# Midterm Exam 2 Review Problems

## Problem 1

Minco Inc. is a small company in Midway, Tennessee, which makes fused magnesia and silica. In the beginning of the 1990s, Minco's continuous improvement efforts led it to look for a capacity and production planning software. To prepare for the use of software, a spreadsheet was first used to determine the capacity requirements for the main equipment (the fusion furnaces) and the production schedule for the main products. A major product had the following forecast sales and committed orders (all in thousand pounds):

| | **January** | | | **February** | | | |
|---|---|---|---|---|---|---|---|
| Week | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Forecast | 56 | 56 | 56 | 66 | 66 | 66 | 66 |
| Committed Order | 44 | 0 | 18 | | | | |

The initial inventory was 119,000 pounds. The scheduler decided to use a lot size of 100,000 pounds per week and the minimum safety stock at the end of each week was to be 83,000 pounds.

1. Prepare a production schedule for this product for the next seven weeks
2. Determine the available-to-promise inventory for the next seven weeks.

| | | January | | | February | | | |
|---|---|---|---|---|---|---|---|---|
| | week | **2** | **3** | **4** | **1** | **2** | **3** | **4** |
| Forecast | | 56 | 56 | 56 | 66 | 66 | 66 | 66 |
| Committed | | 44 | 0 | 18 | | | | |
| Projected on hand (min = 83) | 119 | | | | | | | |
| Produce (lot size = 100) | | | | | | | | |
| ATP | | | | | | | | |

**Solution:**

| | week | January 2 | January 3 | January 4 | February 1 | February 2 | February 3 | February 4 |
|---|---|---|---|---|---|---|---|---|
| Forecast | | 56 | 56 | 56 | 66 | 66 | 66 | 66 |
| Committed | | 44 | 0 | 18 | | | | |
| Projected on hand (min = 83) | 119 | **163** | **107** | **151** | **85** | **119** | **153** | **87** |
| Produce (lot size = 100) | | **100** | | **100** | | **100** | **100** | |
| ATP | | **175** | | **82** | | **100** | **100** | |

## Problem 2

A sports goods manufacturer makes baseball and hockey gloves. Suppose now is the end of December and the manager wishes to plan production for the next four quarters. The forecast demand for aggregate units of pairs of gloves is: Q1: 800, Q2: 900, Q3: 1600, and Q4: 700. There are currently 30 permanent workers. Each worker can make 30 gloves per quarter. The regular production cost is $8 per glove. The holding cost per unit per quarter is $1, and the backorder cost per unit per quarter is $3. The manager has to stay with the same number of workers in the next four quarters (i.e. no hiring/firing), but overtime by full-time workers is possible at 1.5 times the regular wage rate up to a maximum of 20 percent of regular time production. Current inventory level is zero and there is no inventory expected at the end of the planning horizon.

(a) If 30 permanent workers are kept throughout the planning horizon, how many units will the company be short at the end (if any)?

(b) Find the aggregate production plan that minimizes total cost. <u>Assume that it is possible to produce less than the maximum capacity without any additional cost (i.e. you will use the extra available regular production capacity only if the cost is less than other capacity options).</u>

| | | | 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|---|---|
| Forecast | | | 800 | 900 | 1600 | 700 | 4000 |
| Output | | | | | | | |
| Regular | | | | | | | |
| Overtime | | | | | | | |
| Output-Forecast | | | | | | | |
| Inventory | | | | | | | |
| Beginning | | | | | | | |
| Ending | | | | | | | |
| Average | | | | | | | |
| Backlog | | | | | | | |
| Costs | | | | | | | |
| Regular | @ | $8 | | | | | |
| Overtime | @ | $12 | | | | | |
| Inventory | @ | $1 | | | | | |
| Back orders | @ | $3 | | | | | |

Solution:

| | | | 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|---|---|
| Forecast | | | 800 | 900 | 1600 | 700 | 4000 |
| Output | | | | | | | |
| Regular | | | **900** | **900** | **900** | **900** | **3600** |
| Overtime | | | **40** | **180** | **180** | | **400** |
| Output-Forecast | | | **140** | **180** | **-520** | **200** | **0** |
| Inventory | | | | | | | |
| Beginning | | | **0** | **140** | **320** | **0** | |
| Ending | | | **140** | **320** | **0** | **0** | |
| Average | | | **70** | **230** | **160** | **0** | |
| Backlog | | | **0** | **0** | **200** | | |
| Costs | | | | | | | |
| Regular | @ | $8 | **7200** | **7200** | **7200** | **7200** | **$28,800** |
| Overtime | @ | $12 | **480** | **2160** | **2160** | **0** | **$4,800** |
| Inventory | @ | $1 | **70** | **230** | **160** | **0** | **$460** |
| Back orders | @ | $3 | **0** | **0** | **600** | **0** | **$600** |

We need to match the demand in Quarter 3. There is a need for extra 700 units in that period.

Here are possible available options and their costs:

1) Regular in Q1 and keeping in inventory for 2 periods: $8 + 2\times1$ = $10 per glove
2) Regular in Q4 and having a backlog for one period: 8 + 3 = $11 per glove
3) Overtime in Q3: $1.5\times8$ = $12 per glove
4) Overtime in Q2 and keeping in inventory for one period: 12 + 1 = $13 per glove
5) Overtime in Q1 and keeping in inventory for two periods: 12 + 2 = $14 per glove
6) Overtime in Q4 and having a backlog for one period: 12 + 3 = $15 per glove

We start from exploiting the least costly option, which in this case is option number 1. We get 100 extra units there. Then from option number 2, we can have another 200 units. From option number 3, we can have up to 20% of the regular production level which is 180 (=$900\times0.2$). In a similar way, we can get 180 units from option number 4. So far we have 100 + 200 + 180 + 180 = 660 units of those extra requirements covered. The remaining 40 units can be obtained through option number 5.

Now we can put these numbers on the table and complete the calculations.

## Problem 3

The forecast demand for aggregate units of chairs in the next three quarters is: Q1: 8900, Q2: 9700, and Q3: 8600. There are currently 30 permanent workers. Each worker can make 300 chairs per quarter. The regular production cost is $20 per chair. The holding cost per unit per quarter is $2, and the backorder cost per unit per quarter is $8. The manager wants to keep a minimum of 30 workers at all times, and he has the option to hire any number of workers for the hiring cost of $1200 per worker. Assuming that the newly hired worker will be laid off by the end of the third quarter (at the latest), the layoff cost will be $600 per worker. Overtime by full-time workers is possible at $25 per unit up to a maximum of 20 percent of regular time production. Current inventory level is zero, but the manager wants to have at least 400 units in inventory at the end of the third quarter. Find the aggregate production plan that minimizes total cost. <u>Assume that when a worker is hired, they will produce exactly equal to the maximum capacity that they have (i.e. 300 units per worker per quarter).</u>

| | | | 1 | 2 | 3 | **Total** |
|---|---|---|---|---|---|---|
| Forecast | | | | | | |
| Output | | | | | | |
| Regular | | | | | | |
| Overtime | | | | | | |
| Output-Forecast | | | | | | |
| Inventory | | | | | | |
| Beginning | | | | | | |
| Ending | | | | | | |
| Average | | | | | | |
| Backlog | | | | | | |
| Costs | | | | | | |
| Regular | @ | | | | | |
| Overtime | @ | | | | | |
| Inventory | @ | | | | | |
| Back orders | @ | | | | | |
| Hiring | @ | | | | | |
| Layoff | @ | | | | | |

| | | | 1 | 2 | 3 | Total |
|---|---|---|---|---|---|---|
| Forecast | | | 8900 | 9700 | 8600 | |
| Output | | | | | | |
| Regular | | | **9000** | **9000** | **9000** | |
| Overtime | | | **-** | **-** | **-** | |
| Output-Forecast | | | **100** | **-700** | **400** | |
| Inventory | | | | | | |
| Beginning | | | **0** | **100** | **0** | |
| Ending | | | **100** | **0** | **0** | |
| Average | | | | | | |
| Backlog | | | | **600** | **200** | |
| Costs | | | | | | |
| Regular | @ | $20 | | | | |
| Overtime | @ | $25 | | | | |
| Inventory | @ | $2 | | | | |
| Back orders | @ | $8 | | | | |
| Hiring | @ | $1200 | | | | |
| Layoff | @ | $600 | | | | |

Without adding any workers or overtime, the plan, as it shows above, will not be feasible (i.e. there is a backlog at the end of quarter 3 while there was supposed to be 400 units in inventory).

There is a backlog of 600 units at the second quarter. From the demand in quarter 3, it seems like even if we keep the regular production of 9000, we will be able to produce 400 units extra which will satisfy the ending inventory requirement. Thus, we focus on the 600 extra units needed for quarter 2 and see what capacity options we have and how much each one will cost us per unit of product. The options are as follows:

1) Hire and fire two workers in Q2:
Each worker produces 300 units and the total cost of hiring and firing for that worker if 1200+600 = $1800. Thus, the hiring + firing cost per unit is 1800/300 = $6
$\Rightarrow$ The total per unit cost of hiring and firing and the regular production = 20 + 6 = $26

2) Hire one worker at the beginning Q1 and fire them at the beginning of Q3:
One worker can produce $2 \times 300$ = 600 units by the end of Q2. Thus, the hiring + firing cost per unit is 1800/600 = $3

But, for those 300 units that are produced in Q1 (to be used in Q2), there is an additional inventory holding cost of $2. That is for 300 units that this worker produces the unit hiring + firing cost is 3 + 2 = $5, and for the additional 300 units which are produced in Q2, the unit hiring + firing cost is $3. Thus, doing this way of hiring/firing will have an average unit cost of hiring + firing of $4 [=(5+3)/2]. Adding the regular production cost gives us a total unit cost of 20 + 4 = $24.

3) Not hiring anybody, but doing overtime in Q2:
According to the problem, there are $0.2 \times 9000$ = 1800 units of overtime production available in each quarter (having 30 workers as is the case here). Thus, there is enough overtime available in Q2 (i.e. higher than 600 units that we needed). As we know from the question, the overtime production costs us $25.

<u>Note that since we have enough overtime available in Q2, checking for overtime cost in any other periods is not needed</u> (simply because they will cost more than the cost of overtime in Q2, due to the additional inventory holding or backorder cost).

4) Hire one worker at the beginning of Q2 and fire them at the end of Q3:
In a similar way that we did the calculation for option (2), we find that the average unit cost of hiring + firing will be $5.5 [=(3+8)/2] which will give us a total unit cost of 20 + 5.5 = $25.5.

5) Hire one person at the beginning of Q1 and fire them at the end of Q3:
This option will result in 300 more on hand inventory at the end of Q3 than what was required (i.e. it results in 700 units instead of 400).
One worker can produce $3 \times 300$ = 900 units by the end of Q3. Thus, the hiring + firing cost per unit is 1800/900 = $2.
The total unit cost for each unit of those 300 units produced in Q1 = 20 + 2 + holding cost for one quarter = 20 + 2 + 2 = $24
The total unit cost for each unit of those 300 units produced in Q2 = 20 + 2 = $22
This gives an average unit cost of $23 [=(24+22)/2] which seems lower than any other option, but we also have addition 300 units that are produced in Q3 with a regular production cost of

$20 costing us a total of $20 \times 300$ = $6000. If we divide this additional cost by 600 units that we originally needed (and for which we have been going through all this hassle!!!), that adds $10 to our per unit cost, resulting in a total unit cost of 23 + 10 = $33

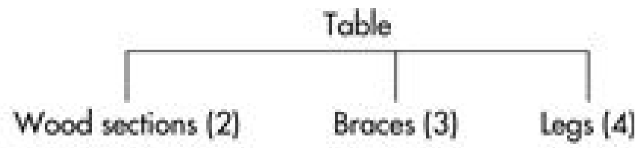
Finally, by comparing these five options above, we find that option 2 is the least costly option and it covers for the whole extra 600 units that we need. Thus, the table for the aggregate plan will be as follows:

| | | | **1** | **2** | **3** | **Total** |
|---|---|---|---|---|---|---|
| Forecast | | | 8900 | 9700 | 8600 | |
| Output | | | | | | |
| Regular | | | **9300** | **9300** | **9000** | |
| Overtime | | | **-** | **-** | **-** | |
| Output-Forecast | | | **400** | **-400** | **400** | |
| Inventory | | | | | | |
| Beginning | | | **0** | **400** | **0** | |
| Ending | | | **400** | **0** | **400** | |
| Average | | | **200** | **200** | **200** | |
| Backlog | | | | **0** | **0** | |
| Costs | | | | | | |
| Regular | @ | $20 | **18,600** | **18,600** | **18,000** | **55,200** |
| Overtime | @ | $25 | **-** | **-** | **-** | **0** |
| Inventory | @ | $2 | **400** | **400** | **400** | **1200** |
| Back orders | @ | $8 | **0** | **0** | **0** | **0** |
| Hiring | @ | $1200 | **1200** | **-** | **-** | **1200** |
| Layoff | @ | $600 | **-** | **-** | **600** | **600** |
| | | | | | | **$58,200** |

## Problem 4

A table is assembled using three components, as shown in the following product structure tree. The company that makes the table wants to ship 100 units at the beginning of day 4, 150 units at the beginning of day 5, and 200 units at the beginning of day 7. Receipts of 100 wood sections are scheduled at the beginning of day 2. There are 120 legs on hand. An additional 10 percent of the order size on legs is added for safety stock. There are 60 braces on hand. Lead time (in days) for all items is a function of each order quantity and is shown below. Prepare the material requirements plan using lot-for-lot ordering.

| Order Quantity | Lead Time (days) |
|---|---|
| 1–200 | 1 |
| 201–550 | 2 |
| 551–999 | 3 |




| Table (*Variable LT) | Beg. Inv. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Gross requirements | | | | | | | | |
| Scheduled receipts | | | | | | | | |
| Projected on hand | | | | | | | | |
| Net requirements | | | | | | | | |
| Planned-order receipts | | | | | | | | |
| Planned-order releases | | | | | | | | |

| Wood Sections * | Beg. Inv. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Gross requirements | | | | | | | | |
| Scheduled receipts | | | | | | | | |
| Projected on hand | | | | | | | | |
| Net requirements | | | | | | | | |
| Planned-order receipts | | | | | | | | |
| Planned-order releases | | | | | | | | |

* Note that lead time is a function of lot size.

| Braces * | Beg. Inv. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Gross requirements | | | | | | | | |
| Scheduled receipts | | | | | | | | |
| Projected on hand | | | | | | | | |
| Net requirements | | | | | | | | |
| Planned-order receipts | | | | | | | | |
| Planned-order releases | | | | | | | | |

| Legs *<br>10% extra safety stock | Beg. Inv. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Gross requirements | | | | | | | | |
| Scheduled receipts | | | | | | | | |
| Projected on hand | | | | | | | | |
| Net requirements | | | | | | | | |
| Planned-order receipts | | | | | | | | |
| Planned-order releases | | | | | | | | |

* Note that lead time is a function of lot size.

**Solution:**

| Table (*Variable LT) | Beg. Inv. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Gross requirements | | | | | 100 | 150 | | 200 |
| Scheduled receipts | | | | | | | | |
| Projected on hand | | | | | | | | |
| Net requirements | | | | | 100 | 150 | | 200 |
| Planned-order receipts | | | | | 100 | 150 | | 200 |
| Planned-order releases | | | | 100 | 150 | | 200 | |

| Wood Sections * | Beg. Inv. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Gross requirements | | | | 200 | 300 | | 400 | |
| Scheduled receipts | | | 100 | | | | | |
| Projected on hand | | | 100 | 100 | 0 | | 0 | |
| Net requirements | | | | 100 | 300 | | 400 | |
| Planned-order receipts | | | | 100 | 300 | | 400 | |
| Planned-order releases | | | 100+<br>300 | | 400 | | | |

| Braces * | Beg. Inv. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Gross requirements | | | | 300 | 450 | | 600 | |
| Scheduled receipts | | | | | | | | |
| Projected on hand | 60 | 60 | 60 | 60 | 0 | | 0 | |
| Net requirements | | | | 240 | 450 | | 600 | |
| Planned-order receipts | | | | 240 | 450 | | 600 | |
| Planned-order releases | | 240 | 450 | 600 | | | | |

| Legs *<br>10% extra safety stock | Beg. Inv. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Gross requirements | | | | 400 | 600 | | 800 | |
| Scheduled receipts | | | | | | | | |
| Projected on hand | 120 | 120 | 120 | 120 | 0 | | 0 | |
| Net requirements | | | | 280 | 600 | | 800 | |
| Planned-order receipts | | | | 308 | 660 | | 880 | |
| Planned-order releases | | 308+<br>660 | | 880 | | | | |

* Note that lead time is a function of lot size.