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A User's Guide To SMALLP

Version 7.0
A Micro-Computer Based
Mathematical Programming Algorithm

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TABLE OF CONTENTS

I. Introduction To SMALLP[1]

A. Purpose and Developmental History

As do most other mathematical programming systems, SMALLP maximizes an algebraically linear objective function subject to a set of linear constraints. SMALLP will also optimize non-linear formulations through linearization of the objective function as additional linear constraints in a primal-dual format. SMALLP provides the user with easy to use interactive input options. It has well-labeled display and output sorted into a readily understandable form. It has options that quickly modify existing models. These features facilitate use well beyond what most general purpose packages do.

SMALLP is an enhanced micro-computer version of MINNLP, an earlier mainframe interactive inequality primal-dual form algorithm. The algorithm is efficient in the use of computer storage space and in its compiled form is capable of solving moderately sized problems in a very reasonable amount of time.

SMALLP in its current version is an example of how computer software evolves over time. This program has a long history of modifications beginning from the work of Foster and Weyrick at the University of New Hampshire published in 1968. As the list of references at the end of this paper indicate, various modifications to this work have occurred since then. A parallel development of the computer software package FMGTLP also provided useful ideas associated with how to present the output and manipulate the data. Both of these programs provided the user with easy to use input options and well-labeled output in a more understandable form than do most general purpose packages. The main frame FORTRAN versions were developed for use on Control Data Corporation Cyber hardware. They were workable on machines with a smaller byte size as well. For accuracy test purposes, a BASIC language version of MINNLP was also developed for Cyber use.

B. Technical Limitations

Operating Systems - Several older versions exist; AppleSoft, Microsoft for the Apple C/PM operating system and a more general C/PM version are all interpreted BASIC versions. These versions are dimensioned to problem sizes which will fit in 64K of memory. They do not contain the latest enhancements in either (a) some user messages, or (b) post solution parameterization discussed in this manual. Other versions in PASCAL and "C" also exist.

The latest and most complete versions, to which this manual refers, are compiled in QUICK BASIC (QB) and TURBO BASIC (TB) and operate with most, if not all, versions of the MS-DOS operating systems. 256K or more of memory are required. Some of the output options require a 132 character line printer.

Accuracy - SMALLP has undergone substantial accuracy testing. Computationally adverse conditions of near singularity, large and small coefficient size and various essential zero specifications were tested. The results provide evidence that this is a sound algorithm for wide spread use. Because AppleSoft did not allow a double precision specification of variables, it was less accurate than the MicroSoft version. However, it is more accurate than single precision MicroSoft. Contact the author if installation is being considered on newer 32 bit machines. Both the operating system and the CPU chip can make a difference.

Contribution to Minnesota Agricultural Experiment Station Project 14-036, Management Information Systems for Minnesota Farm Firms.

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[1] The author wants to note the help of a number of other people over the years--including Eugene Haley, Jim Kelly, Dale Nordquist, Tony Groble, Dave Maloney, Mark Kirchhoff, Alvaro Soler and Vincent Bryon.

__Speed and Size__ - The compiled program may require 5 to 15 minutes solution time with dense problems approaching the currently allowed maximum size of about 4600 (QB) or 8200 (TB) matrix cells. Solution time varies by math co-processor access, CPU used, clock speed and hardware design.

The maximum dimensions of the system may be changed by its user as explained below. The parameters, as listed below, are found in a file called SMALPRAM.ETR.

12, 15, 15, 7, 0, 0, "C:.\"
Max no. of rows & columns - essential zero - - $ - Dollar (objective function unit)
52, 72, 0.000001#, "$", "Dollars", "WHATOGRO.LPD"
13, 19

__Documentation of the SMALPRAM.ETR & DAIRYPRM.ETR files.__

The 1st line contains in order - formfeed, condensed and normal printer signals expressed as ASCII characters. The following 3 values are the foreground and background and border colors. The last is the default data drive\directory. The 2nd line above is currently not used. A revision is planned to use this row to format laser printers for condensed print.

In the case of the SMALPRAM.ETR file the Maximum rows (times) the Maximum columns must be < = to about 4300 cells when compiled using QuickBASIC or 8200 cells if the Turbo Basic version is used. When we find a compiler that accesses more than 64k of memory for data storage a recompilation will allow larger matrices. Versions of the algorithm in Pascal and in C exist. They have not been fully tested for accuracy, speed or programming characteristics. The third value specifies the essential zero parameter.

Values 4 and 5 permit changes in printed monetary units, at least in SMALLP.
NOTE - 2-25-89 added feature a default data drive\dir. and file name.
- 3-23-90 added SKELSET.up data characteristics in SMALPRAM.ETR 1st. line.
- 4-15-91 modified screen display; added file output options and pre-analysis matrix testing

The fourth line is only required by DAIRY218 - a special purpose matrix generator algorithm. It states the last column position for forages and grains in the DBAL.LPD default to a Ext. Bul. 218 based data file. Change it if you add or subtract feeds from DBAL.LPD. An editor such as TED.COM is much more convenient for changing any of these values than is EDLIN, the MS-Dos line editor. TED can also be used to edit .LPD and .LPO or other text files when needed.

All lines but nos. 1, 3 & 4 are ignored by the program(s). TED is distributed with SMALLP. Also distributed is BT.COM, a Better Type command used to display text file material on the screen in SMALLP. A Sorted file DIRectory (SDIR.COM) which is superior to DIR.COM is also included.

C. Installation of SMALLP

Installation of SMALLP requires copying the files marked with asterisks (*) to the appropriate disk or directory. Those marked (*P) may be installed in the system designated PATH in a \UTILities sub directory along with other commonly used utilities in as much as that is what they are. Those marked (*O) for optional installation are not required by SMALLP as a system but are part of the system offered by this distribution. Those not marked are either data files or useful public domain utilities.

```
           Programs and Related Files on This Disk:

 *   SMALPBRF SCN     On-Line Documentation screens
 *   SMALFRST SCN     First Screen for SMALLP
 *   SMALLAST SCN     Last Screen for SMALLP
 *   SMALLMOD SCN     Description of Matrix Modifications available
                      in SMALLP
 *   SMALLP   EXE     Actual Program
 *   SMALLP   TXT     Documentation in a text version (Currently
                      out of date)
 *   SMALLP  .WP5     Documentation Word Perfect 5.  file form
 *O  SMALPRAM FDD     Parameter file for floppy disk
                      (re-name if used)
 *   SMALPRAM ETR        "       "   actually used (rename .HHD or
                      .FFD to it)
 *O  SMALPRAM HDD        "       "    for hard disk drives (list for
                      documentation)
 *O  MENUFILE TXT     Describes the MENU'ed choices available
```

```
     Utilities Which Must be Accessible - May be PATH'ed:

 *O CBT       EXE     Used to examine or Print data (.LPD) files
 *P BRUN10    EXE     Subroutines used by Compiled Quick
                      BASIC (QB) versions
 *O BT        COM     A Utility to Replace the TYPE command
 *O MENU      EXE     A User Oriented Menuing system
    SDIR      COM     A Sorted DIRECTORY Lister

 Example data files For SMALLP:
 (all optional - may be stored in a different disk and/or
 directory)

 BENCHES.LPD  WHEATCRN.LPD  SETASIDE.LPD  WTCRNSBN.LPD  ELEVATOR.LPD
```

II. Structuring the LP Problem for SMALLP

A. The General Matrix

It is easiest to understand this algorithm by viewing the complete tableau as one matrix. This matrix has as its Nth (last) column the right-hand side specifications or resource limits. It has as its Mth (last) row the per column unit values of the objective function or the gross margins from the activities. The algorithm does not explicitly contain slack vectors specified as columns. The slack resources are implicitly priced at zero in this version. A forthcoming version will permit non-zero pricing of the slack or original non-basis vectors. The algorithm is structured in Primal-Dual inequality form.

B. A Mathematical Statement of the LP Problem

1. Maximize $A_{m,n} = \sum_{j=1}^{N1} (A_{m,j})*(X_j)$

Where: $A_{m,n}$ = the value of the optimal plan,
X_j is the level at which the jth activity is utilized.
$A_{m,j}$ is the per unit gross margin returns to an enterprise, i.e., is equal to C_j as frequently denoted in L.P. modeling
m is the last row in the matrix ($m = m1 + 1$)
N1 is the last real activity column in the model
N is the last column in the matrix ($N = N1 + 1$)
M is the last row in the matrix ($M = M1 + 1$)

The objective is to maximize the sum of the returns times the algorithm calculated levels of all of the choice vectors (enterprises).

2. Subject to a set of inequalities relating constraint levels to activities:

$$A_{i,n} \geq \sum_{j=1}^{N1} \sum_{i=1}^{M1} (X_j)*(A_{ij})$$

Where: $A_{i,n}$ is the limited resource level (equal to 'b_i' or the 'RHS' as frequently denoted in L.P.)
X_j is the level at which activity 'i' is utilized
A_{ij} is how much of the "ith" resource is used by a unit of activity 'j'; and
M1 is the last resource constraint ($M = M1 + 1$)

Thus, the objective function value is limited by the sum of the uses of resources which must be less than or equal to the amount of resources available.

And, all $X_j \Rightarrow 0$ for $j=1$ to N1

all $A_{i,n} \Rightarrow 0$ for $i=1$ to M1

For feasibility, all activity levels must be at zero or positive levels (i.e., you can't produce negative amounts) and feasible solutions must force zero or positive levels of constraint levels (i.e. all negative RHS values must be "FORCED OUT" to assure feasibility before optimization rules are followed.

SMALLP SCHEMATIC LAYOUT

ROW	COLUMN LABELS AND UNITS OF MEASURE			SIGN	
ROW LABELS	$A_{1,1}$		$A_{1,N1}$	>=	R.H.S.
	. .		. .	. .	. .
	. .	$A_{i,j}$'s	. .	>=	(or)
	. .	$_i$ = row	. .	. .	$A_{i,n}$
	. .	$_j$ = column	. .	>=	(or)
	. .		. .	. .	b_i's
	$A_{m1,1}$		$A_{m1,n1}$	>=	R.H.S.
	C_j's or $A_{m,j}$'s or objective function			=	$A_{m,n}$

C. An Example Problem and Sample Matrix

The best way to gain an understanding of how SMALLP works is to analyze a small sample problem. This example will show step by step the process of organizing a linear programming problem and creating a SMALLP data file from the tableau. It also demonstrates the main menu options and how output is displayed by SMALLP.

The problem - For an example case, suppose that one would like to model a cash grain farm given the following data.

1) 600 acres of tillable land available
2) 400 hours of labor available during the spring period
3) Expected Gross Margin Returns (excluding overhead) are:
   - a) Corn grain - $125/Acre
   - b) Spring wheat - $ 95/Acre
4) Spring Labor requirement on per acre basis
   - a) Corn grain - 0.75 hours/Acre
   - b) Spring wheat - 0.40 hours/Acre
5) The objective is to maximize expected contribution margin or gross margin returns given the stated resources, alternatives and resource requirements.

<u>An L.P. tableau would be set up as follows:</u>

Activity 1	Grow an acre of Spring Wheat
Activity 2	Grow an acre of Corn Grain
Constraint 1	Available acres of Land
Constraint 2	Available hours of Labor in the spring

The Tableau

	Grow Wheat (acre)	Grow Corn (acre)		RHS
Avail Land (Acres)	1	1	<=	600
Avail Spr Labor(Hrs)	.4	.75	<=	400
Gross Margins Per Acre	95	125		

A_{11} = 1 It takes one acre of land to grow one acre of wheat.
A_{12} = 1 It takes one acre of land to grow one acre of corn.
A_{21} = .4 It takes .4 hours of spring labor to grow one acre of wheat.
A_{22} = .75 It takes .75 hours of spring labor to grow one acre of corn.

The size of the matrix is 2 x 2, not including the RHS or objective function values.

The objective function values are:

A_{31} = $95 Growing 1 acre of wheat contributes $95 to the value of the objective function.
A_{32} = 125 Growing 1 acre of corn contributes $125 to the value of the objective function.

The RHS values are:

A_{13} = 600 Total planted acres cannot exceed the 600 acres available.
A_{23} = 400 Total number of hours of spring labor used can not exceed the 400 hours available.

Some General Notes About The Tableau

A. Each column of the tableau is an activity or process except the last one which is the RHS and contains the specified RHS values.

B. Each row is a resource except the last row which is the objective function or Gross Margin for each activity (the Cj's).

C. Positive Cj's indicate a positive contribution margin while negative Cj's indicate negative returns over directly related expense. (These are usually purchase activities or intermediate products such as crops that are fed.) Positive RHS's imply a maximum specification of the constraint level while a negative RHS value indicates a minimum specification of the constraint level. Positive A_{ij}'s indicate that the activity requires ("**takes from**") the resource. Negative A_{ij}'s indicate the activity provides ("**gives to**") the resource amount (endowment or requirement) in the indicated row (i).

D. Overall Programming Model Design And Use Suggestions

General Comments

SMALLP has few unique features to restrict the user. The lack of an equality constraint specification might require adding an inequality of opposite sign to a model on occasion. But it is rare that an equality really exists anyway. The implicit pricing of all original basis vectors at zero will require explicit additions of resource sale alternatives as additional column vectors.

A dynamic approach to model formulation is encouraged by the ease with which more vectors can be added or the vectors reordered. As newly seen issues turn up and are clarified, they may be added to the model. Be sure to fully utilize the ability to modify the labeling of both the vectors and the entire problem as clarification occurs.

There are good modeling reasons to encourage explicit specification of commodity purchase and sale vectors. The same reasoning holds for putting directly related cash expense items in a internal row rather than subtracting them from the gross product sale values of the objective function. These reasons have to do with doing post solution analysis of the impact of changes in commodity prices and perhaps other sources of risk faced by the firm. Appendix C offers some example models that suggest ways to easily handle such modeling details.

Transportation

Few interesting transportation resource allocation problems are completely modeled by specialized transportation algorithms. See Appendix C for example models using SMALLP.

Integer and Mixed Integer Models

Few situations deserve full integer treatment. Unless acceptable vector levels are constrained to small numbers like 1 or 2, usually little harm is done by post solution rounding. Menu option 6 permits a quick comparison where the necessary levels are made integer. As one does such rounding, consider the accuracy of the data in the model its self. Sometimes it is reasonable to round in ways that imply a solution outside of the specified set of feasibility constraints.

There are two basic ways to model mixed integer situations where acceptable levels are zero or one or perhaps two. For example consider a vector implying the purchase of a major capital item which will expand over all operating capacity but only if a large and "lumpy" up front investment is made. It may strain credit availabilities. It may change the relative merits of different alternatives. But it is an all or nothing situation. For an example see the ELEVATOR models listed in Appendix 3.

One way is to simply adjust the RHS specifications to copies of the base model, giving each a different title and name. Solve and do a comparative analysis of the results after adjusting the objective functions according to the added time period flow costs related to each realistic choice. The other is to add the lumpy vector(s) to the model and set a new constraint at levels to force the inclusion or exclusion as appropriate. This option adds at least a column and a row vector for each investment choice but reduces the necessary post solution calculation. It also can offer additional insight through a comparative sensitivity analysis of the resulting solutions.

III RUNNING SMALLP

A. Initial Menu Options

SMALLP may be run directly from the MS-DOS system by typing SMALLP at the DOS prompt. After an introductory screen, the initial menu is displayed and the user is asked which is the next option to perform.

```
Key-No.    SMALLP Options or Action Description

0   End the analysis - go back to the system menu or,

1   Enter new problem data as row, col.,& value sets,

2   Enter new problem data as column sets of values,

3   See a short SMALLP User's Guide & Instructions,

4   See or print the complete User's Guide,

5   Load a previously stored LP/MP model data file

Key-in The Selected Option (0-5) or Alternatively
Move Cursor to The Proper line With The Up & Down
Arrows And Press <RETURN> to Make A Selection.
```

Options 1, 2 and 5 allow the user to choose how to provide data to the system for the problem being analyzed. Options 1 and 2 are alternative methods of creating a data file the first time a problem is modeled, while option 5 lets one load a data file previously prepared for use by SMALLP. Options 3 and 4 allow the user to view or to print out a set of user run-time instructions including a text version of this document.

A.1 <u>Option 1</u>

After selecting either Option 1 or 2, SMALLP requires that a line be entered that describes the problem being modeled. This description is saved with the data and is used in headings of output tables to identify the problem and analysis.

Under option 1, the A_{ij}'s associated with each activity's resource requirements are entered first. All non-zero A_{ij}'s are entered by designating the row number, then the column number and finally the value. Two sets of these 3 items go on one line. If during an entry a mistake is made, the user can backspace or up arrow back to the error, correct it and continue. If an A_{ij} has been entered (i.e., the enter key has already been pressed) when an error is discovered, re-entering the row, column and correct A_{ij} value will correct the error. More rows or columns can also be inserted or data errors corrected later by using file modification sub-option 4. When all of the A_{ij}s have been entered (not including the RHS of objective function values) a zero row value is entered to signal that all $A_{i,j}$ data has been entered (for now). The total rows and columns are calculated automatically with this option.

```
                    Data Entry Option  1

    Type a line to describe the mathematical programming problem
    (max 75 spaces)

    Example Wheat Corn Farm Plan to show in the User's Guide

To accept the displayed data just press <ENTER> or the up or down arrows
Type each value; then press <ENTER> before typing the next value.
Typing a zero row value will stop data entry.  Slacks aren't entered.
The RHS Column and the Cost/Price row are not entered in this section.

    ROW - COLUMN - A(i,j)    -  Another  ROW - COLUMN - A(i,j) data set
      1       1       1                    1       2          1.000

      2       1       .4                   2       2           .75

      0
```

Following the A_{ij} entry, SMALLP will prompt the user to enter the RHS labels and constraint level in row order. The maximum length available for the label and its units is 17 characters and a visual screen guide line is provided. It is strongly recommended that the description include the units of measurement of the resource being constrained. SMALLP attaches an identifications code to each row and column label. For RHS entries an R and the original row number is added to the descriptive label provided by the user when the data is stored for later use.

```
                  Enter the row labels

         Type a 17 Character Row Label With Row Unit
                        |...5....0....5.|
         RHS    1  Avail Land  Acres
         RHS    2  Avail Spring  Hrs
```

After all of the RHS labels and values are entered, a new screen prompts the user to enter the column labels. The format and procedure here is the same as is used for RHS data. Again, be sure to enter the column unit.

```
                  Now enter the column labels

         Type a 17 Character Col. Label With Col. Unit
                           |...5....0....5.|
         Col No    1  Grow Wheat    Acre
         Col No    2  Grow Corn     Acre
```

The next screen(s) allow entry of the RHS and then the objective function vector values. If negative values are involved, the entry should include the proper sign. A file modification sub-option available later permits a minimum row to be entered now without negative signs and then the entire row to be scaled by a factor of -1 to reduce key data entry strokes.

```
            Option To Change Or Set The RHS Values

    Minimum (-) or Maximum Use Specifications / Limits
    1 Avail Land  Acres (Units)    600
    2 Avail Spring  Hrs (Units)    400

    Data OK?..Want to go ahead (Y OR N);
    (OR <CNTL-Q> = Quit entire analysis) ? y
```

```
     The Objective Function Row Labeled - $ PRICE/COST VAL.
                  Value per Column Unit
         1  Grow Wheat   Acre / Dollars      95
         2  Grow Corn    Acre / Dollars     125
         3  SPECIFED RHS AMT. / Dollars       0

         Data OK?..Want to go ahead (Y OR N);
         (OR <CNTL-Q> = Quit entire analysis) ? y
```

Option 2

For small and fairly dense (over 30% dense) matrices, it requires fewer key strokes to enter data using Option 2 of the INITIAL MENU. After entering the problem description this option prompts for the number of rows and the columns in the problem matrix. This count does not include the row associated with the objective function values nor the last column associated with the RHS values. SMALLP then prompts in column order for the associated A_{ij} starting with the first column. When all of the $A_{i,j}$ entries are finished, the RHS and column labels and values are entered exactly the same as under Option 1.

If Option 2 is selected, the same data items must be entered. However, the process differs. Option 2 is probably quicker for problems containing over 30% non-zero cells.

```
                      Data Entry Option  2

         Type a line to describe the mathematical programming
         problem (max. 75 spaces)

         Corn Wheat Example Farm Plan Problem
         Illustrating Input Option Two
```

```
                      Data Entry Option  2

  To accept the displayed data just press <ENTER>

  Response to the 1st. question, press <ENTER>, then to the
  2nd. etc.

  Excluding the Objective function row and RHS column, type the
  No. of ROWS:   No. of COLUMNS in problem or LP/MP model

              w/o Obj. row        w/o RHS col.
                  2                   2
```

```
Enter RHS labels for this problem

Type a 17 Character Row Label With Row Unit
                   |...5....0....5.|
          RHS    1  Max Land in Acres
          RHS    2  Max Springtime Hr
```

```
Now enter the column labels

Type a 17 Character Col. Label With Col. Unit
                   |...5....0....5.|
          Col No    1  Raise Wheat  Acre
          Col No    2  Raise Corn   Acre
```

The actual A_{ij} values are then entered in column order. Pressing <ENTER> without a value sets that cell to zero. The up and down arrows are used to move to an item requiring correction.

```
        To accept the displayed data just press <ENTER>

For Choice Vector or Column no.  1  Raise Wheat  AcreC 1
Description & Row Unit / Col. Unit - No. of Units
        1 Max Land in Acres   / Col. Unit  1
        2 Max Springtime Hr   / Col. Unit  .4
        3 $ PRICE/COST VAL.   / Col. Unit  95

Data OK?..Want to go ahead (Y OR N);(OR <CNTL-Q> = Quit entire
analysis) ? y
```

```
        To accept the displayed data just press <ENTER>

For Choice Vector or Column No. 2 Raise Corn  AcreC 2
Description & Row Unit / Col. Unit - No. of Units
        1 Max Land in Acres   / Col. Unit  1
        2 Max Springtime Hr   / Col. Unit  .75
        3 $ PRICE/COST VAL.   / Col. Unit  125

Data OK?..Want to go ahead (Y OR N);(OR <CNTL-Q> = Quit entire
analysis) ? y
```

```
        To accept the displayed data just press <ENTER>

Option to Change or set the RHS values

Minimum (-) or Maximum Use Specifications / Limits
     1 Max Land in Acres ( Units )     600
     2 Max Springtime Hr ( Units )     400

Data OK?..Want to go ahead (Y OR N);
(OR <CNTL-Q> = Quit entire analysis) ? y

Use Option #3 to List the Problem Then Option #4 to fix any
noted errors.

          * *  PAUSE..Press any key to continue  * *
```

Once all of the matrix data is entered the screen is cleared and control goes to the OPTION MENU. At this point, having entered the data, it is recommended that Option 7 of the OPTION MENU be used to save the data to a file where it can serve as a back up file. Since the file has just been created, it does not yet have a file name. The user must enter a file name for further use. It can be 8 characters or less in length. No filename extension is necessary since SMALLP automatically adds the extension .LPD.

```
The file is to be saved on which Disk Drive? (A or B etc...)

(The colon is added automatically) or (Esc> = Skip It)
The Current Data Drive is C:.\    (= <ENTER>)  ?

Existing data file code numbers :

0 = Return to the menu instead of selecting one.
1 = BENCHES

Type the corresponding number from (0 to 1 or <Esc> to skip it)
Or type the name (up to 8 characters) of the data file to be
saved ? wheatcrn
```

A data file listing can be obtained when in the system (no longer running SMALLP) by typing BT FILENAME.LPD. A printout can be obtained by typing PRINT FILENAME.LPD. A listing of the names of existing data files can be seen by typing SDIR*.LPD.

Listing of Case Example Data File With Notes Added for Listing Purposes Only
(Line 1 is the title)

```
Example Wheat Corn Farm Plan to Illustrate the User's Guide
     (Rows and Columns in the Aij Proper)
      2            2
      Row          Col          Value
      1            1              1
      2            1             .40
      2            2             .75
      3            3               0 (- ends Aij's)

 (Row  RHS   Amounts)      (Description and Code NO)
  1          600           Avail Land Acres  R 1
  2          400           Avail Spring  Hrs R 2

 (Col Prices Amount)
  1           95           Grow Wheat   AcreC 1
  2          125           Grow Corn    AcreC 2
```

A.2 __Option 5 - Loading A Previously Stored Data File:__

Option 5 allows a user who has previously created a data file using SMALLP and stored it on a disk to load the file back into memory. SMALLP first prompts for the disk drive which contains the file to be loaded. The default drive is designated unless the user changes the default. The user gets a listing of all files with the .LPD extension.

When a file is loaded, the problem description is displayed as well as the size of the matrix (excluding RHS and Objective function values) and also the date the file is last saved.

```
       The file is to be found on which Disk Drive ? (A or B etc...)
        (The colon is added automatically) or (Esc> = Skip It)
                    The Current Data Drive is C:.\   (= <ENTER>)   ?

Existing C:\LP data file code numbers:

      0  = Return to the menu instead of selecting one.

      1  = BENCHES            2  = SETASIDE          3  = WHEATCRN
      4  = WTCRNII            5  = WTCRNIII          6  = WTCRNSBN
      7  = WTCRNXC

Type the corresponding number from (0 to 7 or <Esc> to skip it)? 3

   The data file to be found is C:.\WHEATCRN.LPD
06-24-1991  Example Wheat Corn Farm Plan to Illustrate the User's Guide
 Tableau Size =  2  by  2
```

An __Option 6__ also appears on the Main Menu screen when the user returns to it after working on a particular problem. Option 6 permits continued work on the previously specified problem.

B. Analysis With SMALLP - The Option Menu

At this point, whether through Option 1, 2 or 5, the user now has a set of data ready for SMALLP to use and the screen displays the Review, Analysis and Modifications Menu of options (the Options Menu).

```
        Options Menu to Work on the File WHEATCRN Now in Memory:

   0 =  Quit work on this model & return to the master menu.

   1 =  List the current set of choices and specifications under
        consideration.

   2 =  Print out all or part of the problem under consideration
        in table form.

   3 =  Check the problem structure for feasibility and
        boundedness, etc.

   4 =  Modify the problem structure before going further with it.


   5 =  Solve for the optimal solution given the current choices
        & specifications.

   6 =  Check the computational accuracy or budget out an
        alternative plan by stating which choices & how much of
        each to use - compute resource balances.

   7 =  Copy the working L P data file to disk before returning to
        this menu.

   8 =  Compute an L P solution with out first saving the current
        matrix.

      Key-in the Option Menu No. (1 - 8) or 0 = Go to Main Menu ? 3
```

The options shown in the options menu and that are available are less whenever a solved matrix is in memory. Until an original basis or unsolved matrix is loaded from the main menu, placing another problem (copy in memory), options 3 and 4 will not reappear on the options menu screen. Reloading occurs by selecting either option 6 - checking accuracy or budgeting calculations - or options 1, 2 or 5 from the main menu.

B.1 <u>Option 1</u> - The option displays or prints the activities description label and associated objective function values.

```
        Data File Name = WHEATCRN, Dated 4/15/91
        Example Wheat Corn Farm Plan to show in the User's Guide

           Vector Description (Code)    Original Price or Amount
             Grow Wheat    Acre  C 1              95.00
             Grow Corn     Acre  C 2             125.00
```

followed by the RHS constraint labels and restriction levels.

```
Vector Description (Code)   Original Amount or Price

  Avail Land  acres  R 1          600.00
  Avail Spring  Hrs  R 2          400.00
```

The option is used for viewing the prices or constraint levels. If written to file, the display can be augmented by longer descriptions for purposes of reporting on the analysis alone. Changes in the model can be made using Option 4.

B.2 <u>Option 2</u> - provides a printout of part or all of the existing matrix or problem. Any portion of the matrix can be printed or written to file. The user enters the first and last row number to print and then the first and last column to print. In condensed print 8 1/2" X 11" paper can fit 25 rows by 8 columns. The default values displayed are used to print the entire matrix.

```
Last result file name used was - (files are appended.)

Type the desired file name (> 8 characters / name), (Include Drive
and PATH specifications if needed) ? wheatcrn
To accept the displayed data just press <ENTER>

Response to the 1st question, press <ENTER>, then to the 2nd, etc.
1st. ROW No.       Last ROW Number          (Cost/Price
To Print  1        To Print  3               Row No. = (3)

1st. COLUMN No.    Last COLUMN No.          (RHS or Constraint
To Print  1        To Print  3               Column No. = (3)

Want Results Printed Out [Y(es) or P(rint) or put in a Text
F(ile)]? f

Last result file name used was - wheatcrn (files are appended.)
Type the desired file name (> 8 characters / name),
(Include Drive and PATH specifications if needed ) ?
```

The matrix printout starts with the description line. This option may also be used after a problem has been solved to print out the final matrix. A hidden Option 9 permits printing out all intermediate matrices for problems of less than 8 columns.

PRINTER OUTPUT 1

Data File - WHEATCRN

```
Titled - Example Wheat Corn Farm Plan to Illustrate the User's Guide
        Initial Tableau
```

Row	Description	Grow Wheat Acre COL 1	Grow Corn Acre COL 2	SPECIFIED RHS AMT. COL 3
1	Avail Land Acres	1.000	1.000	600.000
2	Avail Spring Hrs	0.400	0.750	400.000
3	$ PRICE/COST VAL.	95.000	125.000	.

B.3 <u>Option 3 - Verifying the Solvability of the Problem</u> - The following message will appear if no inconsistencies are discovered in the structure of the matrix when options menu choice number 3 is selected:

```
No Gross Vector Errors Were Detected in the Model.
```

A listing of the Gross Vector Errors, which may be detected when choice 3 of the options menu is selected, is shown below. The listing is assumed to be self explanatory. Only some of the nine possible types of errors are likely to appear in any one use of Option 3. This listing appears either on the printer or in an output file if that option was selected previously:

```
1.   All values in ROW vector 1 are non-positive. Is this
     strictly an accumulating account row?

2.   The RHS for Row 1 is ZERO, but all other values are non-
     negative.  This eliminates any column with a positive
     resource requirement.

3.   The RHS is negative in ROW vector 2 while all other
     values are non-negative.  This row is INFEASIBLE!
     Correct it before analysis.

4.   All values in negatively priced column vector 2 are
     non-negative.  This column has NO OPTIMIZING MERIT?
     Advice is to re-check it.

5.   All values in zero priced column vector 3 are
     non-positive.  This column is probably unbounded?
     Advice is to re-check it.

6.   All values in positively priced column vector 1 are
     non-positive.  This column is UNBOUNDED!  Modify or
     delete it before analysis.

7.   All values in COLUMN 3 are ZEROS - delete or correct it.

8.   All values in ROW 3 are ZEROS -
     delete row or correct it.

9.   A least-cost problem with no negative RHS values - The
     result is a do-nothing plan!!?? - modify before analysis.

     A total of 5 vectors in the model were found to need
     re-examination.  This may best be done by using the
     sub-options in modification option number 4 with a print out
     of the original matrix at hand.
```

B.4 Options 5 and 7 - Saving the current file. Whenever option 5 is selected, the current file is eiehter saved or resaved. The user may select option 7 to save the current file at any time.

B.5 <u>Options 5 and 8</u> - Solves the problem and presents the post solution analysis/options. A major feature of SMALLP is its efficient solution algorithm and interactive output capabilities. Selection of Option 5 or 8 begins the solution procedure. As SMALLP solves the problem, it displays the starting time and current iteration count. If a feasible solution is found, the time is again displayed together with the total number of iterations. A hidden Option (9) may also be used on problems of less than 8 columns. Using it will print the solution iteration tableau by tableau.

```
Solving process is beginning. The time is now 20:49:31 Hours
Iter.    Variable Leaving,    Variable Entering,    Plan $ Value

1   Avail Spring  HrsR     Grow Corn    AcreC      66,666.667
2   Avail Land  AcresR     Grow Wheat   AcreC      70,714.286

Starting time was 20:49:31

Optimum solution found (at 20:49:31 ) Through 2 Iterations

Contribution to Overhead (COH) or Gross Margin = $70,714.286

For Example Wheat Corn Farm Plan to Illustrate the User's Guide

Want Results Printed Out [Y(es) or P(rint) or put in a Text
F(file)],  Or just press <ENTER> to First Screen the Results
[i.e., a N(o) Response] ? f

Last result file name used was - wheatcrn (files are appended.)

Type the desired file name (> 8 characters / name),
(Include Drive and PATH specifications if needed) ? wheatcrn
```

There are two report formats available. One is referred to as the full sensitivity analysis and is obtained by typing Y in response to the prompt. An N or simply an <ENTER> will produce an output without a sensitivity analysis. Both formats contain:

1) The problem description line

2) The value of the objective function of the optimal plan

3) Up to Four output tables

   a) Table 1 lists those original non-basis alternatives or activities which were chosen as part of the optimum or basis plan.
   b) Table 2 lists those original basis resources for which the constraints imposed on the problem were not binding and, hence, remained in the basis.
   c) Table 3 lists those original non-basis activities which were not chosen as part of the optimum plan and remained non-basis.
   d) Table 4 lists those original basis resources for which the constraints imposed were binding and became non-basis in the solution.

If either infeasibility or an unbounded basis occurs, an appropriate message will appear. The user can then re-read the problem and modify it.

Interpreting the Simple Analysis Report

The simple analysis report for the example problem is listed below.

```
                03-31-1991 File Name Is wheatcrn
     Example Wheat Corn Farm Plan to Illustrate the User's Guide

  Contribution to Overhead (COH) or Gross Margin = $70,714.286

  Table 1

  Alternatives Selected          Amount/Level        Alternative
     In The Plan                 In The Plan      Unit Cost/Price

  1  Grow Wheat    Acre            142.857             95.000
  2  Grow Corn     Acre            457.143            125.000

  Table 3

  Prices where other alternatives become economically feasible
  Alternative       Needed $ Price change    Minimal Price/Cost

  NOTE ... No Alternatives Went Unused in this Plan ...

  Table 4

  Resource              Residual Marginal Value       Specified
  Description Unit           Dollars / unit        Resource Amount

  1  Avail Land   Acres          60.714               600.000
  2  Avail Spring  Hrs           85.714               400.000
```

The Gross Margin or Value of the objective function is $70,714.286. Under the optimal plan, the projected contribution to overhead is this amount.

From Table 1 we find that the farm plan consisted of 142.857 acres of wheat and 457.143 acres of corn. Notice that:

142.857 acres wheat @ $95/acre =	$13,571.415
457.143 acres corn @ $125/acre =	57,142.875
Value of the Objective Function	$70,714.290

Tables 2 and 3 are empty in the WHEATCRN problem since all available resources were used and both of the two activities are in the plan.

Table 4 lists the two limiting constraints and amounts of the resources available. In this example, this is 600 acres of (available) land and 400 hrs. of available spring labor. It also contains the implied marginal value of one more unit of each resource. Here one more acre of land would increase the Gross Margin by $60.71 to $70,775 while one more hour of spring labor would increase the Gross Margin by $85.71 to $70,800.

Interpreting the Full Sensitivity Analysis Report

The Full Sensitivity Analysis format contains additional analysis concerning the range in prices and constraint levels over which the designated (activities in the) plan would remain stable. In other words, how sensitive the final plan is to the price/cost levels chosen for the activities and the constraint levels chosen for the resources.

In Table 1, as before, we find that the optimal plan includes 142.857 acres of wheat grown at a "price" of $95/acre. Grow wheat would remain in the optimal plan at this level (142.857 acres) for any estimated return from $66.667 (Lowest price) to $125 (Highest price) per acre provided all other specifications remain the same.

The lower bound variable column indicates the variable which will come into the basis when the examined row variable leaves. At prices (returns) below $66.667/acre, no wheat will be grown; and corn will be grown until all of the available spring hours are utilized. This will occur when 533.33 acres of corn are grown, leaving 66.67 acres of land unused, effectively forcing unused or slack available land in as a basis variable.

The upper bound variable refers to the activity or constraint which will enter the basis if the price of growing wheat is higher than $125/acre. At prices (net returns) higher than $125 per acre, wheat is so economically superior an alternative to corn that wheat will be grown either until all of the available spring labor hours or the available land is used up. It is easy to show that in this case land will be the limiting resource. Thus 600 acres of wheat will be grown which will require 240 hours of spring labor. This will leave 160 hours unused, making available spring labor a non-binding (again slack) constraint.

The same interpretation holds for 'Grow Corn Acres'. Here the range in estimated revenue for growing corn in which 457.143 acres of corn will be grown in the final plan is $95 (Lowest price) to $178.125 (Highest price).

Table 2, when present, contains data similar to Table 1 except for non-binding original basis (row) vectors. An original price/cost of zero is used.

Table 3, when present, contains data similar to Table 4 except for rejected original basis (column) vectors. The lower level sensitivity values imply negative and, hence, infeasible activity levels. These levels, while difficult to interpret, have geometric significance regarding intersecting line slopes

In Table 4 we again find that, when land is limited to a maximum of 600 acres, the implied marginal value of one additional (less) acre is $60.714 (-$60.714). Now with the sensitivity analysis data we can see that this implied marginal value will remain constant at this level any time available land is between 533.33 acres and 1000 acres provided all other specifications remain the same. Similarly, one additional (less) hour of spring labor will be worth $85.714 (-$85.714) for any level of available spring labor hours between 240 and 450 hours. Here the lower limiting variable refers to the activity or resource constraint which will leave the basis when the constraint level is lowered or raised beyond the given range.

In our example, if available acres are reduced to less then 533.33, the grow wheat activity would not be chosen and all 533.33 acres would be used to grow corn. If available acres exceeded 1000 acres, only wheat would be grown to make maximum economic use of available spring labor hours, forcing grow corn to leave the basis.

Making Post-Solution Price Or RHS Changes

After a solution is found and the results printed, the user has the option to change one or several RHS or price values in the problem formulation.

PRINTER OUTPUT 2

06-17-1991 File Name Is WHEATCRN
Corn Wheat Example Farm Plan Problem (Example from FARMPLAN)
Contribution to Overhead (COH) or Gross Margin = $70,714.286

Table 1 - Price Sensitivity Analysis of the Optimum Plan

COL No	Selected Alternatives	Unit Price	Amount In Plan	Lowest Price	Lower Bound Variable	Highest Price	Upper Bound Variable
1	Raise Wheat Acre	95.00	142.857	66.667	Max Land in AcresR	125.000	Max Spring HoursR
2	Raise Corn Acre	125.00	457.143	95.000	Max Spring HoursR	178.125	Max Land in AcresR

(Tables 2 and 3 contain no data in this example)

Table 4 Resource Level Sensitivity Range About Original Resource Levels

Row No	Limiting Resource	Original Amount	Residual Marginal Value	Lower Limit	Limiting Variable	Upper Limit	Limiting Variable
1	Max Land in Acres	600.00	60.714	533.333	Raise Wheat Acre C	1,000.000	Raise Corn Acre C
2	Max Spring Hours	400.00	85.714	240.000	Raise Corn Acre C	450.000	Raise Wheat Acre C

```
Want to change any RHS or price values that were used (Y or N) Y
1 = Range (MAP) a specified price (Price/Cost)
2 = Range (MAP) a constraint/resource level (RHS)
3 = Modify (one or several) prices, constraints or both
0 = All done = return to major options.....? 1
A Descriptive Title Line Noting Variable(s) & Modifications
? RANGING GROW WHEAT PRICE FROM 0 TO 150
Original row or column location no. for variable to be ranged ? 1
Now the algebraically lower value of the range (WITH SIGN?)? 0
And now the upper limit of the desired value range ? 150
```

Choice 1 - Ranges a specified price to observe the related activity levels in the solution.

Choice 2 - Ranges a particular resource (constraint) level to observe the effect changes in the level has on the optimum plan

Choice 3 - Allows discrete changes in one or more price or resource levels.

An Example of the Usefulness of Price or RHS Ranging:

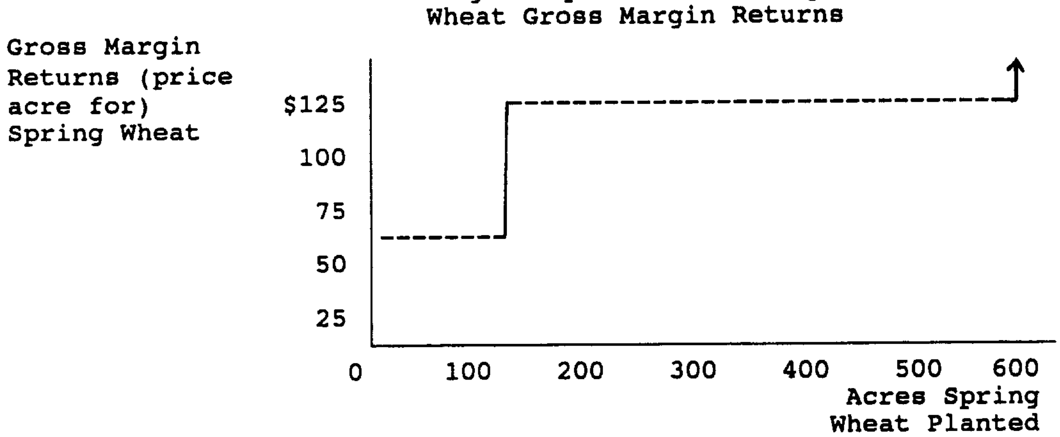
Using Choice 1 to range the price of growing wheat demonstrates one potential use for this option. From the full analysis output format, we found that, for a range in Grow Wheat prices from $66.667 to $125, the level of wheat and corn grown will not change. Choice 1 lets the user explore the effects price levels outside this range will have on the plan. These price boundaries mark the points at which the optimal solution will change. In other words, beyond these points an activity currently in the plan (basis) will be replaced by another activity. By choosing a price level outside of the stable range one can obtain a new solution with a new range of prices within which the plan becomes stable at different levels. SMALLP will automatically start at the lower value of a range determined by the user, solve and identify the break points and move to a price level just beyond the upper break point. It continues this process until all such change levels are identified for a specified range of a particular activity, price or constraint.

From this analysis, one could derive an implied producer supply response for growing wheat, i.e.:

Expected Income Range	Acres of Wheat Grown
0 - 66.667	0
66.667 - 125	142.857
125.01 -	600.

Example Graph

Acreage Response to a change in
Wheat Gross Margin Returns



Notes and Caution:

The last set of parametric changes, once made, remain in the memory until they are again changed perhaps back to their original levels or until a new (the original) file is (re)loaded.

Also, note that after solving a problem it is necessary to return to reload the unsolved file before making any changes in the model or A_{ij} coefficients other than the RHS or Objective vectors. Use menu Option 6 or return to the Main Menu Option 5 to reload an unsolved file.

B.6 Menu Option No. 4 - Modifying the Problem Structure

This option provides a sub menu of problem modifications which may be used to make corrections, additions or improvements in the current model prior to the use of the solution Options 5 or 8.

```
     Modification Sub-Options to Change Problem Specifications

Option No.
    0  =  Return to the main menu (modifications are
          complete),
DELETE a;
    1  =  Row (specification or constraint) from the
          problem,
    2  =  Column (choice vector) from the problem or
          model,
ADD a new;
    3  =  Row (specification or constraint) to the problem,
    4  =  Column (choice vector) to the problem or
          model,
SPECIFY a new ROW as;
    5  =  Max or Min. amount of column(s) that must be
          in plan,
    6  =  An "exact constraint" in plan .. avoid if you
          can,
MOVE an EXISTING;
    7  =  Row vector to a logically preferred
          location,
    8  =  Column vector to a logically preferred location,
CHANGE the LABEL and/or NUMERICAL SCALE (UNITS) of a;
    9  =  Row for logic or accuracy,
    10 = Column for logic or accuracy,
MODIFY or CORRECT a DESIGNATED;
    11 = Row & column location [Ai,j's] in the problem.
    12 = Row [or the Criterion or  Cj's] vector,
    13 = Column [or the RHS or Bi's] vector.

Type Sub-Option No. - (1 to 13 or a 0 = all done or
                      'H' = See Manual) ? 4
```

Having started with a small example problem, it will be easier to begin showing examples of modifications if we begin with Sub-option 4.

Modification Sub-Option 4 - Add A Column To The Problem

Suppose that we would like to also consider growing soybeans as a possible activity and we know that:

Returns	=	$115/acre
Spr. Hrs. Req.	=	.6 hrs.

We could modify the original problem using Option 4 in the following way:

```
                         Sub-Option 4

Label the new Column Vector (no.=  3 )... (17 characters
with units)

                   |...5....0....5.|
                   Grow Soybeans Ac.

To accept the displayed data just press ENTER>
For Choice Vector or Column no.  3  Grow Soybeans Ac.C 3
Description & Row Unit / Col. Unit - No. of Units

          1 Avail Land  Acres  / Col. Unit  1
          2 Avail Spring  Hrs  / Col. Unit  .6
          3 $ PRICE/COST VAL.  / Col. Unit  115
```

The revised problem is shown in **Printer Output 3** (Sub-option 0, Main Option 3 on page 27). Using main Option 5 to solve the problem will cause the modified input data file to be saved to disk.

Note that, when inserting more than one column or row, as soon as the row or column is inserted it becomes part of the original matrix and all higher numbered rows or columns are renumbered. This means that it is very important to keep track of the rows or columns in the original matrix, as well as each new row or column that is inserted, in order to make sure that all new rows or columns are placed in the desired location. It helps in this respect to insert (or delete) from right to left or from the bottom toward the top when several are inserted at the same time.

Modification Sub-Option 3 - Add A Row Or Specification

Sub-option 3 allows the user to add another constraint to the problem. Suppose that available fall labor was also limited, for example, to no more than 750 hours and that the requirements of each activity were:

Wheat	.5 hrs/acre
Soybeans	1.1
Corn	1.5

The user would enter the data as follows:

```
                    Sub-option  3  - Add New Row

Describe the New ROW including it's unit in 17 Characters
(row = no.) 3
                          |...5....0....5..|
                         ? Avail Fall  Hours

To accept the displayed data just press <ENTER> or ^Y or ^X
09:58
Column Descriptions For Row Titled -  Avail Fall  HoursR 3
Number of row units given(-) or taken(+)

            1  Grow Wheat    Acre / Col. unit  .3
            2  Grow Corn     Acre / Col. unit  1.5
            3  Grow Soybeans Ac.  / Col. unit  1.1
            4  SPECIFED RHS AMT.  / Col. unit  750

Data OK?..Want to go ahead (Y OR N);(OR <CNTL-Q> = Quit
entire analysis) ? y
```

The current problem and optimal solution after these modifications are displayed in **Printer Output 4.**

Modification Sub-Option 5 - Specifying Minimum Or Maximum Amount

This sub-option allows the user to specify a minimum or maximum amount of an activity that can or must be included in a solution or plan. For example, suppose that to participate in a government program no more than 300 acres of corn may be grown. This maximum corn acreage limit can be imposed using Sub-option 5.

```
                    Sub-option  5  - Add New Row

Describe the New ROW including it's unit in 17 Characters
(row = no.) 4
                          |...5....0....5..|
                         ? Max Corn Land Ac.

Enter the column location for the (1st) column to bound with
this limit? 2
Enter the minimum (-) or maximum (+) specification limit
(RHS value) ? 300
Enter (next) col. location to 'draw' from the same limit
(0 = no more cols? 0
```

The problem matrix and optimal solution is given in **Printer Output 5.**

Modification Sub-Option 6 - Forcing An 'Exact Amount'

This sub-option permits the user to specify an exact or an upper and lower bounded specification. Potential hazards exist from over specification through the use of this sub-option. Exact restrictions should be avoided whenever possible.

PRINTER OUTPUT 3

Data File - WTCRNSBN
Titled - Expanded Wheat, Corn and Soybeans

Initial Tableau		Grow Wheat Acre	Grow Corn Acre	Grow Soybean Acre	SPECIFED RHS AMT.
Row	Description	COL 1	COL 2	COL 3	COL 4
1	Avail Land Acres	1.000	1.000	1.000	600.000
2	Avail Spring Hrs	0.400	0.750	0.600	400.000
3	$ PRICE/COST VAL.	95.000	125.000	115.000	.

PRINTER OUTPUT 4

Data File - WTCRNSBN
Titled - Expanded Wheat, Corn and Soybeans with Fall Time Needs

Initial Tableau		Grow Wheat Acre	Grow Corn Acre	Grow Soybean Acre	SPECIFED RHS AMT.
Row	Description	COL 1	COL 2	COL 3	COL 4
1	Avail Land Acres	1.000	1.000	1.000	600.000
2	Avail Spring Hrs	0.400	0.750	0.600	400.000
3	Avail Fall Hrs	0.300	1.500	1.100	750.000
4	$ PRICE/COST VAL.	95.000	125.000	115.000	.

PRINTER OUTPUT 5

Data File - WTCRNSBN
Titled - Expanded Wheat, Corn (with 300 Ac limit), Soybeans with Fall Time Needs

Initial Tableau		Grow Wheat Acre	Grow Corn Acre	Grow Soybean Acre	SPECIFED RHS AMT.
Row	Description	COL 1	COL 2	COL 3	COL 4
1	Avail Land Acres	1.000	1.000	1.000	600.000
2	Avail Spring Hrs	0.400	0.750	0.600	400.000
3	Avail Fall Hrs	0.300	1.500	1.100	750.000
4	Max Corn Land Ac.	.	1.000	.	300.000
5	$ PRICE/COST VAL.	95.000	125.000	115.000	.

```
                    Sub-option 6 - Add New Row

Describe the New ROW including it's unit in 17 Characters
(row = no.) 5
                         |...5....0....5..|
                         ?Min Row Crops Ac.
Enter the row no. to copy over to make an 'exactly' opposite
limit ? 1
The copied row's RHS =  600 .  The new row should have a
slightly greater value algebraically and should be of
opposite sign.
Enter the minimum (-) or maximum (+) specification limit
(RHS value) ? -400
```

Modification Sub-Options 1 And 2 - Deleting A Row Or Column

Sub-option 1 allows the user to delete a row or specification from the problem. For example, if the changes made using Sub-option 6 in the previous example were saved before solving the problem, the user might want to go back now and reload the file and delete the last constraint.

```
Sub-options 1 - Delete a specification (row) from further
consideration,

Current No. of row to delete (last rows first) 0=SKIP IT ? 5
```

As each row is deleted, higher numbered rows are renumbered (for example if row 4 were deleted row 5 would become the new row 4, etc.) If more than one row is going to be deleted, the user should start with the highest numbered row and work down in order to avoid deleting the wrong rows.

Sub-option 2 allows the user to delete a column in the same fashion as Sub-option 1 deletes rows.

Modification Sub-Options 7 and 8 - Reordering a Matrix Row or Column

Sub-options 7 and 8 allow the user to reorder an existing choice vector or constraint specification to a logically preferred column or row location. SMALLP prompts for the row or column to be switched and the row or column which will precede it in its new position.

```
                         Sub-option 7

Place an existing choice vector in logically preferred column
location,

ENTER CURRENT CODE NUMBER FOR VECTOR TO RE-LOCATE
(0 = NO MORE ? 3
Where do you want it (After which current vector No.) ? 1
```

Modification Sub-Options 9 And 10 - Scaling A Row Or Column

These sub-options allow an individual row or column to be adjusted by a specific scale factor. This is often used to make simple adjustments in measurement units. For example, to convert from bushels of corn to cwt. of corn, one could use .56 as the scale factor (56 lbs/bu divided by 100 lbs / cwt = .56 cwt/bu). It may be desirable to use the scale option to improve in computational accuracy. Accuracy is best when the A_{ij}'s have no more than three significant digits either to the immediate left or right of the decimal point. SMALLP first prompts for the row to be scaled. It then lists the current row or column description and prompts the user for a new 17 character description. This is to allow the new units to be entered in the description. The scale factor is entered next and SMALLP returns to the sub-option menu.

In least cost problems, the entry of whole rows of negative values becomes tedious. The effort is reduced if they are entered as positive values and then use a '-1' scale factor on the row.

It is also possible to rename a row or column without changing the associated vector by using a scale factor of 1 when using the scaling sub-options. While this is not explicitly stated in the sub-option menu, it is a useful feature.

```
 Sub-option 9 - Numerically scale a row for logic or accuracy

Which row is to be scaled (0 = Forget It) ? 1
Change units on AVAIL LAND ACRES.R 1...Enter new 17 character
description
                        |...5....0....5..|
                       ? AVAIL LAND HA
                   ENTER SCALE FACTOR? .405
```

Modification Sub-Option 11 - Modifying A Specified Cell

This allows a specific A_{ij} to be changed or corrected. Any activity or specification A_{ij} can be changed as well as any specific RHS or Objective function value. SMALLP lists the row number associated with the objective function value and the column number of the RHS values. Changes are entered by entering the row, column, correct A_{ij} value as they were in the Main Menu data entry Option 1. When all individual changes have been made, a zero row value is entered and SMALLP returns to the sub-option menu. It is always possible to return to the main menu to print out the current matrix and then return to Sub-option 11 to be sure that the correct row and column numbers of the coefficient to be changed are used. Even the starting level of A_{mn} may be stated this way.

Revised matrix after adding 1 column and 2 rows

```
                          Data File - WHEATCRN

     Titled - Expanded Wheat, Corn, Soybeans With Fall Time Considerations
     Initial Tableau
                               Grow       Grow        Grow
                               Wheat      Corn        Soybeans      SPECIFIED
                               Acre       Acre        Acre          RHS AMT.
          Row Description      COL 1      COL 2       COL 3          COL 4

        1   Avail Land  Acres  1.000      1.000       1.000         600.000
        2   Avail Spring  Hrs. 0.400      0.750       0.600         400.000
        3   Avail Fall Hrs.    0.300      1.500       1.100         750.000
        4   Max Corn Land Ac.    .        1.000         .           300.000
        5   $ PRICE/COST VAL.  95.000   125.000     115.000            .
```

```
       Sub-option  11 RHS = Column 4   Cost/Price Values = Row 6

  To accept the displayed data just press <ENTER>
  Type each value; then press <ENTER> before typing the next value.
  Typing a zero row value will stop data entry.  Slacks aren't
  entered.
  The RHS Column and the Cost/Price row are not entered in this
  section.
  ROW - COLUMN - A(i,j)    -  Another  ROW - COLUMN - A(i,j) dataset

    1      1       1                     1      5       1.000
    1      5      0.000                  0

              Want to quit A(i,j) entry ( Y or N )   ? y
```

Modification Sub-Option 12 - Modifying the Current RHS Or Other Column Vector

Sub-option 12 displays the current RHS vector resource, a specified column vector, and allows changes to be made quickly in any vector. A carriage return or use of the up and down arrow keys allows the user to skip through any correct values. Negative signs must be entered as appropriate. For instance, maximum resource use specifications are listed as positive values and minimum use specifications are listed as negative values. Any changes entered must also include a '-' (minus sign) if the constraint is a minimum use specification.

```
                 Option to Change or set the RHS values

          Minimum (-) or Maximum Use Specifications / Limits

               1 Avail Land  acres ( Units )       600.000
               2 avail Spring  Hrs ( Units )       400.000
               3 Avail Fall  Hours ( Units )       750.000
               4 Max Corn Land Ac. ( Units )       300.000
               5 Min Row Crops Ac. ( Units )      -400.000

  Data OK?..Want to go ahead (Y OR N); (OR <CNTL-Q> = Quit entire
  analysis) ? y
```

Modification Sub-Option 13 - Modifying Any Current Row Vector Including The Objective Function

Sub-option 13 is similar to Sub-option 12 except it operates on rows instead of columns. Negative signs must be entered along with values.

```
     The Objective Function Row Labeled - $ PRICE/COST VAL.
                                  Value per Column Unit
        1  Grow Wheat    Acre / Dollars          95.000
        2  Grow Corn     Acre / Dollars         125.000
        3  Grow Soybeans Ac. / Dollars          115.000
        4  SPECIFED RHS AMT. / Dollars            0.000

   Data OK?..Want to go ahead (Y OR N);(OR <CNTL-Q> = Quit
   entire analysis) ? y
```

B.7 Menu Option No. 6 - Budget a Solution

This option allows the user to manually specify levels for each activity in a plan. This option may be chosen either before or after solving for the optimal plan and gives the user a chance to quickly compare specific alternative plans such as the original or benchmark plan to the calculated optimum.

SMALLP prompts the user to determine if a list of alternatives and resource/constraints is needed. The current levels are displayed and a carriage return will let the user examine the current activity levels while re-entering new levels. A carriage return at any value accepts the currently displayed level. The budgeted results are then displayed.

Alternatively, a solved problem can be checked for computational accuracy by use of this option menu as well without entering new level data.

IV. Matrix Structure Used To Formulate A Non-Linear Problem

A. General Approach

Problem: To state a non-linear mathematical program with a non-linear objective function in a similar way to that used for linear programs. This allows solving such problems with a modified linear program algorithm such as SMALLP.

Primal-Dual: Every linear programming problem has a counterpart problem called its "dual". The original problem is referred to as a "primal." Consequently, if the primal problem is to maximize output (profit) with a given cost outlay (resource), the dual is to minimize the opportunity costs of not making the best use of the given resources.

Whether or not a particular program should be set up for solution in its primal or dual depends upon:

1. Which formulation yields more directly the desired analysis.
2. Which formulation can more easily be solved (no. of rows versus columns)

While it serves no innately useful purpose, the primal and dual can be combined in the same tableau. The primal-dual simply has all the column and row vectors of both (see the example to follow). All the initial value weights are internalized in the RHS column, thus the C_j are all zeros. The value of the optimum program to this tableau will also be zero.

<u>Counterpart Pairs</u>: Corresponding vectors of the primal-dual are called counterpart pairs. Each resource constraint or original basis variable in the primal is the counterpart of the resource evaluating non-basis vector in the dual. Original basis row vectors that serve to provide slack in the resource evaluating dual formulation are counterparts of the original non-basis column vectors of the primal. A vector process and its counterpart cannot appear in the same solution at the same time at non-zero levels.

<u>The Non-Linear Component to the Objective Function</u>: To form the non-linear or "interaction" component, the dual inequality in the primal-dual is modified. In our example, the value weight of the column vectors are changed to indicate that the value of the output decreases as a factored value in proportion to their level in the solution.

e.g. (value = 16,000 - 60 * wheat acres: Total contribution = 16,000 wheat acres - 2 * 30 x wheat acres)

We have taken the coefficient of wheat acres and multiplied it by a factor of 2 and placed the resultant 60 in the wheat acres column. The effect will be that as wheat acres enters it will require (take) a reduction of 30 ($ per unit) of level in the counterpart "resource" value. The factor of 2 describes the specific non-linear formulation known as Quadratic Programming. See the further notes following the display of the tableau.

B. The Original WHEATCRN As Made Into An Example Non-Linear Problem:

This model assumes a perfect market environment where the gross margin (GM) for wheat = $95 and for corn = $125 / acre. All that can be grown can be sold at prices which reflect these GM's. There is no relationship between the price and the quantity produced. Therefore the GM's are constants. Results were a Contribution to Overhead (COH) of $ 70,714.286 and 600 acres of wheat and corn were grown, using all the land and spring labor available.

Tableau for - WTCRNII - Illustrating the same basic problem but changed to a primal-dual non-linear problem representing a monopoly farm firm where gross margins for wheat and corn are functions of commodity prices. Prices are functions of the quantities put on the market. Wheat and corn prices are assumed to be uncorrelated.

Total GM for wheat (TGMW) = $16,000 - GMW * wheat acres,
Total GM for corn (TGMC) = $12,000 - GMC * corn acres.

Initial Tableau Row Description	Grow Wheat pmlAcr COL 1	Grow Corn pmlAcr COL 2	Opp-cost Land $Ac COL 3	Opp-cost SpLab$Ac COL 4	SPECIFED RHSAMT. COL 5
1:Avail Land pmlAc	1.00	1.00	.	.	600.
(primal or forward)				(null)	
2:Avail Springpmlhr	0.400	0.75	.	.	400.
3:MargRev Wheat $ac	-60.00	.	-1.000	-0.400	-16000.
(interaction)				(dual)	
4:MargRev Corn $ac	.	-40.00	-1.000	-0.750	-12000.
5:QUADRATIC OBJ.f $	-30.00	-20.00	.	. .	.
	(accounting for average revenue)				

The QUADRATIC OBJective function line above was added to the model to sum the value of the solution in as much as it is "zeroed out in the primal dual structure.

6:$ PRICE/COST VAL.	.	(a null vector)	.	.	.

Notes: Model assumes that price and hence GM is a function of the quantity produced. For wheat the relationships upon which the interaction sub-matrix and the RHS amounts are based are:

Wheat price (WP) = $16000 - $30 * wheat acres (WA).
TGMW = $16000 * WA - $30 * WP * WP (Quadratic)

and the marginal wheat gross revenue / acre (MGMW) is:

MGMW = $16000 - 2 * $30 * WP (the derivative)
= $16000 - $60 * WP (a linear relationship)

This implies a linear demand function for wheat and corn. This translates to a quadratic form of the total gross margin (revenue) function, and a marginal revenue (MGMW) function of twice the slope of the demand or average revenue function.

Similar functions are implied for corn as shown in column two and the RHS..

The reader should carefully note where in the sub-matrices the data discussed above is positioned. Note also the labels used for the rows and columns. Further note how the dual component is the inverse of the primal and how the objective function has been internalized into the RHS and the body of the tableau.

Functional relationships of powers (factors) other than 2 may also be used in deriving the coefficients in the tables and functional forms shown above. As argued elsewhere (by Maruyama and Fuller), these coefficients may represent various degrees of market power, risk tradeoff against profits, etc. The major challenge in non-linear programming is to quantify such relationships in order to set up these kinds of models. When that can be done realistically SMALLP procedures permit efficient solution subject to the usual caveats concerning global versus local optima.

Results for WTCRNII as presented and discussed above:

```
      Contribution to Overhead (COH) or Gross Margin = $ 0.00

Table 1
Alternatives Selected         Amount/Level          Alternative
   In the plan                In the Plan         Unit Cost/Price
1  Grow Wheat pmlAcr            266.667                0.000
2  Grow Corn  pmlAcr            300.000                0.000
                                566.667 Acres Grown
Table 2
Resources Remaining Unused    Amount Used   Original    Amount Not Used
1  Avail Land  pmlAc            566.667     600.0000          33.333
2  Avail Springpmlhr            331.667     400.0000          68.333
5  QUADRATIC OBJ.f $        -14,000.000       0.0000      14,000.000
```

Tables 3 and 4 are not shown as they contain no value or level data (all zeros); a common occurrence when ever the solution is interior to the bounds of the constraint set.

WTCRNIII - A Second Example Simular To WTCRNII Except It Assumes That Correlations Exist Between The Gross Margin Relationships Between Corn and Wheat.

This is represented by the coefficients in row 4, column 1 and row 3 column 2.

TABLEAU - Primal-Dual Non-Linear Monopoly Plan III with Price Correlations

Initial Tableau Row Description	Grow Wheat pmlAcr COL 1	Grow Corn pmlAcr COL 2	Opp-cost Land $Ac COL 3	Opp-cost SpLab$Ac COL 4	SPECIFIED RHS AMT. COL 5
1:Avail Land pmlAc	1.	1.00	.	.	600.
2:Avail Springpmlhr	0.4	0.75	.	.	400.
3:MargRev Wheat $ac	-60.0	0.50	-1.000	-0.400	-16000.
4:MargRev Corn $ac.	4.0	-40.00	-1.000	-0.750	-12000.
5:QUADRATIC OBJ.f $	-30.0	-20.00	.	.	.
6:$ PRICE/COST VAL.	.	.	.	.	.

In this case the production of each acre of one commodity incrementally increases (algebraically decreases) the intercept level as shown in the RHS for the other crop. Negative signs for such coefficients should have the reverse effect. In the case of risk management models these data relate to the cross-correlation penalties imposed on emphasizing particular activities.

File Name Is WTCRNIII
Primal-Dual Non-Linear Wheat Corn Farm Plan Monopoly III with Price Correlates
Contribution to Overhead (COH) or Gross Margin = $ 0.000

Table 1

Alternatives selected in the plan	Amount/Level In the Plan	Alternative Unit cost/price
1 Grow Wheat pmlAcr	269.391	0.000
2 Grow Corn pmlAcr	326.939	0.000
	596.330 Acres Grown	

Table 2

Resources Remaining Unused	Amount Used	OriginalAmount	Not Used
1 Avail Land pmlAc	596.330	600.0000	3.670
2 Avail Springpmlhr	352.961	400.0000	47.039
5 QUADRATIC OBJ.f $	-14,620.517	0.0000	14,620.517

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Appendix A

Title: Illustration of the Auxilliary Program LPMTXMOD used to create a Primal-Dual Matrix

First Screen - Selects the B: drive for data

```
Poly-period Matrix block and PRIMAL - DUAL copier for Math Programming.

      The file is to be found on which Disk Drive ? (A or B etc...)
      (The colon is added automatically) or (Esc> = Skip It)
      The Current Data Drive is C:.\ (= <ENTER>) ?b
```

Second Screen - Selects the \CLASS directory on the B: drive with a disk of available models

```
             Available B:\ sub-directory code numbers :

                  0 = Use this directory instead of any sub-directory

                  1 = CLASS                              2 = CLASSMOR
                  3 = DAIRY26                            4 = FEEDMIXS

             Type the corresponding sub-directory number (0 to 4) ? 1
```

Third Screen - Selects the data file \CLASS\WHEATCRN.LPD from the available teaching models.

```
        Existing B:\ data file code numbers:

              0  = Return to the menu instead of selecting one.

              1 = ADDSTOOL          2 = BENCHES           3 = BENCHP-D
              4 = BENCHTDU          5 = COFFEE            6 = COTTON1
              7 = COTTON2           8 = COTTONOP          9 = DIETPOLY
             10 = DIETPROB         11 = ELEVATOR         12 = ELEVBUSI
             13 = FEEDSTOK         14 = GADGETS          15 = NDWTGEXP
             16 = NYCROP90         17 = NYCROPSP         18 = NYCRPRIC
             19 = NYDAIRY          20 = OATCRNAF         21 = PDBENCH
             22 = PRODTRAN         23 = QPBENCH          24 = QPSTUFFD
             25 = QPTABLES         26 = RADIO            27 = REFINEIT
             28 = SETASIDE         29 = SOAP             30 = WHEATCRN
             31 = WHECNQP2         32 = WHECNQP3         33 = WILLEX1
             34 = WILLEX2          35 = WTCRNSBN         36 = XYZ-ABC
             37 = YOYOLLSS

   Type the corresponding number from (0 to 37 or <Esc> to skip it)? 30
```

Fourth Screen - Selects number 6 from the available options to create a primal-dual. Note that number 5 is used to speed up the copying of data blocks for poly period or any other use.

```
Options Menu to Work on the File WHEATCRN Now in Memory:

0 = Quit work on this model & return to the master menu.

1 =  List the current set of choices and specifications under
     consideration.

2 =  Print out all or part of the problem under consideration
     in table form.

3 =  Check   the   problem   structure   for   feasibility   and
     boundedness, et. cetera.

4 = Modify the problem structure before going further with it.

5 = Copy a data block so as to build a Poly-period or Dynamic model.

6 = Convert a Primal to Primal-Dual (ready for non-linear modeling).

7 = Save the file and quit work on this model.

Key-in the Option Menu No. (1 - 7) or 0 = Go to Main Menu ? 6.
```

Fifth Screen - Choose to zero out the objective function or not when creating a primal-dual. Also displays status of processing and completion.

```
The file being converted to PRIMAL - DUAL form is labeled:

Corn Wheat Example Farm Plan Problem Illustrating Input Option Two


Want to zero out the the Objective Function row ready to modify into
a non-linear model by inserting internal coefficients (Y or <ENTER>
= N) ? n

Completed PRIMAL - DUAL Form is now in memory for:

PRIMAL-DUAL Form of Corn Wheat Example Farm Plan Problem

              * *  PAUSE..Press any key to continue  * *
```

Sixth Screen - Returns to the options menu. Select number 7 to save new file to disk after use of the other options.

```
Options Menu to Work on the File WHEATCRN Now in Memory:

0 = Quit work on this model & return to the master menu.

1 = List the current set of choices and
    specifications under consideration.

2 = Print out all or part of the problem under
    consideration in table form.

3 = Check the problem structure for feasibility and
    boundedness et. cetera.

4 = Modify the problem structure before going
    further with it.

5 = Copy a data block so as to build a Poly-period
    or Dynamic model.

6 = Convert a Primal to Primal-Dual (ready for
    non-linear modeling).

7 = Save the file and quit work on this model.

Key-in the Option Menu No. (1 - 7) or 0 = Go to Main Menu ? 7
```

Seventh and Eighth Screens - Selects drive and directory for saving the new or revised file.

```
The file is to be saved on which Disk Drive ? (A or B etc...)
(The colon is added automatically) or (Esc> = Skip It)
The Current Data Drive is B:.\  (= <ENTER>) ?

Available B:\ sub-directory code numbers:

0 = Use this directory instead of any sub-directory

          1 = CLASS                      2 = CLASSMOR
          3 = DAIRY26                    4 = FEEDMIXS

Type the corresponding sub-directory number (0 to 4) ? 0
```

Ninth Screen - Select file name P-DWTCRN to use in saving the new or revised file.

```
Existing B:\ data file code numbers:

0 = Return to the menu instead of selecting one.

        1 = ADD2ND                    2 = ADD3RD
        3 = ADDSTOOL                  4 = PDADDSTL

Type the corresponding number from (0 to 4 or <Esc> to skip it)

Or type a (up to 8 character) name of the data file to be
saved ? P-DWTCRN
```

Screen shown as solution is found by forcing feasibility in the dual counter part vectors by the use of SMALLP Option 5 or 8.

```
Solving process is beginning. The time is now 07:54:08 Hours

Iter. Variable Leaving       Variable Entering    Plan $ Value

 1   Raise Corn Ac.$MRR      Max Land in Ac$MVC   -75,000.000
 2   Max Spring Hr.$MVR      Raise Corn AcreC      -8,333.333
 3   Raise Wheat AC$MRR      Max Spring Hr.$MVC    -4,047.619
 4   Max Land in AcresR      Raise Wheat  AcreC         0.000

Starting time was 07:54:08
Optimum solution found (at 07:54:09) Through 4 Iterations

Contribution to Overhead (COH) or Gross Margin = $0.000

For: PRIMAL-DUAL Form of Corn Wheat Example Farm Plan Problem

Want Results Printed Out [Y(es) or P(rint) or put in a Text F(file)]

Or just press <ENTER> to First Screen the Results [i.e., a N(o)
Response] ?
```

Note how the spaces 15 through 17 in the primal vectors labels have been modified to label the dual counterpart vectors.

$ MR stands for dollars of Marginal Revenue in contribution to the objective of algebraic maximization.

$ MV stands for dollars of Marginal Value in the reduction of the opportunity cost of not using available resources in their highest and best use and thus reducing the penalty of less than the best plan.

These titles may be changed as appropriate by using the SMALLP modification sub-option to scale a vector.

Resulting analysis of the primal-dual example problem:

```
For: PRIMAL-DUAL Form of Corn Wheat Example Farm Plan Problem

Contribution to Overhead (COH) or Gross Margin = $0.000

Table 1
Alternatives selected      Amount/Level        Alternative
in the plan                In the Plan         Unit cost/price

1  Raise Wheat  Acre        142.857             95.000 (Acres to grow
2  Raise Corn   Acre        457.143            125.000  of each crop)
3  Max Land in Ac$MV         60.714           -600.000 (Marginal Values of
4  Max Spring  Hr$MV         85.714           -400.000  Limiting Resources)

Table 2 and 3 are empty in this example

Table 4
Resource              Residual Marginal Value        Specified
Description Unit           Dollars/Unit           Resource Amount

1  Max Land in Acres         60.714          600.000 (Resource values)
2  Max Spring Hours          85.714          400.000
3  Raise Wheat Ac$MR        142.857          -95.000 (Value and acres
4  Raise Corn   Ac$MR       457.143         -125.000  grown for each crop)
```

Matrix for this problem:

```
Data File - P-DWTCRN
Titled - PRIMAL-DUAL Form of Corn Wheat Example Farm Plan Problem
Initial Tableau
                     Raise Wheat Raise Corn  Max Land Max Spring  SPECIFED
                        an Acre    an Acre   in Ac$MV   HRS$MV    RHS AMT.
Row  Description         COL 1     COL 2      COL 3      COL 4     COL 5

1:Max Land in Acres      1.        1.          .          .        600.
2:Max Springtime Hr     0.400      0.75        .          .        400.
3:Raise Wheat Ac$MR       .         .         -1.        -0.4      -95.
4:Raise Corn  Ac$MR       .         .         -1.        -0.75    -125.
5:$ PRICE/COST VAL.     95.       125.      -600.      -400.         .
```

Note how some of the cells A3,1; A4,1; A3,2 and A4,2 would be non-zero whenever objective function values are a function of vector levels. In this case, row 5 is all zeros and column 5 values represent the zero level objective function values. Column 1 and 2 values then are the linear and marginal relationship per unit level change. An additional row 5 could be inserted to serve as an accumulator of the primal column vectors average per unit gross margins.

Appendix B

Programs and Files on This SMALLP Distribution Disk:

SMALPBRF	SCN	On-Line Documentation screens
SMALFRST	SCN	First Screen for SMALLP
SMALLAST	SCN	Last Screen for SMALLP
SMALLMOD	SCN	Description of Matrix Modifications available in SMALLP
SMALLP	EXE	Actual Program
SMALLP	TXT	Documentation in a Text version (Currently out of date
SMALLP	.WP5	" " Word Perfect 5 File Form Documentation
SMALPRAM	FDD	Parameter File for Floppy Disk Data Use (re-name if used)
SMALPRAM	ETR	" " actually used
SMALPRAM	HDD	" " for Hard Disk drive Machines " " "
MENUFILE	TXT	Describes the MENU'd Choices available

Utilities Which Must Be Accessible - May Be PATH'd:

CBT	EXE	Used to examine or Print data (.LPD) files
BRUN10	EXE	Subroutines used by Compiled Quick BASIC
BT	COM	A Utility to Replace TYPE to lists files on the screen
DR	COM	Combines SDIR and BT features. Also deletes and renames files
MENU	EXE	A User Oriented Menuing system
SDIR	COM	A Sorted DIRECTORY Lister with write to the printer features
TED	COM	A simple easy to use text file editor

Example data files For SMALLP also on the distribution disk:

BENCHES.LPD WHEATCRN.LPD SETASIDE.LPD WTCRNSBN.LPD ELEVATOR.LPD

Documentation for the Above Mentioned Utilities:

BT.COM -- A Better Type Screen Displayer - Replaces TYPE (and ST - Super Typer)
BT presents 24 line paged screen file displays under user control.

To Use - Type Either: (Assumes BT.COM is in the path)
BT filename.ext or BT filename.ext /W if it is a WORDSTAR file.
The filename may contain drive and path specifications.

Controlling Key Stroke Commands:
Page Up - PGUP One Line Up - UP Arrow Top of File - HOME
Page Down - PGDN One Line Down - DOWN Arrow End of file - END

Horizontal Movement For Lines Over 80 Characters:
Scroll Right 8 Characters Right Arrow once for each 8 characters,
Scroll back to the left 8 Characters - type the Left Arrow once

Escape back to DOS and the Screen as it was when you activated BT by Typing: ESC (or Ctrl Break ?)

Error Messages - (1) File Not Found,
(2) Unsupported Graphics Mode if DOS is in a graphics mode.

Notes:

Version 2 displays the above instructions on line 25 in inverse video. Requires 33k , 2.0 + to run. Small left arrows represent EOF marks. BT is EGA aware and works with color adapters, but some snow will appear. Under WINDOWS or TOPVIEW (interrupt @ 23h) - Writes directly to Screen. Source:BROWSE.COM in PC Magazine 3/25/1986 & PC Mag DOS POWER TOOLS 2nd ed.

Documentation for MENU - A Program Executing Program:

MENU.EXE offers a simple, uncomplicated presentation of selected program analysis options available to a user. It presents the user with selected sets of available options. It permits the person setting up the system to specify appropriate sets of options through drive and directory designation. These selected groupings are each specified in MENUFILE.TXT files by name and a short description of each program or option.

MENU works with a single directory and/or with a set of subdirectories each of which contains its own MENUFILE.TXT file. If subdirectories exist, the user must select between them when they are displayed. Then the set of options that one contains is displayed. The user may then make a choice. Subdirectory features are ignored if they were not specified as part of the system.

The user can also change default drives and thus the related subdirectories. The actual programs are SHELLED under MENU. At completion, the system will once again display the options available.

Notes:

BRUN1O.EXE must also be available to the 13K version. Both versions allow drive changes. MENUFILE.TXT files must follow certain rules in preparation. Preparation may be done from the system command prompt as follows: Type COPY CON MENUFILE.TXT <cr>. Then (without a prompt) type "a description of the set of choices (a title) of less than 45 spaces", again followed by a carriage return <cr>.

Then for each option or choice type a "FILENAME" (followed by) "a (up to) 65 character description of that FILENAME; (program or option)". Up to 15 similar lines may represent other options (all to be in .EXE, .BAT or .COM form). If less than 10 are used the display will be double spaced and easier to read. Note how quotes are used in the file to include the name and description data (which includes spaces). The last line should be typed as: "END OF FILES", and "END OF FILES".

When COPY CON is being used to prepare a MENUFILE.TXT, finally type F6 to do a COPY it to a disk file and a <CR> will produce the system prompt.

A text editor (TED) can also be used to develop or modify a MENUFILE.TXT.

Display of the MENUFILE.TXT file for this distribution:

```
Executable Programs on this SMALLP91 "
"CBT     .EXE","Displays and screen edits text (.LPData & .LPOutput) files"
"SMALLP  .EXE","Sets up, modifies and parameterizes MP/LP problems"
"END OF FILES","END OF FILES"
```

Another example from Minnesota Computer Decision Aids (MINNAIDS):

"BUSINESS & FINANCE"
"MACRS87 ","1989-?? Depreciation calculations with present values."
"FARMBID ","Determines the Maximum Bid Price for Land or a Farm."
"DEBTCAP ","Determines the Maximum Debt Carrying Capacity of a Farm."
"QUCKLOOK","A Quick and Dirty Farm Business Analysis Based On Limited Data."
"TIMEVALU","A Set of Present & Future Value Analyses for Loans & Cash flow."
"USERDOCS","Explains How to Make Hard Copy Documentation of MINNAIDS."
"END OF FILES","END OF FILES"

Note concerning the 58K version compiled with BCOM10.LIB:

For use with .COM files, and any compiled .EXE files, a second version exists. The SHELL command is involved. Consequently .BAT files can also be accessed. The user is referred to programs like HDM or AUTOMENU for such applications.

Note on the utilization of MENU:

It has been widely observed that intellect or psychology limits exist in software use. Seven + or - 2 applications seems to be a practical limit for most people. Shells and menuing software systems are techniques to assist users to go beyond word processing, spread sheets, data base managers and communication applications. MENU offers a similar potential to combine applications into a software system by bundling applications into a "tree" structure. This structures the choices a user has to make by "bundling" them.

TED.COM - A Text Editor :

Call the ASCII file editor TED.COM as follows:

[path\]TED [path\]name-of or to-be-given.ext the ASCII file <ENTER>

The 1st. 24 lines of the file, if it exists, will appear on the screen. The 25th line provides key documentation of how the function keys are used to control the editor. The directional arrows and page up or down, home (start of line), end (of line), backspace, insert and delete work as to be expected in most programs. The normal mode is insert not type over. <ESC> will let you change your mind after a function key has been typed.

Find or replace options do not exist. Line count is not displayed. If you type lines over 80 characters you cannot see what you wrote. To remedy back space to less than 80 spaces, <ENTER> and move the rest to a new line.

This is an easy to use editor particularly for simple tasks like building or editing autoexec.bat or documentation files. It will also serve as a note recorder or even a memo writer. It is quick to get into and easy to get out of. F1 (ABORT) does not save the file, while F7 (EXIT) allows you to rename it if needed and requires you to save it in order to get out.

SDIR.COM (Sorted DIRectory) replaces the DIR command. It is self-documenting. This is version 2.6 and is better in some ways than V-5.0. DR.COM does provide some useful features that SDIR does not, but the SDIR write to printer option is useful.

DR.COM has name changing and file deletion features. It also displays text files on the screen and runs .EXE, .COM and .BAT files with a Ctrl-ENTER key stroke.

These are all in the public domain, so copy them as you see fit.

Appendix C

Mathematical Programming Models Available in SMALLP Format
(The files listed are all stored on a 720k disk with the LPFILES.BAS and LPMTXMOD.EXE programs)

Directory of B:\FEEDMIXS

Name	Bytes	Rows	Cols	Title or Description
DAIRY85	3907	10	9	1300 70 3.8 WAYNE SMITH-YOUNG AMERICA-BASIC DAIRY FEED 12-31-84
DAIRY90	3925	10	9	1300 70 3.8 WAYNE SMITH-YOUNG AMERICA-BASIC DAIRY FEED 12-31-84
DBAL	9600	12	28	BASIC DAIRY FEED FILE for use with DAIRY218
F250KGDA	2375	9	7	MIN COST DAILY FEED RATION (250 KG STEER)
F250KGST	1795	7	6	7 row version of Min Cost Daily 250 Kg. Steer Feed Ration Example
F800LBST	1040	3	5	Daily Ration for 800 lb. Steers based upon 5 feed stuffs
OPTDYRAT	2254	5	8	The Profit Maximizing Dairy Nutritionist (Quick & Dirty Consultants)
OPTHICOW	6823	12	15	Optimal Ration and Production Level for High Potential Cows (Illustrative Only)
PIG3	7150	13	18	A LEAST COST HOG RATION BALANCER PROBLEM (high energy - tight specs)
STEER	3384	12	12	Steer Calf 2 phase ration calculation

Directory of B:\CLASS

Name	Bytes	Rows	Cols	Title or Description
ADDSTOOL	896	4	3	Example benches, Tables and Stool Manufacturing Problem
BENCHES	421	2	2	EXAMPLE PROBLEM BENCHES AND TABLES
BENCHP-D	775	4	4	Primal-Dual Formulation of the Benches and Tables Problem
BENCHTDU	465	2	2	Dual Formulation of Benches & Tables - Minimizing Resource Use Opportunity cost
COFFEE	851	3	3	Coffee Sales & Processing Weekly Plan for 3 Quantities/Qualities of beans
COTTON1	896	2	5	Derived from Cotton Use of land & water McCorkle & Boles (1954) 1st graphs.
COTTON2	1177	3	6	Derived from Cotton Use of land & water McCorkle & Boles (1954) 1st graphs.
COTTONOP	768	2	4	California Cotton Production - Use of Land & Water ; McCorkle & Boles (1954)
DIETPOLY	1664	9	6	SALLY'S PROBLEM-A TEXTBOOK EXAMPLE HUMAN LEAST COST DIET
ELEVATMX	1609	7	8	Mixed Integer Revision of FEED ELEVATOR Daily OPERATION & Investment
ELEVATOR	1433	6	7	FORMULATION OF THE FEED ELEVATOR DAILY OPERATION
ELEVBUSI	1205	4	7	Feed Business Profit Maximization
FEEDSTOK	1290	5	7	Raise Sheep, Hogs and Cattle based upon Grain and Hay Production
GADGETS	427	2	2	Wadget and Gadget Weekly Production Plan
NDWTGEXP	635	3	3	A NORTH DAKOTA ANNUAL CASH CROP CHOICE EXAMPLE
NYCROP90	3655	16	8	CROPPING PLAN FOR SEVEN CROPS WITH 240 ACRES AVAILABLE PLUS ACTG. EXP.
NYCROPSP	4025	18	8	Determination of the cropping plan which contributes the most annual overhead
NYCRPRIC	3965	17	10	N.Y. Crop Choice model with an explicit Land Rent and Corn sale vector
NYDAIRY	1408	7	6	1st cut at New York Dairy farm - no grain production & 48 cows
OATCRNAF	565	3	3	Cropping Combination of Oats and Corn to Grow and Alfalfa to Harvest
PDBENCH	777	4	4	Benches and tables problem in quadratic form
PRODTRAN	5255	11	28	Produce & transport, 2 plants & 3 consuming regions Given time Period

Name	Bytes	Rows	Cols	Title or Description
QPBENCH	831	4	4	Benches and tables problem in quadratic form
QPSTUFFD	896	4	4	Sectionals and Sofas problem in quadratic form
QPTABLES	1152	6	4	Benches and tables problem in quadratic form
RADIO	982	6	3	The Turned On Radio Manufacturing Company Weekly Production Plan.
REFINEIT	571	3	2	Minimum Cost for Orders of Gasoline, Kerosene & Jet Fuel
SETASIDE	990	4	6	Participation in the Feed Grains Program on a feed short Dairy Farm
SOAP	688	4	2	Minimum Cost Use of 2 Soap Sources to mix 1000 pounds of Product Soap
WHEATCRN	475	2	2	Corn Wheat Example Farm Plan Problem Illustrating Input Option Two
WHECNQP2	985	5	4	Primal-Dual Non-Linear Wheat Corn Farm Plan Monopoly II But no Cross X
WHECNQP3	1055	5	4	Primal-Dual Non-Linear Wheat Corn Farm Plan Monopoly III with Price Correlates
WILLEX1	935	3	5	Williams Exp1, Pgs. 5-7 , Engineering Factory 5 Product & 2 Processes
WILLEX2	1525	5	6	Williams Exp. 2, Pgs. 8-9 & 15-16 Vegetable Oil Blending per Month
WTCRNSBN	855	4	3	Expanded Wheat, Corn (with 300 Ac limit), Soybeans with Fall Time Needs
XYZ-ABC	768	3	3	Weekly XYZ Company plan to Produce Quantities of A, B & C.
YOYOLLSS	645	3	2	Yo-Yo production in the small shop - LL's & SS's

Directory of B:\CLASSMOR

Name	Bytes	Rows	Cols	Title or Description
AFRICADT	896	5	2	African Farm Mgmt 5x2 - Add Min Energy Cameroun Chapt 16 pg 165-170
AFRICLAB	896	4	3	African Farm Management 4x3 Add Labor West Cameroun Chapt 16 pg 165-170
ALLOYMAK	4480	19	11	Least Cost Solution for Aluminum Alloying
CASHFARM	1024	5	3	EXAMPLE CASH GRAIN FARM EXAMPLE
CDYNAMIC	2878	15	12	Class Example of Dynamic Scheduling in Crop Production ,1988-1990
CROPBEEF	2275	10	11	CROPBeef ; An Southern Beef and Cotton Crop Farm Model
FARM1	11008	41	50	Scheduling The Corn & Soybean Farm In Freeborn CO. (near singular)
FARMNORM	1925	10	13	NORMAL YEAR BEST USE OF RESOURCES VIA CROP & FEEDING
GASDSN90	2560	10	16	Gas Distribution 4 Cust. 2 Points + 2 Stripper Wells (in truckloads)
GASPURA1	2075	10	8	Purair aviation gasoline blending; UGLP pg 67, exp 6
GNATCHEZ	5075	16	10	Optimum quantities of gas components in regular and premium gas
JOBSHOP	2048	7	10	FERN STAND PROBLEM
NORWAY	4668	9	16	Norway model of producing required amounts of Milk and beef
PASTBAD	4215	21	10	Richardson Farms Pasture Allocation Problem -- lower returns
PASTGOOD	4215	21	10	Richardson Farms Pasture Allocation Problem -- higher yields
PASTURE	4195	21	10	Richardson Farms Pasture Allocation Problem
POLICEMI	1090	6	6	Minimization of Police Officers on Duty
PRESSMAX	1192	8	4	Maximization of Profit in Printing Company
ROSHEEP	5535	28	14	Rosemount Sheep Unit Revenue Optimization
TRANPROD	5255	11	28	Produce & transport, 2 plants & 3 consuming regions Given time Period
TRANSPRT	2420	14	8	Transportation From Two Factories to Three Warehouses-Costs to Store all
TRANSPT2	2752	12	14	Transport From 2 Factories to 3 Warehouses with excess storage costs
WHISKEY	1290	6	6	Profit Maximization for Blender of Whiskey
WTGEXP90	3980	21	18	AGEC 5020 SPECIAL ASSIGNMENT - SAMPLE CROP FARM PLAN
WTGINND	638	3	3	What to grow in N.D. Example to test graphics
WTGLABOR	4646	23	18	SAMPLE CROP FARM PLAN WITH LABOR REQUIREMENTS

Directory of B:\DAIRY26

Name	Bytes	Rows	Cols	Title or Description
160A1005	29115	60	94	THESIS MODEL: 1 FAMILY; 50 HB4; 16,000 LBS.
160E2010	29125	60	94	THESIS MODEL: 2 FAMILIES; 100 HB8 FULL MECH; 16,000 LBS.
160E3015	29125	60	94	THESIS MODEL: 3 FAMILIES; 150 HB8 FULL MECH; 16,000 LBS.
180A1005	29475	60	94	THESIS MODEL: 1 FAMILY; 50 HB4; 18,000 LBS.
180E2010	29485	60	94	THESIS MODEL: 2 FAMILIES; 100 HB8 FULL MECH; 18,000 LBS.
180E3015	29485	60	94	THESIS MODEL: 3 FAMILIES; 150 HB8 FULL MECH; 18,000 LBS.
DORNMODS	28215	64	88	APPENDIX D: MODIFIED PART OF THE MODEL
LOL40TL	14720	37	40	SO. MN. LOL PROJECT ON ECONOMIES OF SIZE; TIE STALLS, 1 FAMILY, 14,000 LBS.
LOL50FL	14592	37	40	SO. MN. LOL PROJECT ON ECONOMIES OF SIZE; FREE STALLS, 1 FAMILY, 14,000 LBS.
MAXFORAG	2172	6	8	Effect of added D.M. for forage on lactation (365 da. average) feed needs
NEDAIRY	16888	41	48	NORTHERN MINNESOTA EXTENSION MODEL DAIRY FARM
SEDAIRY	15488	40	43	SOUTHERN MINNESOTA EXTENSION SYSTEMS COMMITTEE MODEL FARM
STOMCASH	18134	55	53	AN ECONOMIC EVALUATION OF ALTERNATIVE TILLAGE SYSTEMS IN A DAIRY CATTLE LP

Appendix D

Glossary Of Some Mathematical And Linear Programming (LP/MP) Terms (As Found In Agricultural Economics Literature)

ACTIVITY — Refers to column vector in a LP/MP problem. It is an alternative which may or may not become part of the final plan. Also: unit budgets, production process, process budgets, and columns.

BASIS — In linear programming, any plan or iteration of the matrix or model. The original basis, any succeeding iteration or the final basis.

BENCHMARK — Refers to use of a budget option or forced LP solution where the level of each process is set by the user. This is used to establish a reference point from which to evaluate other solutions. It may refer to a do nothing plan, the current existing plan of an operating firm.

CONSTRAINTS (or restrictions) — The set of limiting specifications. They can include such things as quantity of resources available or the maximum marketable quantity of a commodity. Also: specifications, original R.H.S., rows, equations, inequalities, original basis, and PO's.

CRITERION FUNCTION — A calculated function derived from the objective function. An expression of the marginal economic contribution to the existing resources when expressed in Primal (the "usual") form.

DEGENERACY — A solution where one or more final basis variables have zero values. Usually not serious, but when encountered, worth changing parameters to compare the existing with the alternative solution of similar economic worth.

DUAL — An inverted expression of the primal or forward tableau where the resources make up columns or choice vectors and the rows or constraints reflect the alternatives. In the dual, the objective is to minimize the cost of not selecting the plan which puts resources to their highest and best use.

FARM OR BUSINESS PLAN — Refers to a set of activities (production processes) which might be employed. In other words, a firm organizational scheme. In LP it specifies both the activities and their levels in the plan.

INFEASIBLE — A misspecified model where the constraints are in conflict and a feasible plan cannot be found.

MODEL — A specified set of rows and columns making up a LP/MP tableau and, hence, expressing a (linear) mathematical description of some set of activities and limitations/specifications.

OBJECTIVE FUNCTION — The separable function or profit or cost function which is maximized or minimized. It's also implicitly expresses the need to reduce to a minimum the opportunity costs of not putting resources into their best use while striving to attain required minimum specifications.

OPTIMUM PLAN — Refers to a final (and LP/MP optimal) plan which involves the allocation of the available resources and, therefore, produced the maximum net returns to the given limits placed on the plan. Also: the solution and the final basis.

MATRIX (or tableau) coefficients, transformation rates, original basis, model.

PRICE (CJ) Refers to the net returns from a process or activity. If the price is positive (no sign), it refers to income (net or gross depends on the model). A negative price refers to a cost or a reduction in profit. Prices are always given in terms of some unit or quantity and monetary unit. Also: costs, c_j's (and c_i's), per unit net contribution to overhead, objective function value(s).

PRIMAL-DUAL (1) most algorithms solve the forward or primal or plan and derive the backward or dual, the imputed shadow prices. (2) A redundant formulation of the original basis containing counterpart pairs of vectors and leading to both (1) as expressed above, plus an (2) inverted (dual) based upon the counterpart pairs of vectors.

PROCESS, PRODUCTION PROCESS, PRODUCTION ALTERNATIVE ACTIVITY, COLUMN VECTOR (or production possibility) All refer to activities in which resources can be converted into a product or output. These appear as columns in the LP matrix. Also: process budget, unit budget, or production process, or block budgets.

REDUNDANCY If on constraint is ineffective due to all non-zero coefficients in another being equal or more restrictive, it is redundant; it plays no role in defining the feasible area. Often an over-specified model where one or more vectors is very similar to others and the matrix is "near singular"; cycling in the solution process is likely.

RESIDUAL MARGINAL COST (RMC) (An imputed shadow price) Refers to the cost by which a final non-basis activity was excluded from the plan. RMC is also the dollar amount by which profit would be reduced if a unit of the activity was forced into the plan.

RESIDUAL MARGINAL PRODUCT (RMVP) (or imputed shadow price) Represents the dollar value which the last unit of a resource contributed toward the profit. It can also be interpreted as the maximum one could pay for an additional unit of the resource.

RESOURCES Refers to those items which, through the production processes, can be converted into product or output. Resources, together with the specifications, constraints, and restrictions, generally make up the right hand side (RHS) of the matrix. (The RHS is referred to as the (PO) and b_i's or B vector.

SENSITIVITY ANALYSIS (or stability limits) Refers to the range in levels over which a plan will contain the same vectors. These data are found on the right side of the four complete tables of SMALLP computer output.

SMALLP.EXE A machine language code that has been compiled for use by the computer to solve mathematical programming problems.

SOLUTION Shown as four tables of computer output in SMALLP. The complete solution in SMALLP shows the optimum plan, slack resources, RMVP's, RMC's, and the stability limits for each.

UNBOUNDED A "plan" which is not limited by the constraint set: the objective value is infinite.

VECTOR Refers to any row or column set of coefficients in an LP model. Graphically a line of specified directions in N-dimensional space. If the line is scaled in magnitude it becomes a scaler.

Terms Describing Various Types of Mathematical Programming

DYNAMIC PROGRAMMING	Poly or multi-period modelling where variable levels selected in one time period influence selection or level in other time periods. It may or may not include adherence to the structures of linear or non-linear programming.
INTEGER PROGRAMMING	Like LP except subject to the additional constraints condition that all variable in solution must take on integer values.
LINEAR PROGRAMMING (LP)	A mathematical technique which analyzes (activities or production processes) and select those which make best use of the resources to attain a desired objective such as maximum profit subject to a set of (linear) constraints or specifications.
MIXED INTEGER PROGRAMMING	See Integer Programming - some variables are limited to integer values, others are not.
NON-LINEAR PROGRAMMING	Mathematical programming where the objective function contains powers of the solution levels other than a part of one (linear). Quadratic is a special case. Usually handled via internalization of the objective function power effects into a sub-matrix developed in the intersection of a primal-dual formulation. The system is still subject to a set of linear constraints or equations.
RECURSIVE PROGRAMMING	Is either a dynamic model or a set of individual models for a sequence of time periods where acceptable levels of some variable are constrained based upon the levels obtained in the previous solution in the sequence.
SEPARABLE PROGRAMMING	Modeling where the solution would not or does not change if two or more smaller models of the over all scheme are analyzed separately instead of solving the one over all model.
RISK ANALYSIS	Programming which covers a variety of ways to recognize the utility of risk avoidance. Techniques such as (second degree) stochastic dominance, EV analysis, MOTAD, and chance-constrained programming may be found in the literature.