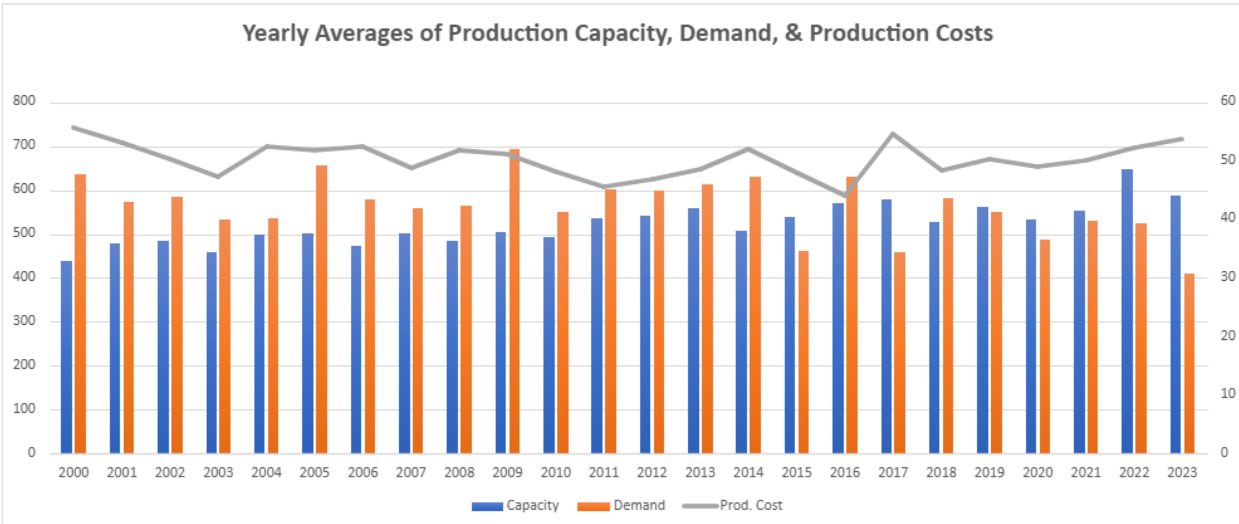
# Module 03 – Production Modeling

## Exploratory Data Analysis

*In this section, you should perform some data analysis on the data provided to you. Please format your findings in a visually pleasing way and please be sure to include these cuts:*

- *Make a table of average demand, production capacity, and costs for each quarter, are there differences between quarters?*
- *Since we have temporal data (i.e. year and quarter), see if you can make a yearly and/or quarterly chart showing these metrics over time.*

| | Capacity | Demand | Prod. Cost |
|---|---|---|---|
| 2000 | 437.285 | 636.065 | 55.75 |
| 2001 | 478.25 | 572.7075 | 53.1325 |
| 2002 | 483.9175 | 585.7725 | 50.285 |
| 2003 | 457.4975 | 533.8 | 47.2925 |
| 2004 | 497.535 | 535.735 | 52.385 |
| 2005 | 501.185 | 655.98 | 51.825 |
| 2006 | 473.1325 | 578.5625 | 52.3825 |
| 2007 | 500.0875 | 558.0025 | 48.7575 |
| 2008 | 484.0875 | 563.19 | 51.745 |
| 2009 | 503.4975 | 693.64 | 51.1625 |
| 2010 | 493.615 | 550.9325 | 48.1275 |
| 2011 | 535.46 | 601.71 | 45.46 |
| 2012 | 540.77 | 599.3575 | 46.785 |
| 2013 | 558.23 | 612.3775 | 48.6625 |
| 2014 | 507.1775 | 629.21 | 52.0775 |
| 2015 | 540.1375 | 462.5025 | 47.955 |
| 2016 | 571.085 | 631.075 | 44.01 |
| 2017 | 578.705 | 458.8375 | 54.5575 |
| 2018 | 526.2975 | 582.9125 | 48.385 |
| 2019 | 560.6 | 548.9925 | 50.2125 |
| 2020 | 533.7875 | 486.115 | 49.095 |
| 2021 | 552.94 | 528.9025 | 50.1375 |
| 2022 | 648.425 | 525.1225 | 52.225 |
| 2023 | 588.2925 | 410.5025 | 53.65 |




| Quarter | Capacity | Demand | Safety Stock | Production Cos |
|---|---|---|---|---|
| 1 | 565 | 659 | 66 | 47.80 |
| 2 | 563 | 485 | 49 | 52.08 |
| 3 | 432 | 678 | 68 | 50.20 |
| 4 | 532 | 435 | 44 | 50.93 |

## Model Formulation

*Write the formulation of the model into here prior to implementing it in your Excel model. Be explicit with the definition of the decision variables, objective function, and constraints*

**Decision Variables (Units Produced):**

$P_1$- 545
$P_2$- 563
$P_3$- 432
$P_4$- 411

**Objective Function:**

**Minimize:** $48.80P_1 + 52.08P_2 + 50.20P_3 + 50.93P_4 + 1.81B_1 + 1.81B_2 + 1.81B_3 + 1.81B_4$

**Constraints:**

$P_1 <= 565$ (Production in Q1 cannot exceed 565 units)
$P_2 <= 563$ (Production in Q2 cannot exceed 563 units)
$P_3 <= 432$ (Production in Q3 cannot exceed 432 units)
$P_4 <= 532$ (Production in Q4 cannot exceed 532 units)

$B_1 >= 66$ (Ending inventory in Q1 must be at least 66 units)
$B_2 >= 49$ (Ending inventory in Q2 must be at least 49 units)
$B_3 >= 68$ (Ending inventory in Q3 must be at least 68 units)
$B_4 >= 44$ (Ending inventory in Q4 must be at least 44 units)
-
$P_i >= 0$ (Production quantities cannot be negative)
$B_i >= 0$ (Ending inventory quantities cannot be negative)

**Model Optimized for Cost Reduction**

*Implement your formulation into Excel and be sure to make it neat. This section should include:*

- *A screenshot of your optimized final model (formatted nicely, of course)A text explanation of what your model is recommending*

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Beginning Inventory | 350 | 236.0004167 | 314 | 68 |
| Units Produced | 545 | 563 | 432 | 411 |
| Units Demanded | 659 | 485 | 678 | 435 |
| Ending Inventory | 236 | 314 | 68 | 44 |
| | | | | |
| Minimum Production | | | | |
| Maximum production | 565 | 563 | 432 | 532 |
| | | | | |
| Minimum Inventory | 66 | 49 | 68 | 44 |
| Maximum Inventory | | | | |
| | | | | |
| Average Inventory | 293.0002083 | 275.0002083 | 191 | 56 |
| | | | | |
| Unit Production Cost | 48.80 | 52.08 | 50.20 | 50.93 |
| Unit Carrying Cost | $ 1.81 | $ 1.81 | $ 1.81 | $ 1.81 |
| | | | | |
| Quarterly Production Cost | 11,516.82 | 16,353.12 | 3,413.60 | 2,240.92 |
| Quarterly Carrying Cost | $ 530.33 | 497.7503771 | 345.71 | 101.36 |
| | | | | |
| Obj Function--> | 34,999.61 | | | |

Explanation:

We achieved this by developing an optimization model that considers production capacity, demand, and the costs associated with each. The model's primary objective is to determine the optimal production quantities for each quarter, balancing the need to meet demand with the desire to minimize expenses.

A key insight is that producing *below* maximum capacity in certain quarters can lead to significant cost savings. While it might seem intuitive to always produce at full capacity, this can result in excess inventory, which incurs holding costs. Our model strategically reduces production in periods where demand is lower, preventing the accumulation of costly surplus. By carefully managing production levels, we minimize not only direct production costs but also the indirect costs associated with storing unsold goods. This approach allows the Candy Shop to operate more efficiently, freeing up valuable resources.

**Model with Stipulation**

*Please copy the tab of your original model before continuing with the next part to avoid messing up your original solution. If we remove the production capacity constraint from the model & we removed the carrying cost, what do you think will happen? Try it out and see if it matches your expectation. Try to explain what is happening and talk a bit about fallbacks of models.*

**Preliminary thoughts:**

I believe that strictly because of the removed carrying cost, the objective function (sum of Quarterly Production Cost and Quarterly Carrying Cost) will decrease. However, because it is not a percentage of the quantity of inventory, but rather a small fixed rate of $1.81/unit, it won't be a massive change. Next, the impacts of removing the production capacity constraint will be more profound in my opinion. This will change the units produced but also allow more ending inventory because there are no holding costs, so there is no penalty for holding more units. Which in turn will drop average inventory, as well as both quarterly production costs and carrying costs (carrying costs to zero).

**After running the model with stipulations:**

So, after removing the production capacity constraint in solver and re-running the model, we see drastic changes in our production and inventory levels. The first thing I noticed by removing production capacity constraints, we allowed the model to produce unrealistic quantities, exceeding any practical production limits. Setting carrying costs to zero created an artificial situation where holding inventory is "free," leading to potentially excessive inventory accumulation. However, this wasn't the case here where ending inventory is relatively low.

This example highlights the importance of carefully defining constraints and cost parameters to reflect real-world conditions. Oversimplifying a model by omitting essential constraints or making unrealistic assumptions can lead to flawed and impractical results. Models are simplifications of reality, and their accuracy depends on how well they represent the actual system being modeled. This demonstrates a key setback of relying solely on cost minimization without considering other critical factors.

I believe this is a worthwhile exercise, although it is a relatively simplified version as we don't have too many constraints to worry about (I'm not saying it's easy). The stipulation portion allows us to speculate how the model may change with any additions or omissions, and then examine the changes after re-running the solver.

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | 1 | 2 | 3 | 4 | |
| 4 | | Beginning Inventory | | 350 | 66 | 49 | 68 | |
| 5 | | Units Produced | | 375 | 468 | 697 | 411 | |
| 6 | | Units Demanded | | 659 | 485 | 678 | 435 | |
| 7 | | Ending Inventory | | 66 | 49 | 68 | 44 | |
| 8 | | | | | | | | |
| 9 | | Minimum Production | | | | | | |
| 10 | | Maximum production | | 565 | 563 | 432 | 532 | |
| 11 | | | | | | | | |
| 12 | | Minimum Inventory | | 66 | 49 | 68 | 44 | |
| 13 | | Maximum Inventory | | | | | | |
| 14 | | | | | | | | |
| 15 | | Average Inventory | | 208 | 57.5 | 58.5 | 56 | |
| 16 | | | | | | | | |
| 17 | | Unit Production Cost | | 48.80 | 52.08 | 50.20 | 50.93 | |
| 18 | | Unit Carrying Cost | | | | | | |
| 19 | | | | | | | | |
| 20 | | Quarterly Production Cost | | 3,220.80 | 2,551.92 | 3,413.60 | 2,240.92 | |
| 21 | | Quarterly Carrying Cost | | $ - | 0 | 0 | 0 | |
| 22 | | | | | | | | |
| 23 | | | | | | | | |
| 24 | | Obj Function--> | | 11,427.24 | | | | |
| 25 | | | | | | | | |