Short-Run Manufacturing Problems at DEC[2]

In the fourth quarter of 1989, the corporate demand/supply group of Digital Equipment Corporation (DEC) was under pressure to come up with a manufacturing plan for dealing with a series of major supply shortfalls that were impacting on the production, revenue, and customer satisfaction of one of DEC's new family of general purpose computer systems and workstations. The critical components for this family of systems that were going to be in short supply in the first quarter of 1989 were CPU chip sets, 1-meg memory boards, 256K memory boards, and disk drives. Pertinent data for these components and their usage in the family of systems is given below:

System	List Price	Chip Sets	1-Meg Memory	256K Memory	Disk Drive Avg.
GP-1	$60,000	1	2	–	0.3
GP-2	$40,000	1	–	2	1.7
GP-3	$30,000	1	–	1	–
WS-1	$30,000	1	–	1	1.4
WS-2	$15,000	1	–	1	–
1989 First Quarter Availability:		7,000	4,000	8 – 16,000	3 – 7,000

Brian Shannahan of corporate supply/demand was asked on short notice to formulate a manufacturing strategy given these shortfalls. Brian wanted to take into account both the importance of revenue for DEC as well as the maintenance of DEC's

[2] This case and the following lecture notes have been prepared and written by Professor Rob Freund, MIT Sloan School of Management.

reputation for customer satisfaction and service. Brian took a quick stab at the market/sales situation and then developed the following target data for the first quarter of 1989:

System	Minimum Acceptable Supply	Maximum Customer Demand
GP-1	–	1,800
GP-2	500	–
GP-3	–	300
WS-1	500	–
WS-2	400	–
GP FAMILY	–	3,800
WS FAMILY	–	3,200

Brian Shannahan then proceeded to analyze DEC's problem and to formulate a manufacturing strategy.

Formulation of Sample DEC Manufacturing Problem

Common Type of Mathematical Model

	New Bedford Steel	DEC Manufacturing
An objective to be optimized	minimize procurement cost	maximize quarterly revenue
A set of decision variables	amount of coal to contract with each supplier A,B,...,H	number of units of each family to produce G1, G2, G3, W1, W2
An objective function that expresses the objective in terms of the decision variables	$49.50A + ... + 80.00H$	$60G1 + ... + 15W2$
Constraints that limit or otherwise impose requirements on the relationships between the decision variables	(Rail capacity) $A + C + G + H \le 650$	(Demand for GP family) $G1 + G2 + G3 \le 3{,}800$
Nonnegativity conditions on the decision variables	$A \ge 0,\ B \ge 0$	$G1 \ge 0, ..., W2 \ge 0$

Constraints can be equality or inequality constraints. If inequality, they can be less than or equal to ($\leq$) or greater than or equal to ($\geq$).

Each constraint can be rearranged to have the format, e.g.,

G1 + G2 + G3	$\leq$	3800
constraint function	relation	right-hand side (RHS)

A feasible plan or feasible solution is an assignment of decision variables that satisfies all constraints and nonnegativity conditions.

The goal of the problem is to find a feasible plan that optimizes the objective function, i.e., an assignment of decision variables that satisfies all constraints and optimizes the objective. This is called a constrained optimization problem.

An optimal plan or optimal solution is a feasible plan that achieves the best value of the objective function over all other feasible plans.

Finally, we call the problem a linear program if all constraint functions are linear, and if the objective function is linear, i.e., of the form,

e.g., $A + 2B - 5C + 7D$, not $AB + C + D$,

not $A^2 + B + C + D$, not $(A^2 - \sin(B/C)) \log(D)$.

How Linear Programs are Solved on the Computer

1. A linear programming model is solved on a computer by a technique called the Simplex Method, developed by Dantzig in 1947. (Some commercial codes now use an alternative method, called the Interior Point method, developed by Karmarkar in 1984.)

2. The simplex method works by performing a sequence of pivots. Each pivot starts with a feasible solution and either generates an improved feasible solution or concludes that the current feasible solution is the optimal solution.

3. At each pivot, the computer must solve a system of m equations in m variables, where m is the number of constraints in the problem.

4. Typically, the number of pivots that must be performed is roughly proportional to the number n of decision variables in the problem. Therefore, the more constraints the problem has (m) and the more decision variables the problem has (n) , the more computer time will be needed to solve the problem.

5. The simplex method is conceptually simple and easy to learn. We will teach it to you in about one hour.

6. Today – solve LP's with 1000's of constraints, 10,000's of decision variables on a desk top machine with commercial packages.

<u>Excel Spreadsheet for DEC Short Run Manufacturing Problem</u>

Short Run Manufacturing Problems at DEC							
			GP-1	GP-2	GP-3	WS-1	WS-2
	Production of						
	Minimum supply		0	500	0	500	400
	Maximum demand		1800	3800	300	3200	3200
		Total					
	Supply						
Chip sets	7000	0	1	1	1	1	1
1 Meg Mem	4000	0	2				
256K Mem	16000	0		2	1	1	1
Disk Drives	3000	0	0.30	1.70		1.40	
	Demand						
GP Family	3800	0	1	1	1		
WS Family	3200	0				1	1
Revenue		0	60	40	30	30	15

Microsoft Excel 4.0 Answer Report
Worksheet: DEC

Target Cell (Max)

Cell	Name	Original Value	Final Value
C24	Revenue Total	0	213912

Adjustable Cells

Cell	Name	Original Value	Final Value
D8	Production of GP-1	0	1800
E8	Production of GP-2	0	1035.29
F8	Production of GP-3	0	300
G8	Production of WS-1	0	500
H8	Production of WS-2	0	2700

Microsoft Excel 4.0 Sensitivity Report
Worksheet: DEC

Changing Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
D8	Production of GP-1	1800	52.94	60	1E+30	52.94
E8	Production of GP-2	1035.29	0	40	1E+30	21.79
F8	Production of GP-3	300	30	30	1E+30	30
G8	Production of WS-1	500	-17.94	30	17.94	1E+30
H8	Production of WS-2	2700	0	15	1E+30	15

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
C15	Chip sets Total	6335	0	7000	1E+30	664.71
C16	1 Meg Mem Total	3600	0	4000	1E+30	400
C17	256K Mem Total	5571	0	16000	1E+30	10429.41
C18	Disk Drives Total	3000	24	3000	1130	910
C21	GP Family Total	3135	0	3800	1E+30	664.71
C22	WS Family Total	3200	15	3200	500	2300