IIE2104 Deterministic Models in OR
2024-1 Term Project

Submission Due: Friday, June 14, 11:59 pm

Instruction:

- Term project is team-based. All the team members are expected to work together.
- It is required to include **CRediT** author statement in the cover page to clarify the roles of team members while working on term project. For **CRediT** statement, refer to the following link https://www.elsevier.com/researcher/author/policies-and-guidelines/credit-author-statement.
- Required deliverables, which are provided as a part of the following project description, must be turned in via the submission link posted in LearnUs by each team.
- Late submissions will not be accepted unless pre-approved by the instructor with an acceptable reason. Not submitting project work will result in a “0” point.
- Grading policy
  - Excellent: 20
  - Very Good: 18
  - Good: 16
  - Satisfactory: 14
  - Not Satisfactory: below 12 (no submission results in ”0”)
- Contact TA (Hyewon Min, heaopen@naver.com) to ask questions regarding term project.

Reference

- Golf-Sport: Managing Operations case study problem from Winston L.W. (2022). *Operations Research: Applications and Algorithms*. 4th Edition. Cengage Learning.
- Refer to lecture notes and recorded lectures for “Optimization Solver with Python.”

Problem Description

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

Products	Resources		
	Labor (Minutes/Unit)	Packing (Minutes/Unit)	Advertising ($/Unit)
Steel shafts	1.0	4.0	1.0
Graphite shafts	1.5	4.0	1.5
Forged iron heads	1.5	5.0	1.1
Metal wood heads	3.0	6.0	1.5
Titanium insert heads	4.0	6.0	1.9
Monthly availability (minutes)	12,000	20,000	-

Table 2: Product-Resource Constraints: Glendale

Products	Resources		
	Labor (Minutes/Unit)	Packing (Minutes/Unit)	Advertising ($/Unit)
Steel shafts	3.5	7.0	1.1
Graphite shafts	3.5	7.0	1.1
Forged iron heads	4.5	8.0	1.1
Metal wood heads	4.5	9.0	1.2
Titanium insert heads	5.0	7.0	1.9
Monthly availability (minutes)	15,000	40,000	-

Table 3: Product-Resource Constraints: Tucson

Products	Resources		
	Labor (Minutes/Unit)	Packing (Minutes/Unit)	Advertising ($/Unit)
Steel shafts	3.0	7.5	1.3
Graphite shafts	3.5	7.5	1.3
Forged iron heads	4.0	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 for the sets at each plant are shown in Table 4.

Table 4: Aseembly Time

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)		
Product	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

	Store (or Plant)		
Product	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 ($)

	Store (or Plant)		
Product	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 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 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.

Requirements and Deliverables

1. Formulate the problem as an LP model. Let us call this model the "Basic Model." Complete LP formulation with clear descriptions of all the decision variables and parameters should be included in the final report to be submitted.

2. Create a CVXPY code to solve the formulated LP model. Note that your code should import all the parameters, e.g., Tables 1-7, from the MS Excel file composed according to your CVXPY codes. Also, comments in the code are absolutely necessary. Comments should be such that one can understand the whole problem and model just by reading your code. In particular, all sets, parameters, variables, objective functions, and constraints should have associated comments clearly defining/explaining them. Your Python code and MS Excel file should be included in the final report and submitted in separate files. Note that the submitted Python code should be runnable based on the submitted Excel file.

3. Solve the problem by running the CVXPY code. Compose the production and sales plan recommendation to the company based on the optimal solution obtained from the code. This should also be included in your final report.

4. In addition, you should also provide the recommendation to the following questions. Note that your recommendation should be composed by conducting sensitivity analysis based on the "Basic Model", e.g., dual prices and reduced costs. Recommendations and proper analysis should be included in the final report.

   (a) If you could get more graphite or advertising cash, what would you be willing to pay?

   (b) 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?

   (c) 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?