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Summary: A computerized Manufacturing Program for Predicting Equipment Requirements (MAPPER) has been developed. MAPPER can be used to interpret component production requirements from shipping schedules, calculate equipment loading versus equipment capacity, display six months prior equipment utilization and display process yield data. MAPPER is written in BASIC computer language and can be executed using GE Mark II Time-Sharing equipment. A typical example of the use of MAPPER is presented.		
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INTRODUCTION

As an aid to management, a computerized Manufacturing Program for Predicting Equipment Requirements (MAPPER) has been developed. This report describes the program.

MAPPER is written in BASIC and can be executed using GE Mark II timesharing. MAPPER can interpret component production requirements backward from shipping schedules to the process of interest, calculate equipment capacity, display six months prior equipment utilization, and display process yield data.

THE MAPPER PLOT

A MAPPER plot for a typical process is shown in Fig. 1 and can be interpreted as follows:

M - Maximum Equipment Capacity

Process 1 has a maximum equipment capacity of approximately 2400 units per month with an allowance of 10 percent for holidays and vacations and 20 percent for equipment downtime.

A - Anticipated Need

Production requirements projected from current shipping schedules indicate that from November 1973 to June 1974 Process 1 will be fully utilized and, thereafter, not have the capacity to meet future commitments.

Several alternatives available to meet these commitments are:

- (1) Work overtime
- (2) Add a third shift
- (3) Farm out work
- (4) Purchase additional equipment

SYMBOL	NO. PTS.	LEGEND
M	36	MAX EQUIPMENT CAPACITY (10% allowance for holidays and vacations and 20% for equipment downtime)
A	30	ANTICIPATED NEED
P	6	PAST PERFORMANCE
Y	6	PROCESS YIELD
U	30	UPPER 95 % CONFIDENCE LIMIT

Figure 1. Typical MAPPER Plot for Process 1.

P - Past Performance

Average equipment utilization for the six-month period from April to September 1972 was nearly two-thirds of the available capacity.

Y - Process Yield

Process yields have improved from a low in April to a high in July and have fallen during August and September.

U - Upper 95 Percent Confidence Limit

The statistical variation between the number of starts and the number of acceptable pieces produced per month has been used to calculate an upper 95 percent limit for future need.

MAPPER Plot Construction

The following example has been included to illustrate the construction of the MAPPER plot shown in Fig. 1. Assume that Process 1 is currently operated on a two-shift basis with two production runs per shift and a maximum equipment loading capacity of 40 pieces per run. If 10 percent allowance is made for holidays and vacation shutdown, and 20 percent allowance for equipment downtime, the maximum number of pieces which can be produced per month is:

$$M = (1-V-D) \text{ PRSW}$$

where: M Maximum equipment capacity
V = Holiday and vacation allowance
D = Downtime allowance
P = Pieces produced per run
R = Number of process runs per shift
S = Number of shifts per week
W = Number of weeks per month

substituting in (1) the maximum equipment capacity (M) is equal to 2424 pieces per month. Equation (1) can be found on line 15 of the MAPPER time-sharing computer program (see Fig. 2) written using the BASIC language.

To calculate an A line (anticipated need) for Process 1, a shipping schedule forecast is required; and for our example, the shipping requirements listed in Table 1 will be used. This data is listed on lines 81 through 83 of the MAPPER program shown in Fig. 2.

The lead time and cumulative yield from Process 1 to shipping are assumed to be three months and 0.75 respectively; therefore, in order to fulfill a shipping requirement of 1000 units in January 1973, Process 1 must have the capability to manufacture 1333 units in October 1972.

Monthly past performance and yield data has been entered on lines 85 and 87 respectively in Fig. 2 to give an indication of past equipment utilization from April to September 1972.

TABLE 1
SHIPPING SCHEDULE FORECAST

<u>Date</u>	<u>Shipping Requirement</u>	<u>Date</u>	<u>Shipping Requirement</u>
1/73	1000 units	4/74	1600 units
2/73	1050	5/74	1850
3/73	1100	6/74	1800
4/73	1125	7/74	1750
5/73	1200	8/74	1800
6/73	1275	9/74	1600
7/73	875	10/74	1700
8/73	950	11/74	1800
9/73	1200	12/74	1900
10/73	1300	1/75	2000
11/73	1400	2/75	2100
12/73	1600	3/75	2200
1/74	1500	4/75	2250
2/74	1800	5/75	2250
3/74	1700 units	6/75	2250 units

Program Execution

As previously stated, the MAPPER program shown in Fig. 2 was written in BASIC and executed using the Mark II time-sharing system. Upon execution of the program (see Fig. 3), the question.....

"ENTER STARTING MONTH AND THE TOTAL
NUMBER OF MONTHS REQUIRED FOR PLOT"

will be printed out via the terminal keyboard, and will require an input of 10,30 to continue. The number 10 corresponds to the starting month of October (3 months lead time from Table 1 shipping schedule data beginning in January), and the number 30 represents the number of data points.

For plotting purposes, a scaling routine has been included in the program (lines 64 through 74, Fig. 2), and use of the previous forecast will result in the printout.....

"X Min = 4, X Max = 39, Y Min = 0, Y Max = 3158.22"

followed by the question.....

DATA FILE NAME

Terminal keyboard response to this question must be PROCESS1 since the statement CHAIN "EZGRAF***", shown on line 79 of Fig. 2, causes the program to be linked to the Mark II plotting program entitled EZGRAF. A Typagraph Model 3 plotter/printer was used to plot the program generated data file PROCESS1 (see Fig. 4) containing the calculated M, A, P, Y and U values. Additional keyboard inputs required by the plotting program are self-explanatory and have been underlined in Fig. 3.

MULTIPRODUCT VARIATIONS

There are many situations where several different products are processed through a common piece of equipment and in order to generate a MAPPER plot for these processes, a modification to the program is required. With this in mind, a second example is

presented to illustrate the construction of a MAPPER plot, and the major differences from the previous example have been noted.

Assume that Process 2 is currently operated on a one-shift basis for 40 hours per week with 10 percent of the available time allocated for holidays and vacations and 20 percent for equipment downtime. Process 2 manufactures seven different products with the setup time, lot size, cycle time and cumulative yield data presented in Table 2.

TABLE 2
PROCESSING DATA FOR PROCESS 2

<u>Product</u>	<u>Setup Time</u>	<u>Lot Size</u>	<u>Cycle Time</u>	<u>Cumulative Yield</u>
A	2.5 hrs.	40 pcs	0.031 hrs/pc	.446
B	2.5	40	0.062	.446
C	3.0	35	0.183	.990
D	2.83	35	0.050	.990
E	0.50	30	0.083	.448
F	0.50	100	0.062	.750
G	0.50 hrs	40 pcs	0.078 hrs/pc	.899

Step #1 - Calculate maximum equipment capacity as a percentage of available capacity (i.e., 40 hrs/wk available equals 100 percent capacity).

$$M = (1 - V - D) 100 \quad (2)$$

where: M = Maximum equipment capacity in percent
V = Holidays and vacation allowance in percent
D = Equipment downtime allowance in percent

substituting in (2) $M = (1 - 0.1 - 0.25) 100$

= 65 percent capacity

Step #2 - Determine maximum available hours/month.

$$XO = HW \quad (3)$$

where: XO = Available equipment hours per month
H = Available hours per week
W = Available weeks per month

substituting in (3) XO = (40) (4.33)

$$= 173.2 \text{ hours/month}$$

Step #3 - Calculate the maximum equipment capacity for Process 2 for each product.

$$X = \frac{XO}{\frac{S}{L} + C} \quad (4)$$

where: X = Maximum number of pieces per month
obtainable by Process 2 for each product
XO = Available equipment hours per month
S = Setup time in hours per setup
L = Lot size in pieces per lot
C = Cycle time in hours per piece

substituting in (4) for product A

$$X_A = \frac{173.2}{\frac{2.5}{40} + 0.031}$$

$$= 1852.4 \text{ pieces/month}$$

Step #4 - Read in shipping schedule forecast for each product and calculate the percent utilization required from Process 2 to support each product.

$$U = \frac{F}{XY} \times 100 \quad (5)$$

where: U = Percent utilization of Process 2 required to support each product
 F = Monthly shipping forecast for each product
 X = Maximum equipment capacity for each product
 Y = Cumulative yield for each product to shipping

substituting in (5) for product A (assume a shipping forecast of 100 units)

$$U_A = \frac{100}{(1852.4)(.446)} \times 100 = 12.10 \text{ percent}$$

Step #5 - Sum the percent utilization each month for all seven products manufactured by Process 2.

$$A = U_A + U_B = \dots + U_G$$

where: A = Total percent utilization per month of Process 2
 U_A = Utilization of Process 2 for product A
 U_B = Utilization of Process 2 for product B
 .
 .
 .
 U_G = Utilization of Process 2 for product G

The remainder of the program logic and plotting is similar to the previous example.

CONCLUSIONS

MAPPER provides an efficient, computerized technique for predicting long-range equipment requirements. This program provides enough lead time that management can carefully evaluate possible solutions to potential equipment loading problems.

EXAMPLE 10/30/72

```
1 DIM A(100),P(100),Y(100),U(100)
2 PRINT "ENTER STARTING MONTH AND THE TOTAL"
3 PRINT "NUMBER OF MONTHS REQUIRED FOR PLOT"
4 INPUT M, M1
5 IF M > 6 THEN 8
6 M = M+6
7 PRINT "STARTING MONTH INCREASED BY 6 FOR PLOTTING PURPOSES"
8 FILES PROCESS1
9 REM
10 REM
11 REM      EQUIPMENT CAPACITY PER MONTH = (1-.1(VACATION)-.2(DOWNTIME))
12 REM      * PIECES/RUN * RUNS/SHIFT * SHIFTS/WEEK * WEEKS/MONTH
13 REM
14 REM
15 I1=.70*40*2*10*4.33
16 Y1=.75
17 SCRATCH #1
18 FOR I=M-6 TO M+M1-1
19 WRITE #1 USING 21, I, I1
20 NEXT I
21: #####.##      #####.##
22 WRITE #1 USING 23
23: 1E37, 1E37
24 FOR I=M TO M+M1-1
25 REM
26 REM
27 READ A(I)
28 REM
29 REM
30 REM
31 REM
32 A(I) = A(I) /Y1
33 WRITE #1 USING 21, I, A(I)
34 NEXT I
35 WRITE #1 USING 23
36 FOR I=M-6 TO M-1
37 REM
38 READ P(I)
39 WRITE #1 USING 21, I, P(I)
40 NEXT I
41 WRITE #1 USING 23
42 FOR I=M-6 TO M-1
43 READ Y(I)
44 WRITE #1 USING 21, I, Y(I)
45 NEXT I
46 WRITE #1 USING 23
47 T=0
48 REM
49 FOR I=M-6 TO M-1
50 U(I) = P(I) -Y(I)
```

MAX CAPACITY LINE

ANTICIPATED NEED LINE

SHIPPING SCHEDULE OFF SET BY AN AMOUNT
EQUIVILENT TO THE LEAD TIME REQUIRED FROM
PROCESS1 TO SHIPPING

PAST PERFORMANCE LINE - TOTAL NUM-
BER OF PIECES PRODUCED PER MONTH

YIELD LINE - NUMBER OF GOOD PIECES PRODUCED

STANDARD DEVIATION CALCULATION FOR UPPER
95 PERCENT CONFIDENCE LIMIT

Figure 2. Basic Time-Sharing Program for Process 1.

EXAMPLE 10/30/72

```
51 T = T+U(I)
52 NEXT I
53 T1=T/6
54 T2 = 0
55 FOR I= M-6 TO M-1
56 T2 = T2 + (U(I) -T1) **2
57 NEXT I
58 T3 = SQR (T2/5)
59 T4 = 2*T3
60 IF T4<2 THEN 64
61 FOR I=M TO M+M1-1
62 WRITE #1 USING 21, I, A(I) + T4
63 NEXT I
64 H=2
65 FOR I = M-6 TO M +M1 -1
66 IF I1 < H THEN 68
67 H = I1
68 IF A (I) < H THEN 70
69 H = A (I)
70 IF P (I) < H THEN 72
71 H = P (I)
72 IF A (I) + T4 < H THEN 74
73 H=A(I)+T4
74 NEXT I
75 PRINT
76 PRINT AS
77 PRINT
78 PRINT" X MIN="; M-6" X MAX="; M + M1-1" Y MIN = 0 Y MAX="; H
79 CHAIN "EZGRAF ***"
80 REM ANTICIPATED NEED "A" LINE DATA
81 DATA 1000, 1050, 1100, 1125, 1200, 1275, 875, 950, 1200, 1300
82 DATA 1400, 1600, 1500, 1800, 1700, 1600, 1850, 1800, 1750, 1800
83 DATA 1600, 1700, 1800, 1900, 2000, 2100, 2200, 2250, 2250, 2250
84 REM PAST PERFORMANCE DATA "P" LINE
85 DATA 1400, 1500, 1800, 1700, 1600,1650
86 REM YIELD DATA "Y" LINE
87 DATA 1302, 1297, 1700, 1690, 1400,1450
88 END
```

UPPER 95 PERCENT LINE

Figure 2. Basic Time Sharing Program for Process 1 (Cont'd.)

READY
OLD
ENTER FILE NAME-- EXAMPLE

READY
RUN

EXAMPLE 12:48EST 10/30/72

ENTER STARTING MONTH AND THE TOTAL
NUMBER OF MONTHS REQUIRED FOR PLOT
? 10,30

X MIN = 4 X MAX= 39 Y MIN = 0 Y MAX= 3158.22

DATA FILE NAME - ?PROCESS1

AXES - ?LINEAR

TITLES-
PLOT - ?MAPPER
X - ?TIME IN MONTHS
Y - ?PROCESS 1

PLACE PLOT SWITCH DOWN ?OPTIONS

OK - ANOTHER OPTION ?FILL

OK - ANOTHER OPTION ?SYMBOLS

Figure 3. Execution of Basic Time Sharing Program for Process 1

ENTER SYMBOL -

SYMBOL 1 - ?M
SYMBOL 2 - ?A
SYMBOL 3 - ?P
SYMBOL 4 - ?Y
SYMBOL 5 - ?U

OK - ANOTHER OPTION ?SCALE

ENTER-XMIN,XMAX,YMIN,YMAX<FREE FORM> ?4,39,0,3000

OK - ANOTHER OPTION ?XDATE

OK - ANOTHER OPTION ?NXDIV

ENTER NO. DIVISIONS AND INCREMENT FOR X-AXIS = ?35,1

OK - ANOTHER OPTION ?NO

PLACE PLOT SWITCH DOWN ? GO

M	36	? <u>MAX EQUIPMENT CAPACITY</u> (10% allowance for holidays and vacations and 20% for equipment downtime)
A	30	? <u>ANTICIPATED NEED</u>
P	6	? <u>PAST PERFORMANCE</u>
Y	6	? <u>PROCESS YIELD</u>
U	30	? <u>UPPER 95 % CONFIDENCE LIMIT</u>

CHANGES FOR NEXT RUN ?STOP

PROGRAM STOP AT 0

USED 5.87 UNITS

Figure 3. Execution of Basic Time Sharing Program for Process 1 (Cont'd.)

PROCESS1 11/09/72

100	4.00,	2424.80,
110	5.00,	2424.80,
120	6.00,	2424.80,
130	7.00,	2424.80,
140	8.00,	2424.80,
150	9.00,	2424.80,
160	10.00,	2424.80,
170	11.00,	2424.80,
180	12.00,	2424.80,
190	13.00,	2424.80,
200	14.00,	2424.80,
210	15.00,	2424.80,
220	16.00,	2424.80,
230	17.00,	2424.80,
240	18.00,	2424.80,
250	19.00,	2424.80,
260	20.00,	2424.80,
270	21.00,	2424.80,
280	22.00,	2424.80,
290	23.00,	2424.80,
300	24.00,	2424.80,
310	25.00,	2424.80,
320	26.00,	2424.80,
330	27.00,	2424.80,
340	28.00,	2424.80,
350	29.00,	2424.80,
360	30.00,	2424.80,
370	31.00,	2424.80,
380	32.00,	2424.80,
390	33.00,	2424.80,
400	34.00,	2424.80,
410	35.00,	2424.80,
420	36.00,	2424.80,
430	37.00,	2424.80,
440	38.00,	2424.80,
450	39.00,	2424.80,
460	1E37, 1E37	
470	10.00,	1333.33,
480	11.00,	1400.00,
490	12.00,	1466.67,
500	13.00,	1500.00,
510	14.00,	1600.00,
520	15.00,	1700.00,
530	16.00,	1166.67,
540	17.00,	1266.67,
550	18.00,	1600.00,
560	19.00,	1733.33,
570	20.00,	1866.67,
580	21.00,	2133.33,
590	22.00,	2000.00,

Figure 4. Process #1 Data File.

PROCESS1 11/09/72

600	23.00,	2400.00,
610	24.00,	2266.67,
620	25.00,	2133.33,
630	26.00,	2466.67,
640	27.00,	2400.00,
650	28.00,	2333.33,
660	29.00,	2400.00,
670	30.00,	2133.33,
680	31.00,	2266.67,
690	32.00,	2400.00,
700	33.00,	2533.33,
710	34.00,	2666.67,
720	35.00,	2800.00,
730	36.00,	2933.33,
740	37.00,	3000.00,
750	38.00,	3000.00,
760	39.00,	3000.00,
770	1E37, 1E37	
780	4.00,	1400.00,
790	5.00,	1500.00,
800	6.00,	1800.00,
810	7.00,	1700.00,
820	8.00,	1600.00,
830	9.00,	1650.00,
840	1E37, 1E37,	
850	4.00,	1302.00,
860	5.00,	1297.00,
870	6.00,	1700.00,
880	7.00,	1690.00,
890	8.00,	1400.00,
900	9.00,	1450.00,
910	1E37, 1E37	
920	10.00,	1491.56,
930	11.00,	1558.22,
940	12.00,	1624.89,
950	13.00,	1658.22,
960	14.00,	1758.22,
970	15.00,	1858.22,
980	16.00,	1324.89,
990	17.00,	1424.89,
1000	18.00,	1758.22,
1010	19.00,	1891.56,
1020	20.00,	2024.89,
1030	21.00,	2291.56,
1040	22.00,	2158.22,
1050	23.00,	2558.22,
1060	24.00,	2424.89,
1070	25.00,	2291.56,
1080	26.00,	2624.89,
1090	27.00,	2558.22,

Figure 4. PROCESS1 Data File (Cont'd.)

PROCESS1 11/09/72

1100	28.00,	2491.56,
1110	29.00,	2558.22,
1120	30.00,	2291.56,
1130	31.00,	2424.89,
1140	32.00,	2558.22,
1150	33.00,	2691.56,
1160	34.00,	2824.89,
1170	35.00,	2958.22,
1180	36.00,	3091.56,
1190	37.00,	3158.22,
1200	38.00,	3158.22,
1210	39.00,	3158.22,

Figure 4. Process #1 Data File (Cont'd)