Aggregate Planning
Coca-Cola produces nearly 40% of the beverages consumed in the U.S.

Matches fluctuating demand by brand to specific plant, labor, and inventory capacity

High facility utilization requires
- meticulous cleaning between batches
- effective maintenance
- efficient employees
- efficient facility scheduling
Aggregate Planning Requires

- Logical overall unit for measuring sales and outputs
- Forecast of demand for intermediate planning period in these aggregate units
- Method for determining costs
- Model that combines forecasts and costs so that planning decisions can be made
Planning

- Setting goals & objectives
  - Example: Meet demand within the limits of available resources at the least cost
- Determining steps to achieve goals
  - Example: Hire more workers
- Setting start & completion dates
  - Example: Begin hiring in Jan.; finish, Mar.
- Assigning responsibility
Planning Tasks and Responsibilities

- **Top executives**
  - Long-range plans (over one year)
  - R&D
  - New product plans
  - Capital expenses
  - Facility location/expansion

- **Operations managers**
  - Intermediate-range plans (3 to 18 months)
  - Sales planning
  - Production planning and budgeting
  - Setting employment, inventory, subcontracting levels
  - Analyzing operating plans

- **Operations managers, supervisors, foremen**
  - Short-range plans (up to 3 months)
  - Job assignments
  - Ordering
  - Job scheduling
  - Dispatching

Responsibility vs. Planning tasks and horizon
Planning Horizons

- **Short-range plans**
  - Job assignments
  - Ordering
  - Job scheduling
  - Dispatching
  - Responsible: Operations managers, supervisors, foremen

- **Intermediate-range plans**
  - Sales planning
  - Production planning and budgeting
  - Setting employment, inventory, subcontracting levels
  - Analyzing operating plans
  - Responsible: Operations managers

- **Long-range plans**
  - R&D
  - New product plans
  - Capital expenses
  - Facility location, expansion
  - Responsible: Top executives

- **Planning Horizon**
  - Today
  - 3 Months
  - 1 year
  - 5 years
Relationships of the Aggregate Plan

Marketplace and Demand

Demand Forecasts, orders

Product Decisions

Process Planning & Capacity Decisions

Research and Technology

Work Force

Inventory On Hand

Raw Materials Available

External Capacity Subcontractors

Aggregate Plan for Production

Master Production Schedule, and MRP systems

Detailed Work Schedules
What’s Needed for Aggregate Planning

A mathematically based aggregate planning model requires considerable:

- **time**
  - problem definition
  - model development
  - model verification
  - model application

- **expertise**
  - people who understand the problem
  - people who understand both the modeling process, and the specific model

- **money**
  - money to pay for all of the above
  - often requires funding for several people for several months!
Aggregate Planning

- Provides the quantity and timing of production for intermediate future
  - Usually 3 to 18 months into future
- Combines (‘aggregates’) production
  - Often expressed in common units
    - Example: Hours, dollars
- Involves capacity and demand variables
Aggregate Planning Goals

- Meet demand
- Use capacity efficiently
- Meet inventory policy
- Minimize cost
  - Labor
  - Inventory
  - Plant & equipment
  - Subcontract
• Capacity Options — change capacity:
  – changing inventory levels
    there are variations in demand over planning horizon. There are two types of time periods;
    Slack months: The months when demand is low
    Peak months: The months when demand is high.
    One planning-thumb-rule is;
      Produce excess than demand during Slack months.
      Keep the excess production in stock (inventory). Since, there will be shortage during “peak” months, overcome the shortage in “peak” periods from the inventory.”
Aggregate Planning Strategies
Pure Strategies

• Capacity Options — change capacity:
  – *varying work force size by hiring or layoffs*

  The utility of work-force increases or decreases with an organization’s work load. During “peak” period, organization requires more and more work force. However, the large pool of work force remains under-utilized in “slack” period. In order to keep tight control over expenses, organizations should employ matching number of workers in “peak” as well as in “slack” periods. This implies that large work force should be employed (“hired”) in peak period and, excess work force should be laid-off (“fired”) in “slack period”.
Aggregate Planning Strategies
Pure Strategies

- Capacity Options — change capacity:
  - 
    - varying production capacity through overtime or idle time

If frequent hiring/firing is not feasible, then organizations will have a constant pool of work force of adequate size. In “slack periods”, some of the work force will remain under-utilized. However, some portion of the work force will be engaged in over time as well during “peak” period. This strategy is far better than frequent hiring and firing of the work force.
Aggregate Planning Strategies
Pure Strategies

• Capacity Options — change capacity:
  – *Subcontracting*
    If some portion of the work order is technically complex and requires special expertise. Also, this work is not of repetitive nature, then organization can award the work to some 3rd party (subcontracting)
  – *using part-time workers*
    If organization’s regular work force is too much occupied with work loads, some portion of work may be assigned to part-time workers.
Aggregate Planning Strategies
Pure Strategies

• Demand Options — change demand:
  – *influencing demand*
    demand rises and goes down because of buying trend of the consumer. Offer special discounts during low-demand periods so as to increase sales.
  – *backordering during high demand periods*
    since capacity is limited and all the demand cannot be met on-time, get permission from customer to deliver the products at a later time; e.g., meeting January demand by producing in March (Late delivery)
  – *counterseasonal product mixing*
    some organizations are engaged in producing more than two products. One product has high demand in winter, and, the other product has demand in summer.
## Aggregate Scheduling Options - Advantages and Disadvantages

<table>
<thead>
<tr>
<th>Option</th>
<th>Advantage</th>
<th>Disadvantage</th>
<th>Some Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changing inventory levels</td>
<td>Changes in human resources are gradual, not abrupt</td>
<td>Inventory holding costs; Shortages may result in lost sales</td>
<td>Applies mainly to production, not service, operations</td>
</tr>
<tr>
<td></td>
<td>Changes in production changes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Varying workforce size by hiring or layoffs</td>
<td>Avoids use of other alternatives</td>
<td>Hiring, layoff, and training costs</td>
<td>Used where size of labor pool is large</td>
</tr>
</tbody>
</table>
## Advantages/Disadvantages - Continued

<table>
<thead>
<tr>
<th>Option</th>
<th>Advantage</th>
<th>Disadvantage</th>
<th>Some Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varying production rates</td>
<td>Matches seasonal fluctuations</td>
<td>Overtime premiums, tired</td>
<td>Allows flexibility within the aggregate plan</td>
</tr>
<tr>
<td>through overtime or idle time</td>
<td>without hiring/training costs</td>
<td>workers, may not meet demand</td>
<td></td>
</tr>
<tr>
<td>Subcontracting</td>
<td>Permits flexibility and smoothing of the firm's output</td>
<td>Loss of quality control; reduced profits; loss of future business</td>
<td>Applies mainly in production settings</td>
</tr>
</tbody>
</table>
## Advantages/Disadvantages - Continued

<table>
<thead>
<tr>
<th>Option</th>
<th>Advantage</th>
<th>Disadvantage</th>
<th>Some Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using part-time workers</td>
<td>Less costly and more flexible than full-time</td>
<td>High turnover/training costs; quality suffers;</td>
<td>Good for unskilled jobs in areas with large temporary labor pools</td>
</tr>
<tr>
<td></td>
<td>workers</td>
<td>scheduling difficult</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Influencing demand</td>
<td>Tries to use excess capacity. Discounts draw</td>
<td>Uncertainty in demand. Hard to match demand to</td>
<td>Creates marketing ideas.</td>
</tr>
<tr>
<td></td>
<td>new customers.</td>
<td>supply exactly.</td>
<td></td>
</tr>
<tr>
<td>Option</td>
<td>Advantage</td>
<td>Disadvantage</td>
<td>Some Comments</td>
</tr>
<tr>
<td>--------</td>
<td>-----------</td>
<td>--------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Back ordering during high-demand periods</td>
<td>May avoid overtime. Keeps capacity constant</td>
<td>Customer must be willing to wait, but goodwill is lost.</td>
<td>Many companies backorder.</td>
</tr>
<tr>
<td>Counterseasonal products and service mixing</td>
<td>Fully utilizes resources; allows stable workforce.</td>
<td>May require skills or equipment outside a firm's areas of expertise.</td>
<td>Difficult finding products or services with opposite demand patterns.</td>
</tr>
</tbody>
</table>
Aggregate Planning Strategies

Level Strategy

Production rate is constant

Chase Strategy

Production equals demand

The Extremes
Aggregate Planning Strategies

• **Mixed strategy**
  – Combines 2 or more aggregate scheduling options
  – uses alternatives mixing inventory, back order, capacity change, work force change, etc

• **Level scheduling strategy**
  – Produce *same amount* of products every day
  – Keep *work force* level constant
  – Vary *non-work force* capacity or demand options
  – Often results in *lowest production* costs
Aggregate Planning Methods

• Graphical & charting techniques
  – Popular & easy-to-understand
  – Trial & error approach

• Mathematical approaches
  – Transportation method
  – Linear decision rule
  – Management coefficients model
  – Linear Programming
  – Simulation
The Graphical Approach to Aggregate Planning

- Forecast the demand for each period
- Determine the capacity for regular time, overtime, and subcontracting, for each period
- Determine the labor costs, hiring and firing costs, and inventory holding costs
- Consider company policies which may apply to the workers or to stock levels
- Develop alternative plans, and examine their total costs
Data for a 6-month production planning problem is given below:

<table>
<thead>
<tr>
<th>Month</th>
<th>Working Days</th>
<th>Demand per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>22</td>
<td>41</td>
</tr>
<tr>
<td>Feb</td>
<td>18</td>
<td>40</td>
</tr>
<tr>
<td>Mar</td>
<td>21</td>
<td>39</td>
</tr>
<tr>
<td>Apr</td>
<td>21</td>
<td>57</td>
</tr>
<tr>
<td>May</td>
<td>22</td>
<td>68</td>
</tr>
<tr>
<td>Jun</td>
<td>20</td>
<td>54</td>
</tr>
</tbody>
</table>

Suppose, “chase strategy” is to be adopted. **Two workers are required to produce one unit.** Propose a feasible plan. Is the plan acceptable?

Employ an exact number of workers so that number of units produced per month is equal to number of units demanded.
## Work Force Requirements & Changes/Month

<table>
<thead>
<tr>
<th>Month</th>
<th>Days/month (A)</th>
<th>Demand/day (B)</th>
<th>Units/month C=(AxB)</th>
<th>Workers/month D=2C</th>
<th>Change/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>22</td>
<td>41</td>
<td>902</td>
<td>1804</td>
<td>0</td>
</tr>
<tr>
<td>Feb</td>
<td>18</td>
<td>40</td>
<td>720</td>
<td>1440</td>
<td>-364</td>
</tr>
<tr>
<td>Mar</td>
<td>21</td>
<td>39</td>
<td>819</td>
<td>1638</td>
<td>198</td>
</tr>
<tr>
<td>Apr</td>
<td>21</td>
<td>57</td>
<td>1197</td>
<td>2394</td>
<td>756</td>
</tr>
<tr>
<td>May</td>
<td>22</td>
<td>68</td>
<td>1496</td>
<td>2992</td>
<td>598</td>
</tr>
<tr>
<td>Jun</td>
<td>20</td>
<td>54</td>
<td>1080</td>
<td>2160</td>
<td>-832</td>
</tr>
</tbody>
</table>

### Bar Chart

- **Workers/month**
  - Jan: 1804
  - Feb: 1440
  - Mar: 1638
  - Apr: 2394
  - May: 2992
  - Jun: 2160
Abrupt Employment (hiring) and Layoff from job (firing) at mass-scale is not acceptable (why)?
Consider 6-month production planning problem once again.

<table>
<thead>
<tr>
<th>Month</th>
<th>Working Days</th>
<th>Demand per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>22</td>
<td>41</td>
</tr>
<tr>
<td>Feb</td>
<td>18</td>
<td>40</td>
</tr>
<tr>
<td>Mar</td>
<td>21</td>
<td>39</td>
</tr>
<tr>
<td>Apr</td>
<td>21</td>
<td>57</td>
</tr>
<tr>
<td>May</td>
<td>22</td>
<td>68</td>
</tr>
<tr>
<td>Jun</td>
<td>20</td>
<td>54</td>
</tr>
</tbody>
</table>

Suppose, “level strategy” is to be adopted. Find a constant production rate so that no shortage occurs.

To find daily production rate so that no shortage occurs;
Divide total demand by total number of days.

Production rate = \( \frac{6214}{124} = 50 \) units (app)
Forecast and Average Forecast Demand

Level production using average monthly forecast demand

Production rate per working day

Jan  22
Feb  18
Mar  21
Apr  21
May  22
Jun  20
Inventory is accumulated

Because Demand < Production during Jan, Feb, Mar.

<table>
<thead>
<tr>
<th>Month</th>
<th>Working Days</th>
<th>Demand per day</th>
<th>Production per day</th>
<th>Inventory (+/-)</th>
<th>Cumm Inventory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>22</td>
<td>41</td>
<td>50</td>
<td>198</td>
<td>198</td>
</tr>
<tr>
<td>Feb</td>
<td>18</td>
<td>40</td>
<td>50</td>
<td>180</td>
<td>378</td>
</tr>
<tr>
<td>Mar</td>
<td>21</td>
<td>39</td>
<td>50</td>
<td>231</td>
<td>609</td>
</tr>
<tr>
<td>Apr</td>
<td>21</td>
<td>57</td>
<td>50</td>
<td>-147</td>
<td>462</td>
</tr>
<tr>
<td>May</td>
<td>22</td>
<td>68</td>
<td>50</td>
<td>-396</td>
<td>66</td>
</tr>
<tr>
<td>Jun</td>
<td>20</td>
<td>54</td>
<td>50</td>
<td>-80</td>
<td>-14</td>
</tr>
</tbody>
</table>

Net Inventory For Production Rate = 50 units/day

Inventory is accumulated in these periods
Shortage Created

Because

demand > Production

in Apr, May and Jun
Cumulative Inventory

This inventory shows the overall total inventory at the end of each period.
Cumulative Production & Demand Graph

The region between production line and demand line shows inventory.
Cumulative Demand Graph for Plan 1

- Cumulative level production using average monthly forecast requirements
- Reduction of inventory
- Cumulative forecast requirements
- Excess inventory

Legend:
- Green line: Reduction of inventory
- Red line: Cumulative forecast requirements
- Black line: Excess inventory

Y-axis: Cumulative Demand (Units)
X-axis: Jan, Feb, Mar, Apr, May, Jun
Transportation Method
Transportation Method of Planning

- Each row in transportation table represents a production period
- Each column in the table represents a demand period
- Each cell in the table represents cost of production and inventory holding cost.

<table>
<thead>
<tr>
<th></th>
<th>Demand Period 1</th>
<th>Demand Period 2</th>
<th>Demand Period 3</th>
<th>Capacity/Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period 1</td>
<td>(c_{11})</td>
<td>(c_{12})</td>
<td>(c_{13})</td>
<td>(P_1)</td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period 2</td>
<td>(\ast)</td>
<td>(c_{22})</td>
<td>(c_{23})</td>
<td>(P_2)</td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period 3</td>
<td>(\ast)</td>
<td>(\ast)</td>
<td>(c_{33})</td>
<td>(P_3)</td>
</tr>
<tr>
<td>Demand</td>
<td>(D_1)</td>
<td>(D_2)</td>
<td>(D_3)</td>
<td></td>
</tr>
</tbody>
</table>
Transportation Method of Planning

- Suppose we have three month planning problem: \{ Jan, Feb, Mar \}
- Demands for Jan, Feb and Mar are: \{ 40, 50, 50 \}
- Production capacity for Jan, Feb and Mar are: \{ 50, 50, 40 \}
- Production cost = $10/unit. Inventory holding cost = $2/unit/period
  \[ c_{11} = c_{22} = c_{33} = 10, \quad c_{12} = 10 + 2 = 12, \quad c_{13} = 10 + 2 + 2 = 14 \]
  \[ c_{23} = 10 + 2 = 12. \]

Entering the data; Transportation Table will look like as follows:

<table>
<thead>
<tr>
<th></th>
<th>Demand Jan</th>
<th>Demand Feb</th>
<th>Demand Mar</th>
<th>Capacity/Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produce in Jan</td>
<td>10</td>
<td>12</td>
<td>14</td>
<td>50</td>
</tr>
<tr>
<td>Produce in Feb</td>
<td>**</td>
<td>10</td>
<td>12</td>
<td>50</td>
</tr>
<tr>
<td>Produce in Mar</td>
<td>**</td>
<td>**</td>
<td>10</td>
<td>40</td>
</tr>
</tbody>
</table>

Demand \rightarrow

<table>
<thead>
<tr>
<th>Demand</th>
<th>40</th>
<th>50</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feb</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Mar</td>
<td></td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>
LINEAR PROGRAM OF THE PROD PLANNING PROBLEM

\[ \text{MIN} = 10 \times (X_1 + X_2 + X_3) + 2 \times (I_1 + I_2 + I_3); \]

! Demand Data;
D1 = 40; D2 = 50; D3 = 50;

! Capacity Data;
P1 = 50; P2 = 50; P3 = 40;

! Subject to;

[Unused_Capacity_For_Period_1] X1 <= P1;
[Unused_Capacity_For_Period_2] X2 <= P2;
[Unused_Capacity_For_Period_3] X3 <= P3;

! Inventory Balance Constraints;
I0 = 0;
I1 = I0 + X1 - D1;
I2 = I1 + X2 - D2;
I3 = I2 + X3 - D3;
Transportation Method of Planning

- Least cost solution;

<table>
<thead>
<tr>
<th></th>
<th>Demand Jan</th>
<th>Demand Feb</th>
<th>Demand Mar</th>
<th>Capacity/Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produce in Jan</td>
<td>40</td>
<td>10</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td></td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Produce in Feb</td>
<td>**</td>
<td></td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>**</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>**</td>
<td>**</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Produce in Mar</td>
<td>**</td>
<td>**</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

Demand→

Production Plan

Demand→

Transportation Method of Planning

- Least cost solution;
Optimal solution for by LP;

Global optimal solution found.
Objective value: 1440.000
Infeasibilities: 0.000000
Total solver iterations: 0

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
<th>Reduced Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>50.000000</td>
<td>0.000000</td>
</tr>
<tr>
<td>X2</td>
<td>50.000000</td>
<td>0.000000</td>
</tr>
<tr>
<td>X3</td>
<td>40.000000</td>
<td>0.000000</td>
</tr>
<tr>
<td>I1</td>
<td>10.000000</td>
<td>0.000000</td>
</tr>
<tr>
<td>I2</td>
<td>10.000000</td>
<td>0.000000</td>
</tr>
<tr>
<td>I3</td>
<td>0.000000</td>
<td>16.000000</td>
</tr>
</tbody>
</table>
Multiple Production Source Problem

- Solve three month planning problem: \{ Mar, Apr, May \}

Demands for Mar, Apr and May are: \{ 800, 1000, 750 \}
Production is to be carried out in Mar, Apr and May.
There are three sources of Production in each month.
  - Regular Time, Overtime and Subcontract
Capacity for each source in each month is:
  - Regular time = 700 units
  - Overtime = 50 units
  - Subcontract = 150 units
Production cost in each month:
  - Regular Time = $40/unit
  - Overtime = $50/unit
  - Subcontract = $70/unit

Inventory holding cost = $2/unit/period
There are 100 units in inventory at the beginning of Mar.
Use Transportation Problem and develop a Production Plan.
<table>
<thead>
<tr>
<th></th>
<th>Period 1 (Mar)</th>
<th>Period 2 (Apr)</th>
<th>Period 3 (May)</th>
<th>Unused Capacity (Dummy)</th>
<th>Total Capacity Available (Supply)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beginning Inventory</strong></td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td><strong>Regular</strong></td>
<td>40</td>
<td>42</td>
<td>44</td>
<td>0</td>
<td>700</td>
</tr>
<tr>
<td><strong>Overtime</strong></td>
<td>50</td>
<td>52</td>
<td>54</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td><strong>Subcontract</strong></td>
<td>70</td>
<td>72</td>
<td>74</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td><strong>Regular</strong></td>
<td>X</td>
<td>40</td>
<td>42</td>
<td>0</td>
<td>700</td>
</tr>
<tr>
<td><strong>Overtime</strong></td>
<td>X</td>
<td>50</td>
<td>52</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td><strong>Subcontract</strong></td>
<td>X</td>
<td>70</td>
<td>72</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td><strong>Regular</strong></td>
<td>X</td>
<td>X</td>
<td>40</td>
<td>0</td>
<td>700</td>
</tr>
<tr>
<td><strong>Overtime</strong></td>
<td>X</td>
<td>X</td>
<td>50</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td><strong>Subcontract</strong></td>
<td>X</td>
<td>X</td>
<td>70</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td><strong>Total Demand</strong></td>
<td>800</td>
<td>1000</td>
<td>750</td>
<td>250</td>
<td>2800</td>
</tr>
</tbody>
</table>
# Transportation Table

<table>
<thead>
<tr>
<th></th>
<th>Period 1 (Mar)</th>
<th>Period 2 (Apr)</th>
<th>Period 3 (May)</th>
<th>Unused Capacity (Dummy)</th>
<th>Total Capacity Available (Supply)</th>
</tr>
</thead>
<tbody>
<tr>
<td>**Beginning **Inventory</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regular</td>
<td>40</td>
<td>42</td>
<td>44</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Overtime</td>
<td>50</td>
<td>52</td>
<td>54</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>Subcontract</td>
<td>70</td>
<td>72</td>
<td>74</td>
<td>0</td>
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</tr>
<tr>
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<td>1000</td>
<td>750</td>
<td>250</td>
<td>2800</td>
</tr>
</tbody>
</table>

Note: Regular and Overtime columns are filled with 'X' where applicable.
Cost of solution:
700*40+52*50+150*72+700*40+50*50+70*50+40*700+50*50=$105,900

Solution by Transportation Model
## Comparison of Three Major Aggregate Planning Methods

<table>
<thead>
<tr>
<th>Techniques</th>
<th>Approaches</th>
<th>Aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charting/graphical methods</td>
<td>Trial and error</td>
<td>Simple to understand, easy to use. Many solutions; one chosen may not be optimal</td>
</tr>
<tr>
<td>Transportation method</td>
<td>Optimization</td>
<td>LP software available; permits sensitivity analysis and constraints. Linear function may not be realistic</td>
</tr>
<tr>
<td>Management coefficient model</td>
<td>Heuristic</td>
<td>Simple, easy to implement; tries to mimic manager’s decision process; uses regression</td>
</tr>
</tbody>
</table>