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Sea Grant Report 16

MS-DOS LINEAR PROGRAMMING BENCHMARKS

for the

IBM XT, Zenith 151, IBM AT, and AT & T 6300

by

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Abstract

This paper reports the setup and solution time requirements for a 201 constraint, 804 activity modified-transhipment model on four different micro computer configurations. Eastern Software Product's LPX88 (87) linear programming software was used. The total time required ranged from 116 minutes on the IBM XT to 41 minutes on an AT&T 6300. The time required to re-solve with an existing basis ranged from 20 minutes with the IBM XT to 6 minutes on the AT&T 6300.

The Model

An APEX model currently running on the Cyber with an interactive MNF Fortran matrix generator was selected for the benchmark testing on MS-DOS computers. The model was originally constructed to analyze potential impacts on Canadian and U.S. grain flows as the below-cost statutory rail rates (or Crow's Nest rates) are phased out. The "Crow's Nest" model is typical of the modified transhipment linear programs used in transportation and logistics research. Such a model requires five types of input (see Appendix A for an example):

1. A supply file containing origin coding abbreviations and originating quantities by commodity.
2. A file linking originating points to intermediate (transhipment) points by mode and commodity using rates, mileage, or both.
3. A file linking transhipment points to the next tier of intermediate points by mode and commodity using rates, mileage, or both.
4. A file linking the second tier of transhipment points to final destinations by commodity using rates, mileage, or both.
5. A demand file containing destination coding abbreviations and demand by commodity.

The Crow's Nest matrix generator written for the MPS input format eliminated the file described in (3) above by generating the internal transhipment activities and transfer rows within the software. Several additional features

existed that required tailoring the mainframe software to the specific problem. These included:

1. A menu selected toggle between actual Crow's Nest transportation rates and U.S. rates obtained by regression on mileage.
2. Problem specific bounds.

Conversion to MS-DOS

The linear programming software that was selected for the conversion was the Eastern Software Products LPX88 (87) sparse matrix program suitable for problems with densities of less than ten percent, activities not exceeding 2,510, and constraints not exceeding 510. The Crow's Nest model density is 1.181 percent with 804 activities and 201 constraints.

A four file data set from a 1983 scenario was downloaded and the matrix generator was re-constructed using Turbo Pascal. Eastern Software Products requires a specialized, comma delimited input format (see Appendix B for an example). The rows and columns must be loaded into the LPX88 (87) software in a default format of X.1 (for col 1), Y.1 (for row 1), etc. and then renamed for meaningful interpretation. This involved the creation of a lookup conversion table and a doubling of the input filesize. The LPX88 (87) software also limits the label length to six

digits, a major adjustment from the APEX and MPS ten character field, requiring recoding all origin, transhipment, destination, and commodity abbreviations.

Turbo Pascal allows the incorporation of a number of user friendly features that are not possible on the Cyber (see Appendix C for sample screens). The MS-Dos version of the Crow's Nest generator creates the linear programming input file, a batch file that may be executed as an option to drive the LPX88 (87) software through to termination, and a copy of the lookup table for debugging purposes.

Computer Equipment Tested

IBM XT - The IBM XT had only 256k of memory and did not have a math co-processor (8087 chip). The XT operates at 4.77 megahertz with no RAM disk due to the memory constraints. The coefficient and inverse temporary files were "put out on the hard disk" requiring a high level of relatively slow IBM XT hard drive accesses.

Zenith 151 - The Zenith 151 that was used had a approximately 2 megabytes of RAM installed. A 20 megabyte hard drive was also present but was not used in the testing. The 8087 math co-processor was used and all program, data, and temporary files were put on the RAM drive. The Zenith 151 operates at 4.77 megahertz.

IBM AT - The IBM AT was set up with a 300k RAM disk for all program, data, and temporary files. The 20 megabyte hard drive was not used for testing. The 80287 math coprocessor was used. The IBM AT operates at 6 megahertz but the 80287 math co-processor only operates at 5 megahertz.

AT&T 6300 - The AT&T operates at 8 megahertz with an 8087-2 math co-processor that also operates at 8 megahertz. The AT&T was set up with a 300k RAM disk for all program, data, and temporary files and the 8087-2 chip was used.

The Test

The four MS-Dos machines were evaluated in six categories:

1. Total time to generate the input file with the Turbo Pascal generator.
2. Total time to load the sequential input file into LPX88 (87).
3. Total solving time.
4. Total time to load an old "Saved Problem".
5. Total time to load the old basis.
6. Total time to solve a changed problem with the old basis.

All tests were timed from final carriage return to eliminate differential responses to menu selections. Cyber APEX comparisons were made where applicable but the Cyber routines were built into a procedure (.PROC) file that included report generation and were difficult to separate. Cyber execution times will also fluctuate depending on the work load from concurrent activity. The time issue with the Cyber is not execution time but total overhead time which includes logging in and the time required to obtain full output reports. These factors were not considered in this test.

The Results

Table 1 and Figure 1 present the results of this test in minutes for an 804 by 201 problem using Eastern Software Products LPX88 (87). The AT&T 6300 provided the best performance on an MS-Dos machine in this test, particularly in the solving operations which take advantage of the AT&T's faster clock speeds. The IBM AT, with true 16 bit internal data transfer, was best with I/O operations but required 18% more time in total. The Z-151 required slightly more than twice the total time of the AT&T 6300. The IBM XT without a RAM disk and the 8087 math co-processor was an hour and fifteen minutes slower than AT&T in total time on the initial solution. In theory, the IBM XT, when upgraded, should approach the total time for the Zenith 151.

The sequential file format that is recommended in the LPX88 manual loads very slowly. Saving the problem and reloading is achieved much more quickly. Re-solving operations with the old basis are accomplished in from 16 to 19 percent of initial load and solve times. Greater total time savings can be achieved by using the built interactive editor for changes rather than editing the input files and regenerating and loading the entire matrix. The decision on interactive editing versus matrix regeneration-reloading depends on the magnitude of the changes and individual preference.

Table 1. Linear Programming on the Micro-Computer (minutes)

Machine	IBM XT	Z-151	IBM AT	AT&T 6300	Cyber
Input File Creation	1.24	1.17	.50	.60	.02
Loading Input File	23.08	21.93	8.20	10.33	Combined
Solve (804 by 201)	91.95	65.42	40.00	30.47	.26
Total	116.28	88.52	48.70	41.40	.28

Re-solving with New Coefficients and the Old Basis

Loading Old "Saved Prob"	.48	.40	.15	.19	.01
Loading Old Basis	1.25	1.01	.35	.47	Combined
Solving w/Basis	20.07	12.82	7.77	5.97	.22
Total	21.80	14.23	8.27	6.63	.23

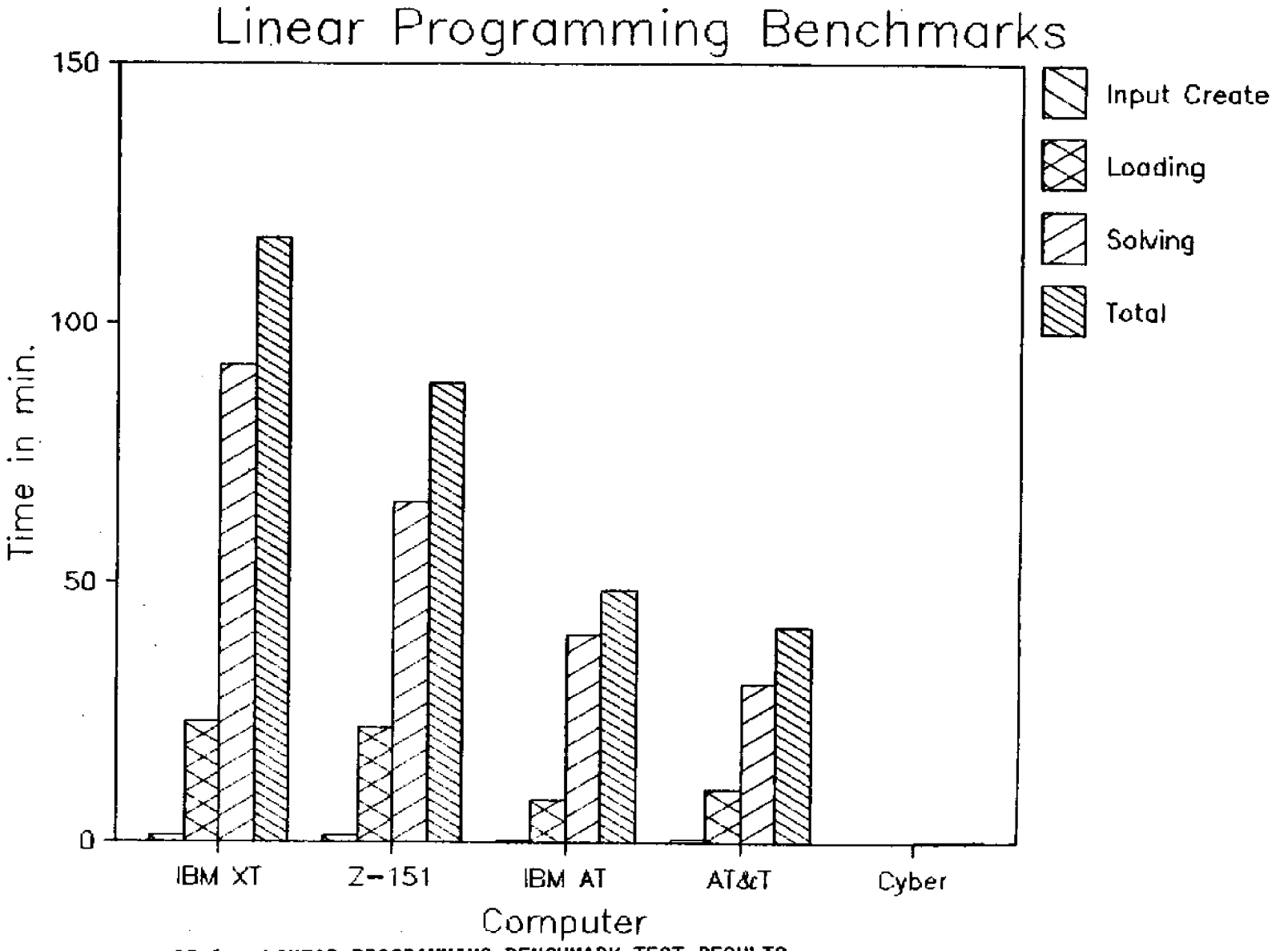

FIGURE 1. LINEAR PROGRAMMING BENCHMARK TEST RESULTS

The original solution was optimal after 358 iterations. The re-solving test was accomplished by changing the Canadian Crow's Nest rates to mileage based rates based on a regression of U.S. rail rates and re-solving with the basis from the initial solution. The re-solved problem was optimal with an additional 48 iterations.

Additional Items

Solving a large LP on a micro computer can place a heavy demand on a dot-matrix printer. The dot-matrix printers typically connected to departmental equipment will not last long as a substitute for high speed, high volume line printers. The alternatives to printing the standard reports from a large, micro computer based linear programming model require additional computer knowledge. These alternatives are:

1. Performing multiple runs with the interactive editor and judiciously using the "Shift-Prtsc" keys for hard copy output.

2. Creating a report writer. The objective of a typical report writer is to extract (from an LP output file) activity and resource utilization information from the large volume of non-basic output generated by the model and present the solution in a concise manner. The report writer is often essential for proper analysis, particularly when further processing is involved, and has the added benefit of substantially reducing the size of the output that requires printing.

3. Routing the output file to a high speed line printer through the UCC mainframe computers.

This approach requires a modem, communications software, knowledge of a mainframe operating system, and a walk to the nearest printing station (125 COB). Figure 2 illustrates a break even at 18 pages (@65 lines per page) between printing output directly to the dot-matrix printer and uploading to a mainframe computer and routing the entire micro-computer output file. For output quantities greater than 18 pages, mainframe printing will provide faster turnaround times than an FX-80 printer under the following assumptions:

a. A 1200 baud modem is used.
b. There are no jobs in the printer queue (usually true).
c. The line printer in COB 125 is on line

Note that micro computer output totalling 18 pages would result from an LP with a combination of rows and columns totalling 1,170 and that the Okidata, FX-80+, and FX-85 printers all print faster than the FX-80 tested.

It is perhaps more important to be aware that routing output files to a mainframe computer for printing is at least competitive with dot matrix printing in terms of turnaround time and that mainframe printing, when possible, makes better use of departmental resources.

The LPX-88 (87) software permits the transfer of large LP Models to the micro-computer environment without the downsizing problems associated with older technologies. Downsizing a model, however, can still dramatically effect micro-computer performance. The policy and Welland Canal issues that the Crow's Nest Model is being used to analyze did not require the examination of the three individual crops in the model. By consolidating the three crops and dealing with the total, the resulting LP was reduced to a

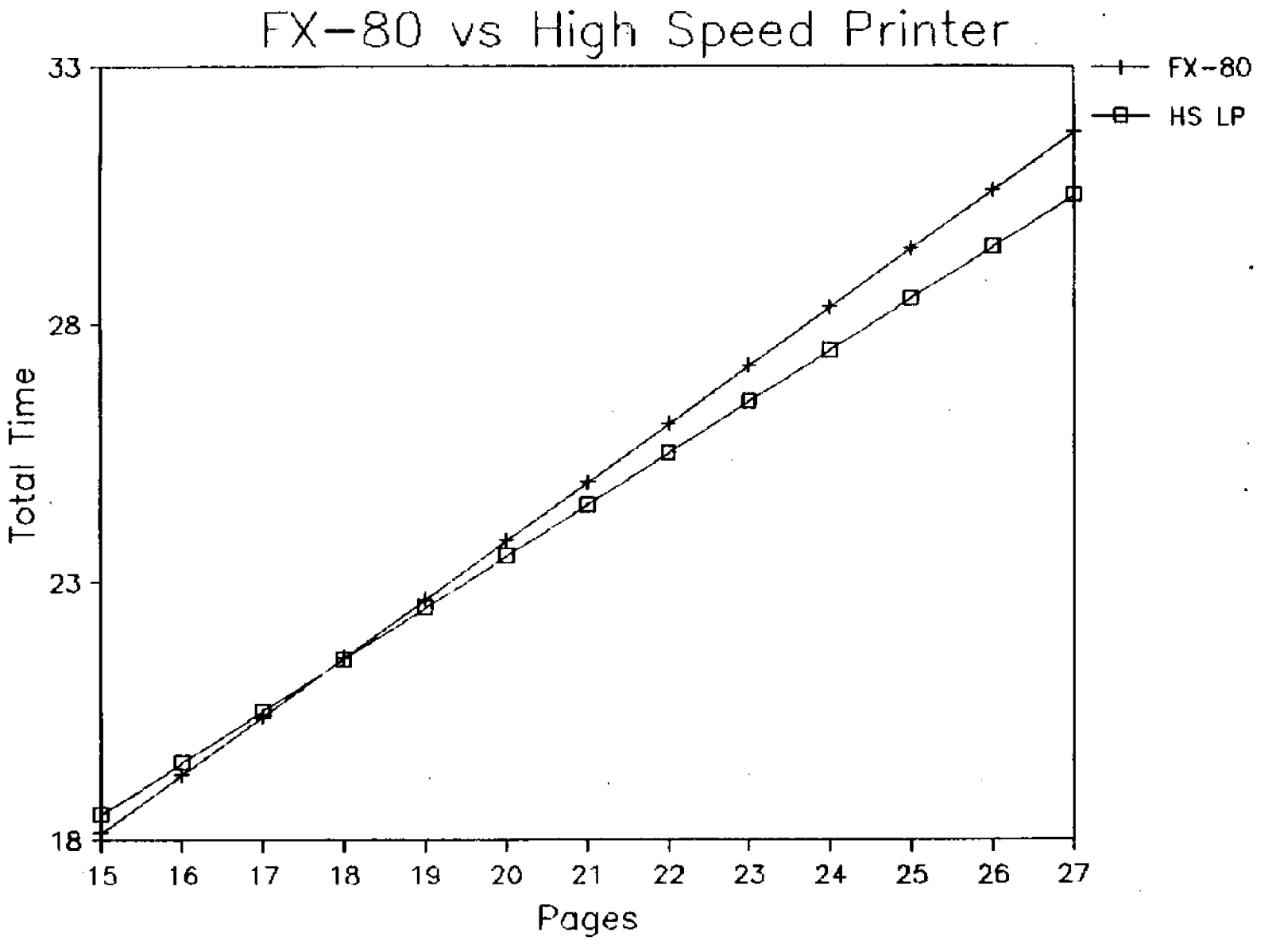

FIGURE 2. FX-80 VERSUS HIGH-SPEED LINE PRINTER (MIN.)

268 activity by 67 constraint problem. Solving times under comparable conditions to those in Table 1 were; 1) 4.23 minutes for the AT&T 6300, 2) 6.18 minutes for the IBM AT, 3) 8.7 minutes for the Zenith Z-151, and, 4) 13.28 minutes for the IBM XT. The load and solve time savings for the downsized problem ranged from 86.8% on the Zenith Z151 to 84.5% on the IBM AT. The reduced Crow's Nest Model was also run on a dual floppy IBM PC with no RAM disk or math co-processor in 25.37 minutes.

Appendices

A. Crow's Nest Linear Programming Model Input Files

B. LPX-88 (87) Sequential Input File.

C. Matrix Generator Status and Prompt Screens.

APPENDIX A

TABLE 1. ORIGIN ABBREVIATIONS AND 1983 PRODUCTION (BUSHELS).

OR	WHEAT	DUR	BARLEY
A	994021	95479	520240
B	1196111	7122	354461
C	1100385	45138	373253
D	530560	5715	153761
E	942655	106942	92814
F	1367715	380784	90063
G	1409485	529155	44556
H	1261852	825643	73900
I	1241140	40819	220690
J	2019650	141254	179863
K	1603834	250557	258053
L	1194267	3599	385997
M	1167418	4383	481205
N	874307	148631	26320
O	877125	124836	203898
P	427583	32522	575832
Q	1309635	3606	703389
R	127819	1	729799
S	129080	1	466016
T	437218	1	677080
U	877124	124836	203897

TABLE 2. ORIGIN, DESTINATION, RAIL MILEAGE & CROW'S NEST RAIL RATES ($).

OR	THUNDER		VANCOUVER		P.RUPERT		MPLS		DULUTH		GALVESTON	
	MILE	CN	MILE	CN	MILE	CN	MILE	CN	MILE	CN	MILE	CN
A	553	7.27	1333	21.64	1626	26.56	578	0.00	513	0.00	1896	0.00
B	720	10.35	1359	22.08	1551	25.30	745	0.00	680	0.00	2063	0.00
C	475	5.87	1419	23.08	1695	27.72	500	0.00	435	0.00	1818	0.00
D	420	4.86	1474	24.01	1750	28.64	445	0.00	380	0.00	1921	0.00
E	684	9.65	1202	19.35	1610	26.20	709	0.00	644	0.00	2027	0.00
F	819	12.10	1067	16.72	1475	23.57	719	0.00	751	0.00	2037	0.00
G	965	14.82	994	15.40	1464	23.29	990	0.00	925	0.00	2308	0.00
H	954	14.55	1397	22.80	1588	26.01	789	0.00	821	0.00	2107	0.00
I	698	9.98	1198	19.28	1481	24.03	723	0.00	658	0.00	2041	0.00
J	899	13.63	1088	16.98	1280	20.20	915	0.00	850	0.00	2262	0.00
K	1028	15.97	1079	16.83	1270	20.04	928	0.00	960	0.00	2246	0.00
L	937	14.35	1147	18.06	1338	21.27	944	0.00	976	0.00	2262	0.00
M	1014	21.43	1018	21.53	1209	26.34	1000	0.00	935	0.00	2347	0.00
N	1076	16.78	871	13.34	1353	21.43	976	0.00	1008	0.00	2294	0.00
O	1143	17.99	751	11.14	1286	20.13	1043	0.00	1075	0.00	2361	0.00
P	1244	19.78	642	9.13	1185	18.25	1153	0.00	1204	0.00	2049	0.00
Q	1101	17.29	889	13.46	1080	16.67	1117	0.00	1052	0.00	2464	0.00
R	1220	19.51	765	11.20	957	14.42	1241	0.00	1188	0.00	2243	0.00
S	1321	21.35	853	12.85	1044	16.06	1334	0.00	1281	0.00	2336	0.00
T	1586	26.30	1128	17.83	1319	21.04	1599	0.00	1546	0.00	2601	0.00
U	1178	18.58	769	11.44	1287	20.14	1085	0.00	1117	0.00	2403	0.00

APPENDIX A

TABLE 3. DESTINATION ABBREVIATIONS AND 1983 RATES TO FOREIGN DEMAND POINTS ($).

DEST	ST.LAWR	NPA	PNW	USB	RIV
SB	11.09	0.0	0.0	12.03	12.03
SK	13.24	0.0	0.0	14.96	14.96
SS	0.00	21.16	21.16	21.16	21.16
PC	23.05	17.47	17.47	23.61	23.61
PD	11.09	0.00	0.00	12.03	12.03
UK	7.97	0.00	0.00	8.36	8.36
JP	0.00	17.41	17.41	23.04	23.04
BZ	15.10	0.00	0.00	13.70	13.70
CB	15.10	0.00	0.00	12.38	12.38
ER	17.87	20.58	20.58	18.09	18.09
BL	27.07	27.56	27.56	25.40	25.40
IQ	32.31	28.21	28.21	29.07	29.07
LB	12.10	16.45	16.45	14.22	14.22
MX	15.10	0.00	0.00	12.38	12.38
IT	12.10	16.45	16.45	14.22	14.22
IA	23.04	27.56	27.56	30.15	30.15
LE	17.87	20.58	20.58	18.09	18.09
IR	32.31	28.21	28.21	29.07	29.07
IS	17.42	17.42	0.00	27.07	27.07
EG	11.09	0.00	0.00	12.03	12.03
BE	8.82	0.00	0.00	10.71	10.71
FL	8.82	0.00	0.00	10.71	10.71
SP	11.42	0.00	0.00	13.24	13.24
IL	17.87	20.58	20.58	18.09	18.09
SR	16.50	19.00	19.00	21.97	21.97
TN	0.00	17.47	17.47	23.61	23.61
CL	15.10	0.00	0.00	13.70	13.70
FR	8.82	0.00	0.00	10.71	10.71
AG	12.10	16.45	16.45	14.22	14.22
ET	16.50	19.00	19.00	21.97	21.97
SY	17.87	20.58	20.58	18.09	18.09
SW	8.82	0.00	0.00	10.71	10.71
WG	8.82	0.00	0.00	10.71	10.71
CY	17.87	20.58	20.58	18.09	18.09

APPENDIX A

TABLE 4. DESTINATION ABBREVIATIONS AND 1983 DEMAND (BUSHELS).

DEST	WHEAT	DURAM	BARLEY
SB	2090312	521481	500233
SK	2090312	521481	500233
SS	1575007	160843	525663
PC	4424287	0	82756
PD	562567	59088	0
UK	1107187	2100	0
JP	1263575	77268	969768
BZ	1502798	0	0
CB	819515	58804	41866
ER	22870	0	0
BL	312484	0	0
IQ	279691	0	100749
LB	63000	47250	0
MX	189282	0	22000
IT	98042	525508	310194
IA	104621	0	0
LE	157500	0	0
IR	107200	0	92024
IS	224212	0	0
EG	281574	26250	599815
BE	23338	0	480774
FL	0	0	0
SP	0	0	409936
IL	0	0	252004
SR	26250	0	0
TN	85050	0	83437
CL	0	0	101073
FR	8534	98719	0
AG	0	511511	0
ET	91978	0	0
SY	241500	0	0
SW	65671	43697	0
WG	798	0	51162
CY	0	0	61321

APPENDIX B

Appendix B. Sample Input File for ESP LPX88 (87)

```
COST,X.1,7.27,Y.1,X.1,1.00,Y.2,X.1,1.00
COST,X.2,7.27,Y.3,X.2,1.00,Y.4,X.2,1.00
COST,X.3,7.27,Y.5,X.3,1.00,Y.6,X.3,1.00
COST,X.4,21.64,Y.1,X.4,1.00,Y.7,X.4,1.00
COST,X.5,21.64,Y.3,X.5,1.00,Y.8,X.5,1.00          Default Activity and Row
COST,X.6,21.64,Y.5,X.6,1.00,Y.9,X.6,1.00                  Creation
COST,X.7,26.56,Y.1,X.7,1.00,Y.10,X.7,1.00
COST,X.8,26.56,Y.3,X.8,1.00,Y.11,X.8,1.00
COST,X.9,26.56,Y.5,X.9,1.00,Y.12,X.9,1.00
                -
                -
COST,X.800,10.71,Y.92,X.800,-1.00,Y.188,X.800,1.00
COST,X.801,10.71,Y.93,X.801,-1.00,Y.189,X.801,1.00
COST,X.802,18.09,Y.91,X.802,-1.00,Y.190,X.802,1.00
COST,X.803,18.09,Y.92,X.803,-1.00,Y.191,X.803,1.00
COST,X.804,18.09,Y.93,X.804,-1.00,Y.192,X.804,1.00
Y.1,REL,(=
Y.1,RHS,     994021
Y.3,REL,(=                                Transition to RHS Specification
Y.3,RHS,      95479
Y.5,REL,(=
Y.5,RHS,     520240
                -
                -
                -
Y.189,REL,=
Y.189,RHS,      51162
Y.190,REL,=
Y.190,RHS,          0
Y.191,REL,=
Y.191,RHS,          0
Y.192,REL,=
Y.192,RHS,      61321
NAME,X.1,PAWT                             Transition to Renaming Activities
NAME,X.2,PADT
NAME,X.3,PABT
NAME,X.4,PAWV
NAME,X.5,PADV
NAME,X.6,PABV
                -
                -
NAME,X.802,OWWCYW
NAME,X.803,OWDCYD
NAME,X.804,OWBCYB
Y.1,NAME,PRDAW                            Transition to Renaming Constraints
Y.2,NAME,TRNTW
Y.3,NAME,PRDAD
Y.4,NAME,TRNTD
Y.5,NAME,PRDAB
                -                         Through Y.201
```

APPENDIX C

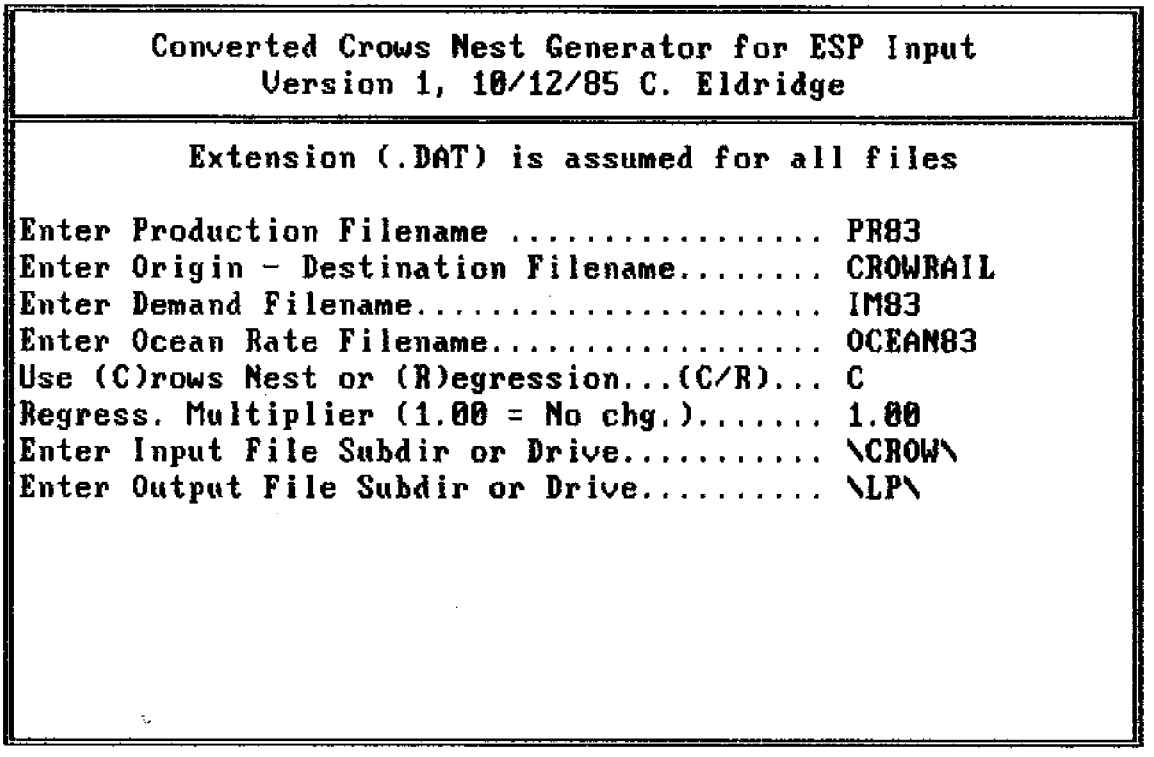

FIGURE 1. INITIAL INPUT SCREEN WITH DEFAULTS SET FOR A HARD DISK SYSTEM (SUBDIRECTORIES CROW AND LP).

APPENDIX C

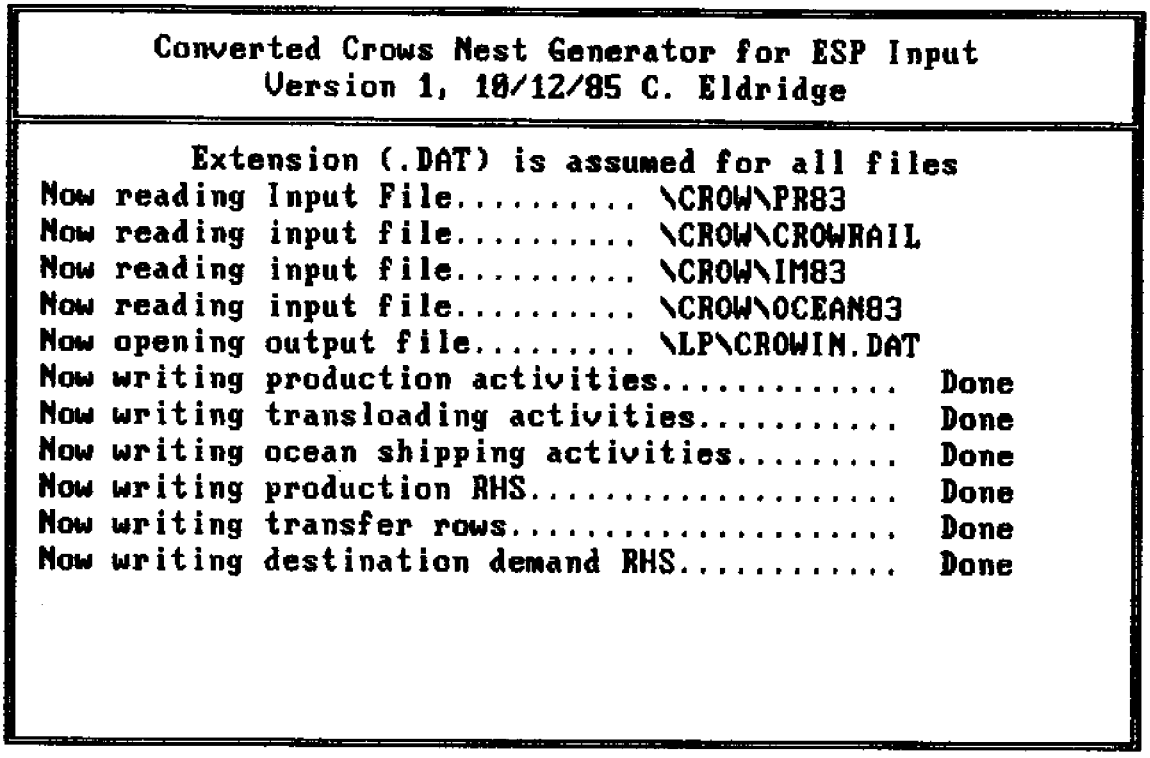

FIGURE 2. PROCESSING STATUS SCREEN

APPENDIX C

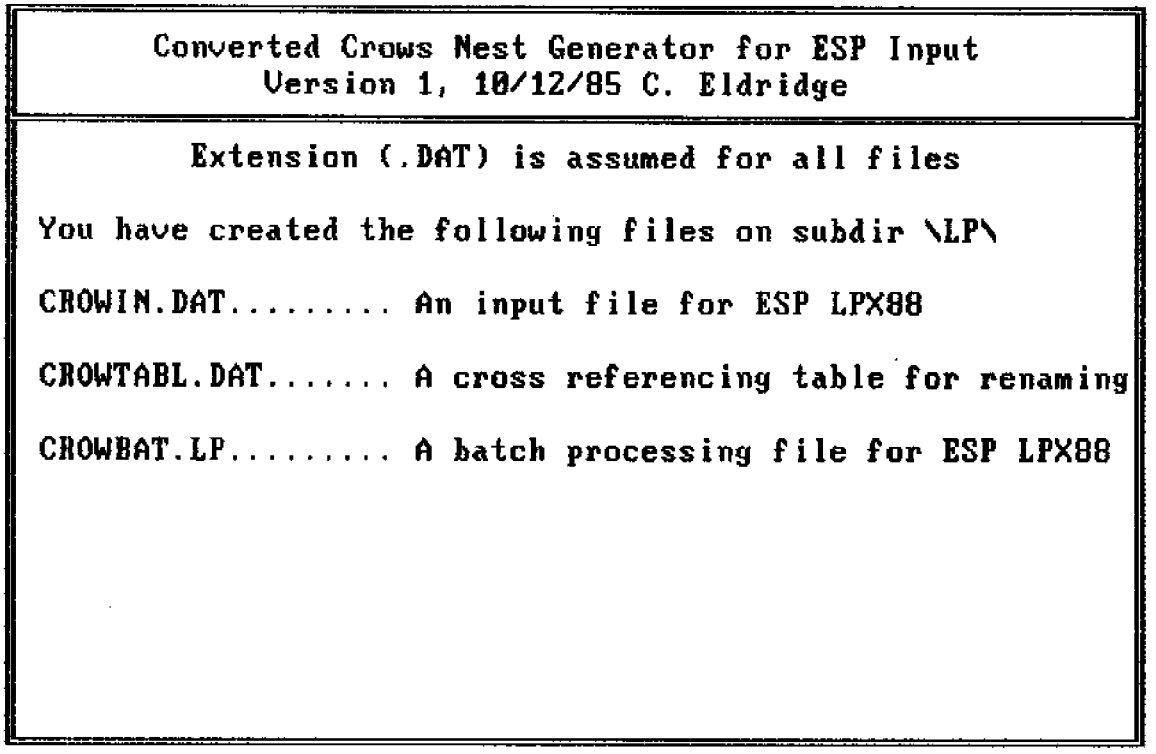

FIGURE 3. SUMMARY SCREEN (SCREEN 3) FOR A HARD DRIVE SYSTEM.