A MICROCOMPUTER LINEAR PROGRAMMING PACKAGE: AN ALTERNATIVE TO MAINFRAMES

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Abstract

This paper presents the capabilities and limitations of a microcomputer linear programming package. The solution algorithm is a version of the revised simplex. Rapid problem entry, user ease of operation, sensitivity analyses on objective function and right hand sides are advantages. A problem size of 150 activities and 64 constraints can be solved in present form. Due to problem size, limitations and lack of parametric and integer programming routines, this package is thought to have the most value in teaching applications and research problems in the smaller size categories.

Key words: linear programming, microcomputers, simplex

Linear programming (LP) codes for mainframe computers have been widely accepted and used. Simplicity and flexibility in regard to problem definition and solution have made them a favored tool of agricultural economists. Mathematical Programming System (MPS by IBM Corporation) and Functional Mathematical Programming System (FMPS by Sperry Univac) represent the standard of comparison for LP packages, although recent experiences by Tice and Kletke raise questions about the reliability of some MPS software-hardware combinations. Nevertheless, these programs have proven to be flexible, accurate in most cases, and relatively easy to use and understand. With due caution in usage and responsible maintenance and correction, these packages are likely to remain the standard for comparison.

While the capabilities and operating characteristics of mainframe LP packages are well documented, LP for microcomputers is relatively new and only recently have reliable, easy to use LP packages become available.[1] This paper presents a microcomputer LP package (DHLLP) and describes its capabilities, input and output formats, and advantages and limitations in use. See Laughlin for further documentation of DHLLP.

THE PROGRAM

The DHLLP package is available for the IBM-PC. It requires at least 128K of random access memory (RAM) and one disk drive. The program is divided into three major sections—(1) a problem setup module, (2) a solution algorithm module, and (3) a MPS/FMPS data file transfer module. All modules are compiled BASIC programs linked by a controlling menu which calls the appropriate functional module upon the user's selection.

The problem setup module performs two distinct functions. It provides the means to enter and store an initial LP tableau, and the means of retrieving, inspecting, changing, and restoring previously entered tableaus. For a new problem, each element of the initial tableau is requested in a format similar to MPS and FMPS procedures. After naming the activities and constraints, the user is prompted to enter each input-output coefficient. Zero elements are assumed where non-zero elements are not provided. After a problem has been entered, it can be viewed and/or edited on the screen by columns or by rows. Also, rows and/or columns can be added or deleted, the problem printed in tableau form on paper, and stored permanently on disk. Further, during problem entry or when adding columns or rows, part or all of the vector being entered can be zeroed instantly and non-zero elements changed to the correct values using the edit feature of the program. Rapid entry or addition of rows or columns having only a few non-zero elements is facilitated. Previously stored problems can be retrieved and examined on the screen, changed, printed on paper, and then stored either as new problems or as permanent revisions of the original problem. The user can easily develop a

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[1] The author is aware of at least one commercially available LP package, Eastern Software Products, Inc. The author has not used this package and, therefore, can make no statement about its capabilities although advertising literature is impressive.

series of similar problems in a relatively short time and permanently store each one.

The solution algorithm for DHLLP is a version of the revised simplex algorithm (Phillips, et al.). Only the inverse of the current basis matrix is maintained in RAM. All other problem information is maintained on disk and retrieved as needed. Other features of the solution algorithm include a rounding error control mechanism and an anti-cycling device defined by Hadley which systematically breaks ties between outgoing rows. In addition to the rows and columns section for the optimal solution, the program contains as optional features an iteration log and sensitivity on the objective function and right hand side.

A third module of the DHLLP program provides the user with the added flexibility of developing the initial tableau using the setup portion of this package then having the problem automatically written into a data file form for use by MPS/FMPS mainframe packages. The MPS/FMPS data file is stored in a sequential file and is available for telecommunication to a mainframe computer and subsequent solution by MPS/FMPS.

DHLLP has a capacity of 150 real activities and 64 constraints. The program automatically adds disposal and artificial activities. Arithmetic is performed in double precision accuracy but initial problem information is stored as single precision real numbers. Requests for the package should be made through your state extension specialists who in turn should contact the Computer Applications and Service Department of the Mississippi Cooperative Extension Service.

SAMPLE PROBLEM

The interactive nature of the DHLLP problem setup program prevents satisfactory illustration of that module. User feedback, however, indicates that the problem setup module is very easy to operate and follow. Printed tableau output from the setup module and solution output from the solution module will be illustrated with a sample problem used in graduate classes in teaching LP techniques. The sample problem is a classic dairy feed ration problem where 13 feed ingredients are available to be mixed in least cost proportions while meeting some ration nutrient content constraints.

Table 1 gives the sample problem coefficients and is an example of the tableau printed by the setup program. The program will accommodate either an 80 or 132-column printer. The problem contains 13 alternative ingredients (measured in hundredweights), each having a cost (objective function coefficient) and containing a coefficient for constraints on dry matter (DM), crude protein (CP), digestible energy (D.E.MIN), calcium (CAL.MAX), phosphorous (PHOS.) and fiber (FIBER). The remaining constraints were used to restrict ingredients; molasses to some minimum amount (MOL.MIN), rice bran to a maximum amount (R.B.MAX), and trace mineral salt (TM SALT), vitamins A & D (VIT.AD), wheat mids (WHT.MDS.), and dyna (DYNA) to specified contrations per unit of the ration. The problem requires DM to equal 1,000 lb. (column RHS contains 1000.0000E in row DM), crude protein greater than or equal to 180 units (column RHS contains 180.0000G in row CP), etc., for each constraint. The letter to the right of the RHS value in each row indicates the direction of the inequality or an equality.

OUTPUT

Tables 2 and 3 illustrate the basic row and column solution outputs for the example problem, respectively. The solution output begins by identifying the problem by file name, giving

TABLE 2. EXAMPLE OF ROWS SECTION OUTPUT FOR DHLLP MICROCOMPUTER LINEAR PROGRAMMING PACKAGE

Problem Name = Feedmx
Status = Optimal
Objective Function 'Cost' Value = 59.50016122554286
Rows section:

Row number	Row name	Initial level	Actual level	Slack amount	Shadow price
1	DM	1000.00000	1000.00000	0.00000	0.00000
2	CP	180.00000	180.00000	0.00000	0.08718
3	D.E. Min	1340.00000	1340.00000	0.00000	0.02942
4	Cal. min	10.00000	10.00000	0.00000	0.05772
5	*Cal. max	12.00000	10.00000	2.00000	0.00000
6	*Phos.	6.00000	6.76314	−0.75314	0.00000
7	*Fat	25.00000	41.85203	−18.85203	0.00000
8	*Fiber	60.00000	59.27831	0.72169	0.00000
9	Mol. min	30.00000	30.00000	0.00000	0.00096
10	R. B. max	100.00000	100.00000	0.00000	0.00358
11	TM salt	10.00000	10.00000	0.00000	0.00000
12	VIT. AD	0.50000	0.50000	0.00000	0.00000
13	WHT. mds.	100.00000	100.00000	0.00000	0.00122
14	Dyna	9.00000	9.00000	0.00000	0.00000

*—Basic variable

TABLE 1. EXAMPLE PROBLEM TABLEAU AS PREPARED BY THE SETUP MODULE, DHLLP MICROCOMPUTER LINEAR PROGRAMMING PACKAGE

Row/col.	TMSALT	CSM4	VIT.AD	Dynam	An. fat	Corn	G.S.	Molasses	Lmstone	Rice. B	Dical	SBM44	Whimds	RHS
Cost	7.000	8.200	80.000	6.700	17.000	5.750	5.000	5.150	2.500	4.500	16.000	9.190	6.000	0.0000
DM	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	1000.0000E
CP	*	43.240	*	*	*	8.890	8.920	4.540	*	12.970	*	43.970	15.820	180.0000G
D. E. min ..	*	141.400	*	*	366.100	160.200	134.600	147.800	*	117.700	*	156.000	152.100	1340.0000G
Cal. min ...	*	0.170	*	*	*	0.020	0.030	0.850	38.800	0.070	22.900	0.200	0.120	10.0000G
Cal. max ...	*	0.170	*	*	*	0.020	0.030	0.850	38.800	0.070	22.900	0.200	0.120	12.0000L
Phos.	*	1.090	*	*	*	0.290	0.310	0.850	*	1.590	19.300	0.580	0.770	6.0000G
Fat	*	4.040	*	*	95.000	3.870	2.910	0.770	*	13.240	*	0.980	3.290	25.0000G
Fiber	*	11.750	*	*	*	2.640	2.210	*	*	11.250	*	7.030	7.820	60.0000L
Mol. min ..	*	*	*	*	*	*	*	100.000	*	*	*	*	*	30.0000G
R. B. max ..	*	*	*	*	*	*	*	*	*	100.000	*	*	*	100.0000L
TM salt	100.000	*	*	*	*	*	*	*	*	*	*	*	*	10.0000E
Vit. AD	*	*	100.000	*	*	*	*	*	*	*	*	*	*	0.5000E
Wht. mds.	*	*	*	*	*	*	*	*	*	*	*	*	100.000	100.0000L
Dyna	*	*	*	100.00	*	*	*	*	*	*	*	*	*	9.0000E

TABLE 3. EXAMPLE OF COLUMN SECTION OUTPUT FOR DHLLP MICROCOMPUTER LINEAR PROGRAMMING PACKAGE

Column section:

Column number	Column name	In basis	Cost value	Basis level	Shadow price
1	Corn	***	5.75000	1.17468	0.00000
2	G.S.	***	5.00000	3.62139	0.00000
3	Molasses	***	5.15000	0.30000	0.00000
4	Lmstone	***	2.50000	0.23200	0.00000
5	Rice. B	***	4.50000	1.00000	0.00000
6	TM Salt	***	7.00000	0.10000	0.00000
7	CSM44	***	8.20000	2.47693	0.00000
8	VIT. AD	***	80.00000	0.00500	0.00000
9	Dynam	***	6.70000	0.09000	0.00000
10	An. fat		17.00000	0.00000	5.96824
11	Dical		16.00000	0.00000	14.41775
12	SBM44		9.19000	0.00000	0.49507
13	WHT mds	***	6.00000	1.00000	0.00000

***—Basic variable

the final solution status, and the value of the objective function for the optimal basis. Rows section output includes row numbers as given by the program, row names as assigned by the user, the initial level for each constraint, i.e., the original RHS value, the amount of each resource used in the optimal solution (ACTUAL LEVEL), the disposal quantities (SLACK AMOUNT), and the final value of the net evaluation row corresponding to each row's disposal activity (SHADOW PRICE). Asterisks (*) beside the row name indicate disposal activities which remain as basic variables. An "AO" will be printed beside names of alternate optima vectors.

The columns section is composed of column number and name, an indicator of whether each activity is in the optimal basis (*** in the INBASIS column), the original objective function value (COST VALUE), the optimal basis level of each activity (BASIS LEVEL), and the net evaluation element for each activity (SHADOW PRICE). An "AO" will replace the *** in the INBASIS column if an activity is an alternate optima.

Upon inspection of the optimal solution output, the user may choose to perform an objective function or right hand side sensitivity analysis, Table 4. Contents of this output differ from the original column output by the addition of RANGE and MAX VALUE. For activities in the optimal basis, an objective function value within

TABLE 4. EXAMPLE OF OBJECTIVE FUNCTION SENSITIVITY ANALYSIS OUTPUT FOR DHLLP MICROCOMPUTER LINEAR PROGRAMMING PACKAGE

Columns:

Variable number	Variable name	Basis level	Cost value	Range Low	Range High	Max value
7	CSM44	2.47693	8.20000	7.59830	8.68442	
1	Corn	1.17468	5.75000	5.55978	5.89516	
2	G.S.	3.62139	5.00000	4.77205	5.21981	
4	Lmstone	0.23200	2.50000	0.26311	6.91798	
5	Rice. B	1.00000	4.50000	*********	4.85814	
13	Whtmds	1.00000	6.00000	*********	6.12158	
3	Molasses	0.30000	5.15000	5.05387	*********	
6	Tmsalt	0.10000	7.00000	*********	*********	
8	VIT. AD	0.00500	80.00000	*********	*********	
9	Dynam	0.09000	6.70000	*********	*********	
10	An. fat	0.00000	17.00000			11.03176
11	Dical	0.00000	16.00000			1.58227
12	SBM44	0.00000	9.19000			8.69492

••••• Objective Function Sensitivity •••••
Problem name = Feedmx
Objective function 'cost' value = 59.50016122554286

TABLE 5. EXAMPLE OF RIGHT HAND SIDE SENSITIVITY ANALYSIS OUTPUT FOR DHLLP MICROCOMPUTER LINEAR PROGRAMMING PACKAGE

Rows:

Row numbers	Row name	Initial level	Actual level	Slack amount	Range Low	Range High
1	DM	1000.00000	1000.00000	0.00000	971,6583	1022.6179
2	CP	180.00000	180.00000	0.00000	146.6738	182.6309
3	D.E. min	1340.00000	1340.00000	0.00000	1309.9611	1382.0956
4	Cal. min	10.00000	10.00000	0.00000	1.2243	12.0000
5	Cal. max	12.00000	10.00000	2.00000	10.0000	*********
6	Phos.	6.00000	6.76314	−0.76314	*********	6.7631
7	Fat	25.00000	41.85203	−16.85203	*********	41.8520
8	Fiber	60.00000	59.27831	0.72169	59.2783	*********
9	Mol. Min	30.00000	30.00000	0.00000	0.0000	207.3696
10	R.B. Max	100.00000	100.00000	0.00000	35.0349	108.7837
11	TM Salt	10.00000	10.00000	0.00000	0.0000	38.3418
12	Vit. Ad	0.50000	0.50000	0.00000	0.0000	28.9418
13	Wht. Mds.	100.00000	100.00000	0.00000	0.0000	121.1554
14	Dyna	9.00000	9.00000	0.00000	0.0000	37.3418

*****Right hand side sensitivity *****
Problem name = feedmx
Objective function 'cost' value = 59.50016122554286

the LOW and HIGH RANGE will render the optimal solution (basis) unchanged. A block of asterisks implies infinity. For non-basic activities, the MAX VALUE is interpreted as the maximum value an objective function coefficient could take and maintain the activity in the basis. In the case of a maximization problem, this changes to MIN VALUE.

Table 5 illustrates a right-hand-side sensitivity analysis for the example problem. Contents of this output differ from the original rows output by the addition of a RANGE. A standard range of feasibility interpretation applies. Original right-hand-side levels between the LOW and HIGH RANGE will render elements of the optimal basis unchanged. Levels of individual activities may change but the elements themselves will not. Again, a block of asterisks indicates infinity.

Output from the MPS/FMPS data file preparation module is not shown. This output is given by the program as a sequential file written to the microcomputer diskette. The resulting file can be telecommunicated to a mainframe quite easily from this status by standard telecommunication software.

COMPARISON

The discussion thus far and the sample problem have outlined and illustrated the capabilities of the DHLLP package. Test users at several universities as well as graduate classes in quantitative analysis at Mississippi State University have reported the package to be easy to use and effective for solving many types of LP problems. Output checks against MPS and FMPS to date have consistently provided identical results. In summary, the program presented herein has been, to the extent possible, user tested and validated against MPS and FMPS via test problems.

One deviation between mainframe and microcomputers for LP could be in the time requirements needed per application. The sample problem can be entered in a relatively few minutes and the problem is solved by DHLLP in less than 40 seconds. Solution time is directly related to problem size in this and most other microcomputer packages. A model of a poultry processing plant with 77 activities and 57 constraints required about 22 minutes to solve using this microcomputer package. Mainframe computers will solve these and much larger problems in only a few seconds. However, for problems within the size limits of this package, it is quite possible that the total problem entry, revision and solution time will be less using the microcomputer than the mainframe. This is especially true for the inexperienced and occasional user, for smaller problems like those used in classroom teaching, and even many of the problems analyzed in much of our agricultural economics research.

Problem size bounds of 150 activities and 64 constraints is an obvious limitation of this package. This limitation is imposed primarily as a result of the limits of RAM addressibility by the current versions of BASIC (the language in which this program is coded). This limitation could be lessened by using disk storage for "scratch" space but processing speeds would likely become a significant disadvantage for larger problems. As RAM addressibility by BASIC becomes larger or if an alternative language was used, and microprocessors are able to handle more information in shorter amounts of time, problem size limitations for microcomputers will be relaxed.

The DHLLP package provides the basic optimal solution output, sensitivity analysis on the objective function and right hand side, and initial tableau printing. Added features often desired and provided by mainframe packages include parametric programming and integer programming. Omission of easy to use parametric routines and integer handling routines is a disadvantage of the DHLLP package. A crude parametric analysis could be set up, however, by saving a series of similar problems and solving each, i.e., returning to the basic principle of parametric programming.

CONCLUSIONS

Linear programming for microcomputers will not replace large scale computer LP packages but may very well complement them to a point where only very large problems must be analyzed on the mainframe. A linear programming package for microcomputers can provide individuals who do not have access to a mainframe computer but can access a microcomputer, the opportunity to use this technique. Further, the ease of operation of this package provides rapid problem entry and solution for both the experienced and inexperienced LP user. Limitations of this package include problem size restrictions and a lack of parametric, integer and mixed integer programming capability. Advantages of this package include its ease of operation, ability to solve many application and teaching problems, the availability of sensitivity analysis, and the ability to transform problems from microcomputer format to mainframe format. This package has been used in several locations and has proven to be a valuable teaching, research, and problem-solving tool.

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