Chapter 2

Product, Process, and Schedule Design

SECTION 2.1

2.1 Identify the hospital functions and departments to be incorporated in the facilities plan. Identify the key entities for which flow requirements will be needed, e.g., people, paperwork, operating rooms, emergency rooms, vehicular movement, etc. Identify the various criteria that will be used to evaluate the alternative facilities plans generated, e.g. patient service, cleanliness, logic of travel between departments, ease of expansion/ updating, cost. Determine the time period over which the facilities requirements will be estimated. Estimate space and flow requirements and determine activity relationships. Generate alternative facilities plans.

2.2 It is important for the various design decisions to be integrated so that all critical issues have been considered before product and process designs are finalized. Using a linear or series approach can result in multiple re-starts of the design process because of "down-stream" consequences of "up-stream" design decisions that are made. Overall optimization is the goal, rather than piecewise optimization.

Knowledgeable representatives from each of the activities or functions need to be involved in the design process.

Several concurrent engineering techniques can be used to improve the design process. Quality Function Deployment is one technique that can prove extremely beneficial. However, all of the approaches described in Section 2.5 should receive serious consideration. Since the text is devoted to facilities planning, every technique presented in the text is a candidate for use in a specific application.

2.3 Research question. Depending on the comprehensiveness of the collection of periodicals and manuscripts in the university library, it might be more helpful to the students to modify the assignment and encourage them to use the Internet in performing the assigned search.

SECTION 2.2

2.4 - 2.6 Research question. Depending on the comprehensiveness of the collection of periodicals and manuscripts in the university library, it might be more helpful to the students to modify the assignment and encourage them to use the Internet in performing the assigned search.

2.7 Research question. The Internet will likely be the best source of information needed to answer this question.

SECTION 2.3

2.8 The assigned chart submitted for a cheeseburger will vary depending on the assumptions regarding ingredients, e.g., mayonnaise, mustard, catsup, onions, pickles, lettuce, tomato, multiple beef patties, multiple slices of cheese, intermediate layer of bread. Likewise, the chart submitted for a taco will vary depending on the ingredients included. It is important to verify that the student follows the steps described in Section 2.3.

2.9 The assembly chart shows only the operations and inspections associated with the assembly of the product. The operation process chart includes all operations and inspections, fabrication and assembly operations and processing times, and purchased materials.

2.10 - 2.11 The solution depends on the recipe chosen.

SECTION 2.4

2.12 $I_1 = 2000/[(0.92)(0.95)(0.95)(0.97)] = 2{,}483$ enclosures (rounded to nearest integer)

2.13 Given System: (all I_k values are rounded to the nearest integer)
$I_1 = 1{,}000/[0.93(0.95)(0.97)] = 1{,}167$ units
$I_2 = 1{,}000/[0.93(0.95)] = 1{,}132$ units
$I_3 = 1{,}000/0.93 = 1{,}075$ units

The scrap values and scrap cost at each step are as follows:
Process 3: 1,075 - 1,000 = 75 units → Scrap Cost = \$15(75) = \$1,125
Process 2: 1,132 - 1,075 = 57 units → Scrap Cost = \$10(57) = \$570
Process 1: 1,167 - 1,132 = 35 units → Scrap Cost = \$5(34) = \$170
Total Scrap Cost for given system = \$1,865

System w/Reversed Scrap Rates:
$I_1 = 1{,}167$ units
$I_2 = 1{,}000/[0.97(0.95)] = 1{,}085$ units
$I_3 = 1{,}000/0.97 = 1{,}031$ units

The scrap values and scrap cost at each step are as follows:
Process 3: 1,031 - 1,000 = 31 units → Scrap Cost = \$15(31) = \$465
Process 2: 1,085 - 1,031 = 54 units → Scrap Cost = \$10(54) = \$540
Process 1: 1,167 - 1,085 = 82 units → Scrap Cost = \$5(82) = \$410
Total Scrap Cost for given system = \$1,415

Due to the lower scrap cost the system with reversed scrap rates would be preferred, which is consistent with the claim made in Section 2.4.2.

2.14 For simplicity the rework operations are indicated by Rk. All I_k values are rounded to the nearest integer.

Given system: Following the derivation method given in Section 2.4.2.2, we have the expression for I_1:

$$I_1 = \frac{O_3}{[[(1-d_3)+d_3(1-d_{R3})][(1-d_2)+d_2(1-d_{R2})][(1-d_1)+d_1(1-d_{R1})]]}$$
$$I_1 = 1{,}000/[[0.93+(0.8)(0.07)][0.95+(0.75)(0.05)][0.97+(0.60)(0.03)]]$$
$$I_1 = 1040 \text{ units}$$

To find the rework cost we need only the required input to each rework process. Thus,

$$I_{R1} = I_1(d_1) = 1{,}040(0.03) = 31 \text{ units}$$
$$I_{R2} = I_1(d_2)[(1-d_1)+d_1(1-d_{R1})] = 1{,}040(0.05)(0.988)$$
$$= 51 \text{ units}$$
$$I_{R3} = I_1(d_3)[(1-d_1)+d_1(1-d_{R1})][(1-d_2)+d_2(1-d_{R2})]$$
$$I_{R3} = 1{,}040(0.07)(0.988)(0.9875) = 71 \text{ units}$$

Therefore, the total rework cost = \$2(31) + \$3(51) + \$4(71) = \$499.

<u>System w/Reversed Scrap Rates</u>: Using the same derivation, we have the following:

$$I_1 = 1{,}000/[[0.97+(0.8)(0.03)][0.95+(0.75)(0.05)][0.93+(0.60)(0.07)]]$$
$$I_1 = 1048 \text{ units}$$

$$I_{R1} = 1{,}048(0.07) = 73 \text{ units}$$
$$I_{R2} = 1{,}048(0.05)(0.972) = 51 \text{ units}$$
$$I_{R3} = 1{,}048(0.03)(0.972)(0.9875) = 30 \text{ units}$$

Therefore, the total rework cost for the system with the reversed scrap rates = \$2(73) + \$3(51) + \$4(30) = \$419.

Based solely on the total rework costs of the two systems, the system with reversed scrap rates is preferred, which is consistent with the result of Problem 2.13. You should note, however, that the system with reversed scrap rates requires more input to the system to meet the demand.

2.15 All I_k values are rounded to the nearest integer.

$$I_B = Q_B = O_B/(1-d_B) = 3{,}000/0.95 = 3{,}158 \text{ units}$$
$$I_A = Q_A = O_B/[(1-d_B)(1-d_A)] = 3{,}000/[0.95(0.98)] = 3{,}222 \text{ units}$$

$$F = S_A(Q_A)/[(E_A)(H)(R_A)] + S_B(Q_B)/[(E_B)(H)(R_B)] + [30(Q_A/500)]/H$$

$$H = 5 \text{ days/week}(18 \text{ hours/day})(60 \text{ min/hr}) = 5{,}400 \text{ min/week}$$

$$F = 3(3{,}222)/[(0.95)(5{,}400)(0.95)] + 5(3{,}158)/[(0.95)(5{,}400)(0.90)]$$
$$+ [30(3{,}222/500)]/5{,}400$$
$$F = 5.439 \approx 6 \text{ milling machines}$$

2.16 We solve this problem working in reverse.

$$O_1 = (1 - d_1)I_1$$
$$O_2 = (1 - d_2)(1 - d_1)I_1$$
$$I_4 = d_2(1 - d_1)I_1$$
$$O_4 = (1 - d_4)(d_2)(1 - d_1)I_1$$
$$I_3 = O_2 + O_4 = [(1 - d_2)(1 - d_1) + (1 - d_4)(1 - d_1)d_2]I_1$$
$$O_3 = (1 - d_3)[(1 - d_2)(1 - d_1) + (1 - d_4)(1 - d_1)d_2]I_1$$

Solving for I_1 and substituting in the appropriate parameters, we have the following:

$$I_1 = 5{,}000/(0.90)[(0.95)(0.95) + (0.98)(0.95)(0.5)]$$
$$I_1 = 5{,}854 \text{ units (rounded to nearest integer)}$$

2.17 All I_k values rounded to the nearest integer. For machines 1, 2, and 3:
$H = (16 \text{ hours/day})(60 \text{ mins/hour})(5 \text{ days/week}) = 4{,}800 \text{ mins/week}$
Machine 4 operates for half of the amount of time as machines 1, 2, and 3.

We know that $I_k = Q_k$. So,

$$F_1 = Q_1(S_1)/[(H)(E_1)(R_2)]$$
$$F_1 = (5{,}854)(3)/[(4{,}800)(1)(0.95)] = 3.85 \approx 4 \text{ machines}$$

$$I_2 = (1 - d_1)I_1 = 0.95(5{,}854) = 5{,}561 \text{ units}$$
$$F_2 = (5{,}561)(2)/[(4{,}800)(0.95)(0.90)] = 2.71 \approx 3 \text{ machines}$$

$$I_3 = O_3/(1 - d_3) = 5{,}000/0.90 = 5{,}556 \text{ units}$$
$$F_2 = (5{,}556)(5)/[(4{,}800)(1.02)(0.90)] = 6.3 \approx 7 \text{ machines}$$

$$I_4 = d_2O_1 = 0.05(0.95)(5{,}584) = 278 \text{ units}$$
$$F_4 = (278)(10)/[(2{,}400)(0.90)(0.95)] = 1.35 \approx 2 \text{ machines}$$

Running the rework operation on the same shift as the remainder of the cell would cause the machine fraction to reduce to 0.68, or 1 machine. This may allow for the addition of the rework machine to the cell.

2.18 All I_k values rounded to nearest integer. Let A1 denote the first step in the production process, and A2 denote the last step.

$$I_{A1} = O_3/[(1 - d_3)(1 - d_2)(1 - d_1)]$$
$$I_{A1} = 10{,}000/[(0.95)(0.95)(0.97)] = 11{,}423 \text{ units}$$

Similarly,

$$I_B = 10{,}000/[(0.95)(0.97)] = 10{,}080 \text{ units}$$
$$I_{A2} = 10{,}000/[0.95] = 10{,}526 \text{ units}$$

$\mathrm{H} = (8\ \text{hours/day})(60\ \text{mins/hour})(6\ \text{days/week}) = 2{,}880\ \text{mins/week}$

We know that $I_k = Q_k$. So,

$$\mathrm{F_A} = \mathrm{Q_{A1}(S_{A1})/[(H)(E_{A1})(R_{A1})] + Q_{A2}(S_{A2})/[(H)(E_{A2})(R_2)]}$$
$$\mathrm{F_A} = (11{,}423)(5)/[(2{,}880)(1.08)(0.98)] + (10{,}526)(3)/[(2{,}880)(0.90)(0.95)]$$
$$\mathrm{F_A} = 31.57 \approx 32\ \text{machines}$$

$$\mathrm{F_B} = \mathrm{Q_B(S_B)/[(H)(E_B)(R_B)]}$$
$$\mathrm{F_A} = (11{,}080)(5)/[(2{,}880)(1.08)(0.98)] = 12.79 \approx 13\ \text{machines}$$

2.19 All I_k values are rounded to the nearest integer.

$$\mathrm{I_{XC}} = \mathrm{O_X}/[1 - \mathrm{d_{XC}}] = 100{,}000/0.97 = 103{,}093\ \text{units}$$
$$\mathrm{I_{XB}} = \mathrm{O_X}/[(1 - \mathrm{d_{XC}})(1 - \mathrm{d_{XB}})]$$
$$\mathrm{I_{XB}} = 100{,}000/[(0.97)(0.96)] = 107{,}388\ \text{units}$$
$$\mathrm{I_{XA}} = \mathrm{O_X}/[(1 - \mathrm{d_{XC}})(1 - \mathrm{d_{XB}})(1 - \mathrm{d_{XA}})]$$
$$\mathrm{I_{XA}} = 100{,}000/[(0.97)(0.96)(0.95)] = 113{,}040\ \text{units}$$

$$\mathrm{I_{YC}} = \mathrm{O_Y}/[1 - \mathrm{d_{YC}}] = 200{,}000/0.97 = 206{,}186\ \text{units}$$
$$\mathrm{I_{YA}} = \mathrm{O_Y}/[(1 - \mathrm{d_{YC}})(1 - \mathrm{d_{YA}})]$$
$$\mathrm{I_{YA}} = 200{,}000/[(0.97)(0.95)] = 217{,}037\ \text{units}$$
$$\mathrm{I_{YB}} = \mathrm{O_Y}/[(1 - \mathrm{d_{YC}})(1 - \mathrm{d_{YA}})(1 - \mathrm{d_{YB}})]$$
$$\mathrm{I_{YB}} = 200{,}000/[(0.97)(0.95)(0.96)] = 226{,}081\ \text{units}$$

Setup times are identical for machines A, B, and C for a particular product. The setup time for product X, regardless of the machine, is 20 mins; the setup time for product Y is 40 mins., regardless of the machine. A critical piece of information needed to determine the number of machines required is the length of production runs between setups. If a single setup is needed to produce the annual requirement of a product on a machine, then the number of machines required is determined as follows:

$$\mathrm{F_A} = \frac{0.15(113{,}040)}{(0.85)(1600)(0.95)} + \frac{0.15(217{,}037)}{(0.85)(1600)(0.95)} + \frac{20 + 40}{(60)(1600)}$$
$$\mathrm{F_A} = 13.12 + 16.8 + 0.00065 = 29.92 \approx 30\ \text{machines}$$

$$\mathrm{F_B} = \frac{0.25(107{,}388)}{(0.90)(1600)(0.90)} + \frac{0.25(226{,}081)}{(0.90)(1600)(0.90)} + \frac{20 + 40}{(60)(1600)}$$
$$\mathrm{F_B} = 20.72 + 17.44 + 0.00065 = 38.16 \approx 39\ \text{machines}$$

$$\mathrm{F_C} = \frac{0.15(103{,}093)}{(0.95)(1600)(0.85)} + \frac{0.15(206{,}186)}{(0.95)(1600)(0.85)} + \frac{20 + 40}{(60)(1600)}$$
$$\mathrm{F_C} = 7.98 + 23.94 + 0.00065 = 31.92 \approx 32\ \text{machines}$$

If setups occur more frequently, then additional machines might be required due to the lost production time consumed by setups.

2.20 All I_k values are rounded to the nearest integer.

Part A: $I_1 = O_6/[(1-d_6)(1-d_4)(1-d_2)(1-d_1)]$
$I_1 = 15{,}000/[(0.70)(0.85)(0.90)(0.80)] = 35{,}014$ units

Part B: $I_3 = 3 * I_4/(1-d_3)$
$I_4 = O_6/[(1-d_6)(1-d_3)] = 15{,}000/[(0.70)(0.85)] = 25{,}210$
Then, $I_3 = (3 * 25{,}210)/0.70 = 108{,}043$ units

Part C: $I_5 = O_6/[(1-d_6)(1-d_5)] = 15{,}000/[(0.70)(0.75)] = 28{,}571$ units

2.21 Using the equations to solve Problem 2.20, we simply change the input values. Let d_k' represent the new scrap percentage. For this solution, we are assuming the 5% reduction is as follows: $d_k' \to d_k - 0.05$. You could also view the problem statement as indicating that $d_k' \to 0.95 * d_k$. All I_k values are rounded to the nearest integer.

Part A: $I_1 = 15{,}000/[(0.75)(0.90)(0.95)(0.85)] = 27{,}520$ units
This represents a 21.4% reduction in the input requirement.

Part B: $I_4 = 15{,}000/[(0.75)(0.90)] = 22{,}222$
$I_3 = (3 * 22{,}222)/0.75 = 88{,}888$ units
This represents a 17.7% reduction in the input requirement.

Part C: $I_4 = 15{,}000/[(0.75)(0.80)] = 25{,}000$ units
This represents a 12.5% reduction in the input requirement.

The opinion response will depend on the student. However, the response should look something like the following.

Estimation Perspective: For most tasks that a process designer may have to plan for there are likely to be many alternatives. The designer must be able to identify the issues related to each alternative and be able to generate an accurate estimate of the scrap rate. Even in the case where there may be only a single alternative the ability to accurately estimate the scrap rate is of great significance.

Continuous Improvement Perspective: Being able to reduce the scrap produced by a process can be shown to significantly reduce the input requirement to a process.

2.22 The value of H is up to the student or instructor. Any value will provide sufficient illustration for the follow-up opinion question. For the purposes of this solution, we will assume H is a variable value and solve symbolically.

<u>Before reduction</u>: $I_4 = Q_4 = 25{,}210$. Thus,
$F_4 = S_4Q_4/[HE_4R_4] = (4 * 25{,}210)/[(H)(0.95)(0.98)] = 108{,}313.64/H$

<u>After reduction</u>: $I_4 = Q_4 = 22{,}222$. Thus,
$F_4 = S_4Q_4/[HE_4R_4] = (4 * 22{,}222)/[(H)(0.95)(0.98)] = 95{,}475.83/H$

It should be apparent that by reducing the scrap percentage will reduce the number of machines necessary. Assuming one 8 hour shift per day, 5 days per week, reducing the scrap percentage as indicated in Problem 2.21 would result in a reduction of 6 machines. This could be a significant reduction in the floor space required to perform a specific process. In addition, reduction of the input needed for a specific process may also reduce the amount of storage space for raw materials/WIP, further reducing floor space requirements. For the facilities planner, space is at a premium, so every advantage should be taken to either improve processes or select processes that produce less scrap.

2.23 $\mathrm{I} = \mathrm{Q} = \mathrm{O}/(1 - \mathrm{d}) = 750/0.80 = 938$ units (rounded to nearest integer)

$\mathrm{F} = \mathrm{SQ/EHR} = [(1/4)(938)]/[(15/20)(7)(0.75)] = 44.67 \approx 45$ machines

Alternatively, you could say that the loss of one hour per shift is a reduction in the reliability. Thus, the denominator would have the following: H = 8, R = 7/8.

2.24 Let CA, CB, B, F, FA, IN, and M represent component A, component B, blanking, forging, final assembly, inspection, and machining, respectively. Let O_{SA} = Amount of demand for spare parts of Component A = 1,000 units; and I_{FA} = Input needed for final assembly for Component A. All I_k values are rounded to the nearest integer.

$\mathrm{I_{FA}} = 2(\mathrm{O_{FA}}/(1 - \mathrm{d_{FA}})) = 2(5{,}000/0.95) = 10{,}526$ units

$\mathrm{I_{CA}} = (\mathrm{O_S} + \mathrm{I_{FA}})/[(1 - \mathrm{d_M})(1 - \mathrm{d_F})(1 - \mathrm{d_B})]$
$\mathrm{I_{CA}} = (1{,}000 + 10{,}526)/[(0.75)(0.85)(0.90)] = 20{,}089$ units

$\mathrm{I_{CB}} = \mathrm{O_{FA}}/[(1 - \mathrm{d_{FA}})(1 - \mathrm{d_{IN}})] = 5{,}000/[(0.95)(0.98)] = 5{,}371$ units

2.25 $I_1 = \lceil O_6/[(1 - d_6)(1 - d_5)(1 - d_4)(1 - d_3)(1 - d_2)(1 - d_1)]\rceil$

Where ⌈xx⌉ stands for the least integer ≥ xx.

2.26 Let BC, BY, CB, DA, IN, KP, and TC represent the bottom cover, battery cover, circuit board, disassembly, inspection, keypad, and top cover, respectively. In addition, let Mxx represent molding operations for specific components; Pxx represent painting operations for specific components; and INx represent inspection stations in order of occurrence. All I_k values are rounded to the nearest integer.

$\mathrm{I_{TC}} = \mathrm{O}/[(1 - \mathrm{d_{MTC}})(1 - \mathrm{d_{PTC}})] = 10{,}000/[(0.95)(0.95)] = 11{,}080$ units
$\mathrm{I_{KP}} = \mathrm{O}/[(1 - \mathrm{d_{MKP}})(1 - \mathrm{d_{PKP}})] = 10{,}000/[(0.98)(0.95)] = 10{,}741$ units

$\mathrm{I_{BY}} = \mathrm{O}/(1 - \mathrm{d_{MBY}}) = 10{,}000/0.92 = 10{,}870$ units
$\mathrm{I_{CB}} = \mathrm{O}/[(1 - \mathrm{d_{IN1}})(1 - \mathrm{d_{IN2}})] = 10{,}000/[(0.97)(0.90)] = 11{,}455$ units

To find the number of units of the bottom cover to mold, we'll assume that it only goes through the inspection process once.

$\mathrm{I_{IN2}} = (1 - \mathrm{d_{MBC}})\mathrm{I_{BC}}$
$\mathrm{O_{IN2}} = (1 - \mathrm{d_{IN2}})\mathrm{I_{IN2}} = (1 - \mathrm{d_{IN2}})(1 - \mathrm{d_{MBC}})\mathrm{I_{BC}}$
$\mathrm{O_{DA}} = \mathrm{d_{IN2}}\mathrm{I_{IN2}}(1 - \mathrm{d_{DA}}) = (1 - \mathrm{d_{MBC}})\mathrm{d_{IN2}}(1 - \mathrm{d_{DA}})\mathrm{I_{BC}}$

Thus, $O = (1 - d_{IN2})(1 - d_{MBC})I_{BC} + (1 - d_{MBC})d_{IN2}(1 - d_{DA})I_{BC}$
$\mathrm{I_{BC}} = \mathrm{O}/[(1 - \mathrm{d_{IN2}})(1 - \mathrm{d_{MBC}}) + (1 - \mathrm{d_{MBC}})(\mathrm{d_{IN2}})(1 - \mathrm{d_{DA}})]$
$\mathrm{I_{BC}} = 10{,}000/[(0.97)(0.90) + (0.90)(0.03)(0.25)] = 11{,}367$ units

2.27 Shown below is the probability mass function for number of good castings produced (x), based on Q castings scheduled for production.

# Good	Number of Castings Scheduled										
Castings	20	21	22	23	24	25	26	27	28	29	30
12	0.10	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.10	0.10	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00
14	0.10	0.10	0.10	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00
15	0.10	0.10	0.10	0.10	0.05	0.05	0.05	0.00	0.00	0.00	0.00
16	0.10	0.10	0.10	0.10	0.05	0.05	0.05	0.05	0.00	0.00	0.00
17	0.10	0.10	0.10	0.10	0.10	0.05	0.05	0.05	0.05	0.00	0.00
18	0.20	0.10	0.10	0.10	0.10	0.05	0.05	0.10	0.05	0.05	0.05
19	0.10	0.15	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.05	0.05
20	0.10	0.10	0.15	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.05
21	0.00	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
22	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
23	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
24	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.10	0.10
25	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.10
26	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.10	0.10	0.10
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.10	0.10
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.05
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05

Shown below is the matrix of net income for each combination of Q and x.

# Good	Number of Castings Scheduled										
Castings	20	21	22	23	24	25	26	27	28	29	30
12	-$8,000	-$8,400	-$8,800	-$9,200	-$9,600	-$10,000	-$10,400	-$10,800	-$11,200	-$11,600	-$12,000
13	-$8,000	-$8,400	-$8,800	-$9,200	-$9,600	-$10,000	-$10,400	-$10,800	-$11,200	-$11,600	-$12,000
14	-$8,000	-$8,400	-$8,800	-$9,200	-$9,600	-$10,000	-$10,400	-$10,800	-$11,200	-$11,600	-$12,000
15	-$8,000	-$8,400	-$8,800	-$9,200	-$9,600	-$10,000	-$10,400	-$10,800	-$11,200	-$11,600	-$12,000
16	-$8,000	-$8,400	-$8,800	-$9,200	-$9,600	-$10,000	-$10,400	-$10,800	-$11,200	-$11,600	-$12,000
17	-$8,000	-$8,400	-$8,800	-$9,200	-$9,600	-$10,000	-$10,400	-$10,800	-$11,200	-$11,600	-$12,000
18	-$8,000	-$8,400	-$8,800	-$9,200	-$9,600	-$10,000	-$10,400	-$10,800	-$11,200	-$11,600	-$12,000
19	-$8,000	-$8,400	-$8,800	-$9,200	-$9,600	-$10,000	-$10,400	-$10,800	-$11,200	-$11,600	-$12,000
20	$16,000	$15,600	$15,200	$14,800	$14,400	$14,000	$13,600	$13,200	$12,800	$12,400	$12,000
21	$0	$16,300	$15,900	$15,500	$15,100	$14,700	$14,300	$13,900	$13,500	$13,100	$12,700
22	$0	$0	$16,600	$16,200	$15,800	$15,400	$15,000	$14,600	$14,200	$13,800	$13,400
23	$0	$0	$0	$16,200	$15,800	$15,400	$15,000	$14,600	$14,200	$13,800	$13,400
24	$0	$0	$0	$0	$15,800	$15,400	$15,000	$14,600	$14,200	$13,800	$13,400
25	$0	$0	$0	$0	$0	$15,400	$15,000	$14,600	$14,200	$13,800	$13,400
26	$0	$0	$0	$0	$0	$0	$15,000	$14,600	$14,200	$13,800	$13,400
27	$0	$0	$0	$0	$0	$0	$0	$14,600	$14,200	$13,800	$13,400
28	$0	$0	$0	$0	$0	$0	$0	$0	$14,200	$13,800	$13,400
29	$0	$0	$0	$0	$0	$0	$0	$0	$0	$13,800	$13,400
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$13,400

For a given value of Q, multiplying the net income in the column by the probability of its occurrence and summing over all values of x yields the following expected profits for each value of Q.

Expected Profit Number of Castings Scheduled										
20	21	22	23	24	25	26	27	28	29	30
-$5,600	-$3,530	-$190	$750	$2,890	$5,030	$5,900	$6,770	$8,910	**$11,050**	$10,720

Based on the results obtained, scheduling 29 castings for production yields the maximum expected profit of $11,050.

2.28 Shown below is the probability mass function for number of good castings produced (x), based on Q castings scheduled for production.

# Good Castings	Number of Castings Scheduled															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
5	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.05	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.10	0.05	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.10	0.10	0.05	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.15	0.10	0.10	0.05	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.15	0.15	0.10	0.10	0.05	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00
15	0.20	0.15	0.15	0.10	0.10	0.05	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00
16	0.00	0.20	0.15	0.15	0.10	0.10	0.05	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00
17	0.00	0.00	0.20	0.15	0.15	0.10	0.10	0.05	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00
18	0.00	0.00	0.00	0.20	0.15	0.15	0.10	0.10	0.05	0.05	0.05	0.05	0.05	0.05	0.00	0.00
19	0.00	0.00	0.00	0.00	0.20	0.15	0.15	0.10	0.10	0.05	0.05	0.05	0.05	0.05	0.05	0.00
20	0.00	0.00	0.00	0.00	0.00	0.20	0.15	0.15	0.10	0.10	0.05	0.05	0.05	0.05	0.05	0.05
21	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.15	0.15	0.10	0.10	0.05	0.05	0.05	0.05	0.05
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.15	0.15	0.10	0.10	0.05	0.05	0.05	0.05
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.15	0.15	0.10	0.10	0.05	0.05	0.05
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.15	0.15	0.10	0.10	0.05	0.05
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.15	0.15	0.10	0.10	0.05
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.15	0.15	0.10	0.10
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.15	0.15	0.10
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.15	0.15
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.15
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20

Shown below is the matrix of net income for each combination of Q and x.

# Good Castings	Number of Castings Scheduled															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
5	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
6	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
7	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
8	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
9	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
10	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
11	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
12	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
13	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
14	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
15	$8,625	$8,150	$7,675	$7,200	$6,725	$6,250	$5,775	$5,300	$4,825	$4,350	$3,875	$3,400	$2,925	$2,450	$1,975	$1,500
16	$0	$9,200	$8,725	$8,250	$7,775	$7,300	$6,825	$6,350	$5,875	$5,400	$4,925	$4,450	$3,975	$3,500	$3,025	$2,550
17	$0	$0	$9,775	$9,300	$8,825	$8,350	$7,875	$7,400	$6,925	$6,450	$5,975	$5,500	$5,025	$4,550	$4,075	$3,600
18	$0	$0	$0	$10,350	$9,875	$9,400	$8,925	$8,450	$7,975	$7,500	$7,025	$6,550	$6,075	$5,600	$5,125	$4,650
19	$0	$0	$0	$0	$10,925	$10,450	$9,975	$9,500	$9,025	$8,550	$8,075	$7,600	$7,125	$6,650	$6,175	$5,700
20	$0	$0	$0	$0	$0	$11,500	$11,025	$10,550	$10,075	$9,600	$9,125	$8,650	$8,175	$7,700	$7,225	$6,750
21	$0	$0	$0	$0	$0	$0	$11,025	$10,550	$10,075	$9,600	$9,125	$8,650	$8,175	$7,700	$7,225	$6,750
22	$0	$0	$0	$0	$0	$0	$0	$10,550	$10,075	$9,600	$9,125	$8,650	$8,175	$7,700	$7,225	$6,750
23	$0	$0	$0	$0	$0	$0	$0	$0	$10,075	$9,600	$9,125	$8,650	$8,175	$7,700	$7,225	$6,750
24	$0	$0	$0	$0	$0	$0	$0	$0	$0	$9,600	$9,125	$8,650	$8,175	$7,700	$7,225	$6,750
25	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$9,125	$8,650	$8,175	$7,700	$7,225	$6,750
26	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$8,650	$8,175	$7,700	$7,225	$6,750
27	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$8,175	$7,700	$7,225	$6,750
28	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$7,700	$7,225	$6,750
29	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$7,225	$6,750
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$6,750

For a given value of Q, multiplying the net income in the column by the probability of its occurrence and summing over all values of x yields the following expected profits for each value of Q.

Expected Profit															
Number of Castings Scheduled															
15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
-$3,975	-$1,878	$378	$2,003	$3,733	$4,780	$5,670	$6,455	$7,135	$7,763	$8,338	$8,125	$7,860	$7,543	$7,173	$6,750

Based on the results obtained, scheduling 25 castings for production yields the maximum expected profit of $8,338.

2.29 Shown below is the probability mass function for number of good castings produced (x), based on Q castings scheduled for production.

# Good	Number of Castings Scheduled															
Castings	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
7	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0008	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9	0.0047	0.0013	0.0003	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0208	0.0067	0.0019	0.0005	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	0.0694	0.0266	0.0091	0.0028	0.0008	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12	0.1696	0.0814	0.0332	0.0120	0.0039	0.0012	0.0003	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13	0.2870	0.1837	0.0937	0.0405	0.0154	0.0053	0.0017	0.0005	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14	0.3006	0.2886	0.1963	0.1060	0.0483	0.0193	0.0070	0.0023	0.0007	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
15	0.1470	0.2822	0.2878	0.2072	0.1181	0.0567	0.0238	0.0090	0.0031	0.0010	0.0003	0.0001	0.0000	0.0000	0.0000	0.0000
16	0.00	0.1293	0.2638	0.2850	0.2166	0.1399	0.0655	0.0288	0.0114	0.0041	0.0014	0.0004	0.0001	0.0000	0.0000	0.0000
17	0.00	0.00	0.1138	0.2458	0.2803	0.2242	0.1413	0.0746	0.0343	0.0141	0.0053	0.0018	0.0006	0.0002	0.0001	0.0000
18	0.00	0.00	0.00	0.1002	0.2284	0.2740	0.2302	0.1519	0.0839	0.0403	0.0173	0.0067	0.0024	0.0008	0.0003	0.0001
19	0.00	0.00	0.00	0.00	0.0881	0.2115	0.2665	0.2345	0.1618	0.0932	0.0466	0.0208	0.0084	0.0031	0.0011	0.0004
20	0.00	0.00	0.00	0.00	0.00	0.0776	0.1955	0.2580	0.2374	0.1709	0.1025	0.0533	0.0247	0.0104	0.0040	0.0014
21	0.00	0.00	0.00	0.00	0.00	0.00	0.0683	0.1802	0.2487	0.2387	0.1790	0.1117	0.0603	0.0290	0.0126	0.0050
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0601	0.1658	0.2387	0.2387	0.1862	0.1207	0.0676	0.0336	0.0151
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0529	0.1522	0.2283	0.2375	0.1924	0.1293	0.0750	0.0386
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0465	0.1395	0.2177	0.2351	0.1971	0.1374	0.0825
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0409	0.1277	0.2069	0.2317	0.2016	0.1451
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0360	0.1167	0.1961	0.2274	0.2047
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0317	0.1065	0.1853	0.2224
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0279	0.0971	0.1747
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0245	0.0884
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0216

Net incomes for feasible combinations of Q and x are shown below.

# Good Castings	Number of Castings Scheduled															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
7	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
8	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
9	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
10	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
11	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
12	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
13	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
14	-$7,125	-$7,600	-$8,075	-$8,550	-$9,025	-$9,500	-$9,975	-$10,450	-$10,925	-$11,400	-$11,875	-$12,350	-$12,825	-$13,300	-$13,775	-$14,250
15	$19,500	$19,500	$19,500	$19,500	$19,500	$19,500	$19,500	$19,500	$19,500	$19,500	$19,500	$19,500	$19,481	$19,436	$19,389	$19,367
16	$0	$20,800	$20,800	$20,800	$20,800	$20,800	$20,800	$20,800	$20,800	$20,800	$20,800	$20,800	$20,781	$20,736	$20,689	$20,667
17	$0	$0	$22,100	$22,100	$22,100	$22,100	$22,100	$22,100	$22,100	$22,100	$22,100	$22,100	$22,081	$22,036	$21,989	$21,967
18	$0	$0	$0	$23,400	$23,400	$23,400	$23,400	$23,400	$23,400	$23,400	$23,400	$23,400	$23,381	$23,336	$23,289	$23,267
19	$0	$0	$0	$0	$24,700	$24,700	$24,700	$24,700	$24,700	$24,700	$24,700	$24,700	$24,681	$24,636	$24,589	$24,567
20	$0	$0	$0	$0	$0	$26,000	$26,000	$26,000	$26,000	$26,000	$26,000	$26,000	$25,981	$25,936	$25,889	$25,867
21	$0	$0	$0	$0	$0	$0	$11,025	$10,550	$10,075	$9,600	$9,125	$8,650	$8,175	$7,700	$7,225	$6,750
22	$0	$0	$0	$0	$0	$0	$0	$10,550	$10,075	$9,600	$9,125	$8,650	$8,175	$7,700	$7,225	$6,750
23	$0	$0	$0	$0	$0	$0	$0	$0	$10,075	$9,600	$9,125	$8,650	$8,175	$7,700	$7,225	$6,750
24	$0	$0	$0	$0	$0	$0	$0	$0	$0	$9,600	$9,125	$8,650	$8,175	$7,700	$7,225	$6,750
25	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$9,125	$8,650	$8,175	$7,700	$7,225	$6,750
26	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$8,650	$8,175	$7,700	$7,225	$6,750
27	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$8,175	$7,700	$7,225	$6,750
28	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$7,700	$7,225	$6,750
29	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$7,225	$6,750
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$6,750

For a given value of Q, multiplying the net income in the column by the probability of its occurrence and summing over all values of x yields the following expected profits for each value of Q. Based on the results obtained, scheduling 21 castings for production yields the maximum expected profit of $22,663.

Expected Profit Number of Castings Scheduled															
15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
-$3,212	$3,721	$10,915	$16,362	$19,904	$22,170	**$22,663**	$20,984	$17,885	$14,593	$11,914	$10,038	$8,800	$7,958	$7,324	$6,785

2.30a Shown below is the probability mass function for the number of good custom-designed castings produced (x), based on Q castings scheduled for production.

# Good Castings	Number of Castings Scheduled			
	4	5	6	7
0	0.0001	0.0000	0.0000	0.0000
1	0.0036	0.0005	0.0001	0.0000
2	0.0486	0.0081	0.0012	0.0002
3	0.2916	0.0729	0.0146	0.0026
4	0.6561	0.3281	0.0984	0.0230
5	0.0000	0.5905	0.3543	0.1240
6	0.0000	0.0000	0.5314	0.3720
7	0.0000	0.0000	0.0000	0.4783

Net incomes for feasible combinations of Q and x are shown below.

# Good Castings	Number of Castings Scheduled			
	4	5	6	7
0	-$60,000	-$75,000	-$90,000	-$105,000
1	-$60,000	-$75,000	-$90,000	-$105,000
2	-$60,000	-$75,000	-$90,000	-$105,000
3	-$60,000	-$75,000	-$90,000	-$105,000
4	$60,000	$45,000	$30,000	$15,000
5	$0	$45,000	$30,000	$15,000
6	$0	$0	$30,000	$15,000
7	$0	$0	$0	$15,000

For a given value of Q, multiplying the net income in the column by the probability of its occurrence and summing over all values of x yields the following expected profits for each value of Q. As shown, the optimum number to schedule is 5, with an expected net profit of $35,335.

Expected Profit Number of Castings Scheduled			
4	5	6	7
$18,732	**$35,225**	$28,098	$14,673

2.30b The probability of losing money on the transaction is the probability of the net income being negative when Q equals 5. From above, a negative net cash flow occurs if less than 4 good castings are produced. The probability of producing less than 4 good castings equals 0.0005 + 0.0081 + 0.0729, or 0.0815.

2.30c Using Excel it is easy to perform the sensitivity analysis. By varying the cost parameter, it is found that a cost of $22,044.96 yields an expected profit of zero for Q = 5. Likewise, when the cost of producing a casting is reduced to $7,873.19, the optimum number to schedule increases to 6. We could not find a cost that would reduce the optimum production batch to 4 and still have a positive expected profit.

2.30d Again, using Excel it is easy to perform sensitivity analyses. For example, if the probability of a good casting is reduced to 0.84248 then the optimum production batch increases to 6; likewise, if the probability of a good casting increases to 0.963781, then the optimum batch production quantity decreases to 4.

2.31 Shown below is the probability mass function for number of good high precision formed parts (x), based on Q parts scheduled for production.

# Good Parts	Number Scheduled		
	10	11	12
0	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000
3	0.0001	0.0000	0.0000
4	0.0012	0.0003	0.0001
5	0.0085	0.0023	0.0006
6	0.0401	0.0132	0.0040
7	0.1298	0.0536	0.0193
8	0.2759	0.1517	0.0683
9	0.3474	0.2866	0.1720
10	0.1969	0.3248	0.2924
11	0.00	0.1673	0.3012
12	0.00	0.00	0.1422
13	0.00	0.00	0.00

Shown below is the matrix of net income for batch sizes of 10, 11, and 12. Also shown below is the expected profit based on batch sizes of 10, 11, and 12, as well as the probability of losing money. A batch size of 12 yields the smallest expected profit. Based on the probability of losing money, the least attractive alternative is a batch size of 10.

# Good Castings	Number Scheduled		
	10	11	12
0	-$4,750	-$5,225	-$5,700
1	-$4,750	-$5,225	-$5,700
2	-$4,750	-$5,225	-$5,700
3	-$4,750	-$5,225	-$5,700
4	-$4,750	-$5,225	-$5,700
5	-$4,750	-$5,225	-$5,700
6	-$4,750	-$5,225	-$5,700
7	-$4,750	-$5,225	-$5,700
8	$150,000	$85,000	$20,000
9	$250,000	$185,000	$120,000
10	$350,000	$285,000	$220,000
11	$0	$285,000	$220,000
12	$0	$0	$220,000
13	$0	$0	$0

Expected Profit and Probability of Losing Money		
10	11	12
$196,293	**$205,834**	$183,746
0.1798	0.0694	0.0239

2.32 Shown below is the probability mass function for the number of good wafers (x) resulting from a production batch size of Q.

# Good Wafers	Number of Wafers Scheduled						
	4	5	6	7	8	9	10
0	0.0039	0.0010	0.0002	0.0001	0.0000	0.0000	0.0000
1	0.0469	0.0146	0.0044	0.0013	0.0004	0.0001	0.0000
2	0.2109	0.0879	0.0330	0.0115	0.0038	0.0012	0.0004
3	0.4219	0.2637	0.1318	0.0577	0.0231	0.0087	0.0031
4	0.3164	0.3955	0.2966	0.1730	0.0865	0.0389	0.0162
5	0.0000	0.2373	0.3560	0.3115	0.2076	0.1168	0.0584
6	0.0000	0.0000	0.1780	0.3115	0.3115	0.2336	0.1460
7	0.0000	0.0000	0.0000	0.1335	0.2670	0.3003	0.2503
8	0.0000	0.0000	0.0000	0.0000	0.1001	0.2253	0.2816
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0751	0.1877
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0563

Shown below is the matrix of net profit resulting from combinations of Q and x.

# Good Wafers	Number of Wafers Scheduled						
	4	5	6	7	8	9	10
0	-$180,000	-$200,000	-$220,000	-$240,000	-$260,000	-$280,000	-$300,000
1	-$180,000	-$200,000	-$220,000	-$240,000	-$260,000	-$280,000	-$300,000
2	-$180,000	-$200,000	-$220,000	-$240,000	-$260,000	-$280,000	-$300,000
3	$70,000	$50,000	$30,000	$10,000	-$10,000	-$30,000	-$50,000
4	$120,000	$100,000	$80,000	$60,000	$40,000	$20,000	$0
5	$0	$150,000	$130,000	$110,000	$90,000	$70,000	$50,000
6	$0	$0	$130,000	$110,000	$90,000	$70,000	$50,000
7	$0	$0	$0	$110,000	$90,000	$70,000	$50,000
8	$0	$0	$0	$0	$90,000	$70,000	$50,000
9	$0	$0	$0	$0	$0	$70,000	$50,000
10	$0	$0	$0	$0	$0	$0	$50,000

Shown below are the expected profits and probabilities of losing money for various batch sizes. The optimum batch size is 7, with a 0.0129 probability of losing money.

Expected Profit Number of Wafers Scheduled and Probability of Losing Money						
4	5	6	7	8	9	10
$20,391	$67,627	$88,826	**$91,073**	$81,888	$66,718	$48,734
0.2617	0.1035	0.0376	0.0129	0.0273	0.0100	0.0035

2.33 Shown below is the probability mass function for the number of good die castings (x) in a production batch of size Q.

# Good Parts	Number of Parts Scheduled					
	25	26	27	28	29	30
20	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
21	0.0013	0.0001	0.0000	0.0000	0.0000	0.0000
22	0.0118	0.0015	0.0002	0.0000	0.0000	0.0000
23	0.0754	0.0131	0.0018	0.0002	0.0000	0.0000
24	0.3079	0.0801	0.0144	0.0020	0.0002	0.0000
25	0.6035	0.3138	0.0847	0.0158	0.0023	0.0003
26	0.0000	0.5914	0.3194	0.0894	0.0173	0.0026
27	0.0000	0.0000	0.5796	0.3246	0.0941	0.0188
28	0.0000	0.0000	0.0000	0.5680	0.3294	0.0988
29	0.0000	0.0000	0.0000	0.0000	0.5566	0.3340
30	0.0000	0.0000	0.0000	0.0000	0.0000	0.5455

Shown below is the matrix of net profits resulting from various combinations of Q and x.

# Good Parts	Number of Parts Scheduled					
	25	26	27	28	29	30
20	-$37,500	-$39,000	-$40,500	-$42,000	-$43,500	-$45,000
21	-$37,500	-$39,000	-$40,500	-$42,000	-$43,500	-$45,000
22	-$37,500	-$39,000	-$40,500	-$42,000	-$43,500	-$45,000
23	-$37,500	-$39,000	-$40,500	-$42,000	-$43,500	-$45,000
24	-$37,500	-$39,000	-$40,500	-$42,000	-$43,500	-$45,000
25	$87,500	$86,000	$84,500	$83,000	$81,500	$80,000
26	$0	$86,000	$84,500	$83,000	$81,500	$80,000
27	$0	$0	$84,500	$83,000	$81,500	$80,000
28	$0	$0	$0	$83,000	$81,500	$80,000
29	$0	$0	$0	$0	$81,500	$80,000
30	$0	$0	$0	$0	$0	$80,000

Shown below are the expected profits and probabilities of losing money for various values of Q, the batch size. From the results obtained, the optimum batch size is 28. The probability of losing money, which is the probability of less than 25 die cast parts being acceptable, equals 0.0022.

Expected Profit & Probability of Losing Money Number of Parts Scheduled					
25	26	27	28	29	30
$37,933	$74,150	$82,456	**$82,721**	$81,468	$79,997
0.3965	0.0948	0.0164	**0.0022**	0.0003	0.0000

2.34a Shown below is the probability mass function for the number of good castings (x) produced when Q castings are produced based on a probability of 0.85 that an individual casting is good. Also shown below is a matrix of net profits resulting from the combination of Q and x. Finally, the expected profit is shown for various values of Q. Based on the results obtained, the optimum lot size is 65, with an expected profit of $55,925.

# Good	Number of Castings Scheduled												
Castings	54	55	56	57	58	59	60	61	62	63	64	65	66
35	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
36	0.0004	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
37	0.0011	0.0005	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
38	0.0029	0.0014	0.0007	0.0003	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
39	0.0067	0.0035	0.0017	0.0008	0.0004	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
40	0.0142	0.0078	0.0041	0.0021	0.0010	0.0005	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
41	0.0275	0.0162	0.0091	0.0049	0.0025	0.0012	0.0006	0.0003	0.0001	0.0001	0.0000	0.0000	0.0000
42	0.0483	0.0307	0.0184	0.0105	0.0057	0.0030	0.0015	0.0007	0.0003	0.0001	0.0001	0.0000	0.0000
43	0.0764	0.0525	0.0339	0.0207	0.0120	0.0066	0.0035	0.0018	0.0009	0.0004	0.0002	0.0001	0.0000
44	0.1082	0.0812	0.0568	0.0374	0.0232	0.0137	0.0077	0.0041	0.0021	0.0011	0.0005	0.0002	0.0001
45	0.1363	0.1124	0.0859	0.0612	0.0409	0.0259	0.0155	0.0089	0.0049	0.0026	0.0013	0.0006	0.0003
46	0.1511	0.1385	0.1163	0.0904	0.0656	0.0446	0.0287	0.0175	0.0102	0.0057	0.0030	0.0015	0.0008
47	0.1457	0.1503	0.1403	0.1199	0.0949	0.0700	0.0484	0.0317	0.0196	0.0116	0.0065	0.0035	0.0018
48	0.1204	0.1419	0.1490	0.1416	0.1232	0.0991	0.0743	0.0523	0.0348	0.0219	0.0131	0.0075	0.0041
49	0.0836	0.1149	0.1379	0.1474	0.1424	0.1261	0.1031	0.0786	0.0563	0.0380	0.0243	0.0148	0.0086
50	0.0474	0.0781	0.1094	0.1336	0.1453	0.1429	0.1286	0.1070	0.0829	0.0603	0.0413	0.0269	0.0166
51	0.0210	0.0434	0.0729	0.1039	0.1292	0.1429	0.1429	0.1307	0.1105	0.0670	0.0643	0.0448	0.0295
52	0.0069	0.0189	0.0397	0.0679	0.0945	0.1246	0.1401	0.1435	0.1325	0.1138	0.0911	0.0683	0.0483
53	0.0000	0.0061	0.0170	0.0363	0.0632	0.0932	0.1199	0.1371	0.1417	0.1329	0.1168	0.0940	0.0723
54	0.0000	0.0013	0.0053	0.0152	0.0332	0.0587	0.0880	0.1151	0.1328	0.1405	0.1349	0.1195	0.0986
55	0.0000	0.0001	0.0011	0.0047	0.0137	0.0302	0.0544	0.0830	0.1103	0.1303	0.1389	0.1355	0.1219
56	0.0000	0.0000	0.0001	0.0010	0.0041	0.0122	0.0275	0.0504	0.0781	0.1054	0.1265	0.1371	0.1357
57	0.0000	0.0000	0.0000	0.0001	0.0008	0.0037	0.0110	0.0250	0.0466	0.0734	0.1006	0.1227	0.1349
58	0.0000	0.0000	0.0000	0.0000	0.0001	0.0007	0.0032	0.0098	0.0228	0.0430	0.0688	0.0959	0.1186
59	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0006	0.0028	0.0087	0.0207	0.0397	0.0645	0.0912
60	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0005	0.0025	0.0078	0.0187	0.0365	0.0603
61	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0022	0.0070	0.0170	0.0336
62	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0019	0.0062	0.0153
63	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0017	0.0055
64	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0015
65	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003
66	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

# Good Castings	Number of Castings Scheduled												
	54	55	56	57	58	59	60	61	62	63	64	65	66
35	-$43,200	-$44,000	-$44,800	-$45,600	-$46,400	-$47,200	-$48,000	-$48,800	-$49,600	-$50,400	-$51,200	-$52,000	-$52,800
36	-$43,200	-$44,000	-$44,800	-$45,600	-$46,400	-$47,200	-$48,000	-$48,800	-$49,600	-$50,400	-$51,200	-$52,000	-$52,800
37	-$43,200	-$44,000	-$44,800	-$45,600	-$46,400	-$47,200	-$48,000	-$48,800	-$49,600	-$50,400	-$51,200	-$52,000	-$52,800
38	-$43,200	-$44,000	-$44,800	-$45,600	-$46,400	-$47,200	-$48,000	-$48,800	-$49,600	-$50,400	-$51,200	-$52,000	-$52,800
39	-$43,200	-$44,000	-$44,800	-$45,600	-$46,400	-$47,200	-$48,000	-$48,800	-$49,600	-$50,400	-$51,200	-$52,000	-$52,800
40	-$43,200	-$44,000	-$44,800	-$45,600	-$46,400	-$47,200	-$48,000	-$48,800	-$49,600	-$50,400	-$51,200	-$52,000	-$52,800
41	-$43,200	-$44,000	-$44,800	-$45,600	-$46,400	-$47,200	-$48,000	-$48,800	-$49,600	-$50,400	-$51,200	-$52,000	-$52,800
42	-$43,200	-$44,000	-$44,800	-$45,600	-$46,400	-$47,200	-$48,000	-$48,800	-$49,600	-$50,400	-$51,200	-$52,000	-$52,800
43	-$43,200	-$44,000	-$44,800	-$45,600	-$46,400	-$47,200	-$48,000	-$48,800	-$49,600	-$50,400	-$51,200	-$52,000	-$52,800
44	-$43,200	-$44,000	-$44,800	-$45,600	-$46,400	-$47,200	-$48,000	-$48,800	-$49,600	-$50,400	-$51,200	-$52,000	-$52,800
45	$46,800	$46,000	$45,200	$44,400	$43,600	$42,800	$42,000	$41,200	$40,400	$39,600	$38,800	$38,000	$37,200
46	$48,800	$48,000	$47,200	$46,400	$45,600	$44,800	$44,000	$43,200	$42,400	$41,600	$40,800	$40,000	$39,200
47	$50,800	$50,000	$49,200	$48,400	$47,600	$46,800	$46,000	$45,200	$44,400	$43,600	$42,800	$42,000	$41,200
48	$52,800	$52,000	$51,200	$50,400	$49,600	$48,800	$48,000	$47,200	$46,400	$45,600	$44,800	$44,000	$43,200
49	$54,800	$54,000	$53,200	$52,400	$51,600	$50,800	$50,000	$49,200	$48,400	$47,600	$46,800	$46,000	$45,200
50	$56,800	$56,000	$55,200	$54,400	$53,600	$52,800	$52,000	$51,200	$50,400	$49,600	$48,800	$48,000	$47,200
51	$58,800	$58,000	$57,200	$56,400	$55,600	$54,800	$54,000	$53,200	$52,400	$51,600	$50,800	$50,000	$49,200
52	$60,800	$60,000	$59,200	$58,400	$57,600	$56,800	$56,000	$55,200	$54,400	$53,600	$52,800	$52,000	$51,200
53	$0	$62,000	$61,200	$60,400	$59,600	$58,800	$58,000	$57,200	$56,400	$55,600	$54,800	$54,000	$53,200
54	$0	$64,000	$63,200	$62,400	$61,600	$60,800	$60,000	$59,200	$58,400	$57,600	$56,800	$56,000	$55,200
55	$0	$66,000	$65,200	$64,400	$63,600	$62,800	$62,000	$61,200	$60,400	$59,600	$58,800	$58,000	$57,200
56	$0	$0	$65,200	$64,400	$63,600	$62,800	$62,000	$61,200	$60,400	$59,600	$58,800	$58,000	$57,200
57	$0	$0	$0	$64,400	$63,600	$62,800	$62,000	$61,200	$60,400	$59,600	$58,800	$58,000	$57,200
58	$0	$0	$0	$0	$63,600	$62,800	$62,000	$61,200	$60,400	$59,600	$58,800	$58,000	$57,200
59	$0	$0	$0	$0	$0	$62,800	$62,000	$61,200	$60,400	$59,600	$58,800	$58,000	$57,200
60	$0	$0	$0	$0	$0	$0	$62,000	$61,200	$60,400	$59,600	$58,800	$58,000	$57,200
61	$0	$0	$0	$0	$0	$0	$0	$61,200	$60,400	$59,600	$58,800	$58,000	$57,200
62	$0	$0	$0	$0	$0	$0	$0	$0	$60,400	$59,600	$58,800	$58,000	$57,200
63	$0	$0	$0	$0	$0	$0	$0	$0	$0	$59,600	$58,800	$58,000	$57,200
64	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$58,800	$58,000	$57,200
65	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$58,000	$57,200
66	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$57,200

Expected Profit Number of Castings Scheduled												
54	55	56	57	58	59	60	61	62	63	64	65	66
$24,084	$32,877	$39,656	$44,687	$48,306	$50,873	$52,699	$54,001	$54,914	$55,514	$55,841	$55,915	$55,793

2.34b Shown below is the probability mass function for the number of good castings (x) produced when Q castings are produced based on a probability of 0.98 that an individual casting is good. Also shown below is a matrix of net profits resulting from the combination of Q and x. Finally, the expected profit is shown for various values of Q. Based on the results obtained, the optimum lot size is 56, with an expected profit of $64,315.

# Good Castings	Number of Castings Scheduled												
	54	55	56	57	58	59	60	61	62	63	64	65	66
45	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
46	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
47	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
48	0.0006	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
49	0.0038	0.0007	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
50	0.0184	0.0041	0.0008	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
51	0.0708	0.0195	0.0044	0.0008	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
52	0.2002	0.0734	0.0206	0.0047	0.0009	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
53	0.0000	0.2036	0.0760	0.0217	0.0060	0.0010	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
54	0.0000	0.3695	0.2069	0.0786	0.0228	0.0054	0.0011	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
55	0.0000	0.3292	0.3687	0.2101	0.0813	0.0240	0.0068	0.0012	0.0002	0.0000	0.0000	0.0000	0.0000
56	0.0000	0.0000	0.3226	0.3678	0.2133	0.0639	0.0252	0.0061	0.0013	0.0002	0.0000	0.0000	0.0000
57	0.0000	0.0000	0.0000	0.3161	0.3667	0.2164	0.0865	0.0264	0.0065	0.0014	0.0003	0.0000	0.0000
58	0.0000	0.0000	0.0000	0.0000	0.3098	0.3656	0.2194	0.0892	0.0277	0.0070	0.0015	0.0003	0.0000
59	0.0000	0.0000	0.0000	0.0000	0.0000	0.3036	0.3644	0.2223	0.0919	0.0289	0.0074	0.0016	0.0003
60	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2976	0.3630	0.2251	0.0945	0.0302	0.0079	0.0017
61	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2916	0.3616	0.2278	0.0972	0.0316	0.0083
62	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2858	0.3601	0.2304	0.0999	0.0330
63	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2801	0.3585	0.2330	0.1025
64	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2745	0.3568	0.2355
65	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2690	0.3550
66	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2636

# Good Castings	Number of Castings Scheduled												
	54	55	56	57	58	59	60	61	62	63	64	65	66
45	$46,800	$46,000	$45,200	$44,400	$43,600	$42,800	$42,000	$41,200	$40,400	$39,600	$38,800	$38,000	$37,200
46	$48,800	$48,000	$47,200	$46,400	$45,600	$44,800	$44,000	$43,200	$42,400	$41,600	$40,800	$40,000	$39,200
47	$50,800	$50,000	$49,200	$48,400	$47,600	$46,800	$46,000	$45,200	$44,400	$43,600	$42,800	$42,000	$41,200
48	$52,800	$52,000	$51,200	$50,400	$49,600	$48,800	$48,000	$47,200	$46,400	$45,600	$44,800	$44,000	$43,200
49	$54,800	$54,000	$53,200	$52,400	$51,600	$50,800	$50,000	$49,200	$48,400	$47,600	$46,800	$46,000	$45,200
50	$56,800	$56,000	$55,200	$54,400	$53,600	$52,800	$52,000	$51,200	$50,400	$49,600	$48,800	$48,000	$47,200
51	$58,800	$58,000	$57,200	$56,400	$55,600	$54,800	$54,000	$53,200	$52,400	$51,600	$50,800	$50,000	$49,200
52	$60,800	$60,000	$59,200	$58,400	$57,600	$56,800	$56,000	$55,200	$54,400	$53,600	$52,800	$52,000	$51,200
53	$0	$62,000	$61,200	$60,400	$59,600	$58,800	$58,000	$57,200	$56,400	$55,600	$54,800	$54,000	$53,200
54	$0	$64,000	$63,200	$62,400	$61,600	$60,800	$60,000	$59,200	$58,400	$57,600	$56,800	$56,000	$55,200
55	$0	$66,000	$65,200	$64,400	$63,600	$62,800	$62,000	$61,200	$60,400	$59,600	$58,800	$58,000	$57,200
56	$0	$0	$65,200	$64,400	$63,600	$62,800	$62,000	$61,200	$60,400	$59,600	$58,800	$58,000	$57,200
57	$0	$0	$0	$64,400	$63,600	$62,800	$62,000	$61,200	$60,400	$59,600	$58,800	$58,000	$57,200
58	$0	$0	$0	$0	$63,600	$62,800	$62,000	$61,200	$60,400	$59,600	$58,800	$58,000	$57,200
59	$0	$0	$0	$0	$0	$62,800	$62,000	$61,200	$60,400	$59,600	$58,800	$58,000	$57,200
60	$0	$0	$0	$0	$0	$0	$62,000	$61,200	$60,400	$59,600	$58,800	$58,000	$57,200
61	$0	$0	$0	$0	$0	$0	$0	$61,200	$60,400	$59,600	$58,800	$58,000	$57,200
62	$0	$0	$0	$0	$0	$0	$0	$0	$60,400	$59,600	$58,800	$58,000	$57,200
63	$0	$0	$0	$0	$0	$0	$0	$0	$0	$59,600	$58,800	$58,000	$57,200
64	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$58,800	$58,000	$57,200
65	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$58,000	$57,200
66	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$57,200

Expected Profit Number of Castings Scheduled												
54	55	56	57	58	59	60	61	62	63	64	65	66
$17,627	$63,800	$64,316	$64,120	$63,528	$62,734	$61,997	$61,199	$60,400	$59,600	$58,800	$58,000	$57,200

2.35 In Example 2.7, a = 2 min, b = 1 min, t = 6 min, n’ = 2.67, C_o = $15/hr, and C_m = $50/hr. Without other constraints the optimum number of machines to assign to an operator was shown to equal 2. Since 2 < n’ < 3, the economic choice was between 2 and 3 machines. Hence, two groups of 2 would be less costly, on a cost per part produced basis, than one group of 4 machines. Here, 11 machines are required to meet the production requirements. How should they be assigned? One of the alternatives being considered is to assign 2 machines to each of 4 operators and then assign 3 machines to one operator; the alternative assignment being considered is to assign 2 machines to each of 5 operators and then assign 1 machine to one operator.

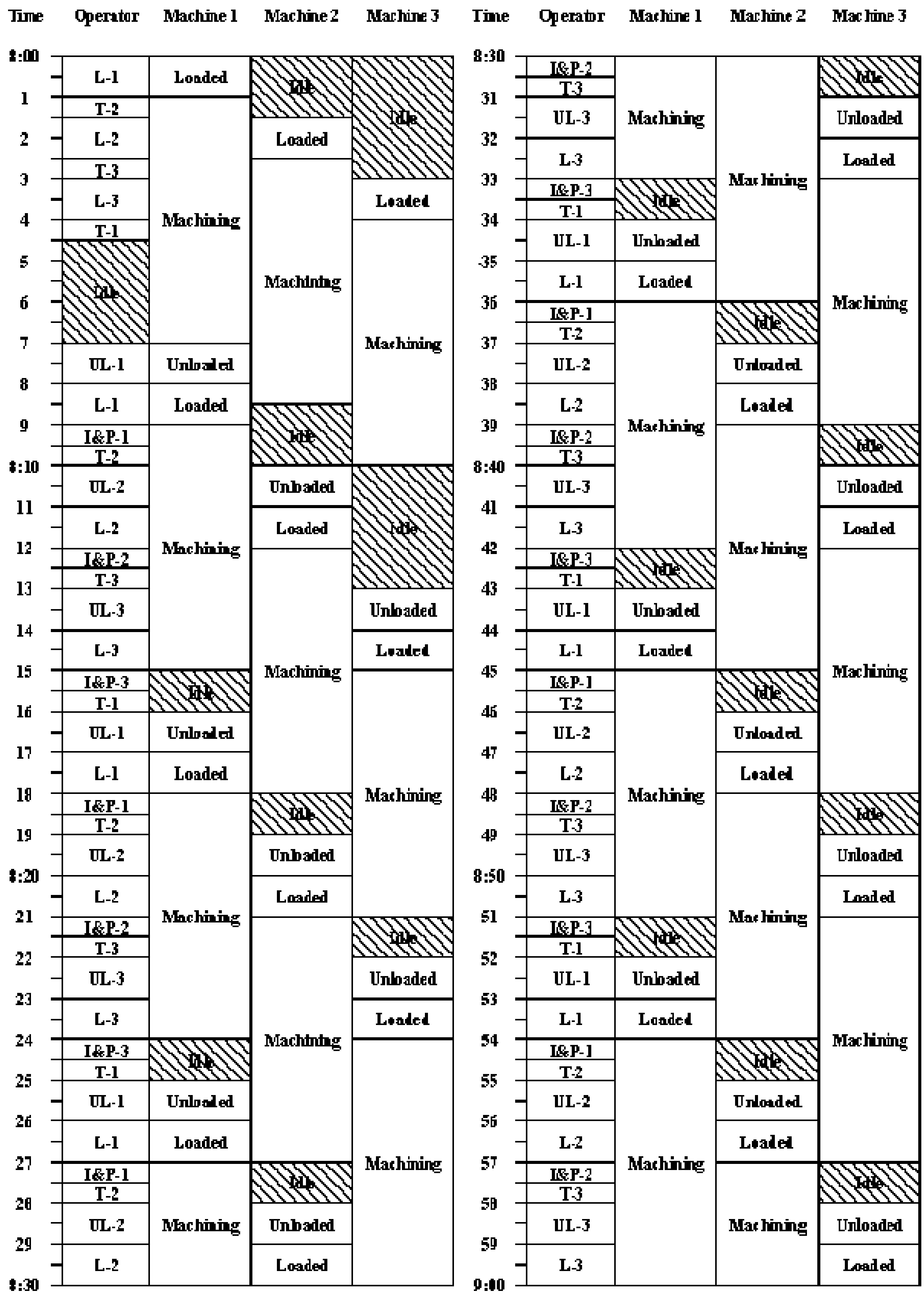
To calculate the cost per unit produced for each scenario, it is useful to evaluate each alternative using a length of time equal to the least common multiple of the cycle times for each machine-operator assignment in the scenario. For example, with the {2, 2, 2, 2, 3} scenario, T_c = 8 min for m = 2 and T_c = 9 min for m = 3; therefore, a time period equal to 72 minutes will be used. During a period of 72 mins each 2-machine combination will perform 9 cycles and produce 18 parts; likewise, over the same time period, the 3-machine assignment will perform 8 cycles and produce 24 parts. Hence, over a 72 min. period, a total of 4(18) + 24, or 96 parts will be produced. The total cost per unit produced over a 72 min. period equals [(5 op)($15/hr-op) + (11 mach)($50/hr-mach)](72 min/60 min/hr.)(1/96) parts), or $7.81/part.

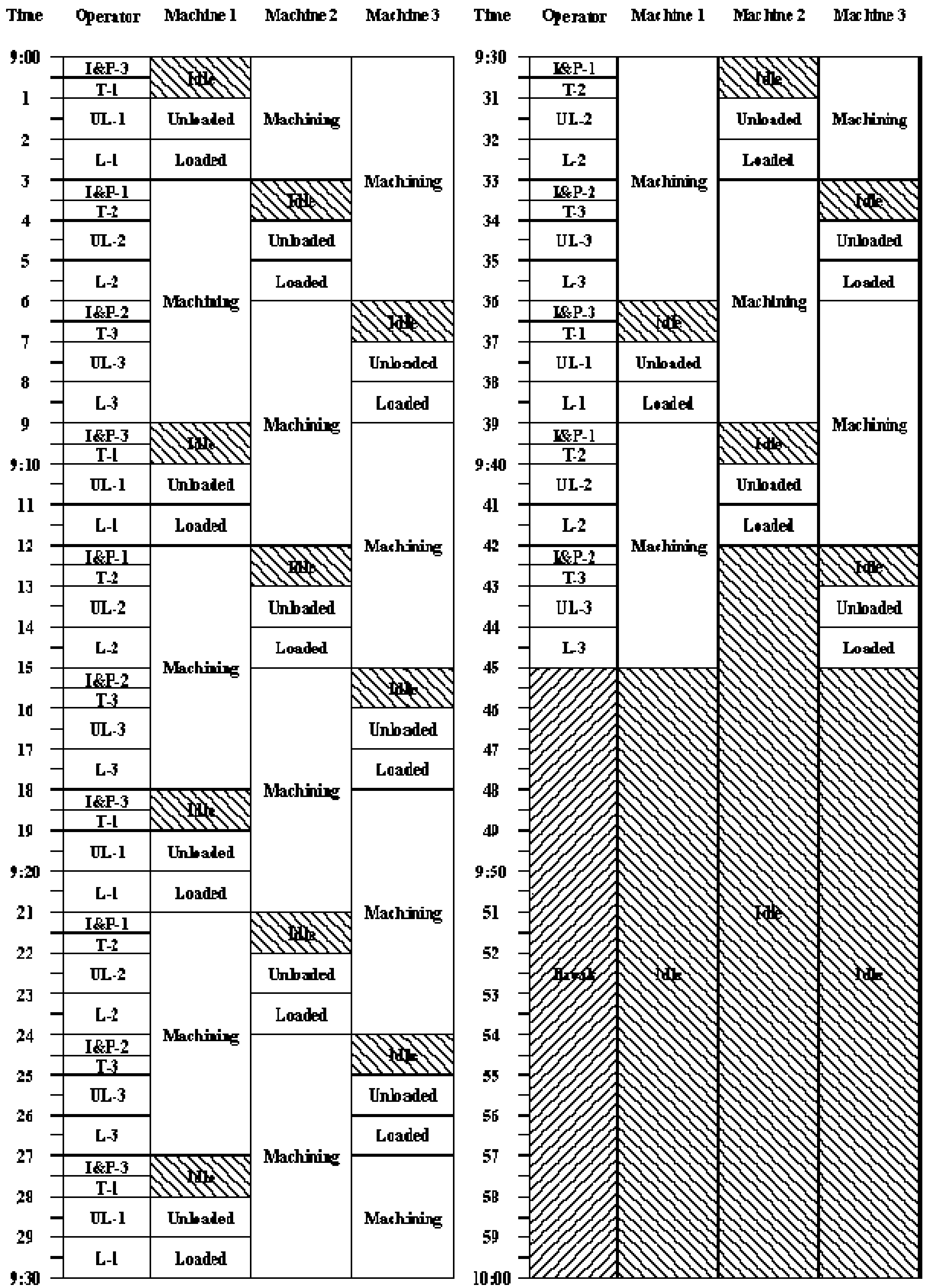
For the {2, 2, 2, 2, 2, 1} scenario, T_c = 8 min for both m = 1 and m = 2. During an 8 min. time period a total of 11 parts are produced. The total cost per unit produced over an 8 min. period equals [6(15) + 11(50)](8/60)(1/11), or $7.76/part. Hence, the least cost alternative, in terms of cost per unit produced, is the {2, 2, 2, 2, 2, 1} scenario.

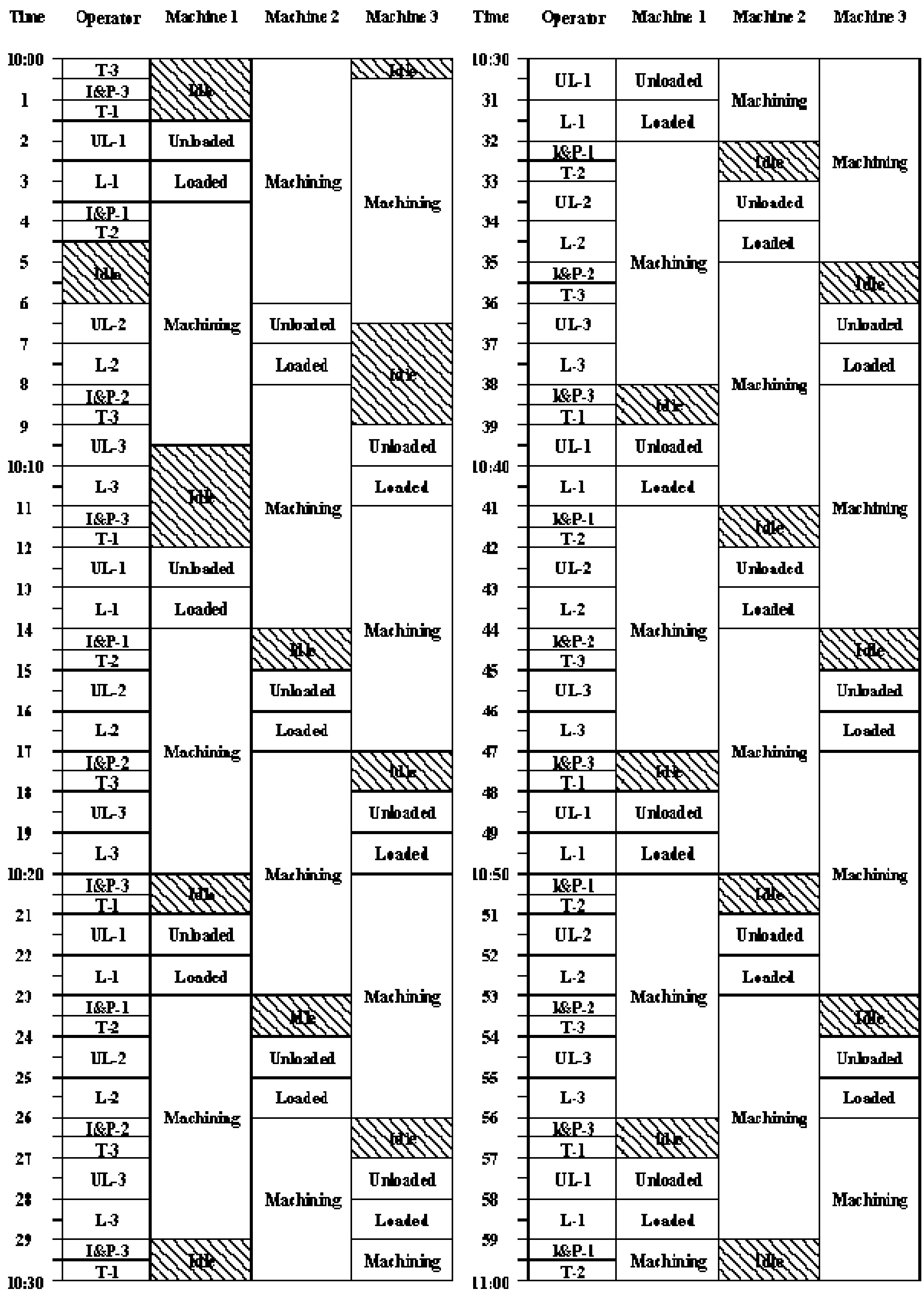
Are there other scenarios that are less costly than the two considered? No! From Example 2.7, n* = 2. Hence, any scenario involving multiple assignments of single machines will be more costly than assignments of 2 machines per operator. Likewise, from the analysis performed above, any scenario involving a 3-machine assignment will be more expensive than one with a 2-machine and a 1-machine assignment. Further, any scenario having a 4-machine assignment will be more costly than one that substitutes two 2-machine assignments for the 4-machine assignment. From the analysis performed above, a 5-machine assignment will be more expensive than a {2, 2, 1} assignment. By similar analyses, there are no other scenarios that need to be considered for the assignment of 11 machines.

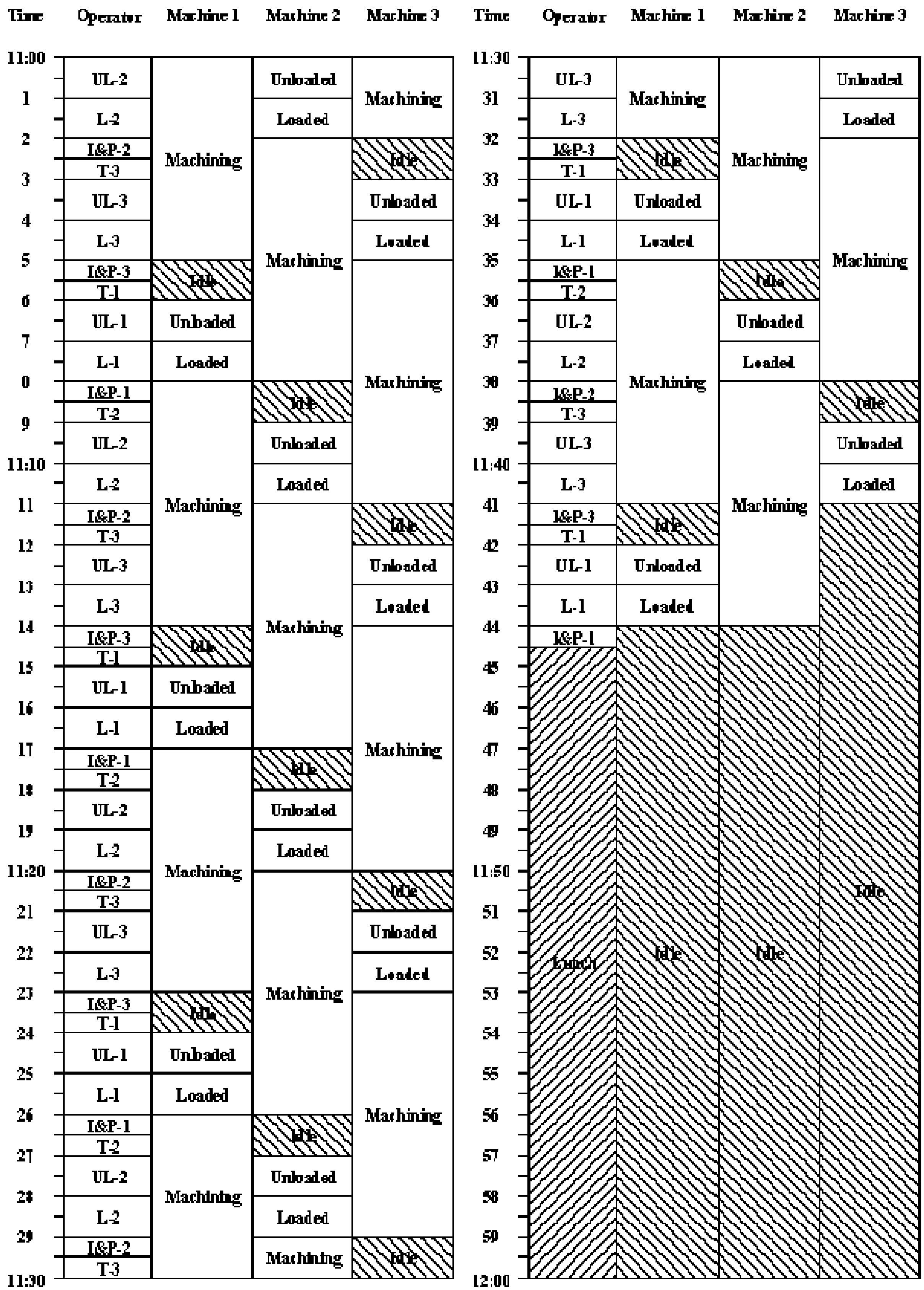
2.36 For the optimum assignment in Example 2. 5 to remain unchanged, M < 1. Recall, in Example 2.5, n' = 2.67, C_o = $15/hr, C_m = $50/hr, and , = C_o/C_m = 15/Cm. Therefore, for M < 1, $(\epsilon + n)(n') < (\epsilon + n + 1)(n)$, or $(\epsilon + 2)(2.67) < (\epsilon + 3)(2)$, or $(15 + 2C_m)(2.67) < (15 + 3C_m)(2)$, or $(15)(2.67 - 2) < (6 - 5.33)C_m$, or $C_m >$ $15/hr. Hence, for a machine cost of $15 or more per machine-hour, the optimum assignment will be 2 machines per operator.

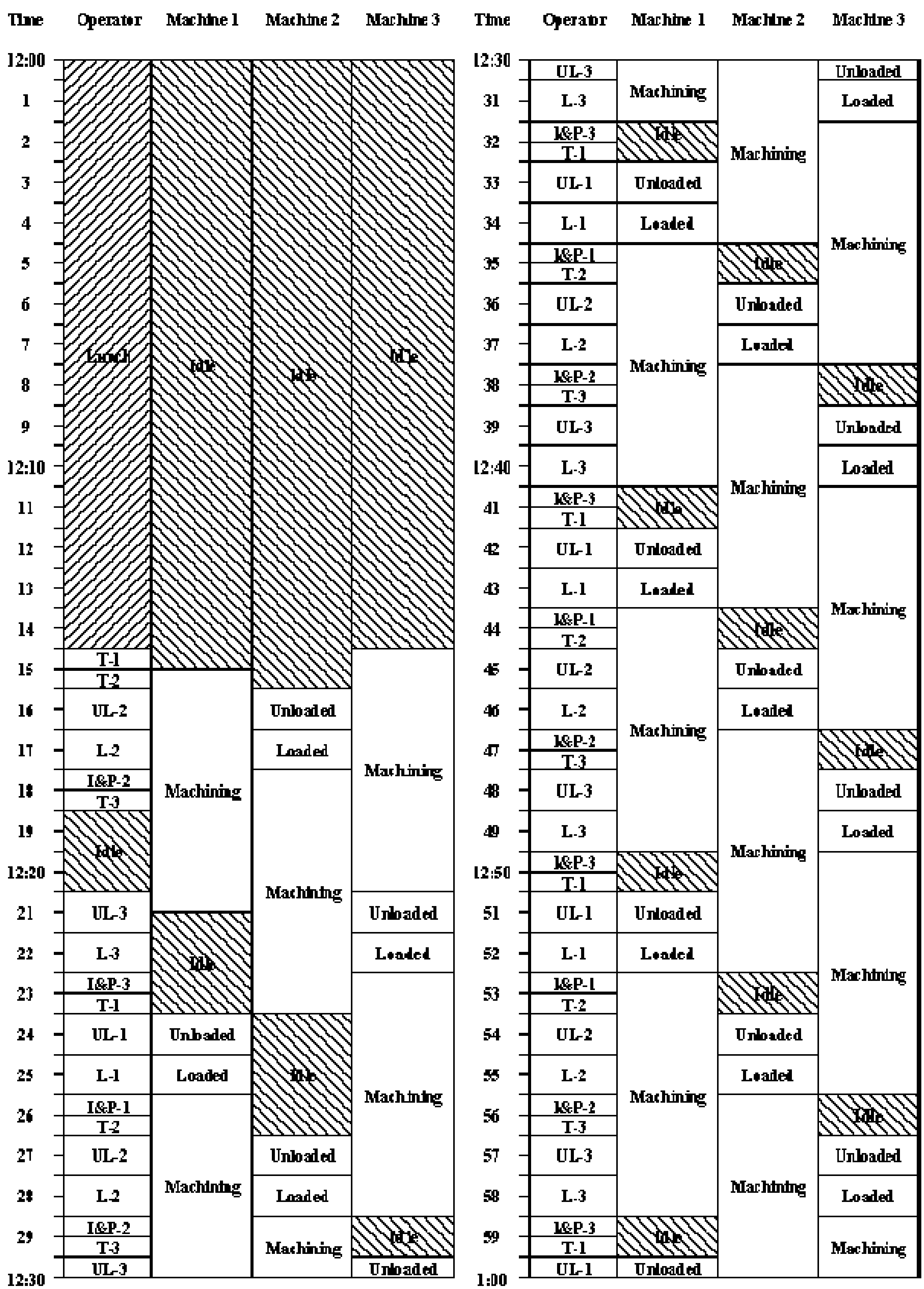
2.37 During 7 hours of work for the operator between 8:00 a.m. and 4:00 p.m., 136 units were produced by the 3 machines. In steady state conditions, the repeating cycle is 9 minutes. Hence, in steady state conditions a total of 140 units are produced. Transient conditions due to start-up and shut-down for breaks, lunch, and beginning/ending of the shift diminish the production by only 4 units. If replacement labor is provided to keep the machines working during the entire 8-hour shift and 3 shifts operate per day, then steady state production will result in 160 units being produced per 8-hour shift. This situation is illustrated in the following multiple activity charts.

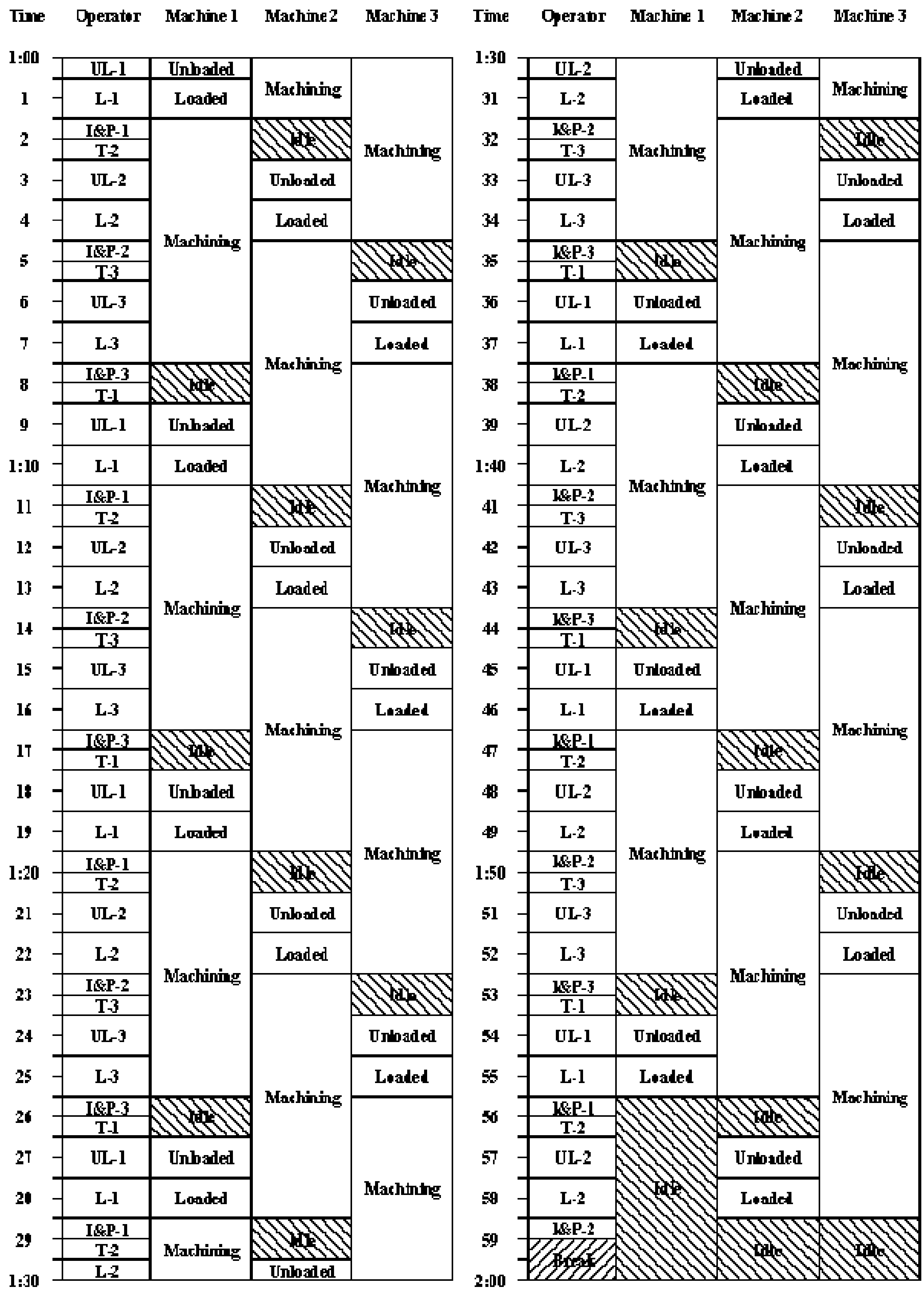

Time
Operator
Machine 1
Machine 2
Machine 3
8:00
8:10
8:20
8:30
8:40
8:50
9:00
L-1
T-2
L-2
T-3
L-3
T-1
Idle
UL-1
I&P-1
UL-2
I&P-2
UL-3
I&P-3
Loaded
Machining
Unloaded


Time
Operator
Machine 1
Machine 2
Machine 3
9:00
1
2
3
4
5
6
7
8
9
9:10
11
12
13
14
15
16
17
18
19
9:20
21
22
23
24
25
26
27
28
29
9:30
I&P-3
T-1
UL-1
L-1
I&P-1
T-2
UL-2
L-2
I&P-2
T-3
UL-3
L-3
Idle
Unloaded
Loaded
Machining
31
32
33
34
35
36
37
38
39
9:40
41
42
43
44
45
46
47
48
49
9:50
51
52
53
54
55
56
57
58
59
10:00
Break


Time
Operator
Machine 1
Machine 2
Machine 3
Time
Operator
Machine 1
Machine 2
Machine 3


Time
Operator
Machine 1
Machine 2
Machine 3
11:00
11:10
11:20
11:30
11:40
11:50
12:00
Machining
Unloaded
Loaded
Idle
Lunch


Time
Operator
Machine 1
Machine 2
Machine 3
12:00
12:10
12:20
12:30
12:40
12:50
1:00
Lunch
Idle
T-1
T-2
UL-2
L-2
I&P-2
T-3
UL-3
L-3
I&P-3
UL-1
L-1
I&P-1
Machining
Unloaded
Loaded


Time
Operator
Machine 1
Machine 2
Machine 3
1:00
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3
4
5
6
7
8
9
1:10
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12
13
14
15
16
17
18
19
1:20
21
22
23
24
25
26
27
28
29
1:30
UL-1
L-1
I&P-1
T-2
UL-2
L-2
I&P-2
T-3
UL-3
L-3
I&P-3
T-1
UL-1
L-1
I&P-1
T-2
UL-2
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I&P-2
T-3
UL-3
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Machining
1:30
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1:40
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44
45
46
47
48
49
1:50
51
52
53
54
55
56
57
58
59
2:00
UL-2
L-2
I&P-2
T-3
UL-3
L-3
I&P-3
T-1
UL-1
L-1
I&P-1
T-2
UL-2
L-2
I&P-2
T-3
UL-3
L-3
I&P-3
T-1
UL-1
L-1
I&P-1
T-2
UL-2
L-2
I&P-2
T-3
UL-3
L-3
I&P-3
T-1
UL-1
L-1
I&P-1
T-2
UL-2
L-2
I&P-2
Break
Machining
Idle
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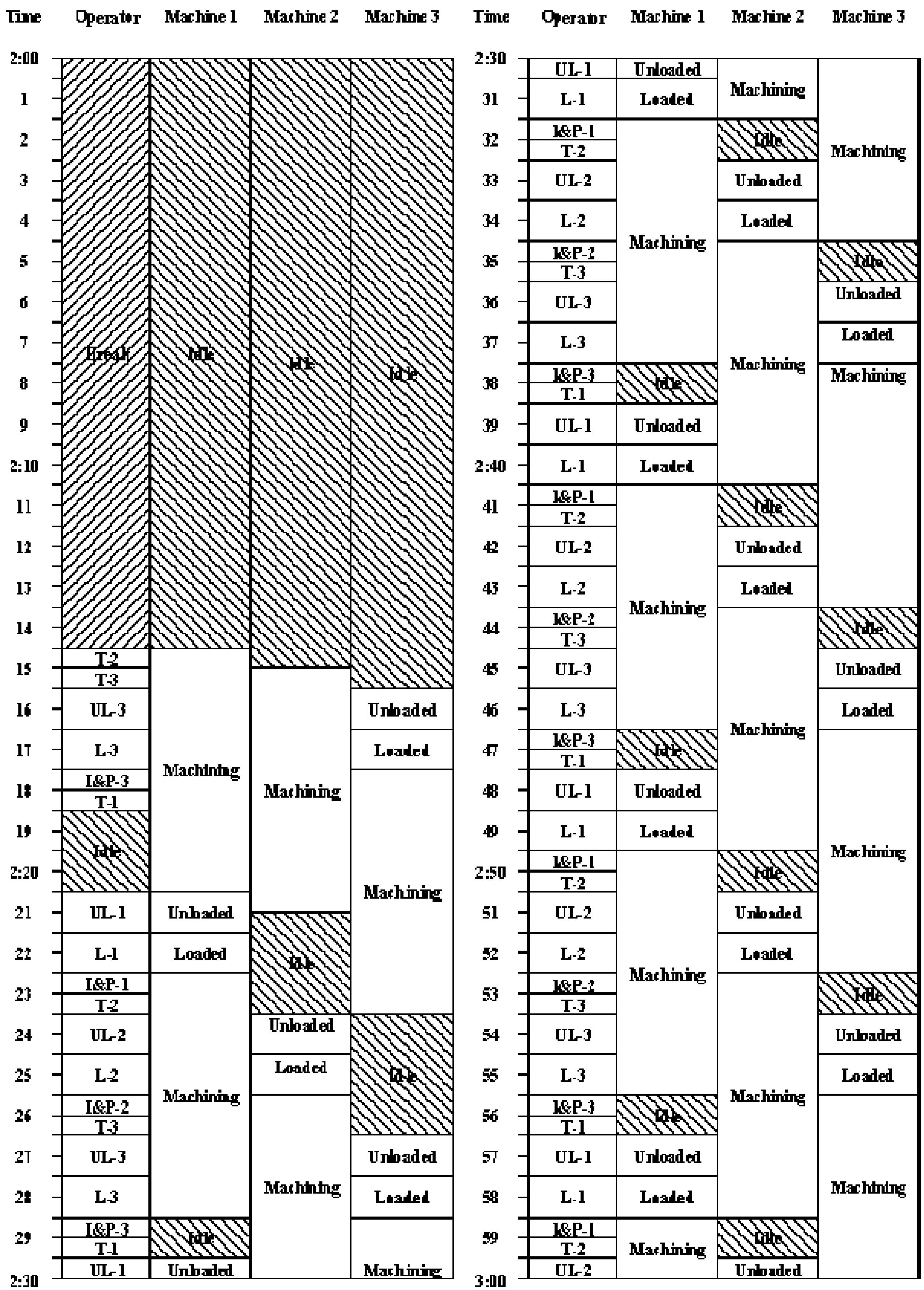

Time
Operator
Machine 1
Machine 2
Machine 3
2:00
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2
3
4
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6
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8
9
2:10
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12
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14
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2:20
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28
29
2:30
Break
Idle
Idle
Idle
T-2
T-3
UL-3
L-3
I&P-3
T-1
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UL-1
L-1
I&P-1
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I&P-2
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I&P-3
T-1
UL-1
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Machining
Idle
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Machining
Time
Operator
Machine 1
Machine 2
Machine 3
2:30
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2:40
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2:50
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3:00
UL-1
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Loaded
Machining


Time
Operator
Machine 1
Machine 2
Machine 3
Time
Operator
Machine 1
Machine 2
Machine 3
3:00
3:10
3:20
3:30
3:40
3:50
4:00

2.38 The problem statement was overly simplified, assuming sufficient demand exists to keep 5 machines busy and sales prices of the products are such that the calculation of cost per unit produced can be performed by summing the units produced for both products. Also, it is assumed that a machine is dedicated to producing either product 1 or product 2 and cannot be assigned to produce a combination of the two products due to changeover times.

From Example 2.7, we know that two machines producing product 1 should be assigned an operator to minimize the cost per unit produced. For product 2, the optimum number of machines to assign an operator is obtained as follows for producing product 2: $n_2' = (2.5 + 8)/(2.5 + 1.5) = 2.625$; $\epsilon = 0.3$; and $\Phi = (2.3/3.3)(2.625/2) = 0.9148 < 1$; therefore, $n_2^* = 2$. Hence, it appears that 2 machines should be assigned to produce product 1 and 2 machines should be assigned to produce product 2; however, that leaves 1 machine unassigned. From the solution to Problem 2.35, we know that {2, 1} is less costly than {3} for product 1.

The alternatives to be evaluated are as follows: assign 2 machines producing product 1 to an operator and 3 machines producing product 2 to an operator; assign 2 machines producing product 1 to an operator, 2 machines producing product 2 to an operator, and 1 machine producing product 2 to an operator; assign 2 machines producing product 1 to an operator, 1 machine producing product 1 to an operator, and 2 machines producing product 2 to an operator.

Assign 2 machines producing product 1 to an operator and 3 machines producing product 2 to an operator. From Example 2.7, for product 1 the repeating cycle is 8 minutes. The repeating cycle is 3(2.5 + 1.5), or 12 min., for product 2. Hence, in 24 minutes, the 2 machines producing product 1 perform 3 repeating cycles and produce 6 parts, and 6 parts are produced by the 3 machines making product 2 while performing 2 repeating cycles. The total hourly cost of 2 operators and 5 machines is $280. During a period of 24 minutes, the cost will be $112.00; hence, the cost per unit to produce 12 parts in 8 minutes is $9.33/part.

Assign 2 machines producing product 1 to an operator, 2 machines producing product 2 to an operator, and 1 machine producing product 2 to an operator. The repeating cycle for product 2 is 10.5 minutes. Hence, in 168 minutes there will be 21 repeating cycles for machines producing product 1 and 16 repeating cycles of machines producing product 2. The total hourly cost of 3 operators and 5 machines is $295. During a period of 168 minutes, the cost will be $826; hence, the cost per unit to produce 90 parts (42 of product 1 and 48 of product 2) in 168 minutes is $9.18/part.

Assign 2 machines producing product 1 to an operator, 1 machine producing product 1 to an operator, and 2 machines producing product 2 to an operator. As in the previous case, the repeating cycles are 8 and 10.5 minutes. Hence, over a 168 minute time frame, there will be 21 repeating cycles of the 3 machines producing product 1 and 16 repeating cycles of the 2 machines producing product 2. The cost per unit to produce 63 units of product 1 and 32 units of product 2 is ($295)(168)/(60)(95), or $8.69/part. Since this is the least cost option, it would be recommended.

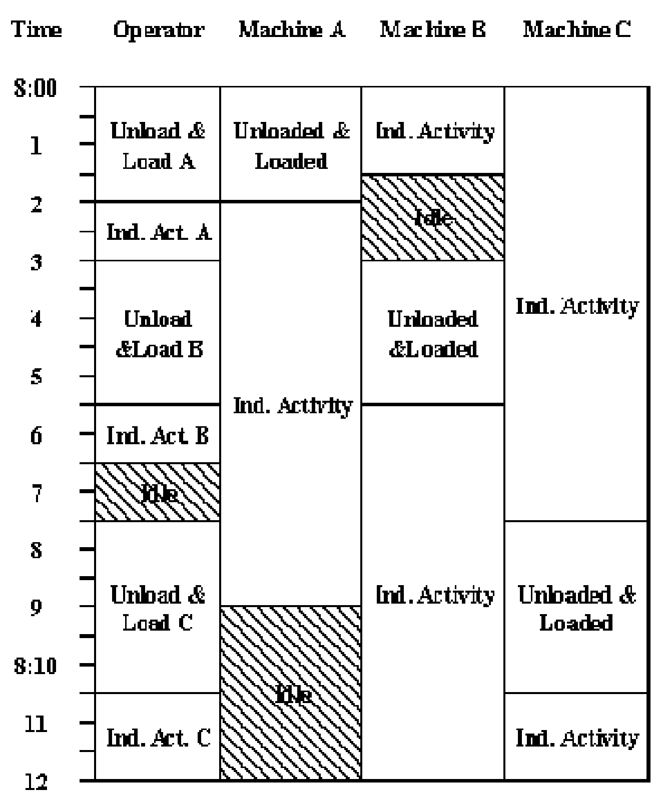
As noted, a simplified approach was used to arrive at a preference in the assignment of the 5 machines to the 2 products. With more information regarding sales prices, demands, changeover times, etc., a more informed decision could be made. The underlying objective in presenting the machine-assignment problem was to provide students with experience in using simple mathematical models in making decisions regarding the assignment of machines to operators.

2.26a $a = 6 + 4 = 10$; $b = 6$; and $t = 30$. $n' = (10 + 30)/(10 + 6) = 2.5$. No more than 2 mixers can be assigned without idle mixer time.

2.26b C_o = \$12/hr; C_m = \$25/hr; and $\epsilon = C_o/C_m = 0.48$.
Therefore, $\Phi = [(\epsilon + n)(n')]/[(\epsilon + n + 1)(n)] = [(2.5)(2.48)]/[(3.48)(2)]$, or $\Phi = 0.89 < 1$. Hence, 2 mixers should be assigned to an operator.

2.40 The multiple activity chart is provided on the following page. The length of the repeating cycle is given by the maximum of the following values: $(a_A + b_A + a_B + b_B + a_C + b_C)$; $(a_A + t_A)$; $(a_B + t_B)$; $(a_C + t_C)$, or max (11, 9, 10.5, 12), or 12. The repeating cycle is determined by machine C. As shown, the operator will have 1 minute of idle time during a repeating cycle, machine A will have 3 minutes of idle time, machine B will have 1.5 minutes of idle time, and machine C will have no idle time during a repeating cycle.

Multiple Activity Chart



2.41a a = 5 min; b = 1 min; t = 20 min; C_o = \$12/hr, and C_m = \$30/hr.
n' = (5 + 20)/(5 + 1) = 4.167; Therefore, 4 is the maximum number of machines that can be assigned an operator without creating machine idle time during a repeating cycle.

2.41b $\epsilon = C_o/C_m = 0.4$. Therefore,
$\Phi = [(\epsilon + n)(n')]/[(\epsilon + n + 1)(n)] = [(4.4)(4.167)]/[(5.4)(4)]$, or $\Phi = 0.8488 < 1$.
Hence, 4 mixers should be assigned to an operator.

2.41c $TC(m = 4) = \left[\left(12 + 4(30)\right)(5 + 20)\right]/[(60)(4)] = \$13.75/\text{unit}$

2.41d For n* = 4, either $\Phi < 1$ when n = 4 or $\Phi > 1$ for n = 3.
<u>Φ < 1 case</u>: $\Phi = [(0.4 + 4)(n')]/[(0.4 + 5)(4)] < 1$ or
$\Phi = [(4.4)(a + 20)]/[(a + 1)(5.4)(4)] \Longrightarrow (4.4a + 88) < (21.6a + 21.6)$.
Hence, 17.2a > 66.4, or a > 3.86 min.

<u>Φ > 1 case</u>: $\Phi = [(3.4)(a + 20)]/[(a + 1)(4.4)(3)] < 1$. Thus, (3.4a + 68) > (13.2a + 13.2). Hence, 9.8a < 54.8, or a < 5.59 min. Hence, the optimum assignment of 4 machines occurs when 3.86 min < a < 5.59 min.

2.41e Consider the alternatives: {5, 5, 5}, {4, 4, 4, 3}, and {4, 5, 6}.
<u>{5, 5, 5} case</u>: T_c = 30 min.
TC{5, 5, 5} = [3(\$12) + 15(\$30)](30/60)(1/15) = \$16.20/unit.

<u>{4, 4, 4, 3} case</u>: T_c = 25 min.
TC{4, 4, 4, 3} = [4(\$12) + 15(\$30)](25/60)(1/15) = \$13.83/unit.

<u>{4, 5, 6} case</u>: $T_c(4)$ = 25 min., $T_c(5)$ = 30 min., $T_c(6)$ = 36 min. In 2,700 minutes, 1,332 units will be produced: 4(108), or 432, by the 4- machine assignment; 5(90), or 450, by the 5-machine assignment; and 6(75), or 450, by the 6-machine assignment.
TC{4, 5, 6} = [3(\$12) + 15(\$30)](2700/60)(1/1332) = \$16.42/unit.

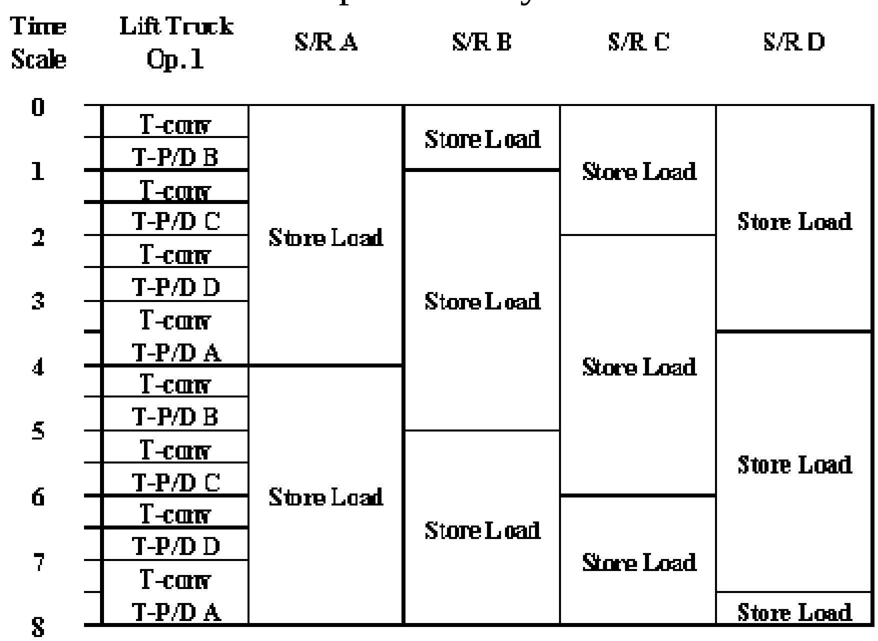
The least costly assignment of 15 machines is {4, 4, 4, 3}. We do not need to consider {3, 3, 3, 3, 3} since it has the same repeating cycle as {4, 4, 4, 3} and requires an additional operator. Likewise, there is no reason to consider an alternative involving a {3, 5} combination since we know from part a) that {4, 4} is less costly.

2.42 a = 4 min; b = 5 min + 3 min = 8 min; and t = 40 min. n' = (4 + 40)/(4 + 8) or n' = 3.67 and 3 is the maximum number of automatic palletizers on operator can be assigned without creating idle time for the palletizers.

2.43 The problem statement does not mention retrievals by the S/R; hence, no travel between the P/D station and the outbound conveyor is required. It is assumed that the travel between the P/D station of one S/R aisle and the inbound conveyor for another S/R aisle also requires 0.5 minute.

For the problem, there is no concurrent activity. As long as a load is at the P/D station, the S/R machine will retrieve it automatically. Hence, for the problem, b = 0.5 min to travel to the P/D station + 0.5 min to travel from the P/D station = 1.0 and t = 4 min to store a load and return to the end-of-the-aisle. (In Chapter 10, we define this as a single command cycle for the S/R machine.) With b = 1 and t = 4, n' = 4. Hence, as shown below, one lift truck operator can service 4 S/R machines; the operator and the S/R machines will be busy 100% of the time. For 5 S/R machines, 2 lift truck operators will be required.

Multiple Activity Chart

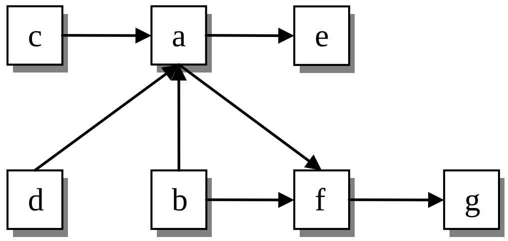


2.44 a = 0.25 min; b = 0; and t = 1.0. Therefore, n' = 1.25/0.25 = 5.0. An operator can tend 5 carousels without creating idle time for the conveyors; the operator will also be 100% occupied.

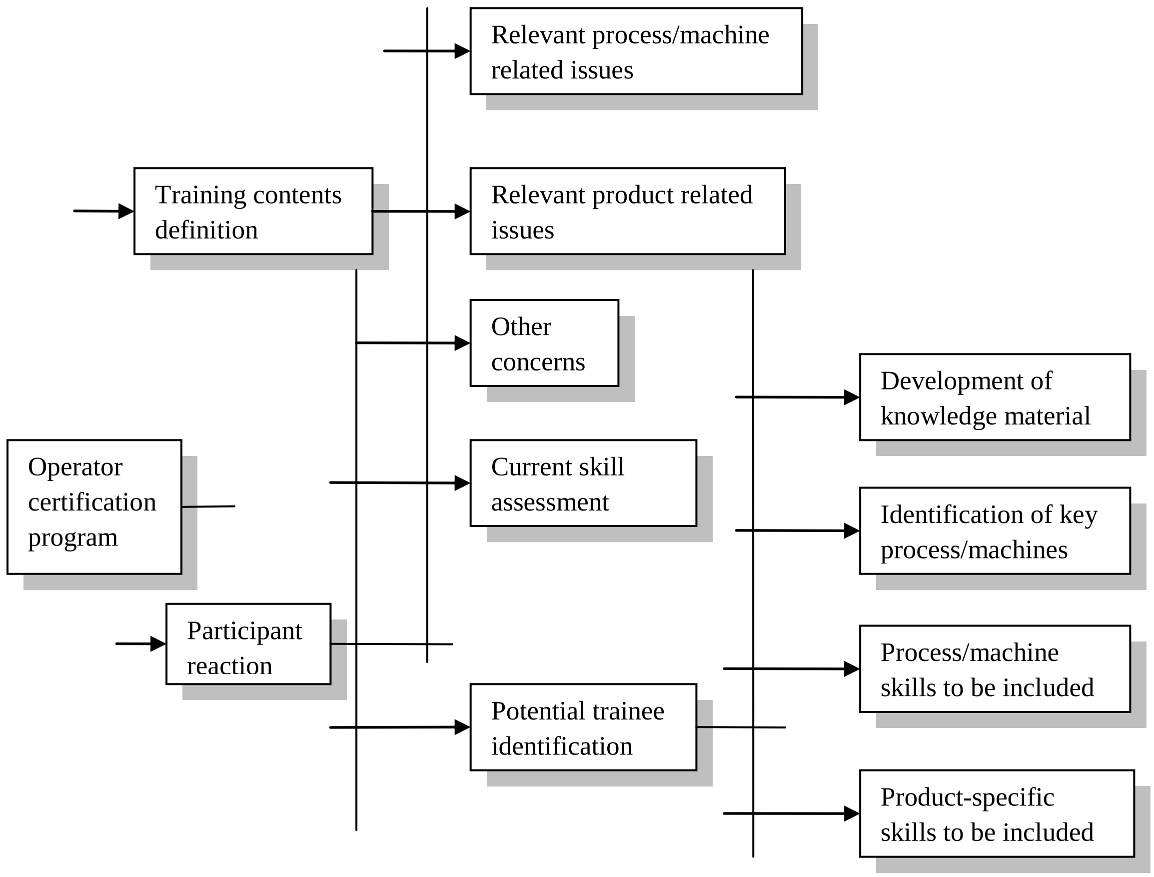
SECTION 2.5

2.45 a. Board for part shortages
b. Board for back-orders
c. Feedback from material handlers when part has low physical inventory
d. Feedback from operator handlers when part has low physical inventory

2.46



2.47



2.48 - 2-50 The answers to these questions depend on choices made and course specifics. See Section 2.5 for details on each of the 7 M&P tools.

2.51 Follow the instructions provided in Section 2.5 for each of the 7 M&P tools.