ hx2sum/(lxcount)-(hxsum/(lxcount))**2
print *, 'small error variance = ',
+ lerror2sum/lecount-(lerrorsum/lecount)**2
write(12,*) 'small error variance = ',
+ lerror2sum/lecount-(lerrorsum/lecount)**2

```

```

      print *, 'large error variance = ',
+   herror2sum/hecount-(herrorsum/hecount)**2
      write(12,*) 'large error variance = ',
+   herror2sum/hecount-(herrorsum/hecount)**2

```

END

```

      subroutine errorcomp(x,y,error,errorsum,error2sum)

```

```

      double precision error,errorsum,error2sum
      real x(4)

```

```

      yactual=0
      do 60 p=1,4
        yactual = yactual+x(p)
60      continue
      error=y-yactual
      errorsum=errorsum+error
      error2sum=error2sum+error*error

```

return

END

```

      subroutine endprint(n,ind,nex,ss,errorsum,error2sum,
+   lerrorsum,lerror2sum,exsum,ex2sum,xsum,x2sum,xprod,
+   herrorsum,herror2sum,
+   lxsum,lx2sum,hxsum,hx2sum,lxcount,
+   hxcount,nameoffile,inum)

```

```

      integer n,ind(6),nex,ss,lxcount,hxcount,inum
      double precision errorsum,error2sum,lerrorsum,
+   lerror2sum,exsum(3),ex2sum(3),xsum(4),x2sum(4),
+   xprod(4,4),r(4,4),v(4),herrorsum,herror2sum,ev(3),
+   lxsum,lx2sum,hxsum,hx2sum,rsum,ex1,ex2
      character*6 nameoffile(64)

```

1000 format(5x,4(f15.5,lx))

1010 format(5x,4(i10,lx))

```

      print *, (ind(7-i),i=1,6)
      write(12,*) (ind(7-i),i=1,6)
      print *, ' ',ind(1),' there are ',nex,' extraneous
+ variables'
      write(12,*) ' ',ind(1),' there are ',nex,' extraneous
+ variables'

```

```

      do 50 k=1,4
50      v(k)=x2sum(k)/n-(xsum(k)/n)**2
      continue

```

```

    rsum=0
    do 30 i=1,4
    do 40 j=1,i
    rn=xprod(i,j)/n-(xsum(i)/n)*(xsum(j)/n)
    r(i,j)=rn/sqrt(v(i)*v(j))
    r(j,i)=r(i,j)
    if(i.ne.j) then
        rsum=rsum+r(i,j)
    endif
40    continue
30    continue

    print *, ' ',ind(2),' correlation ',rsum/6
    write(12,*) ' ',ind(2),' correlation ',rsum/6

    do 35 i=1,4
    print *, (r(i,j),j=1,4)
    write(12,1000) (r(i,j),j=1,4)
35    continue

    ex1=0
    ex2=0
    do 10 j=1, nex
    ev(j)=ex2sum(j)/n-(exsum(j)/n)**2
    ex1=ex1+exsum(j)
    ex2=ex2+ex2sum(j)
10    continue
    ve=(ex2/(n*nex))-(ex1/(n*nex))**2
    print *, ' ',ind(3),' variarce of extraneous ',ve
    write(12,*) ' ',ind(3),' variance of extraneous ',ve
    print *, (ev(k),k=1,nex)
    write(12,1000) (ev(k),k=1,nex)
    write(12,1000) (exsum(i),i=1,nex)
    write(12,1000) (ex2sum(i),i=1,nex)
    write(12,1010) n,n*nex

    x1=xsum(1)+xsum(2)+xsum(3)+xsum(4)
    x2=x2sum(1)+x2sum(2)+x2sum(3)+x2sum(4)
    vx=x2/(4*n)-(x1/(4*n))**2
    print *, ' ', ind(4),' variance of independent ',vx
    write(12,*) ' ', ind(4),' variance of independent ',vx

    if(vx.lt..00125) then
        lxsum=lxsum+x1
        lx2sum=lx2sum+x2
        lxcount=lxcount+4*n
        write(9,*) nameoffile(inum),ind(4),
+ x2/(4*n)-(x1/(4*n))**2
    else

```

```

        hxsum=hxsum+x1
        hx2sum=hx2sum+x2
        hxcount=hxcount+4*n
        write(8,*) nameoffile(inum),ind(4),
+ x2/(4*n)-(x1/(4*n))**2
        endif

        print *, ' ',ind(5),' the sample size is ',ss
        write(12,*) ' ',ind(5),' the sample size is ',ss

        print *, ' ',ind(6),' error variance =',
+ error2sum/n-(errorsum/n)**2
        write(12,*) ' ',ind(6),' error variance =',
+ error2sum/n-(errorsum/n)**2

        if(ind(6).eq.0) then
            lerrorsum=lerrorsum+errorsum
            lerror2sum=lerror2sum+error2sum
        else
            herrorsum=herrorsum+errorsum
            herror2sum=herror2sum+error2sum
        endif

        close (unit=10)
        return
        END
*****

        subroutine extra(nex,ex,exsum,ex2sum)
        integer nex
        real ex(3)
        double precision exsum(3),ex2sum(3)
        do 10 i=1,nex
            exsum(i)=exsum(i)+ex(i)
            ex2sum(i)=ex2sum(i)+ex(i)*ex(i)
10      continue
        return

        END
*****

        subroutine xi(x,xsum,x2sum,xprod)
        real x(4)
        double precision xsum(4),x2sum(4),xprod(4,4)
        do 10 i=1,4
            xsum(i)=xsum(i)+x(i)
            do 20 j=1,4
                xprod(i,j)=xprod(i,j)+x(i)*x(j)
20      continue
10      continue
        do 30 k=1,4
            x2sum(k)=xprod(k,k)
30      continue

```

return

END

```

*****
*****  FORTRAN PROGRAM BETA1.FOR *****
*****

```

SUBROUTINE BETA1

```

INTEGER VARNUM,MODELNUM,J,K,L,N,P,TOTALLINES,CHARPOS
REAL R2, B0, BETA(4), SORTED_BETAS(4)

```

```

CHARACTER*132 LINE
CHARACTER*2 MODEL(4)

```

TOTALLINES=0

```

OPEN (unit=10, file='miller1beta.lis',status='OLD',
+      iostat=IERROR,err=1500)
OPEN (unit=11, file='miller1beta.dat',status='NEW',
+      iostat=IERROR,err=1500)

```

```

5      CONTINUE
      READ (10,900,END=888) LINE
900    FORMAT (A132)

```

```

      DO 10 J=1,132
        IF (LINE(J:J).EQ.'I') THEN
          CHARPOS = J
          GO TO 20

```

```

        ENDIF
10     CONTINUE
        GO TO 5

```

20 CONTINUE

```

      DO 35 L=1,4
        SORTED BETAS(L)=0.0
        BETA(L)=0.0
35     CONTINUE

```

```

      IF ((LINE((CHARPOS+1):(CHARPOS+1))).EQ.'N') THEN
        READ (10,*)
        READ (10,*,END=1300) VARNUM, R2, B0
        VARNUM = VARNUM-1
        IF (VARNUM.GT.0) GO TO 1200
        WRITE (11,902) VARNUM, B0
902    FORMAT
+      (1X,I1,5X,F9.5,7X,'0.00000',7X,'0.00000',7X,'0.00000',
+      7X,'0.00000')
        TOTALLINES=TOTALLINES+1

```

```

      ELSE
        IF ((LINE((CHARPOS+1):(CHARPOS+1))).EQ.'n') THEN

```

```

      K=1
      DO 30 J=CHARPOS,132
      IF(((LINE(J:J)).EQ.'X').OR.((LINE(J:J)).EQ.'E'))
      THEN
        MODEL(K) = LINE(J:(J+1))
        K = K+1
      ENDIF
30    CONTINUE
      MODELNUM = K-1
      IF (MODELNUM.LT.1) GO TO 1100
      READ (10,*)
      VARNUM=0
      READ (10,*,END=1300)VARNUM, R2,
+      B0,(BETA(N),N=1,VARNUM)
      IF (VARNUM.NE.MODELNUM) GO TO 1000

      DO 40 P=1,VARNUM
      IF (MODEL(P).EQ.'X1') SORTED_BETAS(1)=BETA(P)
      IF (MODEL(P).EQ.'X2') SORTED_BETAS(2)=BETA(P)
      IF (MODEL(P).EQ.'X3') SORTED_BETAS(3)=BETA(P)
      IF (MODEL(P).EQ.'E1') SORTED_BETAS(4)=BETA(P)
40    CONTINUE

      WRITE (11,901) VARNUM, B0,(SORTED BETAS(N),N=1,4)
901  FORMAT(1X,11,5X,F9.5,5X,F9.5,5X,F9.5,5X,F9.5,5X,F9.5)
      TOTALLINES = TOTALLINES+1
      ENDIF
      ENDIF
      GO TO 5

888  CONTINUE
      CLOSE(10)
      CLOSE(11)
      PRINT *, 'FILTERING OF MILLER1BETA.LIS IS COMPLETE.'
      PRINT *, TOTALLINES, ' LINES WRITTEN TO
+ MILLER1BETA.DAT.'
      PRINT *, ' '
      GO TO 1600

1000 CONTINUE
      PRINT *, 'Unexpected file format!',
+      ' # of variable names does not',
+      ' correspond to # of variables read.'
      GO TO 1600

1100 CONTINUE
      PRINT *, 'Unexpected file format!',
+      ' Could not find X1, X2, X3, or E1.'
      GO TO 1600

1200 CONTINUE

```

```

        PRINT *, 'Unexpected file format!  Expecting ONLY B0.'
        GO TO 1600

1300    CONTINUE
        PRINT *, 'Unexpected file format!  Encountered EOF
+ while ',
+       'attempting to read VARNUM, R2, B0, and/or
+ Betas.'
        GO TO 1600

1500    CONTINUE
        PRINT 1501, '+++ ERROR WHILE OPENING FILE +++',
+               'error code = ', IERROR
1501    FORMAT (/1X, A/ 1X, A, I8/)

1600    CONTINUE
        END

```

```
*****
***** FORTRAN PROGRAM BETA3.FOR*****
*****
```

SUBROUTINE BETA3

```
INTEGER VARNUM,MODELNUM,J,K,L,N,P,TOTALLINES,CHARPOS
REAL R2, B0, BETA(6), SORTED_BETAS(6)
```

```
CHARACTER*132 LINE
CHARACTER*2 MODEL(6)
```

```
TOTALLINES=0
```

```
OPEN (unit=12, file='miller3beta.lis',status='OLD',
+      iostat=IERROR,err=1500)
OPEN (unit=13, file='miller3beta.dat',status='NEW',
+      iostat=IERROR,err=1500)
```

```
5      CONTINUE
      READ (12,900,END=888) LINE
900    FORMAT (A132)

      DO 10 J=1,132
        IF (LINE(J:J).EQ.'I') THEN
          CHARPOS = J
          GO TO 20
        ENDIF
10     CONTINUE
      GO TO 5
```

```
20     CONTINUE

      DO 35 L=1,6
        SORTED BETAS(L)=0.0
        BETA(L)=0.0
35     CONTINUE
```

```
      IF ((LINE((CHARPOS+1):(CHARPOS+1))).EQ.'N') THEN
        READ (12,*)
        READ (12,*,END=1300) VARNUM, R2, B0
        VARNUM = VARNUM-1
        IF (VARNUM.GT.0) GO TO 1200
        WRITE (13,902) VARNUM, B0
902    FORMAT (1X,I1,5X,F9.5,7X,'0.00000',7X,'0.00000',
+           7X,'0.00000',7X,'0.00000',7X,'0.00000',
+           7X,'0.00000')
        TOTALLINES=TOTALLINES+1
```

```
      ELSE
```

```

      IF ((LINE((CHARPOS+1):(CHARPOS+1))).EQ.'n') THEN
        K=1
        DO 30 J=CHARPOS,132.
      IF ((LINE(J:J)).EQ.'X').OR.((LINE(J:J)).EQ.'E'))
      THEN
        MODEL(K) = LINE(J:(J+1))
        K = K+1
      ENDIF
30    CONTINUE
      MODELNUM = K-1
      IF (MODELNUM.LT.1) GO TO 1100
      READ (12,*)
      VARNUM=0
      READ (12,*,END=1300)VARNUM, R2,
+      B0,(BETA(N),N=1,VARNUM)
      IF (VARNUM.NE.MODELNUM) GO TO 1000

      DO 40 P=1,VARNUM
        IF (MODEL(P).EQ.'X1') SORTED_BETAS(1)=BETA(P)
        IF (MODEL(P).EQ.'X2') SORTED_BETAS(2)=BETA(P)
        IF (MODEL(P).EQ.'X3') SORTED_BETAS(3)=BETA(P)
        IF (MODEL(P).EQ.'E1') SORTED_BETAS(4)=BETA(P)
        IF (MODEL(P).EQ.'E2') SORTED_BETAS(5)=BETA(P)
        IF (MODEL(P).EQ.'E3') SORTED_BETAS(6)=BETA(P)
40    CONTINUE

      WRITE (13,901) VARNUM, B0,
+ (SORTED_BETAS(N),N=1,6)
901  FORMAT (1X,I1,5X,F9.5,5X,F9.5,5X,F9.5,5X,F9.5,5X,
+      F9.5,5X,F9.5,5X,F9.5)
      TOTALLINES = TOTALLINES+1
      ENDIF
      ENDIF
      GO TO 5

888  CONTINUE
      CLOSE(12)
      CLOSE(13)
      PRINT *, 'FILTERING OF MILLER3BETA.LIS IS COMPLETE.'
      PRINT *, TOTALLINES, ' LINES WRITTEN TO
+ MILLER3BETA.DAT.'
      PRINT *, ' '
      GO TO 1600

1000 CONTINUE
      PRINT *, 'Unexpected file format!',
+      ' # of variable names does not',
+      ' correspond to # of variables read.'
      GO TO 1600

1100 CONTINUE

```

```

      PRINT *, 'Unexpected file format!',
+      ' Could not find X1, X2, X3, E1, E2, E3.'
      GO TO 1600

1200  CONTINUE
      PRINT *, 'Unexpected file format!  Expecting ONLY B0.'
      GO TO 1600

1300  CONTINUE
      PRINT *, 'Unexpected file format!  Encountered EOF
+ while ',
+      ' attempting to read VARNUM, R2, B0, and/or
+ Betas.'
      GO TO 1600

1500  CONTINUE
      PRINT 1501, '+++ ERROR WHILE OPENING FILE +++',
+      ' error code = ', IERROR
1501  FORMAT (/1X, A/ 1X, A, I8/)

1600  CONTINUE
      END

```

```
*****
***** FORTRAN PROGRAM COUNT1.FOR*****
*****
```

```
SUBROUTINE Count1 (NewOut)
```

```
integer num(15),i,j,k,ptrmse,ptrsp
integer ptrcp,varsmse,varssp,varscp
integer check(4)
integer n,emse,esp,ecp,DesignPoint
integer ccp,cmse,csp,cumemse,cumecp,cumesp
integer chartmse(0:3,0:3),chartcp(0:3,0:3)
integer chartsp(0:3,0:3)
real MSE(15),Sp(15),cp(15),r2(15)
real minmse,minsp,mincp,nummse,numcp,numsp
real mseeer,cpeer,speer
real msepm,cppm,sppm
character*2 m(4,15)
character*20 NewOut
check(1)=1
check(2)=5
check(3)=11
check(4)=15
DesignPoint=1
```

3
7

```
do 7 i = 0,3
  do 3 k = 0,3
    chartmse(i,k)=0
    chartcp(i,k)=0
    chartsp(i,k)=0
  continue
continue
```

```
varsmse=0
varssp =0
varscp =0
cumemse=0
cumesp=0
cumecp=0
```

```
open (unit=11, file='temp.dat', status='old',
+ iostat=IERROR, err=1000)
open (unit=12, file=NewOut, status='new',
+ iostat=IERROR, err=1000)
open (unit=13, file='PM1.dat', status='new',
+ iostat=IERROR, err=1000)
write(13,*)' DESIGNPOINT MSE
+ 'SP CP'
```

```
Do 50 jj=1,63,2
  Write(12,*)' '
```

```

Write(12,*)' '
Write(12,*)' '
Write(12,*) '***** DESIGN POINT ',
+ DesignPoint,' *****'
Write (12,*)' '
DesignPoint=DesignPoint + 2

do 20 k=1,60
do 10 i=1,15
    emse=0
    esp=0
    ecp=0
    read(11,'(1X,I1)',end=40)num(i)

    IF (num(i).EQ.1) THEN
+   read(11,905,end=40)num(i),r2(i),cp(i),MSE(i),Sp(i)
+   ,m(1,i)
905   format(7X,I1,4X,F10.8,3X,F9.5,3X,F9.7,2X,
+   F10.8,2X,A2)
    ELSE
    IF (num(i).EQ.2) THEN
+   read(11,910,end=40)num(i),r2(i),cp(i),MSE(i),Sp(i)
+   ,(m(j,i),j=1,2)
910   format(7X,I1,4X,F10.8,3X,F9.5,3X,F9.7,2X,
+   F10.8,1X,2(1X,A2))
    ELSE
    IF (num(i).EQ.3) THEN
+   read(11,915,end=40)num(i),r2(i),cp(i),MSE(i),Sp(i)
+   ,(m(j,i),j=1,3)
915   format(7X,I1,4X,F10.8,3X,F9.5,3X,F9.7,2X,
+   F10.8,1X,3(1X,A2))
    ELSE
    IF (num(i).EQ.4) THEN
+   read(11,920,end=40)num(i),r2(i),cp(i),MSE(i),Sp(i)
+   ,(m(j,i),j=1,4)
920   format(7X,I1,4X,F10.8,3X,F9.5,3X,F9.7,2X,
+   F10.8,1X,4(1X,A2))
    ELSE
    Print *, 'Number of variables not found;',
+   'input file in wrong format!'

    ENDIF
    ENDIF
    ENDIF
    ENDIF

    minmse=10000
    minsp =10000
    mincp =10000
    ptrmse=0
    ptrcp =0

```

```

ptrsp =0
do 30 j= 1,4
  if(mse(check(j)).lt.minmse) then
    minmse=mse(check(j))
    ptrmse=check(j)
  endif
  if(sp(check(j)).lt.minsp) then
    minsp=sp(check(j))
    ptrsp=check(j)
  endif
  if(cp(check(j)).lt.mincp) then
    mincp=cp(check(j))
    ptrcp=check(j)
  endif
30  continue
10  continue
40  continue

  varsmse=varsmse+num(ptrmse)
  varssp =varssp +num(ptrsp)
  varscp =varscp +num(ptrcp)

  do 70 n=1,num(ptrmse)
    if(m(n,ptrmse).EQ 'E1') then
      emse=emse+1
    endif
70  continue

  do 80 n=1,num(ptrsp)
    if(m(n,ptrsp).eq.'E1') then
      esp=esp+1
    endif
80  continue

  do 90 n=1,num(ptrcp)
    if(m(n,ptrcp).eq.'E1') then
      ecp=ecp+1
    endif
90  continue

  cumemse=cumemse+emse
  cumesp=cumesp+esp
  cumecp=cumecp+ecp
  cmse=num(ptrmse)-emse
  ccp=num(ptrcp)-ecp
  csp=num(ptrsp)-esp
  chartmse(cmse,emse)=chartmse(cmse,emse)+1
  chartcp(ccp,ecp)=chartcp(ccp,ecp)+1

```

```
chartsp(csp,esp)=chartsp(csp,esp)+1
```

```

write(12,*) 'MSE',num(ptrmse),mse(ptrmse)
+ ,Sp(ptrmse),cp(ptrmse),' ',
+ (m(j,ptrmse),j=1,num(ptrmse))
write(12,*) 'Sp ',num(ptrsp),mse(ptrsp)
+ ,Sp(ptrsp),cp(ptrsp),' ',
+ (m(j,ptrsp),j=1,num(ptrsp))
write(12,*) 'Cp ',num(ptrcp),mse(ptrcp)
+ ,Sp(ptrcp),cp(ptrcp),' ',
+ (m(j,ptrcp),j=1,num(ptrcp))
write(12,*) '*****'
+ '*****',
+ '*****'
write(12,*) ' '
write(12,*) ' '

```

20

```
continue
```

```

nummse = real(varsmse)/60.0
numsp = real(varssp)/60.0
numcp = real(varscp)/60.0
mseer= real(cumemse)/60.0
cpeer = real(cumecp) /60.0
speer = real(cumesp) /60.0
msepm = 1-(mseer/nummse)
cppm = 1-(cpeer/numcp)
sppm = 1-(speer/numsp)

```

```

write(12,*) 'The avg number of vars using MSE',
+ ' was ', nummse
write(12,*) 'The avg number of extraneous vars from
+ MSE',
+ ' was', mseer
write(12,*) '***** The PM for MSE was ', msepm,'
+ *****'
write(12,*) ' '
write(12,*) 'The avg number of vars using Sp was ',
+ numsp
write(12,*) 'The avg number of extraneous vars from
+ Sp',
+ ' was ',speer
write(12,*) '***** The PM for Sp was ', sppm,'
+ *****'
write(12,*) ' '
write(12,*) 'The avg number of vars using Cp was',
+ numcp
write(12,*) 'The avg number of extraneous vars
+ from Cp',
+ ' was ',cpeer
write(12,*) '***** The PM for Cp was ', cppm,'
+ *****'

```

```

        write(12,*) ' '
        write(12,*) ' '
        write(12,*) 'Correct Vars (0-3, wn) -VS- ',
+       'Extraneous Vars (0-, across)'
        write(12,*) ' '
        write(12,*) 'MSE TABLE'
        write(12,*) ' '
        do 100 i=0,3
            write(12,*) (chartmse(i,j),j=0,3)
100      continue
        write(12,*) ' '
        write(12,*) ' '
        write(12,*) 'Sp TABLE'
        write(12,*) ' '
        do 110 i=0,3
            write(12,*) (chartsp(i,j),j=0,3)
110      continue
        write(12,*) ' '
        write(12,*) ' '
        write(12,*) 'Cp TABLE'
        do 120 i=0,3
            write(12,*) (chartcp(i,j),j=0,3)
120      continue
        write(13,*) (DesignPoint-2), ' ', msep, ' ',
+       sppm, ' ', cppm
50      Continue
        Close(11)
        Close(12)
        Close(13)
        GO TO 1200

* Error trap: *****

1000  Continue
        Print 1100, '+++ ERROR WHILE OPENING FILE +++',
+       'error code = ', IERROR
1100  FORMAT(/1X, A/ 1X, A, I8/)

*****

1200  CONTINUE
        Print *, 'Counting complete. ', NewOut, ' written.'
        END

```

```
*****
*****  FORTRAN PROGRAM COUNT3.FOR  *****
*****
```

```
SUBROUTINE COUNT3 (NewOut)
```

```
integer num(63),i,j,k,ptrmse,ptrsp
integer ptrcp,varsmse,varssp,varscp
integer check(6)
integer n,emse,esp,ecp,DesignPoint
integer ccp,cmse,csp
integer chartmse(0:3,0:3),chartcp(0:3,0:3)
integer chartsp(0:3,0:3)
real MSE(63),Sp(63),cp(63),r2(63)
real minmse,minsp,mincp,nummse,numcp,numsp
real mseeer,cpeer,speer
real msepm,cppm,sppm
character*2 m(6,63)
character*20 NewOut
check(1)=1
check(2)=7
check(3)=22
check(4)=42
check(5)=57
check(6)=63
DesignPoint=2
```

```
do 7 i = 0,3
  do 3 k = 0,3
    chartmse(i,k)=0
    chartcp(i,k)=0
    chartsp(i,k)=0
  continue
3 continue
7 continue
```

```
varsmse=0
varssp =0
varscp =0
cumemse=0
cumesp=0
cumecp=0
```

```
open (unit=11, file='temp.dat', status='old',
+ iostat=IERROR, err=1000)
open (unit=12, file=NewOut, status='new',
+ iostat=IERROR, err=1000)
open (unit=13, file='PM3.dat', status='new',
+ iostat=IERROR, err=1000)
write(13,*)' DESIGNPOINT MSE
+ 'SP CP'
```

```
Do 50 jj=2,64,2
```

```

Write(12,*)' '
Write(12,*)' '
Write(12,*)'***** DESIGN POINT ',
+      DesignPoint,' *****'
Write(12,*)' '
DesignPoint=DesignPoint+2

do 20 k=1,60
do 10 i=1,63
    emse=0
    esp=0
    ecp=0
    read(11,'(1X,I1)',end=40)num(i)

    IF (num(i).EQ.1) THEN
read(11,905,end=40)num(i),r2(i),cp(i),MSE(i),Sp(i)
+      ,m(1,i)
905      format(7X,I1,4X,F10.8,3X,F9.5,3X,F9.7,2X,
+      F10.8,2X,A2)
    ELSE
    IF (num(i).EQ.2) THEN
read(11,910,end=40)num(i),r2(i),cp(i),MSE(i),Sp(i)
+      ,(m(j,i),j=1,2)
910      format(7X,I1,4X,F10.8,3X,F9.5,3X,F9.7,2X,
+      F10.8,1X,2(1X,A2))
    ELSE
    IF (num(i).EQ.3) THEN
read(11,915,end=40)num(i),r2(i),cp(i),MSE(i),Sp(i)
+      ,(m(j,i),j=1,3)
915      format(7X,I1,4X,F10.8,3X,F9.5,3X,F9.7,2X,
+      F10.8,1X,3(1X,A2))
    ELSE
    IF (num(i).EQ.4) THEN
read(11,920,end=40)num(i),r2(i),cp(i),MSE(i),Sp(i)
+      ,(m(j,i),j=1,4)
920      format(7X,I1,4X,F10.8,3X,F9.5,3X,F9.7,2X,
+      F10.8,1X,4(1X,A2))
    ELSE
    IF (num(i).EQ.5) THEN
read(11,925,end=40)num(i),r2(i),cp(i),MSE(i),Sp(i)
+      ,(m(j,i),j=1,5)
925      format(7X,I1,4X,F10.8,3X,F9.5,3X,F9.7,2X,
+      F10.8,1X,5(1X,A2))
    ELSE

```

```

        IF (num(i).EQ.6) THEN
read(11,930,end=40)num(i),r2(i),cp(i),MSE(i),Sp(i)
930  +      ,(m(j,i),j=1,6)
      +      format(7X,I1,4X,F10.8,3X,F9.5,3X,F9.7,2X,
                    F10.8,1X,6(1X,A2))
      ELSE
      Print *, 'Number of variables not found;',
      +      'input file in wrong format!'
      ENDIF
      ENDIF
      ENDIF
      ENDIF
      ENDIF
      ENDIF

      minmse=10000
      minsp =10000
      mincp =10000
      ptrmse=0
      ptrcp =0
      ptrsp =0
      do 30 j= 1,6
        if(mse(check(j)).lt.minmse) then
          minmse=mse(check(j))
          ptrmse=check(j)
        endif
        if(sp(check(j)).lt.minsp) then
          minsp=sp(check(j))
          ptrsp=check(j)
        endif
        if(cp(check(j)).lt.mincp) then
          mincp=cp(check(j))
          ptrcp=check(j)
        endif
      endif

30    continue
10    continue
40    continue

      varsmse=varsmse+num(ptrmse)
      varssp =varssp +num(ptrsp)
      varscp =varscp +num(ptrcp)

      do 70 n=1,num(ptrmse)
        if(m(n,ptrmse).EQ.'E1') then
          emse=emse+1
        elseif(m(n,ptrmse).eq.'E2') then
          emse=emse+1
        elseif(m(n,ptrmse).eq.'E3') then
          emse=emse+1

```

```

        else
            continue
        endif

70      continue
      do 80 n=1,num(ptrsp)
        if(m(n,ptrsp).eq.'E1') then
          esp=esp+1
        elseif(m(n,ptrsp).eq.'E2') then
          esp=esp+1
        elseif(m(n,ptrsp).eq.'E3') then
          esp=esp+1
        else
          continue
        endif

80      continue
      do 90 n=1,num(ptrcp)
        if(m(n,ptrcp).eq.'E1') then
          ecp=ecp+1
        elseif(m(n,ptrcp).eq.'E2') then
          ecp=ecp+1
        elseif(m(n,ptrcp).eq.'E3') then
          ecp=ecp+1
        else
          continue
        endif

90      continue
      cumemse=cumemse+emse
      cumesp=cumesp+esp
      cumeecp=cumeecp+ecp
      cmse=num(ptrmse)-emse
      ccp=num(ptrcp)-ecp
      csp=num(ptrsp)-esp
      chartmse(cmse,emse)=chartmse(cmse,emse)+1
      chartcp(ccp,ecp)=chartcp(ccp,ecp)+1
      chartsp(csp,esp)=chartsp(csp,esp)+1

      write(12,*) 'MSE',num(ptrmse),mse(ptrmse)
+      ,Sp(ptrmse),cp(ptrmse),' ',
+      (m(j,ptrmse),j=1,num(ptrmse))
      write(12,*) 'Sp ',num(ptrsp),mse(ptrsp)
+      ,Sp(ptrsp),cp(ptrsp),' ',
+      (m(j,ptrsp),j=1,num(ptrsp))
      write(12,*) 'Cp ',num(ptrcp),mse(ptrcp)
+      ,Sp(ptrcp),cp(ptrcp),' ',
+      (m(j,ptrcp),j=1,num(ptrcp))
+      write(12,*) '*****',
+      '*****'

```

```

write(12,*) ' '
write(12,*) ' '
20 continue
   nummse = real(varsmse)/60.0
   numsp  = real(varssp)/60.0
   numcp  = real(varscp)/60.0
   mseeer= real(cumemse)/60.0
   cpeer  = real(cumecp) /60.0
   speer  = real(cumesp) /60.0
   msepmp = 1-(mseeer/nummse)
   cppm   = 1-(cpeer/numcp)
   sppm   = 1-(speer/numsp)

   write(12,*) 'The avg number of vars using MSE',
+           ' was ', nummse
   write(12,*) 'The avg number of extraneous vars
+ from MSE',
+           ' was ', mseeer
   write(12,*) '*** The PM for MSE was ',msepmp,' ****'
   write(12,*) ' '
   write(12,*) 'The avg number of vars using Sp was',
+           numsp
   write(12,*) 'The avg number of extraneous vars
+from Sp',
+           ' was ',speer
   write(12,*) '***** The PM for Sp was ',sppm,' ****'

   write(12,*) ' '
   write(12,*) 'The avg number of vars using Cp was',
+           numcp
   write(12,*) 'The avg number of extraneous vars
+ from Cp',
+           ' was ',cpeer
   write(12,*) '***** The PM for Cp was ',cppm,' ****'
   write(12,*) ' '
   write(12,*) ' '
   write(12,*) 'Correct Vars (0-3,down) -VS- ',
+           'Extraneous Vars (0-3,across)'
   write(12,*) ' '
   write(12,*) ' MSE TABLE'
   write(12,*) ' '
   do 100 i=0,3
       write(12,*) (chartmse(i,j),j=0,3)
100 continue
   write(12,*) ' '
   write(12,*) ' '
   write(12,*) 'Sp TABLE'
   write(12,*) ' '
   do 110 i=0,3
       write(12,*) (chartsp(i,j),j=0,3)

```

```

110          continue

              write(12,*) ' '
              write(12,*) ' '
              write(12,*) 'Cp TABLE'
              do 120 i=0,3
                  write (12,*) (chartcp(i,j),j=0,3)
120          continue
              write(13,*)(DesignPoint-2), ' ',msepmm,
+              ',sppm,' ',cppm

50      Continue

          Close(11)
          Close(12)
          Close(13)
          GO TO 1200

* Error trap: *****

1000      Continue
          Print 1100, '+++ ERROR WHILE OPENING FILE +++',
+              'error code = ', IERROR
1100      FORMAT(/1X, A/ 1X, A, I8/)

*****

1200      CONTINUE
          Print *, 'Counting complete. ', NewOut, ' written.'
          END

```

FILCOUNT.FOR

*This program takes SAS R-Squared listings in any file and
 *extracts models with the lowest MSE, Cp, and Sp and then
 *figures the performance measure (PM). This program calls
 *subroutines Count1.for and Count3.for and write the *calcu-
 *lated PM's to *PM1.dat and PM3.dat, respectively.

Character*20 NewIn
 Character*20 NewOut
 Character*80 Line
 CHARACTER I, J
 Integer Var
 Logical VarFlag

```

5  Continue
   Print *, 'Name of file to examine? (20 char or less;',
+     ' "*" to quit)'
   Read (*, '(A20)') NewIn
   If (NewIn(1:1).EQ.'*') GO TO 999
   Print *, 'Output file? (20 char or less)'
   Read (*, '(A20)') NewOut
7  Continue
   Print *, 'Number of extraneous variables? (1 or 3
+ONLY!!)'
   Read (*, '(I1)') Var
   If ((Var.NE.1).AND.(Var.NE.3)) GO TO 7
9  Continue
   VarFlag = (Var.EQ.3)

   Open (unit=10, file=NewIn, status='OLD',
&       iostat=IERROR, err=1000)

   Open (unit=11, file='temp.dat', status='NEW',
&       iostat=IERROR, err=1000)
10 Continue
   Read(10,200,END=888) Line
   I = LINE (8:8)
   J = LINE (9:11)

   IF (VarFlag) GO TO 777

   IF ((I.EQ.'1').AND.(J.EQ.' ')) THEN
     WRITE (11,201) I
     WRITE (11,200) LINE
   ELSE

     IF ((I.EQ.'2').AND.(J.EQ.' ')) THEN
       WRITE (11,201) I

```

```

WRITE (11,200) LINE
ELSE

  IF ((I.EQ.'3').AND.(J.EQ.' ')) THEN
    WRITE (11,201) I
    WRITE (11,200) LINE
  ELSE

    IF ((I.EQ.'4').AND.(J.EQ.' ')) THEN
      WRITE (11,201) I
      WRITE (11,200) LINE
    ENDIF

  ENDIF

ENDIF

ENDIF

GO TO 10

777 Continue
IF ((I.EQ.'1').AND.(J.EQ.' ')) THEN
  WRITE (11,201) I
  WRITE (11,200) LINE
ELSE

  IF ((I.EQ.'2').AND.(J.EQ.' ')) THEN
    WRITE (11,201) I
    WRITE (11,200) LINE
  ELSE

    IF ((I.EQ.'3').AND.(J.EQ.' ')) THEN
      WRITE (11,201) I
      WRITE (11,200) LINE
    ELSE

      IF ((I.EQ.'4').AND.(J.EQ.' ')) THEN
        WRITE (11,201) I
        WRITE (11,200) LINE
      ELSE

        IF ((I.EQ.'5').AND.(J.EQ.' ')) THEN
          WRITE (11,201) I
          WRITE (11,200) LINE
        ELSE

          IF ((I.EQ.'6').AND.(J.EQ.' ')) THEN
            WRITE (11,201) I
            WRITE (11,200) LINE
          ENDIF
        ENDIF
      ENDIF
    ENDIF
  ENDIF
ENDIF

```

```

                ENDIF
            ENDIF
        ENDIF
    ENDIF
    GO TO 10

200  Format (A80)
201  Format (1X,A1)
888  Continue
      Close(10)
      Close(11)

      Print *, 'Filtering complete on ', NewIn, '. Counting
+ begun.'

      IF (VarFlag) THEN
          Call Count3(NewOut)
          Print *, 'Counting complete. PM"s calculated for',
+              ' designpoints with 3 extraneous variables',
+              ' and written to PM3.dat.'
          Print *, ' '
      ELSE
          Call Count1(NewOut)
          Print *, 'Counting complete. PM"s calculated for',
+              ' designpoints with 1 extraneous variable',
+              ' and written to PM1.dat.'
          Print *, ' '
      ENDIF
      GO TO 5

999  Continue

      Print *, 'Processing complete. Program terminated.'
      Stop

* Error trap: *****
1000 Continue
      Print 1100, '+++ ERROR WHILE OPENING FILE +++',
      &          ' error code = ', IERROR
1100 FORMAT(/1X, A/ 1X, A, 18/)
      GO TO 5
*****
      END

```

FILSTEPCOUNT.FOR

*This program takes SAS Forward Selection Stepwise listings
 *in any file and extracts models according to Miller's
 *Method and then figures the performance measure (PM). The
 *program reads 1 extraneous variable data files from
 *Step1_Input.dat and 3 extraneous variables data files from
 *Step3_Input.dat, forms a temporary file called TEMP.DAT and
 *then calls subroutines StepCount1.for and StepCount3.for to
 *analysis the data.

Character*14 NewIn
 Character*20 NewOut
 Character*80 Line
 Character*1 I, J
 Character*2 K
 Integer Var
 Logical VarFlag, BatchFlag

```

5  Continue
   Print *, 'Interactive(I) or Batch(B) mode? (I or B
+only):'
   Read (*, '(A1)') Mode
   IF ((Mode.NE.'I').AND.(Mode.NE.'B')) Go to 5
   BatchFlag=(Mode.EQ.'B')
   IF (BatchFlag) Go to 6
   Print *, 'Name of file to examine? (20 char or less;',
+   ' *** to quit)'
   Read (*, '(A20)') NewIn
   If (NewIn(1:1).EQ.'*') GO TO 999
6  Continue
   Print *, 'Output file? (20 char or less)'
   Read (*, '(A20)') NewOut
7  Continue
   Print *, 'Number of extraneous variables? (1 or 3
+ONLY!!)'
   Read (*, '(I1)') Var
   If ((Var.NE.1).AND.(Var.NE.3)) GO TO 7
9  Continue
   VarFlag = (Var.EQ.3)

   IF ((VarFlag).AND.(BatchFlag)) THEN
     Open (unit=9, file='Step3 Input.dat', status='OLD',
+       iostat=IERROR, err=I000)
   ELSE
     IF ((.NOT.VarFlag).AND.(BatchFlag)) THEN
       Open (unit=9, file='Step1_Input.dat',
+ status='OLD',

```

```

+          iostat=IERROR, err=1000)

      ENDIF
      ENDIF
11      Continue
      IF (LatchFlag) Read(9, '(A14)', END=666) NewIn
      Print *, 'Filtering begun on ', NewIn, '.Filtered data ',
+          'is being dumped to TEMP.DAT.'

      Open (unit=10, file=NewIn, status='OLD',
&          iostat=IERROR, err=1000)

      Open (unit=11, file='temp.dat', status='NEW',
&          iostat=IERROR, err=1000)

10      Continue
      Read(10, 200, END=888) Line
      I = LINE (5:5)
      J = LINE (6:8)
      K = LINE (4:5)

      IF (VarFlag) GO TO 777

      IF ((I.EQ.'1').AND.(J.EQ.' ')) THEN
          WRITE (11, 200) LINE
      ELSE

          IF ((I.EQ.'2').AND.(J.EQ.' ')) THEN
              WRITE (11, 200) LINE
          ELSE

              IF ((I.EQ.'3').AND.(J.EQ.' ')) THEN
                  WRITE (11, 200) LINE
              ELSE

                  IF ((I.EQ.'4').AND.(J.EQ.' ')) THEN
                      WRITE (11, 200) LINE
                  ELSE

                      IF ((I.EQ.'5').AND.(J.EQ.' ')) THEN
                          WRITE (11, 200) LINE
                      ELSE

                          IF ((I.EQ.'6').AND.(J.EQ.' ')) THEN
                              WRITE (11, 200) LINE
                          ELSE

                              IF ((I.EQ.'7').AND.(J.EQ.' ')) THEN
                                  WRITE (11, 200) LINE
                              ELSE

                                  IF ((I.EQ.'8').AND.(J.EQ.' ')) THEN

```

```

        WRITE (11,200) LINE
        ENDIF

    ENDIF

ENDIF

ENDIF

ENDIF

ENDIF

ENDIF

ENDIF

GO TO 10

777 Continue
IF ((I.EQ.'1').AND.(J.EQ.' ')) THEN
    WRITE (11,200) LINE
ELSE
    IF ((I.EQ.'2').AND.(J.EQ.' ')) THEN
        WRITE (11,200) LINE
    ELSE
        IF ((I.EQ.'3').AND.(J.EQ.' ')) THEN
            WRITE (11,200) LINE
        ELSE
            IF ((I.EQ.'4').AND.(J.EQ.' ')) THEN
                WRITE (11,200) LINE
            ELSE
                IF ((I.EQ.'5').AND.(J.EQ.' ')) THEN
                    WRITE (11,200) LINE
                ELSE
                    IF ((I.EQ.'6').AND.(J.EQ.' ')) THEN
                        WRITE (11,200) LINE
                    ELSE
                        IF ((I.EQ.'7').AND.(J.EQ.' ')) THEN
                            WRITE (11,200) LINE
                        ELSE
                            IF ((I.EQ.'8').AND.(J.EQ.' ')) THEN
                                WRITE (11,200) LINE
                            ELSE

```

```
IF ((I.EQ.'9').AND.(J.EQ.' ')) THEN  
  WRITE (11,200) LINE  
ELSE
```

```
IF ((K.EQ.'10').AND.(J.EQ.' ')) THEN  
  WRITE (11,200) LINE  
ELSE
```

```
IF ((K.EQ.'11').AND.(J.EQ.' ')) THEN  
  WRITE (11,200) LINE  
ELSE
```

```
IF ((K.EQ.'12').AND.(J.EQ.' ')) THEN  
  WRITE (11,200) LINE  
ENDIF
```

```
ENDIF
```

```
ENDIF
```

```
ENDIF
```

```
ENDIF
```

```
ENDIF
```

```
ENDIF
```

```
ENDIF
```

```
ENDIF
```

```
ENDIF
```

```
ENDIF
```

```
ENDIF
```

```
GO TO 10
```

```
200  Format (A80)
```

```
666  Continue  
      BatchFlag=.FALSE.
```

```
888  Continue  
      IF (BatchFlag) THEN  
        Close(10)  
        Go to 11  
      ELSE  
        Close(9)
```

```

        Close(10)
        Close(11)
    ENDIF

    Print *, 'Filtering complete. Analysis of data in',
+      ' TEMP.DAT has begun.', ' Analysis results
+will',
+      ' be dumped to ', Newout, ' .'

    IF (VarFlag) THEN
        Call Stepcount3(NewOut)
    ELSE
        Call Stepcount1(NewOut)
    ENDIF
    GO TO 5

999  Continue

    Print *, 'Processing complete. Program terminated.'
    Stop

* Error trap: *****
1000 Continue
    Print 1100, '+++ ERROR WHILE OPENING FILE +++',
    &      ' error code = ', IERROR
1100 FORMAT(/1X, A/ 1X, A, I8/)
    GO TO 5
*****
    END

```

```
*****
*****  FORTRAN PROGRAM MILLBETA.FOR  *****
*****
```

```
Logical ErrFlag
CALL BETA1
CALL BETA3
```

```
ErrFlag = .FALSE.
```

```
Call MILLTM1(ErrFlag)
If (ErrFlag) Go to 999
Print *, 'TMSEP''s calculated for designpoints with',
+      ' 1 extraneous variables and written to
+ MILLTM1.DAT.'
Print *, ' '
```

```
Call MILLTM3(ErrFlag)
If (ErrFlag) Go to 999
Print *, 'TMSEP''s calculated for designpoints with',
+      ' 3 extraneous variables and written to
+ MILLTM3.DAT.'
Print *, ' '
```

```
999 Continue
```

```
Print *, 'Processing complete. Program terminated.'
```

```
STOP
END
```

```
*****
*****      FORTRAN PROGRAM MILLSAS.FOR      *****
*****
```

```
INTEGER VarInModel, DP, REP, ActualREP
```

```
CHARACTER*3 J
CHARACTER*6 filename
CHARACTER*11 Modellex
CHARACTER*17 Model3ex
CHARACTER*80 LINE
```

```
OPEN (unit=10, file='Miller1Beta.sas', status='NEW',
+      iostat=IERROR, err=1400)
OPEN (unit=11, file='Miller3Beta.sas', status='NEW',
+      iostat=IERROR, err=1400)
OPEN (unit=12, file='Step1 all.dat', status='OLD',
+      iostat=IERROR, err=1400)
OPEN (unit=13, file='Step3 all.dat', status='OLD',
+      iostat=IERROR, err=1400)
```

```
Do 60 DP=1,64
```

```
VarInModel = 0
ActualREP = 0
filename = '
Modellex = '
Model3ex = '
```

```
IF (DP.EQ.1) THEN
    filename = '01.dat'
    GO TO 10
ENDIF
```

```
IF (DP.EQ.2) THEN
    filename = '02.dat'
    GO TO 20
ENDIF
```

```
IF (DP.EQ.3) THEN
    filename = '03.dat'
    GO TO 10
ENDIF
```

```
IF (DP.EQ.4) THEN
    filename = '04.dat'
    GO TO 20
ENDIF
```

```
IF (DP.EQ.5) THEN
  filename = '05.dat'
  GO TO 10
ENDIF
```

```
IF (DP.EQ.6) THEN
  filename = '06.dat'
  GO TO 20
ENDIF
```

```
IF (DP.EQ.7) THEN
  filename = '07.dat'
  GO TO 10
ENDIF
```

```
IF (DP.EQ.8) THEN
  filename = '08.dat'
  GO TO 20
ENDIF
```

```
IF (DP.EQ.9) THEN
  filename = '09.dat'
  GO TO 10
ENDIF
```

```
IF (DP.EQ.10) THEN
  filename = '10.dat'
  GO TO 20
ENDIF
```

```
IF (DP.EQ.11) THEN
  filename = '11.dat'
  GO TO 10
ENDIF
```

```
IF (DP.EQ.12) THEN
  filename = '12.dat'
  GO TO 20
ENDIF
```

```
IF (DP.EQ.13) THEN
  filename = '13.dat'
  GO TO 10
ENDIF
```

```
IF (DP.EQ.14) THEN
  filename = '14.dat'
  GO TO 20
ENDIF
```

```
IF (DP.EQ.15) THEN
  filename = '15.dat'
```

```

GO TO 10
ENDIF

IF (DP.EQ.16) THEN
    filename = '16.dat'
    GO TO 20
ENDIF

IF (DP.EQ.17) THEN
    filename = '17.dat'
    GO TO 10
ENDIF

IF (DP.EQ.18) THEN
    filename = '18.dat'
    GO TO 20
ENDIF

IF (DP.EQ.19) THEN
    filename = '19.dat'
    GO TO 10
ENDIF

IF (DP.EQ.20) THEN
    filename = '20.dat'
    GO TO 20
ENDIF

IF (DP.EQ.21) THEN
    filename = '21.dat'
    GO TO 10
ENDIF

IF (DP.EQ.22) THEN
    filename = '22.dat'
    GO TO 20
ENDIF

IF (DP.EQ.23) THEN
    filename = '23.dat'
    GO TO 10
ENDIF

IF (DP.EQ.24) THEN
    filename = '24.dat'
    GO TO 20
ENDIF

IF (DP.EQ.25) THEN
    filename = '25.dat'
    GO TO 10
ENDIF

```

```
IF (DP.EQ.26) THEN
    filename = '26.dat'
    GO TO 20
ENDIF

IF (DP.EQ.27) THEN
    filename = '27.dat'
    GO TO 10
ENDIF

IF (DP.EQ.28) THEN
    filename = '28.dat'
    GO TO 20
ENDIF

IF (DP.EQ.29) THEN
    filename = '29.dat'
    GO TO 10
ENDIF

IF (DP.EQ.30) THEN
    filename = '30.dat'
    GO TO 20
ENDIF

IF (DP.EQ.31) THEN
    filename = '31.dat'
    GO TO 10
ENDIF

IF (DP.EQ.32) THEN
    filename = '32.dat'
    GO TO 20
ENDIF

IF (DP.EQ.33) THEN
    filename = '33.dat'
    GO TO 10
ENDIF

IF (DP.EQ.34) THEN
    filename = '34.dat'
    GO TO 20
ENDIF

IF (DP.EQ.35) THEN
    filename = '35.dat'
    GO TO 10
ENDIF

IF (DP.EQ.36) THEN
    filename = '36.dat'
```

```
GO TO 20
ENDIF

IF (DP.EQ.37) THEN
    filename = '37.dat'
    GO TO 10
ENDIF

IF (DP.EQ.38) THEN
    filename = '38.dat'
    GO TO 20
ENDIF

IF (DP.EQ.39) THEN
    filename = '39.dat'
    GO TO 10
ENDIF

IF (DP.EQ.40) THEN
    filename = '40.dat'
    GO TO 20
ENDIF

IF (DP.EQ.41) THEN
    filename = '41.dat'
    GO TO 10
ENDIF

IF (DP.EQ.42) THEN
    filename = '42.dat'
    GO TO 20
ENDIF

IF (DP.EQ.43) THEN
    filename = '43.dat'
    GO TO 10
ENDIF

IF (DP.EQ.44) THEN
    filename = '44.dat'
    GO TO 20
ENDIF

IF (DP.EQ.45) THEN
    filename = '45.dat'
    GO TO 10
ENDIF

IF (DP.EQ.46) THEN
    filename = '46.dat'
    GO TO 20
ENDIF
```

```
IF (DP.EQ.47) THEN
    filename = '47.dat'
    GO TO 10
ENDIF

IF (DP.EQ.48) THEN
    filename = '48.dat'
    GO TO 20
ENDIF

IF (DP.EQ.49) THEN
    filename = '49.dat'
    GO TO 10
ENDIF

IF (DP.EQ.50) THEN
    filename = '50.dat'
    GO TO 20
ENDIF

IF (DP.EQ.51) THEN
    filename = '51.dat'
    GO TO 10
ENDIF

IF (DP.EQ.52) THEN
    filename = '52.dat'
    GO TO 20
ENDIF

IF (DP.EQ.53) THEN
    filename = '53.dat'
    GO TO 10
ENDIF

IF (DP.EQ.54) THEN
    filename = '54.dat'
    GO TO 20
ENDIF

IF (DP.EQ.55) THEN
    filename = '55.dat'
    GO TO 10
ENDIF

IF (DP.EQ.56) THEN
    filename = '56.dat'
    GO TO 20
ENDIF

IF (DP.EQ.57) THEN
    filename = '57.dat'
```

```

        GO TO 10
    ENDIF

    IF (DP.EQ.58) THEN
        filename = '58.dat'
        GO TO 20
    ENDIF

    IF (DP.EQ.59) THEN
        filename = '59.dat'
        GO TO 10
    ENDIF

    IF (DP.EQ.60) THEN
        filename = '60.dat'
        GO TO 20
    ENDIF

    IF (DP.EQ.61) THEN
        filename = '61.dat'
        GO TO 10
    ENDIF

    IF (DP.EQ.62) THEN
        filename = '62.dat'
        GO TO 20
    ENDIF

    IF (DP.EQ.63) THEN
        filename = '63.dat'
        GO TO 10
    ENDIF

    IF (DP.EQ.64) THEN
        filename = '64.dat'
        GO TO 20
    ENDIF

```

```

10      CONTINUE

924      CONTINUE
        READ (12,925,END=1350) LINE
925      FORMAT(1X,A80)
        J = LINE(1:3)
        IF (J.NE.'Rep') GO TO 924

        DO 30 REP=1,60

        READ (12,900,END=1000) ActualREP, VarInModel, Modellex
900      FORMAT(5X,I2,12X,I1,6X,A11)

        IF (REP.NE.ActualREP) GO TO 1100

```

```

    WRITE (10,901) FILENAME
901  FORMAT (1X,'FILENAME NEW ',A6,' ');

    WRITE (10,902)
902  FORMAT (1X,'DATA NEW;')

    WRITE (10,903)
903  FORMAT (1X,'INFILE NEW;')

    WRITE (10,904)
904  FORMAT (1X,'INPUT SETNUM Y X1 X2 X3 X4 E1;')

    WRITE (10,905) ActualREP
905  FORMAT (1X,'IF SETNUM^=',I2,' THEN DELETE;')

    IF (VarInModel.EQ.0) THEN

        WRITE (10,906)
906  FORMAT (1X,'INTERCEP = 1;')

        WRITE (10,907)
907  FORMAT (1X,'PROC RSQUARE DATA=NEW NOINT B;')

        WRITE (10,908)
908  FORMAT (1X,'MODEL Y = INTERCEP;')

    ELSE

        WRITE (10,909)
909  FORMAT (1X,'PROC RSQUARE DATA=NEW B;')

        WRITE (10,910) Modellex, VarInModel
910  FORMAT (1X,'MODEL Y = ',A11,' /INCLUDE=',I1,' ');

    ENDIF

    WRITE (10,*)

30  CONTINUE

    GO TO 50

20  CONTINUE

926  CONTINUE
    READ (13,927,END=1375) LINE
927  FORMAT(1X,A80)
    J = LINE(1:3)

```

```

        IF (J.NE.'Rep') GO TO 926
        DO 40 REP=1,60

        READ (13,911,END=1200) ActualREP, VarInModel, Model3ex
911    FORMAT(5X,I2,12X,I1,6X,A17)

        IF (REP.NE.ActualREP) GO TO 1300

        WRITE (11,912) FILENAME
912    FORMAT (1X,'FILENAME NEW ',A6,',';')

        WRITE (11,913)
913    FORMAT (1X,'DATA NEW;')

        WRITE (11,914)
914    FORMAT (1X,'INFILE NEW;')

        WRITE (11,915)
915    FORMAT (1X,'INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;')

        WRITE (11,916) ActualREP
916    FORMAT (1X,'IF SETNUM^=',I2,' THEN DELETE;')

        IF (VarInModel.EQ.0) THEN

            WRITE (11,917)
917    FORMAT (1X,'INTERCEP = 1;')

            WRITE (11,918)
918    FORMAT (1X,'PROC RSQUARE DATA=NEW NOINT B;')

            WRITE (11,919)
919    FORMAT (1X,'MODEL Y = INTERCEP;')

        ELSE

            WRITE (11,920)
920    FORMAT (1X,'PROC RSQUARE DATA=NEW B;')

            WRITE (11,921) Model3ex, VarInModel
921    FORMAT (1X,'MODEL Y = ',A17,' /INCLUDE=',I1,',';')

        ENDIF

        WRITE (11,*)

40    CONTINUE

50    CONTINUE

```

```

60      CONTINUE

        CLOSE (10)
        CLOSE (11)
        CLOSE (12)
        CLOSE (13)

        PRINT *, 'Program completed successfully with ',
+             DP-1, ' designpoints and ', REP-1,
+             'replications.'

        GO TO 1500

* ERROR TRAP*****

1000     CONTINUE

        PRINT *, 'ERROR WHILE READING STEP1_ALL.DAT.',
+             'UNEXPECTED END OF FILE.'
        GO TO 1500

1100     CONTINUE

        PRINT *, 'STEP1_ALL.DAT IN UNEXPECTED FORMAT.',
+             'REP COUNTER DOES NOT AGREE WITH FILE.'
        GO TO 1500

1200     CONTINUE

        PRINT *, 'ERROR WHILE READING STEP3_ALL.DAT.',
+             'UNEXPECTED END OF FILE.'
        GO TO 1500

1300     CONTINUE

        PRINT *, 'STEP3_ALL.DAT IN UNEXPECTED FORMAT.',
+             'REP COUNTER DOES NOT AGREE WITH FILE.'
        GO TO 1500

1350     CONTINUE

        PRINT *, 'STEP1_ALL.DAT IN UNEXPECTED FORMAT.',
+             'DP COUNTER DOES NOT AGREE WITH FILE.'

1375     CONTINUE

        PRINT *, 'STEP3_ALL.DAT IN UNEXPECTED FORMAT.',
+             'DP COUNTER DOES NOT AGREE WITH FILE.'

1400     CONTINUE
        PRINT 1401, '+++ ERROR WHILE OPENING FILE +++',
+             'error code = ', IERROR

```

1401 FORMAT (/1X, A/ 1X, A, I8/)

1500 CONTINUE
 STOP
 END

```

*****
*                               FORTRAN PROGRAM MILLTM1.FOR
*
* This program is designed to take the 64 groups of 60
* models selected via Miller's method and the corresponding
* 3840 data sets and find the "real" MSEP for each of the 32
* odd designpoints of 64 design points.
*****

```

```

      Subroutine MILLTM1(ErrFlag)

      Integer h,i,j,k,p,r,s
      Integer num

      Real b0, betas(4)
      Real x(4,20),x3ex1(4,20),ex,y
      Real ypredmillers
      Real ymsepmillers
      Real yssepmillers
      Real sumyssepmillers
      Real sumdifmillers
      Real dpymsepmillers

      Character*6 Infile

      Logical ErrFlag
      Open(unit=11,file= 'MILLER1BETA.DAT',status='old',
+         iostat=IERROR, err=1000)
      Open (unit=13,file='MILLTM1.DAT',status='new',
+         iostat=IERROR, err=1002)

      Write (13,902)
902   Format (1X,'TMSEPs calculated for the Miller''s
+ method:')

      Write (13,901)
901   Format (1X,'DP',9X,'Miller''s')

      Do 5 r=1,63,2

      If (r.EQ.1) then
        Infile='01.dat'
      Else
        If (r.EQ.3) then
          Infile='03.dat'
        Else
          If (r.EQ.5) then
            Infile='05.dat'
          Else
            If (r.EQ.7) then
              Infile='07.dat'
            Else

```

```

If (r.EQ.9) then
  Infile='09.dat'
Else
  If (r.EQ.11) then
    Infile='11.dat'
  Else
    If (r.EQ.13) then
      Infile='13.dat'
    Else
      If (r.EQ.15) then
        Infile='15.dat'
      Else
        If (r.EQ.17) then
          Infile='17.dat'
        Else
          If (r.EQ.19) then
            Infile='19.dat'
          Else
            If (r.EQ.21) then
              Infile='21.dat'
            Else
              If (r.EQ.23) then
                Infile='23.dat'
              Else
                If (r.EQ.25) then
                  Infile='25.dat'
                Else
                  If (r.EQ.27) then
                    Infile='27.dat'
                  Else
                    If (r.EQ.29) then
                      Infile='29.dat'
                    Else
                      If (r.EQ.31) then
                        Infile='31.dat'
                      Else
                        If (r.EQ.33) then
                          Infile='33.dat'
                        Else
                          If (r.EQ.35) then
                            Infile='35.dat'
                          Else
                            If (r.EQ.37) then
                              Infile='37.dat'
                            Else
                              If (r.EQ.39) then
                                Infile='39.dat'
                              Else
                                If (r.EQ.41) then
                                  Infile='41.dat'
                                Else
                                  If (r.EQ.43) then

```



```

+
+ yssepmlers

50      Continue

      sumyssepmlers = sumyssepmlers + yssepmlers
      sumdifmlers = sumdifmlers + (s-num)

20      Continue

      dpymsepmlers = sumyssepmlers / sumdifmlers

900     Write(13,900) r, dpymsepmlers
      Format (1X,12,5X,F10.6)

      Close (12)

5       Continue

      Close (11)
      Close (13)
      Go to 1300
*****Error trap*****

1000    Print *, 'Something''s wrong with MILLER1BETA.DAT.'
      Go to 1100
1001    Print *, 'Something''s wrong with ',Infile
      Go to 1100
1002    Print *, 'Can''t seem to create MILLTMI.DAT.'
      Go to 1100
1003    Print *, 'MILLER1BETA.DAT in unexpected format.'
      ErrFlag = .TRUE.
      Go to 1300
1004    Print *, 'File ',Infile,' is in an unexpected format.'
      ErrFlag = .TRUE.
      Go to 1300

1100    Continue
      Print 1200, '+++ ERROR WHILE OPENING FILE +++',
+
+      error code = ',IERROR
1200    Format (/1X, A/ 1X, A, I8/)
      ErrFlag = .TRUE.
*****

1300    Continue

      END

```

```

*****
*
*
*               FORTRAN PROGRAM MILLTM3.FOR
*
* This program is designed to take the 64 groups of 60
* models selected via Miller's method and the corresponding
* 3840 data sets and find the "real" MSEP for each of the 32
* even design points of 64 design points.
*****

```

```

      Subroutine MILLTM3(ErrFlag)

      Integer n,i,j,k,p,r,s
      Integer num

      Real b0, betas(6)
      Real x(4,20),x3ex3(6,20),y,ex1,ex2,ex3
      Real ypredmillers
      Real ymsepmillers
      Real yssepmillers
      Real sumyssepmillers
      Real sumdifmillers
      Real dpymsepmillers

      Character*6 Infile

      Logical ErrFlag

      Open(unit=11,file= 'MILLER3BETA.DAT',status='old',
+         iostat=IERRCR,err=1000)
+ Open(unit=13,file='MILLTM3.DAT',status='new',
+ iostat=IERROR, err=1002)

      Write (13,902)
902  Format (1X,'TMSEPs calculated for Miller's method:')

      Write (13,901)
901  Format (1X,'DP',9X,'Miller's')

      Do 5 r=2,64,2

      If (r.EQ.2) then
        Infile='02.dat'
      Else
        If (r.EQ.4) then
          Infile='04.dat'
        Else
          If (r.EQ.6) then
            Infile='06.dat'
          Else
            If (r.EQ.8) then
              Infile='08.dat'

```

```

Else
  If (r.EQ.10) then
    Infile='10.dat'
  Else
    If (r.EQ.12) then
      Infile='12.dat'
    Else
      If (r.EQ.14) then
        Infile='14.dat'
      Else
        If (r.EQ.16) then
          Infile='16.dat'
        Else
          If (r.EQ.18) then
            Infile='18.dat'
          Else
            If (r.EQ.20) then
              Infile='20.dat'
            Else
              If (r.EQ.22) then
                Infile='22.dat'
              Else
                If (r.EQ.24) then
                  Infile='24.dat'
                Else
                  If (r.EQ.26) then
                    Infile='26.dat'
                  Else
                    If (r.EQ.28) then
                      Infile='28.dat'
                    Else
                      If (r.EQ.30) then
                        Infile='30.dat'
                      Else
                        If (r.EQ.32) then
                          Infile='32.dat'
                        Else
                          If (r.EQ.34) then
                            Infile='34.dat'
                          Else
                            If (r.EQ.36) then
                              Infile='36.dat'
                            Else
                              If (r.EQ.38) then
                                Infile='38.dat'
                              Else
                                If (r.EQ.40) then
                                  Infile='40.dat'
                                Else
                                  If (r.EQ.42) then
                                    Infile='42.dat'
                                  Else

```

```

If (r.EQ.44) then
  Infile='44.dat'
Else
  If (r.EQ.46) then
    Infile='46.dat'
  Else
    If (r.EQ.48) then
      Infile='48.dat'
    Else
      If (r.EQ.50) then
        Infile='50.dat'
      Else
        If (r.EQ.52) then
          Infile='52.dat'
        Else
          If (r.EQ.54) then
            Infile='54.dat'
          Else
            If (r.EQ.56) then
              Infile='56.dat'
            Else
              If (r.EQ.58) then
                Infile='58.dat'
              Else
                If (r.EQ.60) then
                  Infile='60.dat'
                Else
                  If (r.EQ.62) then
                    Infile='62.dat'
                  Else
                    If (r.EQ.64) then
                      Infile='64.dat'
                    Endif
                  Endif
                Endif
              Endif
            Endif
          Endif
        Endif
      Endif
    Endif
  Endif
Endif

```



```

70      Continue

      yssepmlillers = ((ypredmlillers-yactual)**real(2))
+      + yssepmlillers

50      Continue

      sumyssepmlillers = sumyssepmlillers + yssepmlillers
      sumdifmlillers = sumdifmlillers + (s-num)

20      Continue

      dpymsepmlillers = sumyssepmlillers / sumdifmlillers

      Write(13,900) r, dpymsepmlillers
900     Format (1X,I2,5X,F10.6)

      Close (12)

5       Continue

      Close (11)
      Close (13)
      Go to 1300

*****Error trap*****

1000    Print *, 'Something' 's wrong with MILLER3BETA.DAT.'
        Go to 1100
1001    Print *, 'Something' 's wrong with ', Infile
        Go to 1100
1002    Print *, 'Can' 't seem to create MILLTM3.DAT.'
        Go to 1100
1003    Print *, 'MILLER3BETA.DAT in unexpected format.'
        ErrFlag = .TRUE.
        Go to 1300
1004    Print *, 'File ', Infile, ' is in an unexpected format.'
        ErrFlag = .TRUE.
        Go to 1300

1100    Continue
        Print 1200, '+++ ERROR WHILE OPENING FILE +++',
+        '          error code = ', IERROR
1200    Format (/1X, A/ 1X, A, I8/)
        ErrFlag = .TRUE.
*****
1300    Continue

      END

```

```

*****
*****  FORTRAN PROGRAM STEPCOUNT1.FOR  *****
*****

```

```

SUBROUTINE Stepcount1 (NewOut)

```

```

    integer num, numvar, h, i, j, k, n, p, q, r, s, t, v, w, x, y, z
    integer emiller, varsmiller, cumemiller, cmiller
    integer chartmiller(0:3,0:3), ReadCount
    real avgvars, avgevars, millerpm
    character*1 numchar
    character*2 m(9), Model_var, Good_model(5)
    character*20 NewOut
    logical ModelNotFound, EndOfFile

```

```

    num=0
    emiller=0
    varsmiller=0
    cumemiller=0
    cmiller=0
    ReadCount=0
    ModelNotFound=.TRUE.
    EndOfFile=.FALSE.

```

```

10      do 10 i=1,8
           m(i)=' '
        continue

```

```

20      do 20 j=1,4
           Good_model(j)=' '
        continue

```

```

40      do 30 k=0,3
           do 40 h=0,3
                chartmiller(k,h)=0
            continue
        30 continue

```

```

+      open (unit=11, file='temp.dat', status='old',
+           iostat=IERROR, err=1000)
+      open (unit=12, file=NewOut, status='new',
+           iostat=IERROR, err=1000)
+      open (unit=13, file='PMstep1.dat', status='new',
+           iostat=IERROR, err=1000)
+      write(13,*)'      DESIGNPOINT MILLER'S PM'

```

```

900      ReadCount=ReadCount+1
           Read(11,900,end=90)numchar, Model_var
           Format(4X,A1,4X,A2)
           IF (numchar.EQ.'1') THEN

```

```

    num=1
ELSE
  IF (numchar.EQ.'2') THEN
    num=2
  ELSE
    IF (numchar.EQ.'3') THEN
      num=3
    ELSE
      IF (numchar.EQ.'4') THEN
        num=4
      ELSE
        IF (numchar.EQ.'5') THEN
          num=5
        ELSE
          IF (numchar.EQ.'6') THEN
            num=6
          ELSE
            IF (numchar.EQ.'7') THEN
              num=7
            ELSE
              IF (numchar.EQ.'8') THEN
                num=8
              ELSE
                Print *, 'Unexpected format in TEMP.DAT: ',
+                'Numbers 1,2,3, etc., not found!'
                Go to 1300
              ENDIF
            ENDIF
          ENDIF
        ENDIF
      ENDIF
    ENDIF
  ENDIF
ENDIF

IF (num.NE.1) THEN
+ Print *, 'Processing terminated. Input file ',
  'in unexpected format: 1st number must be 1.'
  Go to 1300
ELSE
  m(num)=Model_var
ENDIF

Do 60 n=1,63,2
  Write(12,*)' '
  Write(12,*)' '
  Write(12,*)' '
  Write(12,*) '***** DESIGN POINT '
+  n, '*****'
  Write (12,*)' '
  Write(12,*)'Replication   #Vars   Model'

```

```

do 70 p=1,60

80      Continue
      IF (EndOfFile) THEN
+      Print *, 'Unexpected file format! File does not ',
        'have correct # of design points and reps.'
        Go to 1300
      ENDIF
      ReadCount=ReadCount+1
      Read(11,900,end=90) numchar, Model_var

      IF (numchar.EQ.'1') THEN
        num=1
      ELSE
        IF (numchar.EQ.'2') THEN
          num=2
        ELSE
          IF (numchar.EQ.'3') THEN
            num=3
          ELSE
            IF (numchar.EQ.'4') THEN
              num=4
            ELSE
              IF (numchar.EQ.'5') THEN
                num=5
              ELSE
                IF (numchar.EQ.'6') THEN
                  num=6
                ELSE
                  IF (numchar.EQ.'7') THEN
                    num=7
                  ELSE
                    IF (numchar.EQ.'8') THEN
                      num=8
                    ELSE
+          Print *, 'Unexpected format in TEMP.DAT: ',
            'Numbers 1,2,3, etc., not found!'
            Go to 1300
          ENDIF
        ENDIF
      ENDIF
    ENDIF
  ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF

110      Continue
      IF (num.NE.1) THEN
        m(num)=Model_var
      ELSE
        continue

```

```

do 100 q=1,4
  IF ((m(q)(1:1).NE.'R').AND.ModelNotFound) THEN
    Good_model(q)=m(q)
    numvar=numvar+1
  ELSE
    ModelNotFound=.FALSE.
  ENDIF
100   continue
      Write(12,901)p, numvar, (Good_model(r),r=1,4)
901   FORMAT ('      ,4X,I2,11X,I2,6X,A2,1X,A2,1X,
+      A2,1X,A2)
      Go to 120
    ENDIF
    GO TO 80

120   continue
      IF (numvar.LE.0) Go to 140
      do 130 s=1,numvar
        if(m(s).EQ.'E1') then
          emiller=emiller+1
        endif
130   continue

140   varsmiller=varsmiller+numvar
      cumemiller=cumemiller+emiller
      cmiller=numvar-emiller
      chartmiller(cmiller,emiller)=chartmiller(cmiller,
+      emiller)+1

      do 150 t=1,8
        m(t)=' '
150   Continue

      m(num)=Model_var

      do 160 v=1,4
        Good_model(v)=' '
160   continue

      emiller=0
      numvar=0
      ModelNotFound=.TRUE.

70    continue

      write(12,*) ' '
      write(12,*) '*****';
+      write(12,*) '*****';
      write(12,*) ' '

      IF (varsmiller.GT.0) THEN

```

```

    avgvars = real(varsmiller)/60.0
    avgevars = real(cumemiller)/60.0
    millerpm = 1-(avgevars/avgvars)
ELSEF
    avgvars=0
    avgevars=0
    millerpm=0
ENDIF

    write(12,*) 'The avg number of vars using
+ Miller''s',
+ ' method was ', avgvars
    write(12,*) 'The avg number of extraneous vars
+ from',
+ ' Miller''s method was', avgevars
    write(12,*) '***** The PM for Miller''s was ',
+ millerpm, ' *****'
    write(12,*) ' '
    write(12,*) ' '
    write(12,*) 'Correct Vars (0-3, down) -VS- ',
+ 'Extraneous Vars (0-3,across)'
    write(12,*) ' '
    write(12,*) ' Table for Miller''s Method'
    write(12,*) ' '
    do 170 w=0,3
        write(12,*) (chartmiller(w,x),x=0,3)
170        continue
    Write(13,*) n, ' ',millerpm

    do 180 y = 0,3
        do 190 z = 0,3
            chartmiller(y,z)=0
190        continue
180    continue

    varsmiller=0
    cumemiller=0

60    Continue
    Close(11)
    Close(12)
    Close(13)
    GO TO 1200

* Error trap: *****

1000    Continue
    Print 1100, '+++ ERROR WHILE OPENING FILE +++',
+ ' error code = ', IERROR
1100    FORMAT(/1X, A/ 1X, A, I8/)

```

```
1200  CONTINUE
      Print *, 'Counting complete. ', NewOut, ' written.'
      Go to 1300

90    Print *, 'End of File encountered at line ', ReadCount
      Print *, 'Design Point:', n, ' Replication:', p
      num=1
      Model var='**'
      EndOfFile=.TRUE.
      Go to 110

1300  CONTINUE
      END
```

```
*****
*****  FORTRAN PROGRAM STEPCOUNT3.FOR  *****
*****
```

SUBROUTINE Stepcount3 (NewOut)

```

integer num, numvar,h,i,j,k,n,p,q,r,s,t,v,w,x,y,z
integer emiller, varsmiller, cumemiller, cmiller
integer chartmiller(0:3,0:3), ReadCount
real avgvars, avgevars, millerpm
character*2 m(13), Model_var, Good_model(7), numchar
character*20 NewOut
logical ModelNotFound, EndOfFile

num=0
emiller=0
varsmiller=0
cumemiller=0
cmiller=0
ReadCount=0
ModelNotFound=.TRUE.
EndOfFile=.FALSE.

do 10 i=1,12
    m(i)=' '
10 continue

do 20 j=1,6
    Good_model(j)=' '
20 continue

do 30 k=0,3
    do 40 h=0,3
        chartmiller(k,h)=0
40 continue
30 continue

+ open (unit=11, file='temp.dat', status='old',
+       iostat=IERROR, err=1000)
+ open (unit=12, file=NewOut, status='new',
+       iostat=IERROR, err=1000)
+ open (unit=13, file='PMstep3.dat', status='new',
+       iostat=IERROR, err=1000)
write(13,*)'      DESIGNPOINT MILLER'S PM'

ReadCount=ReadCount+1
900 Read(11,900,end=90)numchar, Model_var
    Format(3X,A2,4X,A2)
    IF (numchar.EQ.' 1') THEN
        num=1

```



```

+       'in unexpected format: 1st number must be 1.'
      Go to 1300
    ELSE
      m(num)=Model_var
    ENDIF

    Do 60 n=2,64,2
      Write(12,*)' '
      Write(12,*)' '
      Write(12,*)' '
      Write(12,*)'***** DESIGN POINT ',
+       n,'*****'
      Write (12,*)' '
      Write(12,*)'Replication    #Vars    Model'

    do 70 p=1,50

80      Continue
      IF (EndOfFile) THEN
+      Print *, 'Unexpected file format! File does not ',
        'have the correct # of design points and reps.'
      Go to 1300
    ENDIF
    ReadCount=ReadCount+1
    Read(11,900,end=90) numchar, Model_var

    IF (numchar.EQ.' 1') THEN
      num=1
    ELSE
      IF(numchar.EQ.' 2') THEN
        num=2
      ELSE
        IF (numchar.EQ.' 3') THEN
          num=3
        ELSE
          IF (numchar.EQ.' 4') THEN
            num=4
          ELSE
            IF (numchar.EQ.' 5') THEN
              num=5
            ELSE
              IF (numchar.EQ.' 6') THEN
                num=6
              ELSE
                IF (numchar.EQ.' 7') THEN
                  num=7
                ELSE
                  IF (numchar.EQ.' 8') THEN
                    num=8
                  ELSE
                    IF (numchar.EQ.' 9') THEN
                      num=9

```

```

ELSE
  IF (numchar.EQ.'10') THEN
    num=10
  ELSE
    IF (numchar.EQ.'11') THEN
      num=11
    ELSE
      IF (numchar.EQ.'12') THEN
        num=12
      ELSE
        Print *, 'Unexpected format in TEMP.DAT: ',
          'Numbers 1,2,3, etc., not found!'
        Go to 1300
      ENDIF
    ENDIF
  ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
110 Continue
IF (num.NE.1) THEN
  m(num)=Model_var
ELSE
  continue
  do 100 q=1,6
  IF ((m(q)(1:1).NE.'R').AND.ModelNotFound) THEN
    Good_model(q)=m(q)
    numvar=numvar+1
  ELSE
    ModelNotFound=.FALSE.
  ENDIF
  continue
100 Write(12,901)p, numvar, (Good_model(r),r=1,6)
901 FORMAT (' ',4X,I2,11X,I2,6X,A2,1X,A2,1X,
+      A2,1X,A2,1X,A2,1X,A2)
      Go to 120
ENDIF
GO TO 80

120 continue
IF (numvar.LE.0) Go to 140
do 130 s=1,numvar
  if((m(s).EQ.'E1').OR.(m(s).EQ.'E2').OR.
+   (m(s).EQ.'E3')) then
    emiller=emiller+1

```

```

endif
130 continue

140 varsmiller=varsmiller+numvar
    cumemiller=cumemiller+emiller
    cmiller=numvar-emiller
    chartmiller(cmiller,emiller)=chartmiller(cmiller,
+      emiller)+1

do 150 t=1,12
    m(t)=' '
150 Continue

m(num)=Model_var

do 160 v=1,6
    Good_model(v)=' '
160 continue

emiller=0
numvar=0
ModelNotFound=.TRUE.

70 continue

write(12,*) ' '
write(12,*) '*****',
+ '*****'
write(12,*) ' '

IF (varsmiller.GT.0) THEN
    avgvars = real(varsmiller)/60.0
    avgevars = real(cumemiller)/60.0
    millerpm = 1-(avgevars/avgvars)
ELSE
    avgvars=0
    avgevars=0
    millerpm=0
ENDIF

write(12,*) 'The avg number of vars using Miller''s',
+ ' method was ', avgvars
write(12,*) 'The avg number of extraneous vars from',
+ ' Miller''s method was ', avgevars
write(12,*) '***** The PM for Miller''s was ',
+ millerpm, ' *****'
write(12,*) ' '
write(12,*) ' '
write(12,*) 'Correct Vars (0-3, down) -VS- ',
+ 'Extraneous Vars (0-3,across)'
write(12,*) ' '

```

```

        write(12,*) ' Table for Miller''s Method'
        write(12,*) ' '
        do 170 w=0,3
            write(12,*) (chartmiller(w,x),x=0,3)
170      continue
        Write(13,*) n,'      ',millerpm

        do 180 y = 0,3
            do 190 z = 0,3
                chartmiller(y,z)=0
190      continue
180      continue

        varsmiller=0
        cumemiller=0

60      Continue
        Close(11)
        Close(12)
        Close(13)
        GO TO 1200

* Error trap: *****

1000  Continue
        Print 1100, '+++ ERROR WHILE OPENING FILE +++',
+      '      error code = ', IERROR
1100  FORMAT(/1X, A/ 1X, A, IC/)

*****

1200  CONTINUE
        Print *, 'Counting complete. ', NewOut, ' written.'
        Go to 1300

90      Print*, 'End of File encountered at line ', ReadCount
        Print*, 'Design Point:', n, ' Replication:', p
        num=1
        Model var='**'
        EndOfFile=.TRUE.
        Go to 110

1300  CONTINUE
        END

```

```

*****
*                               TMSEP.FOR                               *
* This program takes SAS R-Squared listings in any file
* (with switches MSE, SP, CP, and B) and extracts models
* with the lowest MSE, Cp, and Sp. Then, using the original
* data files (01.dat, 02.dat,...,64.dat), it calculates the
* theoretical performance measure (TMSEP). This program
* calls subroutines * * TMSEP1.FOR, TMSEP2.FOR, TMSEP3.FOR,
* and TMSEP4.FOR and writes the calculated TMSEP's to
* TMSEP.DAT.
*****

```

```

Character*20 NewIn
Character*132 Line
CHARACTER I, J, K, L
Integer Var
Logical VarFlag, ErrFlag

5  Continue
   Print *, 'Name of file to examine? (20 char or less;',
+   ' " *" to quit)'
   Read (*, '(A20)') NewIn
   If (NewIn(1:1).EQ.'*') GO TO 999

7  Continue
   Print *, 'Number of extraneous variables? (1 or 3
+ONLY!!)'
   Read (*, '(I1)') Var
   If ((Var.NE.1).AND.(Var.NE.3)) Go To 7

   VarFlag = (Var.EQ.3)

   Open (unit=10, file=NewIn, status='OLD',
&       iostat=IERROR, err=1000)

   Open (unit=11, file='temp.dat', status='NEW',
&       iostat=IERROR, err=1000)

10 Continue
   Read(10,200,END=888) Line
   I = LINE (14:14)
   J = LINE (15:17)
   K = LINE (9:9)
   L = LINE (10:12)

   IF (VarFlag) GO TO 777

   IF ((I.EQ.'1').AND.(J.EQ.' ')) THEN
     WRITE (11,200) LINE
   ELSE

```

```
IF ((J.EQ.'2').AND.(J.EQ.' ')) THEN  
  WRITE (11,200) LINE  
ELSE
```

```
  IF ((I.EQ.'3').AND.(J.EQ.' ')) THEN  
    WRITE (11,200) LINE  
  ELSE
```

```
    IF ((I.EQ.'4').AND.(J.EQ.' ')) THEN  
      WRITE (11,200) LINE  
    ENDIF
```

```
  ENDIF
```

```
ENDIF
```

```
ENDIF
```

```
GO TO 10
```

```
777 Continue
```

```
IF ((K.EQ.'1').AND.(L.EQ.' ')) THEN  
  WRITE (11,200) LINE  
ELSE
```

```
  IF ((K.EQ.'2').AND.(L.EQ.' ')) THEN  
    WRITE (11,200) LINE  
  ELSE
```

```
    IF ((K.EQ.'3').AND.(L.EQ.' ')) THEN  
      WRITE (11,200) LINE  
    ELSE
```

```
      IF ((K.EQ.'4').AND.(L.EQ.' ')) THEN  
        WRITE (11,200) LINE  
      ELSE
```

```
        IF ((K.EQ.'5').AND.(L.EQ.' ')) THEN  
          WRITE (11,200) LINE  
        ELSE
```

```
          IF ((K.EQ.'6').AND.(L.EQ.' ')) THEN  
            WRITE (11,200) LINE  
          ENDIF
```

```
        ENDIF
```

```
      ENDIF
```

```
    ENDIF
```

```
  ENDIF
```

```

ENDIF

GO TO 10

200  Format (A132)
888  Continue
      Close(10)
      Close(11)

      Print *, 'Filtering complete on ', NewIn, '.',
+      ' TMSEP calculations begun.'

      ErrFlag = .FALSE.

      IF (VarFlag) THEN
        Call TMSEP3(ErrFlag)
        If (ErrFlag) Go to 5
        Print *, 'TMSEP''s calculated for designpoints with',
+      ' 3 extraneous variables and written to TMSEP3.DAT.'
        Print *, ' '
      ELSE
        Call TMSEP1(ErrFlag)
        If (ErrFlag) Go to 5
        Print *, 'TMSEP''s calculated for designpoints with',
+      ' 1 extraneous variables and written to
TMSEP1.DAT.'
        Print *, ' '
      ENDIF
      GO TO 5

999  Continue

      Print *, 'Processing complete. Program terminated.'
      Stop

* Error trap: *****
1000 Continue
      Print 1100, '+++ ERROR WHILE OPENING FILE +++',
+      ' error code = ', IERROR
1100 FORMAT(/1X, A/ 1X, A, I8/)
      GO TO 5
*****
      END

```

```

*****
*                                     FORTRAN PROGRAM TMSEP1.FOR
*
* This program is designed to take a modified SAS program and
* an existing data set and find the "real" MSEP for the
* models chosen by mse, sp, and cp criteria.
*****

```

```

      Subroutine TMSEP1(ErrFlag)

      Integer h,i,j,k,p,r,s,ptrmse,ptrsp,ptrcp
      Integer check(4),num(15)

      Real b0(15),r2(15),cp(15),mse(15),sp(15),betas(4,15)
      Real x(4,20),x3ex1(4,20),ex,y
      Real minmse,mincp,minsp
      Real ypredcp,ypredmse,ypredsp
      Real ymsepmse,ymsepsp,ymsepcp
      Real ysepmse,yssepsp,yssepcp
      Real sumyssepmse,sumyssepsp,sumyssepcp
      Real sumdifmse,sumdifsp,sumdifcp
      Real dpymsepmse,dpymsepsp,dpymsepcp

      Character*6 Infile

      Logical ErrFlag
      check(1)=1
      check(2)=5
      check(3)=11
      check(4)=15

      Open(unit=11,file='TEMP.DAT',status='old',
+ iostat=IERROR,err=1000)
      Open (unit=13,file='TMSEP1.DAT',status='new',
+ iostat=IERROR,err=1002)

      Write (13,902)
902  Format (1X,'TMSEPs calculated for the following
+ methods:')

      Write (13,901)
901  Format (1X,'DP',9X,'MSE',13X,'SP',13X,'CP')

      Do 5 r=1,63,2

      If (r.EQ.1) then
        Infile='01.dat'
      Else
        If (r.EQ.3) then
          Infile='03.dat'
        Else
          If (r.EQ.5) then

```

```

Infile='05.dat'
Else
If (r.EQ.7) then
  Infile='07.dat'
Else
If (r.EQ.9) then
  Infile='09.dat'
Else
If (r.EQ.11) then
  Infile='11.dat'
Else
If (r.EQ.13) then
  Infile='13.dat'
Else
If (r.EQ.15) then
  Infile='15.dat'
Else
If (r.EQ.17) then
  Infile='17.dat'
Else
If (r.EQ.19) then
  Infile='19.dat'
Else
If (r.EQ.21) then
  Infile='21.dat'
Else
If (r.EQ.23) then
  Infile='23.dat'
Else
If (r.EQ.25) then
  Infile='25.dat'
Else
If (r.EQ.27) then
  Infile='27.dat'
Else
If (r.EQ.29) then
  Infile='29.dat'
Else
If (r.EQ.31) then
  Infile='31.dat'
Else
If (r.EQ.33) then
  Infile='33.dat'
Else
If (r.EQ.35) then
  Infile='35.dat'
Else
If (r.EQ.37) then
  Infile='37.dat'
Else
If (r.EQ.39) then
  Infile='39.dat'

```



```

Endif
If (cp(check(j)).lt.mincp) then
  mincp = cp(check(j))
  ptrcp = check(j)
Endif
30 Continue

If(((r.GE.17).AND.(r.LE.32)).OR.(r.GE.49)) then
  s = 20
Else
  s = 10
Endif

Do 50 h= 1,s

  Read (12,*,end=1004) set,y,x(1,h),x(2,h),x(3,h),
+   x(4,h),ex

  ypredmse= b0(ptrmse)
  ypredsp = b0(ptrsp)
  ypredcp = b0(ptrcp)
  yactual = 0
  x3ex1(1,h)= x(1,h)
  x3ex1(2,h)= x(2,h)
  x3ex1(3,h)= x(3,h)
  x3ex1(4,h)= ex

  Do 60 p=1,4
    yactual = yactual+x(p,h)
60 Continue

  Do 70 p=1,4
    ypredmse = ypredmse + betas(p,ptrmse)*x3ex1(p,h)
    ypredsp = ypredsp + betas(p,ptrsp) *x3ex1(p,h)
    ypredcp = ypredcp + betas(p,ptrcp) *x3ex1(p,h)
70 Continue

+   yssepms = ((ypredmse-yactual)**real(2)) +
    yssepms
    yssepsp = ((ypredsp -yactual)**real(2)) + yssepsp
    yssepcp = ((ypredcp -yactual)**real(2)) + yssepcp

50 Continue

sumyssepms = sumyssepms + yssepms
sumyssepsp = sumyssepsp + yssepsp
sumyssepcp = sumyssepcp + yssepcp
sumdifms = sumdifms + (s-num(ptrmse))
sumdifsp = sumdifsp + (s-num(ptrsp))
sumdifcp = sumdifcp + (s-num(ptrcp))

20 Continue

```

```

dpymsepmse = sumyssepmse / sumdifmse
dpymsepsp  = sumyssepsp  / sumdirsp
dpymsepcp  = sumyssepcp  / sumdifcp

900  Write(13,900) r, dpymsepmse, dpymsepsp, dpymsepcp
      Format (1X,I2,5X,F10.6,5X,F10.6,5X,F10.6)

      Close (12)

5     Continue

      Close (11)
      Close (13)
      Go to 1300
*****Error trap*****

1000  Print *, 'Something''s wrong with TEMP.DAT.'
      Go to 1100
1001  Print *, 'Something''s wrong with ',Infile
      Go to 1100
1002  Print *, 'Can''t seem to create TMSEP1.DAT.'
      Go to 1100
1003  Print *, 'TEMP.DAT in unexpected format.'
      Go to 1300
1004  Print *, 'File ',Infile,' is in an unexpected format.'
      Go to 1300

1100  Continue
      Print 1200, '+++ ERROR WHILE OPENING FILE +++',
+      error code = ',IERROR
1200  Format (/1X, A/ 1X, A, I8')
      ErrFlag = .TRUE.
*****
1300  Continue

      END

```

```

*****
*                               FORTRAN PROGRAM TMSEP3.FOR
*
* This program is designed to take a modified SAS program and
* an existing data set and find the "real" MSE for the
* models chosen by mse, sp, and cp criteria.
*
*****

```

```

Subroutine TMSEP3(ErrFlag)

```

```

Integer h,i,j,k,p,r,s,ptmsep,ptrsp,ptrcp
Integer check(6),num(63)

```

```

Real b0(63),r2(63),cp(63),mse(63),sp(63),betas(6,63)
Real x(4,20),x3ex3(6,20),y,ex1,ex2,ex3
Real minmse,mincp,minsp
Real ypredcp,ypredmse,ypredsp
Real ymsepmse,ymsepsp,ymsepcp
Real yssepmse,yssepsp,yssepcp
Real sumyssepmse,sumyssepsp,sumyssepcp
Real sumdifmse,sumdifsp,sumdifcp
Real dpymsepmse,dpymsepsp,dpymsepcp

```

```

Character*6 Infile

```

```

Logical ErrFlag
check(1)=1
check(2)=7
check(3)=22
check(4)=42
check(5)=57
check(6)=63

```

```

Open(unit=11,file='TEMP.DAT',status='old',
+iostat=IERROR,err=1000)
Open (unit=13,file='TMSEP3.DAT',status='new',
+iostat=IERROR,err=1002)

```

```

902 Write (13,902)
Format (1X,'TMSEPs calculated for the following
+ method: ')

```

```

901 Write (13,901)
Format (1X,'DP',9X,'MSE',13X,'SP',13X,'CP')

```

```

Do 5 r=2,64,2

```

```

If (r.EQ.2) then
Infile='02.dat'
Else
If (r.EQ.4) then

```

```

Infile='04.dat'
Else
  If (r.EQ.6) then
    Infile='06.dat'
  Else
    If (r.EQ.8) then
      Infile='08.dat'
    Else
      If (r.EQ.10) then
        Infile='10.dat'
      Else
        If (r.EQ.12) then
          Infile='12.dat'
        Else
          If (r.EQ.14) then
            Infile='14.dat'
          Else
            If (r.EQ.16) then
              Infile='16.dat'
            Else
              If (r.EQ.18) then
                Infile='18.dat'
              Else
                If (r.EQ.20) then
                  Infile='20.dat'
                Else
                  If (r.EQ.22) then
                    Infile='22.dat'
                  Else
                    If (r.EQ.24) then
                      Infile='24.dat'
                    Else
                      If (r.EQ.26) then
                        Infile='26.dat'
                      Else
                        If (r.EQ.28) then
                          Infile='28.dat'
                        Else
                          If (r.EQ.30) then
                            Infile='30.dat'
                          Else
                            If (r.EQ.32) then
                              Infile='32.dat'
                            Else
                              If (r.EQ.34) then
                                Infile='34.dat'
                              Else
                                If (r.EQ.36) then
                                  Infile='36.dat'
                                Else
                                  If (r.EQ.38) then
                                    Infile='38.dat'

```

```

Else
  If (r.EQ.40) then
    Infile='40.dat'
  Else
    If (r.EQ.42) then
      Infile='42.dat'
    Else
      If (r.EQ.44) then
        Infile='44.dat'
      Else
        If (r.EQ.46) then
          Infile='46.dat'
        Else
          If (r.EQ.48) then
            Infile='48.dat'
          Else
            If (r.EQ.50) then
              Infile='50.dat'
            Else
              If (r.EQ.52) then
                Infile='52.dat'
              Else
                If (r.EQ.54) then
                  Infile='54.dat'
                Else
                  If (r.EQ.56) then
                    Infile='56.dat'
                  Else
                    If (r.EQ.58) then
                      Infile='58.dat'
                    Else
                      If (r.EQ.60) then
                        Infile='60.dat'
                      Else
                        If (r.EQ.62) then
                          Infile='62.dat'
                        Else
                          If (r.EQ.64) then
                            Infile='64.dat'
                          Endif
                        Endif
                      Endif
                    Endif
                  Endif
                Endif
              Endif
            Endif
          Endif
        Endif
      Endif
    Endif
  Endif
Endif

```

```

                                Endif
                                Endif
                                Endif
                                Endif
                                Endif
                                Endif
                                Endif
                                Endif
                                Endif
                                Endif
                                Endif
                                Endif
                                Endif
                                Endif
                                Endif
                                Endif
                                Endif
                                Open(unit=12,file=Infile,status='old',iostat=IERROR,
+                               err=1001)

sumyssepmsp = 0
sumyssepsp = 0
sumyssepcp = 0
sumdifmse = 0
sumdifsp = 0
sumdifcp = 0

Do 20 k=1,60

    minmse = 10000
    minsp = 10000
    mincp = 10000
    yssepmsp=0
    yssepsp =0
    yssencp =0
    ptrmse = 0
    ptrsp = 0
    ptrcp = 0

    Do 10 i=1,63
        Read (11,*,end=1003) num(i), r2(i), cp(1),
+       mse(i), sp(i), b0(i), betas(1,i), betas(2,i),
+       betas(3,i), betas(4,i),
+       betas(5,i), betas(6,i)
    Continue

    Do 30 j=1,6
        If(mse(check(j)).lt.minmse) then
            minmse = mse(check(j))
            ptrmse = check(j)

```

```

        Endif
        If (sp(check(j)).lt.minsp) then
            minsp = sp(check(j))
            ptrap = check(j)
        Endif
        If (cp(check(j)).lt.mincp) then
            mincp = cp(check(j))
            ptrcp = check(j)
        Endif
30      Continue

      If ((r.GE.17).AND.(r.LE.32)).OR.(r.GE.49)) then
          s = 20
      Else
          s = 10
      Endif

      Do 50 h= 1,s

          Read (12,*,end=1004) set,y,x(1,h),x(2,h),
+          x(3,h),x(4,h),ex1,ex2,ex3

          ypredmse= b0(ptrmse)
          ypredsp = b0(ptrsp)
          ypredcp = b0(ptrcp)
          yactual = 0
          x3ex3(1,h)= x(1,h)
          x3ex3(2,h)= x(2,h)
          x3ex3(3,h)= x(3,h)
          x3ex3(4,h)= ex1
          x3ex3(5,h)= ex2
          x3ex3(6,h)= ex3

          Do 60 p=1,4
              yactual = yactual+x(p,h)
60          Continue

          Do 70 p=1,6
              ypredmse = ypredmse + betas(p,ptrmse)*x3ex3(p,h)
              ypredsp = ypredsp + betas(p,ptrsp) *x3ex3(p,h)
              ypredcp = ypredcp + betas(p,ptrcp) *x3ex3(p,h)
70          Continue

          yssepmse = ((ypredmse-yactual)**real(2)) +
+          yssepmse
          yssepsp = ((ypredsp -yactual)**real(2)) + yssepsp
          yssepcp = ((ypredcp -yactual)**real(2)) + yssepcp

50      Continue

      sumyssepmse = sumyssepmse + yssepmse
      sumyssepsp = sumyssepsp + yssepsp

```

```

sumyssepcp = sumyssepcp + yssepcp
sumdifmse = sumdifmse + (s-num(ptrmse))
sumdifsp = sumdifsp + (s-num(ptrsp))
sumdifcp = sumdifcp + (s-num(ptrcp))

20      Continue

      dpymsepmse = sumyssepmse / sumdifmse
      dpymsepsp = sumyssepsp / sumdifsp
      dpymsepcp = sumyssepcp / sumdifcp

900      Write(13,900) r, dpymsepmse, dpymsepsp, dpymsepcp
      Format (1X,I2,5X,F10.6,5X,F10.6,5X,F10.6)

      Close (12)

5      Continue

      Close (11)
      Close (13)
      Go to 1300
*****Error trap*****

1000      Print *, 'Something''s wrong with TEMP.DAT.'
      Go to 1100
1001      Print *, 'Something''s wrong with ',Infile
      Go to 1100
1002      Print *, 'Can''t seem to create TMSEP3.DAT.'
      Go to 1100
1003      Print *, 'TEMP.DAT in unexpected format.'
      Go to 1300
1004      Print *, 'File ',Infile,' is in an unexpected format.'
      Go to 1300

1100      Continue
      Print 1200, '+++ ERROR WHILE OPENING FILE +++',
+          '          error code = ',IERROR
1200      Format (/1X, A/ 1X, A, I8/)
      ErrFlag = .TRUE.
*****

1300      Continue

      END

```

Appendix J. SAS Programs

List of SAS Programs

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```

;                               SAS Program ERROR1_ALL.SAS
;
option linesize=80;
filename new '01.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 ;
proc rsquare data=new  mse sp cp;
by set;
  model y= x1 x2 x3 e1  ;

filename new '03.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 ;
proc rsquare data=new  mse sp cp;
by set;
  model y= x1 x2 x3 e1  ;

filename new '05.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 ;
proc rsquare data=new  mse sp cp;
by set;
  model y= x1 x2 x3 e1  ;

filename new '07.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 ;
proc rsquare data=new  mse sp cp;
by set;
  model y= x1 x2 x3 e1  ;
.
.
.
.
.
.
.
filename new '63.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 ;
proc rsquare data=new  mse sp cp;
by set;
  model y= x1 x2 x3 e1  ;

```

```

;                               SAS Program ERROR3_ALL.SAS
;
option linesize=80;
filename new '02.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3 @;
proc rsquare data=new  mse sp cp;
by set;
model y= x1 x2 x3 e1 e2 e3;

filename new '04.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3 @;
proc rsquare data=new  mse sp cp;
by set;
model y= x1 x2 x3 e1 e2 e3;

filename new '06.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3 @;
proc rsquare data=new  mse sp cp;
by set;
model y= x1 x2 x3 e1 e2 e3 ;

filename new '08.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3 @;
proc rsquare data=new  mse sp cp;
by set;
model y= x1 x2 x3 e1 e2 e3 ;

.
.
.
.
.
.
.
.
.
filename new '64.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3 @;
proc rsquare data=new  mse sp cp;
by set;
model y= x1 x2 x3 e1 e2 e3 ;

```

```
;
;
;          SAS Program MILLER1BETA.SAS
;
```

```
FILENAME NEW '01.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1;
IF SETNUM^= 1 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X1 X3 X2 /INCLUDE=3;
```

```
FILENAME NEW '01.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1;
IF SETNUM^= 2 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X1 X3 X2 /INCLUDE=3;
```

```
FILENAME NEW '01.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1;
IF SETNUM^= 3 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X2 /INCLUDE=1;
```

```
FILENAME NEW '01.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1;
IF SETNUM^= 4 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X3 /INCLUDE=1;
```

```
FILENAME NEW '01.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1;
IF SETNUM^= 5 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X1 X3 /INCLUDE=2;
```

```
FILENAME NEW '01.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1;
IF SETNUM^= 6 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X1 X3 E1 /INCLUDE=3;
```

```
.
.
```

.
. .
. .
. .

```
FILENAME NEW '03.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1;
IF SETNUM^= 1 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X1 X3 X2 E1 /INCLUDE=4;
```

```
FILENAME NEW '03.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1;
IF SETNUM^= 2 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X1 X3 /INCLUDE=2;
```

```
FILENAME NEW '03.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1;
IF SETNUM^= 3 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X1 X2 X3 /INCLUDE=3;
```

```
FILENAME NEW '03.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1;
IF SETNUM^= 4 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X3 X2 X1 E1 /INCLUDE=4;
```

```
FILENAME NEW '03.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1;
IF SETNUM^= 5 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X3 X1 /INCLUDE=2;
```

```
FILENAME NEW '03.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1;
IF SETNUM^= 6 THEN DELETE;
PROC RSQUARE DATA=NEW B;
```

MODEL Y = X3 X1 X2 /INCLUDE=3;

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FILENAME NEW '63.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1;
IF SETNUM^= 1 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X1 X3 X2 E1 /INCLUDE=4;

FILENAME NEW '63.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1;
IF SETNUM^= 2 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X1 X2 X3 /INCLUDE=3;

FILENAME NEW '63.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1;
IF SETNUM^= 3 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X3 X2 X1 E1 /INCLUDE=4;

FILENAME NEW '63.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1;
IF SETNUM^= 4 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X3 X2 X1 /INCLUDE=3;

FILENAME NEW '63.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1;
IF SETNUM^= 5 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X2 X1 X3 /INCLUDE=3;

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```
FILENAME NEW '63.dat';  
DATA NEW;  
INFILE NEW;  
INPUT SETNUM Y X1 X2 X3 X4 E1;  
IF SETNUM^=60 THEN DELETE;  
PROC RSQUARE DATA=NEW B;  
MODEL Y = X2 X1 X3 /INCLUDE=3;
```

```
;
;
;          SAS Program MILLER3BETA.SAS
```

```
FILENAME NEW '02.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;
IF SETNUM^= 1 THEN DELETE;
INTERCEP = 1;
PROC RSQUARE DATA=NEW NOINT B;
MODEL Y = INTERCEP;
```

```
FILENAME NEW '02.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;
IF SETNUM^= 2 THEN DELETE;
INTERCEP = 1;
PROC RSQUARE DATA=NEW NOINT B;
MODEL Y = INTERCEP;
```

```
FILENAME NEW '02.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;
IF SETNUM^= 3 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X3 E2 X2          /INCLUDE=3;
```

```
FILENAME NEW '02.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;
IF SETNUM^= 4 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X3 X2 X1          /INCLUDE=3;
```

```
FILENAME NEW '02.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;
IF SETNUM^= 5 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X1 X3 E1          /INCLUDE=3;
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```

FILENAME NEW '04.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;
IF SETNUM^= 1 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X2 X3 X1 /INCLUDE=3;

```

```

FILENAME NEW '04.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;
IF SETNUM^= 2 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X2 X1 X3 /INCLUDE=3;

```

```

FILENAME NEW '04.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;
IF SETNUM^= 3 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X2 X3 /INCLUDE=2;

```

```

FILENAME NEW '04.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;
IF SETNUM^= 4 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X3 /INCLUDE=1;

```

```

FILENAME NEW '04.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;
IF SETNUM^= 5 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X2 X1 X3 /INCLUDE=3;

```

```

FILENAME NEW '04.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;
IF SETNUM^= 6 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X2 X1 /INCLUDE=2;

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```

FILENAME NEW '64.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;
IF SETNUM^= 1 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X2 X3 X1 /INCLUDE=3;

```

```

FILENAME NEW '64.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;
IF SETNUM^= 2 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X2 X3 X1 E3 E2 /INCLUDE=5;

```

```

FILENAME NEW '64.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;
IF SETNUM^= 3 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X1 X2 X3 /INCLUDE=3;

```

```

FILENAME NEW '64.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;
IF SETNUM^= 4 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X3 X2 /INCLUDE=2;

```

```

FILENAME NEW '64.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;
IF SETNUM^= 5 THEN DELETE;
PROC RSQUARE DATA=NEW B;
MODEL Y = X1 X2 X3 E1 /INCLUDE=4;

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FILENAME NEW '64.dat';
DATA NEW;
INFILE NEW;
INPUT SETNUM Y X1 X2 X3 X4 E1 E2 E3;

```

```
IF SETNUM^=60 THEN DELETE;  
PROC RSQUARE DATA=NEW B;  
MODEL Y = X2 X1 X3 /INCLUDE=3;
```

```

;                               SAS Program PM.SAS
;
option linesize=80;
filename new 'PM.dat';
data new;
infile new;
input  DP ymse ysp ycp YMILLERS CONST A B AB C AC BC ABC D
AD BD ABD
      CD ACD BCD ABCD E AE BE ABE CE ACE BCE ABCE DE
      ADE BDE ABDE CDE ACDE BCDE ABCDE F AF BF ABF CF ACF
      BCF ABCF DF ADF BDF ABDF CDF ACDF BCDF ABCDF EF AEF
BEF
      ABEF CEF ACEF BCEF ABCEF DEF ADEF BDEF ABDEF CDEF
ACDEF BCDEF ABCDEF;

PROC PRINT;
TITLE 'Analysis of Performance Measures and Significant
Contributing Factors';
ID DP;
VAR ymse ysp ycp YMILLERS CONST A B AB C AC BC ABC D AD BD
ABD
      CD ACD BCD ABCD E AE BE ABE CE ACE BCE ABCE DE
      ADE BDE ABDE CDE ACDE BCDE ABCDE F AF BF ABF CF ACF
      BCF ABCF DF ADF BDF ABDF CDF ACDF BCDF ABCDF EF AEF
BEF
      ABEF CEF ACEF BCEF ABCEF DEF ADEF BDEF ABDEF CDEF
ACDEF BCDEF ABCDEF;

proc stepwise;
  model ymse = A B AB C AC BC ABC D AD BD ABD
            CD ACD BCD ABCD E AE BE ABE CE ACE BCE ABCE DE
            ADE BDE ABDE CDE ACDE BCDE ABCDE F AF BF ABF CF ACF
            BCF ABCF DF ADF BDF ABDF CDF ACDF BCDF ABCDF EF AEF
BEF
            ABEF CEF ACEF BCEF ABCEF DEF ADEF BDEF ABDEF CDEF
ACDEF BCDEF ABCDEF
            / stepwise slstay=.01;

proc stepwise;
  model ysp = A B AB C AC BC ABC D AD BD ABD
            CD ACD BCD ABCD E AE BE ABE CE ACE BCE ABCE DE
            ADE BDE ABDE CDE ACDE BCDE ABCDE F AF BF ABF CF ACF
            BCF ABCF DF ADF BDF ABDF CDF ACDF BCDF ABCDF EF AEF
BEF
            ABEF CEF ACEF BCEF ABCEF DEF ADEF BDEF ABDEF CDEF
ACDEF BCDEF ABCDEF
            / stepwise slstay=.01;

proc stepwise;
  model ycp = A B AB C AC BC ABC D AD BD ABD

```

```

CD ACD BCD ABCD E AE BE ABE CE ACE BCE ABCE DE
ADE BDE ABDE CDE ACDE BCDE ABCDE F AF BF ABF CF ACF
BCF ABCF DF ADF BDF ABDF CDF ACDF BCDF ABCDF EF AEF
BEF
ABEF CEF ACEF BCEF ABCEF DEF ADEF BDEF ABDEF CDEF
ACDEF BCDEF ABCDEF
/ stepwise slstay=.01;

proc stepwise;
model YMILLERS = A B AB C AC BC ABC D AD BD ABD
CD ACD BCD ABCD E AE BE ABE CE ACE BCE ABCE DE
ADE BDE ABDE CDE ACDE BCDE ABCDE F AF BF ABF CF ACF
BCF ABCF DF ADF BDF ABDF CDF ACDF BCDF ABCDF EF AEF
BEF
ABEF CEF ACEF BCEF ABCEF DEF ADEF BDEF ABDEF CDEF
ACDEF BCDEF ABCDEF
/ stepwise slstay=.01;

```

```

;                               SAS Program STEP11_ALL.SAS
;
option linesize=80 pagesize=57;
filename new '01.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);
  r3=RANNOR(0);
  r4=RANNOR(0);
proc stepwise data=randset;
  by set;
  model y= x1 x2 x3 e1 r1 r2 r3 r4 /forward slentry=1;

filename new '03.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);
  r3=RANNOR(0);
  r4=RANNOR(0);
proc stepwise data=randset;
  by set;
  model y= x1 x2 x3 e1 r1 r2 r3 r4 /forward slentry=1;
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.
filename new '31.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);
  r3=RANNOR(0);
  r4=RANNOR(0);
proc stepwise data=randset;
  by set;
  model y= x1 x2 x3 e1 r1 r2 r3 r4 /forward slentry=1;

```

```

;          SAS Program STEP12_ALL.SAS
;
option linesize=80 pagesize=57;
filename new '33.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);
  r3=RANNOR(0);
  r4=RANNOR(0);
proc stepwise data=randset;
  by set;
  model y= x1 x2 x3 e1 r1 r2 r3 r4 /forward slentry=1;

filename new '35.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);
  r3=RANNOR(0);
  r4=RANNOR(0);
proc stepwise data=randset;
  by set;
  model y= x1 x2 x3 e1 r1 r2 r3 r4 /forward slentry=1;
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.
filename new '63.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);
  r3=RANNOR(0);
  r4=RANNOR(0);
proc stepwise data=randset;
  by set;
  model y= x1 x2 x3 e1 r1 r2 r3 r4 /forward slentry=1;

```

```

;          SAS Program STEP31_ALL.SAS
;
option linesize=80 pagesize=57;
filename new '02.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);
  r3=RANNOR(0);
  r4=RANNOR(0);
  r5=RANNOR(0);
  r6=RANNOR(0);
proc stepwise data=randset;
  by set;
  model y= x1 x2 x3 e1 e2 e3 r1 r2 r3 r4 r5 r6 /forward
  slentry=1;

filename new '04.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);
  r3=RANNOR(0);
  r4=RANNOR(0);
  r5=RANNOR(0);
  r6=RANNOR(0);
proc stepwise data=randset;
  by set;
  model y= x1 x2 x3 e1 e2 e3 r1 r2 r3 r4 r5 r6 /forward
  slentry=1;
.
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.
filename new '16.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);
  r3=RANNOR(0);
  r4=RANNOR(0);

```

```
r5=RANNOR(0);  
r6=RANNOR(0);  
proc stepwise data=randset;  
  by set;  
  model y= x1 x2 x3 e1 e2 e3 r1 r2 r3 r4 r5 r6 /forward  
slentry=1;
```

```

;          SAS Program STEP32_ALL.SAS
;
option linesize=80 pagesize=57;
filename new '18.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);
  r3=RANNOR(0);
  r4=RANNOR(0);
  r5=RANNOR(0);
  r6=RANNOR(0);
proc stepwise data=randset;
  by set;
  model y= x1 x2 x3 e1 e2 e3 r1 r2 r3 r4 r5 r6 /forward
slentry=1;

filename new '20.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);
  r3=RANNOR(0);
  r4=RANNOR(0);
  r5=RANNOR(0);
  r6=RANNOR(0);
proc stepwise data=randset;
  by set;
  model y= x1 x2 x3 e1 e2 e3 r1 r2 r3 r4 r5 r6 /forward
slentry=1;
.
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.
filename new '32.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);
  r3=RANNOR(0);

```

```
r4=RANNOR(0);  
r5=RANNOR(0);  
r6=RANNOR(0);  
proc stepwise data=randset;  
  by set;  
  model y= x1 x2 x3 e1 e2 e3 r1 r2 r3 r4 r5 r6 /forward  
slentry=1;
```

```

;                               SAS Program STEP33_ALL.SAS
;
option linesize=80 pagesize=57;
filename new '34.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);
  r3=RANNOR(0);
  r4=RANNOR(0);
  r5=RANNOR(0);
  r6=RANNOR(0);
proc stepwise data=randset;
  by set;
  model y= x1 x2 x3 e1 e2 e3 r1 r2 r3 r4 r5 r6 /forward
  slentry=1;

filename new '36.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);
  r3=RANNOR(0);
  r4=RANNOR(0);
  r5=RANNOR(0);
  r6=RANNOR(0);
proc stepwise data=randset;
  by set;
  model y= x1 x2 x3 e1 e2 e3 r1 r2 r3 r4 r5 r6 /forward
  slentry=1;
.
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.
filename new '48.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);
  r3=RANNOR(0);

```

```
r4=RANNOR(0);  
r5=RANNOR(0);  
r6=RANNOR(0);  
proc stepwise data=randset;  
  by set;  
  model y= x1 x2 x3 e1 e2 e3 r1 r2 r3 r4 r5 r6 /forward  
slentry=1;
```

```

;          SAS Program STEP34_ALL.SAS
;
option linesize=80 pagesize=57;
filename new '50.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);
  r3=RANNOR(0);
  r4=RANNOR(0);
  r5=RANNOR(0);
  r6=RANNOR(0);
proc stepwise data=randset;
  by set;
  model y= x1 x2 x3 e1 e2 e3 r1 r2 r3 r4 r5 -6 /forward
slentry=1;

filename new '52.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);
  r3=RANNOR(0);
  r4=RANNOR(0);
  r5=RANNOR(0);
  r6=RANNOR(0);
proc stepwise data=randset;
  by set;
  model y= x1 x2 x3 e1 e2 e3 r1 r2 r3 r4 r5 r6 /forward
slentry=1;
.
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filename new '64.dat';
data dataset;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3;
data randset;
  set dataset;
  r1=RANNOR(0);
  r2=RANNOR(0);

```

```
r3=RANNOR(0);  
r4=RANNOR(0);  
r5=RANNOR(0);  
r6=RANNOR(0);  
proc stepwise data=randset;  
  by set;  
  model y= x1 x2 x3 e1 e2 e3 r1 r2 r3 r4 r5 r6 /forward  
  slentry=1;
```

```

;                               SAS Program TM.SAS
;
option linesize=80;
filename new 'TM.dat';
data new;
infile new;
input  DP ymse ysp ycp YMILLERS CONST A B AB C AC BC ABC D
AD BD ABD
      CD ACD BCD ABCD E AE BE ABE CE ACE BCE ABCE DE
      ADE BDE ABDE CDE ACDE BCDE ABCDE F AF BF ABF CF ACF
      BCF ABCF DF ADF BDF ABDF CDF ACDF BCDF ABCDF EF AEF
BEF
      ABEF CEF ACEF BCEF ABCEF DEF ADEF BDEF ABDEF CDEF
ACDEF BCDEF ABCDEF;

PROC PRINT;
TITLE 'Analysis of Performance Measures and Significant
Contributing Factors';
ID DP;
VAR ymse ysp ycp YMILLERS CONST A B AB C AC BC ABC D AD BD
ABD
      CD ACD BCD ABCD E AE BE ABE CE ACE BCE ABCE DE
      ADE BDE ABDE CDE ACDE BCDE ABCDE F AF BF ABF CF ACF
      BCF ABCF DF ADF BDF ABDF CDF ACDF BCDF ABCDF EF AEF
BEF
      ABEF CEF ACEF BCEF ABCEF DEF ADEF BDEF ABDEF CDEF
ACDEF BCDEF ABCDEF;

proc stepwise;
model ymse = A B AB C AC BC ABC D AD BD ABD
      CD ACD BCD ABCD E AE BE ABE CE ACE BCE ABCE DE
      ADE BDE ABDE CDE ACDE BCDE ABCDE F AF BF ABF CF ACF
      BCF ABCF DF ADF BDF ABDF CDF ACDF BCDF ABCDF EF AEF
BEF
      ABEF CEF ACEF BCEF ABCEF DEF ADEF BDEF ABDEF CDEF
ACDEF BCDEF ABCDEF
      / stepwise slstay=.01;

proc stepwise;
model ysp = A B AB C AC BC ABC D AD BD ABD
      CD ACD BCD ABCD E AE BE ABE CE ACE BCE ABCE DE
      ADE BDE ABDE CDE ACDE BCDE ABCDE F AF BF ABF CF ACF
      BCF ABCF DF ADF BDF ABDF CDF ACDF BCDF ABCDF EF AEF
BEF
      ABEF CEF ACEF BCEF ABCEF DEF ADEF BDEF ABDEF CDEF
ACDEF BCDEF ABCDEF
      / stepwise slstay=.01;

proc stepwise;
model ycp = A B AB C AC BC ABC D AD BD ABD

```

```

CD ACD BCD ABCD E AE BE ABE CE ACE BCE ABCE DE
ADE BDE ABDE CDE ACDE BCDE ABCDE F AF BF ABF CF ACF
BCF ABCF DF ADF BDF ABDF CDF ACDF BCDF ABCDF EF AEF
BEF
ABEF CEF ACEF BCEF ABCEF DEF ADEF BDEF ABDEF CDEF
ACDEF BCDEF ABCDEF
/ stepwise slstay=.01;

proc stepwise;
model YMILLERS = A B AB C AC BC ABC D AD BD ABD
CD ACD BCD ABCD E AE BE ABE CE ACE BCE ABCE DE
ADE BDE ABDE CDE ACDE BCDE ABCDE F AF BF ABF CF ACF
BCF ABCF DF ADF BDF ABDF CDF ACDF BCDF ABCDF EF AEF
BEF
ABEF CEF ACEF BCEF ABCEF DEF ADEF BDEF ABDEF CDEF
ACDEF BCDEF ABCDEF
/ stepwise slstay=.01;

```

```

;          SAS Program TMSEP1_ALL.SAS
;
filename new '01.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 ;
proc rsquare data=new  mse sp cp b;
by set;
  model y= x1 x2 x3 e1  ;

filename new '03.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 ;
proc rsquare data=new  mse sp cp b;
by set;
  model y= x1 x2 x3 e1  ;

filename new '05.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 ;
proc rsquare data=new  mse sp cp b;
by set;
  model y= x1 x2 x3 e1  ;

filename new '07.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 ;
proc rsquare data=new  mse sp cp b;
by set;
  model y= x1 x2 x3 e1  ;

filename new '09.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 ;
proc rsquare data=new  mse sp cp b;
by set;
  model y= x1 x2 x3 e1  ;
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.
filename new '63.dat';
data new;
infile new;

```

```
input set y x1 x2 x3 x4 e1 ;  
proc rsquare data=new mse sp cp b;  
by set;  
model y= x1 x2 x3 e1 ;
```

```

;          SAS Program TMSEP3_ALL.SAS
;
filename new '02.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3 @;
proc rsquare data=new  mse sp cp b;
by set;
  model y= x1 x2 x3 e1 e2 e3;

filename new '04.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3 @;
proc rsquare data=new  mse sp cp b;
by set;
  model y= x1 x2 x3 e1 e2 e3;

filename new '06.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3 @;
proc rsquare data=new  mse sp cp b;
by set;
  model y= x1 x2 x3 e1 e2 e3 ;

filename new '08.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3 @;
proc rsquare data=new  mse sp cp b;
by set;
  model y= x1 x2 x3 e1 e2 e3 ;

filename new '10.dat';
data new;
infile new;
input  set y x1 x2 x3 x4 e1 e2 e3 @;
proc rsquare data=new  mse sp cp b;
by set;
  model y= x1 x2 x3 e1 e2 e3 ;
.
.
.
.
.
.
.
filename new '64.dat';
data new;
infile new;

```

```
input set y x1 x2 x3 x4 e1 e2 e3 @;  
proc rsquare data=new mse sp cp b;  
by set;  
model y= x1 x2 x3 e1 e2 e3 ;
```

Appendix K: Calculated Performance Measure Values for PM

DP	MSE _{pm}	S _{p pm}	C _{p pm}	MILLERS _{pm}
1	0.8483146	0.9230769	0.9121622	0.8721805
2	0.6313559	0.7272727	0.7127072	0.7578948
3	0.8560000	0.9203821	0.9102167	0.9187500
4	0.6569038	0.7414248	0.7315789	0.8616352
5	0.8682311	0.9304348	0.9178947	0.9230769
6	0.6528354	0.7266436	0.7217391	0.8141593
7	0.8748318	0.9348172	0.9255814	0.9259259
8	0.6569343	0.7335058	0.7278646	0.8471338
9	0.8721560	0.9282051	0.9188514	0.8688524
10	0.6557515	0.7311715	0.7254488	0.7983193
11	0.8755596	0.9261186	0.9178499	0.9322034
12	0.6597511	0.7431272	0.7348877	0.8418079
13	0.8723077	0.9229391	0.9143357	0.8769231
14	0.6631016	0.7472284	0.7362963	0.8174603
15	0.8725817	0.9200000	0.9112782	0.8994414
16	0.6633970	0.7509628	0.7395766	0.8545455
17	0.8766962	0.9201878	0.9125575	0.9352941
18	0.6724851	0.7601580	0.7501410	0.8983051
19	0.8786920	0.9198337	0.9120046	0.9179487
20	0.6803313	0.7726582	0.7640507	0.8800000
21	0.8789900	0.9225013	0.9134766	0.9076087
22	0.6854778	0.7806333	0.7723727	0.8518519
23	0.8792879	0.9256921	0.9169847	0.9322917
24	0.6923876	0.7895842	0.7820244	0.8620690
25	0.8801917	0.9274911	0.9190726	0.9470588
26	0.6963887	0.7929838	0.7863479	0.8444445
27	0.8800296	0.9282787	0.9197581	0.9270833
28	0.6977226	0.7966524	0.7905237	0.8421053
29	0.8809360	0.9288433	0.9205695	0.9180328
30	0.7002484	0.7979497	0.7921906	0.8410257
31	0.8810290	0.9304224	0.9220280	0.9090909
32	0.7022486	0.8001853	0.7948084	0.8900000
33	0.8808873	0.9289100	0.9209040	0.9345794
34	0.7007086	0.7967742	0.7916055	0.7619048
35	0.8794798	0.9267033	0.9188332	0.9057971
36	0.6968085	0.7930265	0.7888703	0.8120806
37	0.8795711	0.9254237	0.9174978	0.8983051
38	0.6940168	0.7899920	0.7851990	0.7377049
39	0.8784777	0.9255319	0.9174870	0.9071429
40	0.6909701	0.7874936	0.7823755	0.8214286
41	0.8779142	0.9241438	0.9163203	0.8938053
42	0.6885246	0.7851059	0.7803864	0.7614679
43	0.8772098	0.9234708	0.9151068	0.9127907
44	0.6867860	0.7835648	0.7789670	0.8654971
45	0.8757166	0.9216650	0.9139459	0.8770492
46	0.6866655	0.7838199	0.7796952	0.7777778

Calculated Performance Measure Values for PM (continued)

DP	MSE _{pm}	S _{p pm}	C _{p pm}	MILLERS _{pm}
47	0.8764809	0.9221646	0.9141683	0.9204546
48	0.6851399	0.7825346	0.7784675	0.8383234
49	0.8771561	0.9231497	0.9154701	0.9268293
50	0.6869755	0.7837176	0.7800328	0.8170732
51	0.8781572	0.9236174	0.9162409	0.9125683
52	0.6898949	0.7878609	0.7846002	0.9053254
53	0.8803269	0.9259421	0.9186071	0.9695122
54	0.6912658	0.7896428	0.7863248	0.8412699
55	0.8800600	0.9260113	0.9189467	0.9349113
56	0.6936138	0.7914847	0.7882611	0.8870968
57	0.8798051	0.9265981	0.9194219	0.9259259
58	0.6940785	0.7930974	0.7898628	0.8541667
59	0.8806620	0.9273645	0.9204350	0.9421053
60	0.6952754	0.7946640	0.7912852	0.9179487
61	0.8807000	0.9280630	0.9213628	0.9301075
62	0.6971050	0.7972907	0.7940019	0.8750000
63	0.8820463	0.9288945	0.9222420	0.9230769
64	0.6984938	0.7990220	0.7955985	0.8725491

Appendix L: Calculated Performance Measure Value for TMSEP

DP	MSE _{tm}	S _{p tm}	C _{p tm}	MILLERS _{tm}
1	0.7650620	0.8087910	1.0234350	1.1609520
2	0.6637320	0.7893480	1.0953370	1.6926820
3	0.1487610	0.1595710	0.2381690	0.1970290
4	0.1581330	0.1644490	0.2421660	0.2214360
5	0.8993290	0.9814150	1.2547690	1.3781180
6	0.6908280	0.7437650	1.2031360	1.4195740
7	0.1405690	0.1471160	0.2459100	0.1979690
8	0.1488380	0.1552430	0.2376890	0.2127430
9	77.9380340	83.1626890	108.2751310	132.1354680
10	56.1681590	61.7997280	98.8873060	135.7216490
11	10.2727160	10.7429670	20.8164410	12.9381190
12	7.9198800	9.1730830	20.6267190	15.4755950
13	75.7267150	82.3265460	113.1051330	131.7463990
14	53.3580280	61.4832120	107.3695450	141.4950870
15	9.5692500	9.8932590	19.2865920	12.2740480
16	8.0496980	8.8758070	18.0312250	16.5588720
17	0.9292540	0.9358480	1.4927760	1.1517850
18	0.8593490	0.8651500	1.4510400	1.0863170
19	0.1407100	0.1423830	0.2824660	0.1426570
20	0.1367260	0.1338730	0.2878020	0.1418870
21	0.9471070	0.9643650	1.4791970	1.0234790
22	0.8688670	0.8869560	1.5071520	1.0349690
23	0.1427590	0.1425130	0.2991620	0.1468790
24	0.1363060	0.1346770	0.2990880	0.1383570
25	89.9664610	90.8934100	147.2874150	101.9961320
26	84.1691510	85.6997380	141.4162900	102.0691220
27	12.1973890	12.3373200	26.9606130	12.7069930
28	10.9168790	11.2033390	26.4688630	12.9651400
29	91.0713040	91.3485720	142.1083830	101.7852550
30	84.5563960	85.3022690	144.7259980	98.6170500
31	12.4259120	12.5170760	28.0536590	12.4964480
32	11.2453370	11.4638000	27.5978010	12.0174870
33	0.9804800	1.1347960	1.3585030	1.5437970
34	0.8325220	0.8686400	1.1092190	1.4102540
35	0.2638300	0.2741530	0.2970570	0.3223040
36	0.3523780	0.3504670	0.3609280	0.3678640
37	0.9159700	0.9888550	1.3031770	1.4501740
38	0.9021820	0.9639130	1.1355340	1.3516600
39	0.2787260	0.2903530	0.3201970	0.3200920
40	0.3576060	0.3316960	0.3655560	0.3798990
41	68.9201740	74.7250060	108.4361880	124.8693010
42	57.7932780	65.6259770	97.4607010	132.9111790
43	9.4603400	9.7781960	18.6886480	13.1972780
44	8.4567630	9.0632910	20.8584960	15.7659790
45	79.2766190	83.3591160	107.4557270	119.1930390

Calculated Performance Measure Value for TMSEP

DP	MSE _{tm}	S _{p tm}	C _{p tm}	MILLERS _{tm}
46	62.0207100	70.4859700	102.2720180	134.2141570
47	10.2950660	10.8312980	19.9675880	12.3031880
48	7.6850630	9.1260600	19.7178250	17.8853320
49	0.9873370	0.9887390	1.5157680	1.2343050
50	0.9494320	0.9554130	1.4946450	1.3705840
51	0.1949640	0.1986370	0.3434490	0.2177160
52	0.2108450	0.2073290	0.3380340	0.2504210
53	1.0238520	1.0291120	1.5982300	1.1669810
54	0.9318340	0.9543170	1.5202000	1.0758220
55	0.1930650	0.1973760	0.3198640	0.2236930
56	0.2103010	0.2086840	0.3424410	0.2333300
57	92.1139220	92.9549100	148.0592800	119.4541400
58	83.7433850	85.6070180	142.4074100	96.1285930
59	12.0630550	12.1251390	26.6133730	12.2637760
60	10.9248680	11.0991730	26.7097450	11.5297640
61	93.2993090	94.0328060	151.9314420	96.3185420
62	85.7757420	87.8176350	140.6162720	106.2438430
63	11.7405510	11.8084090	26.8109000	11.8390310
64	11.1539340	11.2962640	25.5540160	11.6543080

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Vita

Capt David P. Woollard was born 21 July 1961 in Dayton, Ohio. He graduated from high school in Miamisburg, Ohio, in 1979 and attended David Lipscomb University, Nashville, Tennessee. In 1983 he received a Bachelor of Science degree, majoring in mathematics and computer science. He joined the United States Air Force in 1986 and received his commission through Officer Training School. His first assignment was with the 2048th Communications Squadron, Carswell AFB. He held various leadership positions in the maintenance and operations branches with his last position being Chief of Communications Operations. In 1990, he completed his first Masters degree, obtaining a Master of Liberal Arts degree from Texas Christian University. He was reassigned to the Air Force Institute of Technology in May 1991.

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13. ABSTRACT (Maximum 200 words) This thesis implements a variable selection method proposed by Alan J. Miller, and makes an extension of Ross J. Hansen's 1988 thesis research by comparing the methods he examined: Minimum MSE, Minimum S_p , and Minimum C_p with Miller's method. Response Surface methodology is employed with two performance measures: the percentage of correct variables in a model and the Theoretical Mean Squared Error of Prediction (TMSEP). Each technique is applied on generated data with known multicollinearities, variances, random predictors, and sample sizes. Both performance measures are computed for models selected under each technique. A full factorial design using each performance measure is set up to study the effectiveness of each variable selection technique with respect to the known data characteristics. Equations are generated which relate these data characteristics to each combination of performance measure and selection method. A graphical analysis of variance is performed to summarize each technique's performance. Miller's method is shown to be the best overall technique for selecting models with the highest percentage of correct variables. Minimum MSE, followed closely by Minimum S_p , selected models with the least TMSEP.				
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