Project in Operations Research

Golf-Sport: Managing Operations

Team: one or two students in a group
Due date: October 24 – Each group submits a hardcopy of the final report.

The **objective** of the course is to give you experience in modeling, solving, and analyzing problems using MS, especially linear programming. I expect you to develop the skills to consider real-world problems and determine whether or not linear programming is an appropriate modeling framework; develop linear programming models that consider the key elements of the real problem; solve the models for their optimal solutions; interpret the models' solutions and infer solutions to the real-world problems.

Requirements:

a. Formulate the problems.
b. Use LINGO/LINDO/Excel Solver or Matlab Optimizer to solve your problems and perform sensitivity analysis.
c. Interpret the solutions and infer the solutions and sensitivity analysis to answer the questions at the end of the problem description (see the next page). In addition to the optimal solutions for the decisions and the optimal objective values, you also need to make the conclusions and suggestions to the decision makers based on the optimal solutions.

Project report: The final report should be a well-typed printed document with a cover page. Handwriting report is not acceptable. Please use Times New Roman font, 12 pt in size, the single line spacing, and 1 in for margins. Each paragraph should be correctly indented. The final report should at least include:

a. Problem description: a brief description of the problem, summarizing the data (e.g., the explanations of the parameters), clarifying the problem and the tasks, and highlighting the main idea for addressing the problems. Please specify the tool that you choose to address the problems.
b. LP model and its illustration: decision variables, objective function, and constraints. Please provide the detailed (verbal) illustrations of the models, e.g., the objective function and constraints.
c. Computational results: the outputs from the Solver including clear solution report and sensitivity report. You should have them as appendix and answer the questions based on them. Do not include the entire solution report and sensitivity report in the main context in your report. Please try to present and organize the optimal solutions in the tables if appropriate.
d. Detailed interpretations, if applicable: interpretation of results, reduced cost for basic variables and nonbasic variables, shadow prices for binding constraints and nonbinding constraints, the sensitivity analysis on the objective coefficients and the rhs of constraints.

Description of the problem

Golf-Sport is a small-sized company that produces high-quality components for people who build their own golf clubs and prebuilt sets of clubs. There are five components—steel shafts, graphite shafts, forged iron heads, metal wood heads, and metal wood heads with titanium inserts—made in three plants—Chandler, Glendale, and Tucson—in the Golf-Sport system. Each plant can produce any of the components, although each plant has a different set of individual constraints and unit costs. These constraints cover labor and packaging machine time (the machine is used by all components); the specific values for each component–plant combination are given in Tables 1–3. Note that even though the components are identical in the three plants, different production processes are used, and therefore the products use different amounts of resources in different plants.

TABLE 1
Product-Resource Constraints: Chandler

	Resources		
Products	Labor (Minutes/Unit)	Packing (Minutes/Unit)	Advertising ($/Unit)
Steel shafts	1	4	1.0
Graphite shafts	1.5	4	1.5
Forged iron heads	1.5	5	1.1
Metal wood heads	3	6	1.5
Titanium insert heads	4	6	1.9
Monthly availability (minutes)	12,000	20,000	—

TABLE 2
Product-Resource Constraints: Glendale

	Resources		
Products	Labor (Minutes/Unit)	Packing (Minutes/Unit)	Advertising ($/Unit)
Steel shafts	3.5	7	1.1
Graphite shafts	3.5	7	1.1
Forged iron heads	4.5	8	1.1
Metal wood heads	4.5	9	1.2
Titanium insert heads	5.0	7	1.9
Monthly availability (minutes)	15,000	40,000	—

TABLE 3
Product-Resource Constraints: Tucson

	Resources		
Products	Labor (Minutes/Unit)	Packing (Minutes/Unit)	Advertising ($/Unit)
Steel shafts	3	7.5	1.3
Graphite shafts	3.5	7.5	1.3
Forged iron heads	4	8.5	1.3
Metal wood heads	4.5	9.5	1.3
Titanium insert heads	5.5	8.0	1.9
Monthly availability (minutes)	22,000	35,000	—

Besides component sales, the company takes the components and manufactures sets of golf clubs. Each set requires 13 shafts, 10 iron heads, and 3 wood heads. All of the shafts in a set must be the same type (steel or graphite), and all of the wood heads must be the same type (metal or metal with inserts). Assembly times per month for the sets at each plant are shown in Table 4.

TABLE 4

Plant	Time (Minutes per set)	Total Time Available (Minutes)
Chandler	65	5,500
Glendale	60	5,000
Tucson	65	6,000

Each plant of Golf-Sport has a retail outlet to sell components and sets, and the specific plant is the only supplier for its retail outlet. The minimum and maximum amounts of demand for each plant–product pair are given in Table 5. Note that, although the minimums must be satisfied, you do not need to satisfy demand up to the maximum amount.

TABLE 5
Minimum and Maximum Product Demand per Month

	Store (or Plant)		
Products	Chandler	Glendale	Tucson
Steel shafts	[0, 2,000]	[0, 2,000]	[0, 2,000]
Graphite shafts	[100, 2,000]	[100, 2,000]	[50, 2,000]
Forged iron heads	[200, 2,000]	[200, 2,000]	[100, 2,000]
Metal wood heads	[30, 2,000]	[30, 2,000]	[15, 2,000]
Titanium insert heads	[100, 2,000]	[100, 2,000]	[100, 2,000]
Set: Steel, metal	[0, 200]	[0, 200]	[0, 200]
Set: Steel, insert	[0, 100]	[0, 100]	[0, 100]
Set: Graphite, metal	[0, 300]	[0, 300]	[0, 300]
Set: Graphite, insert	[0, 400]	[0, 400]	[0, 400]

This planning problem is for two months. The costs in Table 6 increase by 12% for the second month, and production times are stationary. Inventory costs are based on end-of-period inventory for each product set and cost out at 8% of the cost values in Table 6. Table 7 lists the revenue generated by each product. Initially, there is no inventory.

TABLE 6
Material, Production, and Assembly Costs ($) per Part or Set

	Plants		
Products	Chandler	Glendale	Tucson
Steel shafts	6	5	7
Graphite shafts	19	18	20
Forged iron heads	4	5	5
Metal wood heads	10	11	12
Titanium insert heads	26	24	27
Set: Steel, metal	178	175	180
Set: Steel, insert	228	220	240
Set: Graphite, metal	350	360	370
Set: Graphite, insert	420	435	450

TABLE 7
Revenue per Part or Set ($)

	Plants		
Products	Chandler	Glendale	Tucson
Steel shafts	10	10	12
Graphite shafts	25	25	30
Forged iron heads	8	8	10
Metal wood heads	18	18	22
Titanium insert heads	40	40	45
Set: Steel, metal	290	290	310
Set: Steel, insert	380	380	420
Set: Graphite, metal	560	560	640
Set: Graphite, insert	650	650	720

The corporation controls the capital available for expenses; the cash requirements for each product are given in the last column of Tables 1–3. There is a total of $20,000 available for advertising the production for the entire system during each month, and any money not spent in a month is not available the next month. The corporation also controls graphite. Each graphite shaft requires 4 ounces of graphite; a total of 1,000 pounds is available for each of the two months.

Your job is to determine a recommendation for the company. A recommendation must include a plan for production and sales. In addition, you should also address the following sensitivity-analysis

issues in your recommendation:

- If you could get more graphite or advertising cash, how much would you like, how would you use it, and what would you be willing to pay?
- At what site(s) would you like to add extra packing machine hours, assembly hours, and/or extra labor hours? How much would you be willing to pay per hour and how many extra hours would you like?
- Marketing is trying to get Golf-Sport to consider an advertising program that promises a 50% increase in their maximum demand. Can we handle this with the current system or do we need more resources? How much more is the production going to cost if we take on the additional demand?

Note that (1) The production costs for the sets (products 6, 7, 8, 9) in the objective account for the assembly cost (the costs in Table 6 – the costs for the components) (2) The unit inventory costs for the sets are based on the total cost in Table 6 (i.e., the assembly cost and the costs of components). (3) 1 pound = 16 ounce (4) Decision variables are treated as continuous.