Chapter 7

Output and Capacity

- What is a Constraint?
  - Any factor that limits system performance and restricts its output.

- Capacity is the maximum rate of output of a process or system.

- A Bottleneck
  - An output constraint that limits a company’s ability to meet market demand.
  - Also called Capacity Constraint Resource or CCR

Measures of Capacity

- Output Measures
- Input Measures
- Utilization
  - Utilization = \frac{\text{Average output rate}}{\text{Maximum capacity}} \times 100\%
- Performance Measures in TOC
  - Inventory (I)
  - Throughput (T)
  - Operating Expense (OE)
  - Utilization (U)

Theory of Constraints (TOC)

- A systematic approach that focuses on actively managing constraints that are impeding progress.

- Constraint Management
  - Short-Term Capacity Planning
    - Theory of Constraints
    - Identification and management of bottlenecks
    - Product Mix Decisions using bottlenecks
  - Long-term Capacity Planning
    - Economies and Diseconomies of Scale
    - Capacity Timing and Sizing Strategies
    - Systematic Approach to Capacity Decisions

How Operational Measures Relate to Financial Measures

<table>
<thead>
<tr>
<th>Operational Measures</th>
<th>TOC View</th>
<th>Relationship to Financial Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventory (I)</td>
<td>All the money invested in the system in purchasing things that it intends to sell.</td>
<td>An increase in I leads to an increase in net profit, ROI, and cash flow.</td>
</tr>
<tr>
<td>Throughput (T)</td>
<td>Rate at which the system generates money through sales.</td>
<td>An increase in T leads to an increase in net profit, ROI, and cash flow.</td>
</tr>
<tr>
<td>Operating Expense (OE)</td>
<td>All the money the system spends to turn inventory into throughput.</td>
<td>An increase in OE leads to an increase in net profit, ROI, and cash flow.</td>
</tr>
<tr>
<td>Utilization (U)</td>
<td>The degree to which equipment, space, or labor is currently being used, and measured as the ratio of average output rate to maximum capacity, expressed as a %.</td>
<td>An increase in U at the bottleneck leads to an increase in net profit, ROI, and cash flow.</td>
</tr>
</tbody>
</table>
Chapter 7

7 Key Principles of TOC

1. The focus is on balancing flow, not on balancing capacity.
2. Maximizing output and efficiency of every resource will not maximize the throughput of the entire system.
3. An hour lost at a bottleneck or constrained resource is an hour lost for the whole system. An hour saved at a non-constrained resource does not necessarily make the whole system more productive.
4. Inventory is needed only in front of the bottlenecks to prevent them from sitting idle, and in front of assembly and shipping points to protect customer schedules. Building inventories elsewhere should be avoided.
5. Work should be released into the system only as frequently as the bottlenecks need it. Bottleneck flows should be equal to the market demand. Pacing everything to the slowest resource minimizes inventory and operating expenses.
6. Activation of non-bottleneck resources cannot increase throughput, nor promote better performance on financial measures.
7. Every capital investment must be viewed from the perspective of its global impact on overall throughput (T), inventory (I), and operating expense (OE).

Application of TOC

1. Identify The System Bottleneck(s).
2. Exploit The Bottleneck(s).
3. Subordinate All Other Decisions to Step 2
4. Elevate The Bottleneck(s).
5. Do Not Let Inertia Set In.

Bal Seal Engineering
Managerial Practice 7.1

Theory of Constraints in Practice

➢ Bal Seal had problems with excessive inventory, long lead times and long work hours.
➢ They were operating above capacity but on-time shipment rate was 80-85%
➢ Bal Seal implemented TOC with dramatic and almost immediate results.
   ➢ Excessive inventory dried up
   ➢ Extra capacity was experienced everywhere but at the constraint
   ➢ Total production increased over 50%
   ➢ Customer response time decreased from 6 weeks to 8 days
   ➢ On-time shipments went up to 97%

Identification and Management of Bottlenecks

➢ A Bottleneck is the process or step which has the lowest capacity and longest throughput.
➢ Throughput Time is the total time from the start to the finish of a process.
➢ Bottlenecks can be internal or external to a firm.
Chapter 7

Setup Time

- If multiple services or products are involved, extra time usually is needed to change over from one service or product to the next.
- This increases the workload and could be a bottleneck.
- **Setup Time** is the time required to change a process or an operation from making one service or product to making another.

Where is the Bottleneck?

**Example 7.1**

It takes 10 + 20 + max (15, 12) + 5 + 10 = 60 minutes to complete a loan application. Unless more resources are added at step B, the bank will be able to complete only 3 loan accounts per hour, or 15 new load accounts in a five-hour day.

1. Check loan documents and put them in order (10 minutes)
2. Categorize loans (20 minutes)
3. Check for credit rating (15 minutes)
4. Enter loan application data into the system (12 minutes)
5. Is loan approved? (5 min)
   - Yes
   - No
5.1 Check loan documents and put them in order (10 minutes)
5.2 Categorize loans (10 minutes)
5.3 Check for credit rating (10 minutes)
6. Complete paperwork for new loan (10 minutes)

Where is the Bottleneck?

**Barbara’s Boutique Application 7.1**

Two types of customers enter Barbara’s Boutique shop for customized dress alterations. After T1, Type A customers proceed to T2 and then to any of the three workstations at T3, followed by T4, and then T7. After T1, Type B customers proceed to T5 and then T6 and T7. The numbers in the circles are the minutes it takes that activity to process a customer.

- What is the capacity per hour for Type A customers?
- If 30% of customers are Type A customers and 70% are Type B, what is the average capacity?
- Where would Type A customers experience waiting lines, assuming there are no Type B customers in the shop?
- Where would Type B customers have to wait, assuming no Type A customers?

**Barbara’s Boutique Application 7.1 Solution**

The average capacity is \( \frac{3 \times 3.33 + 7 \times 2.73}{10} = 2.9 \) customers per hour.

Diablo Electronics

**Examples 7.2 and 7.3**

Diablo Electronics makes 4 unique products, (A,B,C,D) with various demands and selling prices. Batch setup times are negligible. There are 5 workers (1 for each of the 5 work centers V, W, X, Y, Z) paid $18/hour. Overhead costs are $8500/week.

- Plant runs 1 Shift/day or 40 hours/week
- Your objective:
  1. Which of the four workstations W, X, Y, or Z has the highest total workload, and thus serves as the bottleneck for Diablo Electronics?
  2. What is the most profitable product to manufacture?
  3. What is the best product mix given bottleneck based approach?
Chapter 7

**Diablo Electronics**

**Flowchart for Products A, B, C, D**

**Identifying the Bottleneck at Diablo Electronics**

**Example 7.2**

**Step 1 at Workstation V**
- Finish with Step 3 at Workstation X (10 min)

**Product:** A
- Price: $75/unit
- Demand: 60 units/wk

**Step 1 at Workstation Y**
- Finish with Step 2 at Workstation X (20 min)

**Product:** B
- Price: $72/unit
- Demand: 80 units/wk

**Step 1 at Workstation W**
- Step 3 at Workstation X (5 min)
- Finish with Step 4 at Workstation Y (5 min)

**Product:** C
- Price: $45/unit
- Demand: 80 units/wk

**Step 2 at Workstation Z**
- Finish with Step 3 at Workstation Y (5 min)

**Product:** D
- Price: $38/unit
- Demand: 100 units/wk

**Raw Materials**
- Product: A
- Price: $10/unit
- Demand: 60 units/wk

**Raw Materials**
- Product: B
- Price: $5/unit
- Demand: 80 units/wk

**Raw Materials**
- Product: C
- Price: $5/unit
- Demand: 80 units/wk

**Purchased Part**
- Product: A
- Price: $3/unit
- Demand: 80 units/wk

**Purchased Part**
- Product: C
- Price: $2/unit
- Demand: 80 units/wk

**Purchased Part**
- Product: D
- Price: $6/unit
- Demand: 100 units/wk

**Determining the Product Mix at Diablo Electronics**

**Example 7.3**

**Decision rule 1: Traditional Method - Select the best product mix according to the highest overall profit margin of each product.**

**Step 1:** Calculate the profit margin per unit of each product.

<table>
<thead>
<tr>
<th>Product</th>
<th>Price</th>
<th>Raw materials &amp; parts</th>
<th>Labor</th>
<th>Profit margins</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$75.00</td>
<td>-10.00</td>
<td>-15.00</td>
<td>$50.00</td>
</tr>
<tr>
<td>B</td>
<td>$72.00</td>
<td>-6.00</td>
<td>-9.00</td>
<td>$58.00</td>
</tr>
<tr>
<td>C</td>
<td>$45.00</td>
<td>-5.00</td>
<td>-6.00</td>
<td>$34.00</td>
</tr>
<tr>
<td>D</td>
<td>$38.00</td>
<td>-5.00</td>
<td>-9.00</td>
<td>$19.00</td>
</tr>
</tbody>
</table>

When ordering from highest to lowest, the profit margin per unit order of these products is B,A,C,D.

**Step 2:** Allocate resources V,W,X,Y,Z to the products in the order decided in step 1. Satisfy each demand until the bottleneck resource (workstation X) is encountered. Subtract minutes away from 2,400 minutes available for each week at each stage.

The best product mix according to this traditional approach is then 60 A, 80 B, 40 C, and 100 D.

**Traditional Method Product Mix at Diablo Electronics**

**Step 3:** Compute profitability for the product mix.

**Revenue:** (60x$75) + (80x$72) + (40x$45) + (100x$38) = $15,860

**Materials:** (60x$10) + (80x$5) + (40x$5) + (100x$10) = $2,200

**Labor:** (5 workers) x (8 hours/day) x (5 days/wk) x ($18/hr) = $3,600

**Overhead:** $8,500

**Profit:** $1,560

Notice that in the absence of overtime, the labor cost is fixed at $3,600 per week regardless of the product mix selected.

Manufacturing the product mix of 60 A, 80 B, 40 C, and 100 D will yield a profit of $1,560 per week.

**Bottleneck-based Approach at Diablo Electronics**

**Decision rule 2: Bottleneck-based approach - The solution can be improved by better using the bottleneck resource. Calculate profit margin per minute at the bottleneck (BN).**

**Step 1:** Calculate profit margin/minute at bottleneck

<table>
<thead>
<tr>
<th>Product</th>
<th>Profit Margin</th>
<th>Time at X</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$50.00</td>
<td>10 min.</td>
</tr>
<tr>
<td>B</td>
<td>$58.00</td>
<td>20 min.</td>
</tr>
<tr>
<td>C</td>
<td>$34.00</td>
<td>5 min.</td>
</tr>
<tr>
<td>D</td>
<td>$19.00</td>
<td>0 min.</td>
</tr>
</tbody>
</table>

Allocate resources in order D,C,A,B, which happens to be the reverse under the traditional method. New profitability is computed with new production quantities as follows: 60 A, 70 B, 80 C, 100 D.
Chapter 7

Constraint Management 5

Step 2: Allocate resources V, W, X, Y, and Z to the products in the order decided in step 1. Satisfy each demand until the bottleneck resource (workstation X) is encountered. Subtract minutes away from 2,400 minutes available for each week at each stage.

<table>
<thead>
<tr>
<th>Work Center</th>
<th>Before Start</th>
<th>After Making W</th>
<th>After Making X</th>
<th>After Making Y</th>
<th>After Making Z</th>
<th>Can Only Make</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>2,400</td>
<td>2,400</td>
<td>2,400</td>
<td>400</td>
<td>600</td>
<td>X</td>
</tr>
<tr>
<td>W</td>
<td>2,400</td>
<td>400</td>
<td>508</td>
<td>500</td>
<td>900</td>
<td>X</td>
</tr>
<tr>
<td>X</td>
<td>2,400</td>
<td>2,000</td>
<td>2,000</td>
<td>1,400</td>
<td>1,400</td>
<td>X</td>
</tr>
<tr>
<td>Y</td>
<td>2,400</td>
<td>1,900</td>
<td>1,800</td>
<td>1,000</td>
<td>300</td>
<td>X</td>
</tr>
<tr>
<td>Z</td>
<td>2,400</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
<td>X</td>
</tr>
</tbody>
</table>

The best product mix according to this bottleneck-based approach is then 60 A, 70 B, 80 C, and 100 D.

Step 3: Compute profitability for the product mix.

Revenue: \((60 \times 75) + (70 \times 72) + (80 \times 45) + (100 \times 38) = 16,940\)

Materials: \((60 \times 10) + (70 \times 5) + (80 \times 5) + (100 \times 10) = 2,350\)

Labor: \((5 \text{ workers} \times 8 \text{ hours/day} \times 5 \text{ days/wk} \times \$18/\text{hr}) = 3,600\)

Overhead: \(- \$6,500\)

Profit: \(\$2,490\)

Manufacturing the product mix of 60 A, 70 B, 80 C, and 100 D will yield a profit of \$2,490 per week.

O'Neill Enterprises Applications 7.2 and 7.3

O'Neill Enterprises manufactures three unique products (A, B, C) that are fabricated and assembled in four different workstations (W, X, Y, Z). Each workstation processes every one of the four products, though not necessarily in the same order.

Batch setup times are negligible. A flowchart that denotes the path each product follows through the manufacturing process is shown next, where each product's price, demand per week, and processing times per unit are indicated. Arrows with triangles represent purchased parts and raw materials consumed per unit at different workstation.

O'Neill can make and sell up to the limit of its demand per week, and there are no penalties for not being able to meet all of the demand. Each workstation is staffed by a worker dedicated to work on that workstation alone, and is paid \$12 per hour. Variable overhead costs are \$800 per week. The plant operates one 8-hour shift per day, or 40 hours/week.

O'Neill Enterprises Application 7.2

Which of the four workstations W, X, Y, or Z has the highest total workload, and hence cannot in the bottleneck for O'Neill Enterprises?

Solution

Identify the bottleneck by computing total workload at each workstation. The first workstation to finish each of the products is known as the bottleneck. Workstation W has the highest total workload, as shown by the shaded area. Multiplying the processing time at each station for a given product by the number of units demanded per week yields the capacity load. These loads are summed across all products going through that workstation and then compared with the existing capacity of 2,400 minutes.

<table>
<thead>
<tr>
<th>Work Station</th>
<th>Load from Product A</th>
<th>Load from Product B</th>
<th>Load from Product C</th>
<th>Total Load (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>1,200</td>
</tr>
<tr>
<td>X</td>
<td>2,000</td>
<td>2,000</td>
<td>2,000</td>
<td>6,000</td>
</tr>
<tr>
<td>Y</td>
<td>1,900</td>
<td>1,800</td>
<td>1,000</td>
<td>6,700</td>
</tr>
<tr>
<td>Z</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
<td>3,000</td>
</tr>
</tbody>
</table>

O'Neill Enterprises Application 7.3

The senior management at O'Neill Enterprises wants to improve the profitability by accepting the right set of orders. Currently, decisions are made to accept as much of the highest contribution margin product as possible (up to the limit of its demand), followed by the next highest contribution margin product, and so on until no more capacity is available.

Since the firm cannot satisfy all the demand, the product mix must be chosen carefully.

Jane Hathaway, the newly hired production supervisor, is knowledgeable about the theory of constraints and bottleneck based scheduling. She believes that profitability can indeed be improved if bottleneck resources were exploited to determine the product mix.

What is the change in profits if instead of the traditional method that O'Neill has used thus far, a bottleneck based approach advocated by Jane is used instead for selecting the product mix?
Chapter 7

**O’Neill Enterprises**

### Determining Product Mix

**Decision rule 1: Traditional Method** - Select the best product mix according to the highest overall profit margin of each product.

**Step 1:** Calculate the profit margin per unit of each product as shown below.

<table>
<thead>
<tr>
<th>Product</th>
<th>Price</th>
<th>Raw Material &amp; Purchased Parts</th>
<th>Labor</th>
<th>Profit Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$80.00</td>
<td>-15.00</td>
<td>-10.00</td>
<td>$67.00</td>
</tr>
<tr>
<td>B</td>
<td>$85.00</td>
<td>-14.00</td>
<td>9.00</td>
<td>$62.00</td>
</tr>
<tr>
<td>C</td>
<td>$80.00</td>
<td>-13.00</td>
<td>-7.40</td>
<td>$57.60</td>
</tr>
</tbody>
</table>

When ordering from highest to lowest, the profit margin per unit order of these products is **A, B, C**.

---

### Traditional Method Scheduling

**Step 2:** Allocate resources **W, X, Y, and Z** to the products in the order decided in step 1. Satisfy each demand until the bottleneck resource (workstation **Z**) is encountered. Subtract minutes away from 2400 minutes available for each week at each stage.

### Traditional Method Profit

**Step 3:** Compute profitability for the selected product mix.

<table>
<thead>
<tr>
<th>Revenue</th>
<th>Materials</th>
<th>Overhead</th>
<th>Labor</th>
<th>Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$15400</td>
<td>-2500</td>
<td>-8000</td>
<td>-1920</td>
<td>$2980</td>
</tr>
</tbody>
</table>

Manufacturing the product mix of **65A, 70B, and 45C** will yield a profit of $2980.

---

### Bottleneck-based Approach

**Decision Rule 2:** Bottleneck-based approach - Select the best product mix according to the dollar contribution per minute of processing time at the bottleneck workstation **Z**. This rule would take advantage of the principles outlined in the theory of constraints and get the most dollar benefit from the bottleneck.

**Step 1:** Calculate the contribution/minute of processing time at bottleneck workstation **Z**:

When ordering from highest to lowest contribution margin/minute at the bottleneck, the manufacturing sequence of these products is **C, B, A**.

### Bottleneck-based Scheduling

**Step 2:** Allocate resources **W, X, Y, and Z** to the products in the order decided in step 1. Satisfy each demand until the bottleneck resource (workstation **Z**) is encountered. Subtract minutes away from 2400 minutes available for each week at each stage.

### Bottleneck-based Profit

**Step 3:** Compute profitability for the selected product mix. The new profitability figures are shown below based on the new production quantities of **80 C, 70 B, and 43 A**.

Manufacturing the product mix of **43A, 70B, and 80C** will yield a profit of $3561.

The increase in profit by using the bottleneck scheduling method is $581. By focusing on the bottleneck resources in accepting customer orders and determining the product mix, O’Neill was able to increase the firm’s profitability by 19.5% over the traditional contribution margin method.
Chapter 7

**Long-Term Capacity Planning**

**Constraint Management**

- Short-Term Capacity Planning
  - Theory of Constraints
  - Identification and management of bottlenecks
  - Product Mix Decisions using bottlenecks

- Long-Term Capacity Planning
  - Economies and Diseconomies of Scale
  - Capacity Timing and Sizing Strategies
  - Systematic Approach to Capacity Decisions

**Economies of Scale**

- Economies of scale occur when the average unit cost of a service or good can be reduced by increasing its output rate.
- Diseconomies of scale occur when the average cost per unit increases as the facility's size increases.

**Capacity Timing and Sizing Strategies**

1. Sizing Capacity Cushions
2. Timing and Sizing Expansions
3. Linking Process Capacity and other operating decisions.

**Capacity Cushions**

A capacity cushion is the amount reserve capacity a firm has available.

\[ \text{Capacity Cushion} = 100\% - \text{Utilization Rate (\%)} \]

How much capacity cushion depends on:
- The uncertainty and/or variability of demand
- The cost of lost business
- The cost of idle capacity

**Capacity Expansion Expansionist Strategy**

Staying ahead of demand

- Planned unused capacity
- Forecast of capacity required
- Time between increments
- Capacity increment
- Time
Chapter 7

Capacity Expansion
Wait-and-See Strategy

Chasing demand
Planned use of short-term options
Forecast of capacity required
Capacity Increment
Time between increments

Linking Process Capacity and Other Decisions

- Competitive Priorities
- Quality
- Process Design
- Aggregate Planning

A Systematic Approach To Long-Term Capacity Decisions

1. Estimate future capacity requirements.
2. Identify gaps by comparing requirements with available capacity.
3. Develop alternative plans for filling the gaps.
4. Evaluate each alternative and make a final choice.

Estimating Capacity Requirements

- Capacity Requirement is determined over some future period based on demand and desired capacity cushion.
- Planning Horizon is a set of consecutive future time periods for planning purposes.

Output Measures for Estimating Capacity Requirements

- Output Measures are the simplest way to express capacity.
- Products produced or customers served per unit of time

Example: Current capacity is 50 per day and demand is expected to double in five years. Management uses a capacity cushion of 20%.

Capacity (M) in 5 years should be:

\[ M = \frac{100}{1 - 0.2} = 125 \text{ customers} \]

Input Measures for Estimating Capacity Requirements

Input Measures are typically based on resource availability.

Processing hours required for year’s demand

\[ M = \frac{D_p}{N[1 - (C/100)]} \]

- \( D \) = demand forecast for the year
- \( p \) = processing time
- \( N \) = total number of hours per year during which the process operates
- \( C \) = desired capacity cushion, expressed as a percentage
Chapter 7

Surefoot Sandal Company Application 7.4

- Put together a capacity plan for a critical bottleneck operation at the Surefoot Sandal Company. Capacity is measured as number of machines. Three products (men’s, women’s, & children’s sandals) are manufactured. The time standards, lot sizes, and demand forecasts are given below. There are two 8-hour shifts operating 5 days per week, 50 weeks per year. Experience shows that a capacity cushion of 5 percent is sufficient.

<table>
<thead>
<tr>
<th>Product</th>
<th>Processing (hr/pair)</th>
<th>Setup (hr/pair)</th>
<th>Lot Size (pairs)</th>
<th>Demand (pairs/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men’s sandals</td>
<td>0.05</td>
<td>0.5</td>
<td>240</td>
<td>80,000</td>
</tr>
<tr>
<td>Women’s sandals</td>
<td>0.1</td>
<td>2.2</td>
<td>180</td>
<td>60,000</td>
</tr>
<tr>
<td>Children’s sandals</td>
<td>0.02</td>
<td>3.8</td>
<td>360</td>
<td>120,000</td>
</tr>
</tbody>
</table>

- Time standards:

<table>
<thead>
<tr>
<th>Product</th>
<th>Processing (hr/pair)</th>
<th>Setup (hr/pair)</th>
<th>Lot Size (pairs)</th>
<th>Demand (pairs/yr)</th>
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<td>0.02</td>
<td>3.8</td>
<td>360</td>
<td>120,000</td>
</tr>
</tbody>
</table>

- Time standards:

- How many machines are needed?
- If the operation currently has two machines, what is the capacity gap?

Surefoot Sandal Company Application 7.4 Solution

- Identifying Gaps and Developing Alternatives

- A Capacity Gap is any difference, positive or negative, between forecast demand and current capacity.
- Alternatives can be anything from doing nothing (Base Case), short-term measured, long-term expansion, or a combination.
- Evaluation of each alternative is important.

Grandmother’s Chicken Restaurant Example 7.5

- Grandmother’s Chicken Restaurant expects to serve a total of 80,000 meals this year. Although the kitchen is operating at 100 percent capacity, the dining room can handle a total of 105,000 dinners per year. Forecasted demand for the next five years is 90,000 meals for next year, followed by a 10,000-meal increase in each of the succeeding years.
- One alternative is to expand both the kitchen and the dining room now, bringing their capacities up to 130,000 meals per year. The initial investment would be $200,000, made at the end of this year (year 0). The average meal is priced at $10, and the before-tax profit margin is 20 percent. The 20 percent figure was arrived at by determining that, for each $10 meal, $6 covers variable costs and $2 goes toward fixed costs (other than depreciation). The remaining $2 goes to pretax profit.
- What are the pretax cash flows from this project for the next five years compared to those of the base case of doing nothing?
Chapter 7

Grandmother's Chicken Restaurant Example 7.5 Solution

Year 0: Demand = 80,000; Cash flow = $80,000
Year 1: Demand = 90,000; Cash flow = $90,000 - $80,000 = $10,000
Year 2: Demand = 100,000; Cash flow = $100,000 - $80,000 = $20,000
Year 3: Demand = 110,000; Cash flow = $110,000 - $80,000 = $30,000
Year 4: Demand = 120,000; Cash flow = $120,000 - $80,000 = $40,000
Year 5: Demand = 130,000; Cash flow = $130,000 - $80,000 = $50,000

- If the new capacity were smaller than the expected demand in any year, we would subtract the base case capacity from the new capacity (rather than the demand).
- The owner should account for the time value of money, applying such techniques as the net present value or internal rate of return methods.

Grandmother's Chicken Restaurant Example 7.5 NVP Calculation

The NPV of this project at a discount rate of 10% is calculated as shown below, and equals $13,051.75

\[ NPV = \frac{-200,000 + \left(\frac{20,000}{1.1}\right) + \left(\frac{40,000}{1.1^2}\right) + \left(\frac{60,000}{1.1^3}\right) + \left(\frac{80,000}{1.1^4}\right) + \left(\frac{100,000}{1.1^5}\right)}{1.1^5} \]

\[ = -200,000 + 18,181.82 + 33,057.85 + 45,078.89 + 54,641.07 + 62,092.13 \]

\[ = 13,051.75 \]

Grandmother's Chicken Restaurant Application 7.5

Two-stage expansion
- A capacity alternative for Grandmother's Chicken Restaurant is a two-stage expansion.
- This alternative expands the kitchen at the end of year 0, raising its capacity from 80,000 meals per year to that of the dining area (105,000 meals per year).
- If sales in year 1 and 2 live up to expectations, the capacities of both the kitchen and the dining room will be expanded at the end of year 3 to 130,000 meals per year.
- This upgraded capacity level should suffice up through year 5. The initial investment would be $80,000 at the end of year 0 and an additional investment of $170,000 at the end of year 3. The pretax profit is $2 per meal.
- What are the pretax cash flows for this alternative through year 5, compared with the base case?

Grandmother's Chicken Restaurant Two-Stage Expansion Application 7.5

The Table shows the cash inflows and outflows.

Year 3 cash flow is unusual in two respects:
- First, the cash inflow from sales is $50,000 rather than $60,000. The increase in sales over the base is 25,000 meals (105,000 – 80,000) instead of 30,000 meals (110,000 – 80,000) because the restaurant’s capacity falls somewhat short of demand.
- Second, a cash outflow of $170,000 occurs at the end of year 3, when the second-stage expansion occurs. The net cash flow for year 3 is $50,000 - $170,000 = -$120,000.

Evaluating Alternatives

Qualitative Concerns
- The fit between alternatives and strategy
- Demand uncertainty
- Reactions of the competition
- Changes in technology

Quantitative Concerns
- Cash flows
- The difference between the flows of funds into and out of an organization over time, including revenues, costs, and changes in assets and liabilities.
Chapter 7

Tools for Capacity Planning

- Waiting Line Models
  - Supplement C
- Simulation
  - Supplement B
- Decision Trees
  - Supplement A

Capacity Planning using Waiting Lines

Capacity Planning using Decision Trees

Low demand [0.40]: 
- Small expansion: $70 \times 0.40 = $28$
- High demand [0.60]:
  - Expand: $135 \times 0.60 = $81$

High demand [0.60]:
- $220 \times 0.60 = $132$