2.008 Design & Manufacturing II
Spring 2025

Beer Game Activity

March 31, 2025

Your Name and Supply Chain Role:

SOLUTIONS

Team Number:

THE BEER GAME: **Do not talk strategy with your team until after Game 1!**

Role: You will be placed into a beer production environment with one of the following four roles: retailer, wholesaler, distributor, and manufacturer.

Length: A game extends over 35 rounds or "weeks". Each round should take approximately 30 seconds for all four players to decide their order quantity so a game should be around 20 minutes.

Rounds: *In each round, the following happens*

- You receive goods from your supplier
- You receive orders from your customer
- You deliver to your customer as ordered if you can
- <u>You order new goods</u> (only action you as a player have control over)

Object of the game: There are two costs involved in the Beer Game, inventory carrying costs ($1.00/week) and backorder (running out of inventory) costs ($2.00/week). Your goal is to minimize cost. There is a two-week lead time that will complicate your decisions. You will want to be monitoring your stock and backorder consistently through the live graph but you will not be able to see the rest of the supply chain.

The customer demand is "unknown" but expect to be ordering roughly 0-20 units per week. <u>DO NOT ORDER 100s</u>, it will make your final data harder to understand.

Statistics: Other than very simple math to assist your decision with order quantity, you need not do any calculations during the game. All of the statistics will be calculated automatically at the end for you to analyze.

<u>Do not search anything about the game online</u> as it might influence your strategy. While your objective within the game is to reduce cost, the purpose for the challenge is to correctly analyze your data afterwards.

PLAY THE BEER GAME

1. Decide on a name for your brewery as a team!

Name of Brewery:

2. Do not discuss the game with your team beforehand or while playing

a. (20 minutes) Go to the Google Sheet on Canvas and find your team number to access the link to your assigned Game 1.

Again do not discuss the game with your team beforehand or while playing! As you are playing **Game 1**, take a few notes or write a brief summary of your strategy with regards to cost, stock and ordering. Use the “Statistics” button on the left side of the screen to see the tracked game information. You don’t need to document any numbers since once **Game 1** has finished, you will be sent to the debrief summary page where it will assemble all of the data for you.

In this simulation the main focus is to keep **the sum of both costs** as low as possible. However, during each stage, your strategy might be to either focus on reducing backorder or overstock since it is difficult to do both, you might also want to consider where you are in the supply chain to decide which one of those is a higher priority and more likely to be an issue for you.

- Shouldn't have backorder/delays - they drive penalties and lost sales.
- Shouldn't have too much stock - this increases storage costs, immobilized assets and obsolescence risk.

Follow the challenge to understand the intricacies of the detailed game debrief and answer questions as a group **before** playing again. You will use what you learn about supply chain and cost dynamics to improve your next performance.

All of the data you will need about your game is on the debrief page. **All of the graphs are interactive and you can show/hide each role or metric by**

clicking it on the legend. You can also download the excel sheet with your data to help compare different areas.

3. Investigate how stock, backorder, and fill rate affect your supply chain.

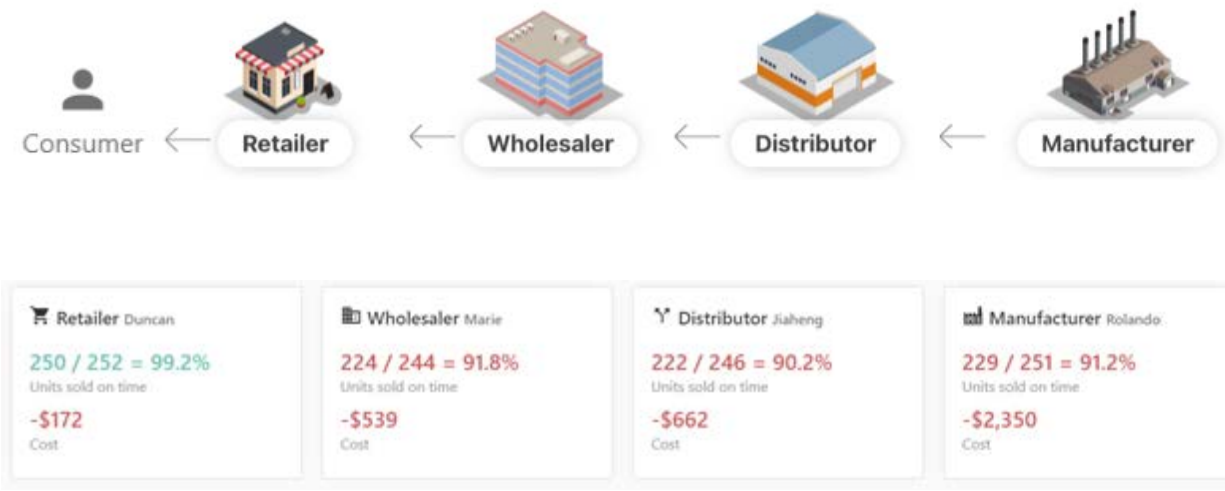
a. Which contributed more to the total cost: total backlog or total stock? Why? You don't need to calculate anything specific if you're able to tell from your "Supply Chain evolution" graphs, but the excel sheet may be of use here if you'd like to compare more exactly. Remember backorders contribute $2.00 and stock contributes $1.00.

The answer to this will vary between groups and what their strategy was.

+1 You can figure this out exactly by looking at the sum of the stock column (minus your starting stock since you're not charged for week zero) *$1 and comparing it to the sum of the Backlog column *$2. Note that the two added together should equal the last row of the cost columns since that reports the total cost for each role.

b. Find the fill rate (% of units shipped on time) for each role. Does it scale the way you would expect it to when thinking about each role's order within the chain? Comment on the result!

Reminder of Chain order:



For some systems, the relationships may be more obvious than others. You might note that it is much easier for the Retailer to achieve a high fill rate, even if the rest of the chain had filling issues. This is because they are first to place the orders when they need them and aren't as prone to backorder build up. However, the improvements that you make with the Retailer are likely to be canceled out by rising costs for the Distributor and Manufacturer. There is a roughly inverse relationship here, but of course every game is different and you could easily target one role to improve over the others (which might happen in real life)!

At each stage, the capacity to fulfill the clients needs can be expressed with the 'Fill rate' (% of units shipped on time). One of the main topics in Supply-Chain strategy is to balance costs with fill rate. Targeting a Fill rate below 100% could actually help significantly reduce supply-chain costs.

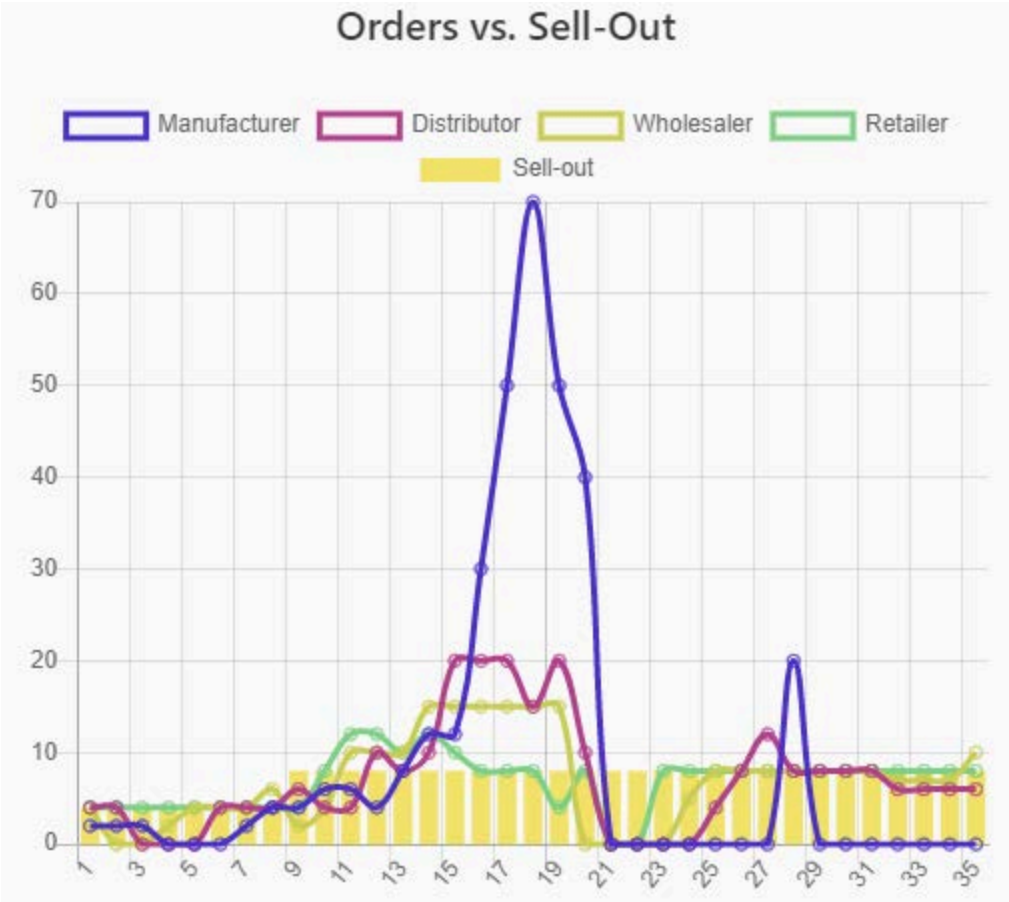
Also note that this was a somewhat arbitrary timeline of 35 weeks but in real-life you may have "quarterly" or "yearly" reports or metrics that a business needs to hit which may shift priorities throughout the infinite supply and demand cycle.

It's difficult to react in a timely manner in systems with long lead time, so demands can build up while each link is waiting for their last orders to come in. The supply chain is a total of 8 weeks long (2 weeks from manufacturer to distributor + 2 weeks distributor to wholesaler + 2 weeks wholesaler to retailer + 2 weeks retailer to consumer) so the backlog peaks happen ~ 8 weeks after the first role gets a backlog

4. As you have now experienced, variability plays a huge role in the supply chain.

a. Find the biggest order from the consumer and the biggest order from each of the roles and note what weeks those were in. Use the “Orders vs. Final Demand” graph to collect that data. Note the differences in magnitude and week when the spike occurred between roles and answer the following questions:

Why do you think it happened this way?	See solutions below
Is there a pattern for when the maximum order happens in different roles?	
Are there any other pieces of data provided outside that graph that would also help you determine how well your supply chain is reacting to variability?	



“Orders vs Sell-Out” is what the previous version of the game called “Orders vs Final Demand”. Often the manufacturer will order something much higher than the consumer in this non-optimized system to make up for a huge backorder. They don’t know what demand is coming and are completely reactive.

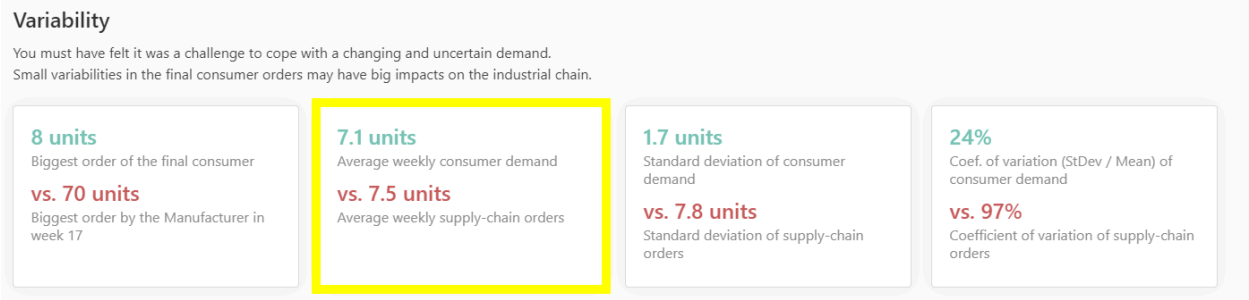
The largest orders from different roles are typically offset from each other so that they’re not the same weeks but are close. This is because an uptick in ordering downstream, usually kicked off from the customer, will cascade through the system with each role reacting to the new numbers after the shipping time has elapsed.

It’s difficult to make a strategy when you have next to no data about what quantities may or may not be expected. Established systems rely on past data to

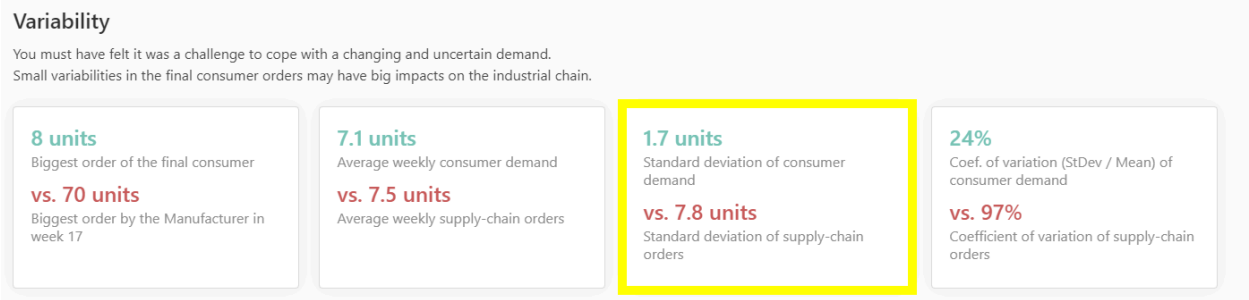
help make predictions about the future, but they're still just predictions and are still affected by variability within the chain.

It is a challenge to cope with a changing and uncertain customer demand. Small variabilities in the consumer orders may have big impacts on the industrial chain. Customer demand variability is far more crucial than the magnitude or average or response. If you had the same strategy but more variability, the high-variability scenario would typically have the higher cost.

You can also look at the average weekly demand by the consumer compared to the average weekly supply chain orders. The closer they are the more likely it is that the supply chain is functioning smoothly. With practice and communication any team's average orders should converge towards the weekly consumer demand, but since you didn't have practice and couldn't communicate for Game 1 your situation could be wildly different.



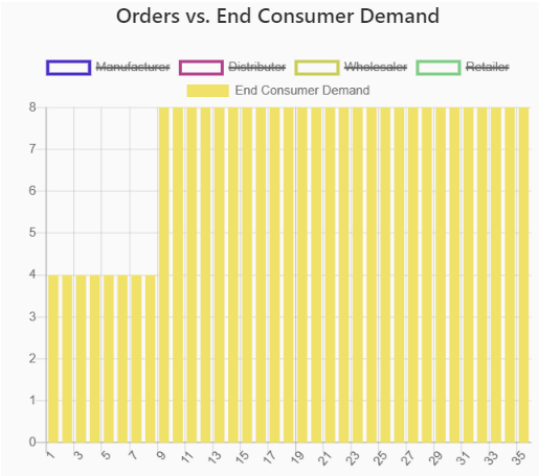
The standard deviation is also reported and that can tell you more about if most orders were close to your averages or if they jumped around.



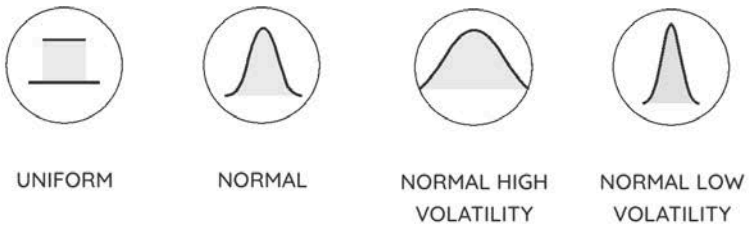
Most teams will see that the supply chain has a higher standard deviation than the customer demand. This is mostly due to everybody having their own role and personal strategy rather than an overall plan.

There is nothing stopping our system from having a lower standard deviation but since we were not communicating, this is likely to spike with every role ordering independently based on their needs. You could imagine that slight changes in the deviation of the consumer demand lead to large ripples downstream and pump up our standard deviation.

b. The step-function demand pattern from this game (8 weeks of a demand quantity of 4, 27 weeks of a demand quantity of 8) is an example of a Normal Low Volatility distribution, because we only had two unique values and they were relatively close in magnitude.



Put the following distribution patterns in order of easiest to hardest to respond to within your supply chain system (ie: which one is the most simple to plan for?) and explain your reasoning.



Remember these are the distribution of the magnitude of customers weekly orders NOT the demand per week from the summary graphs. Therefore you are considering what happens when the magnitudes of the customers' weekly orders are chosen randomly with a distribution matching the ones displayed above.

Distributions of customer orders, from easiest to hardest to respond to:

1. Normal Low Volatility: Small stocks necessary to respond to small fluctuations
2. Normal: Stocks necessary and potential for out-of-stock
3. Normal High Volatility: Largest stocks required, higher likelihood of out-of-stock situation due to wide variation in demand
4. Uniform: Could be anything

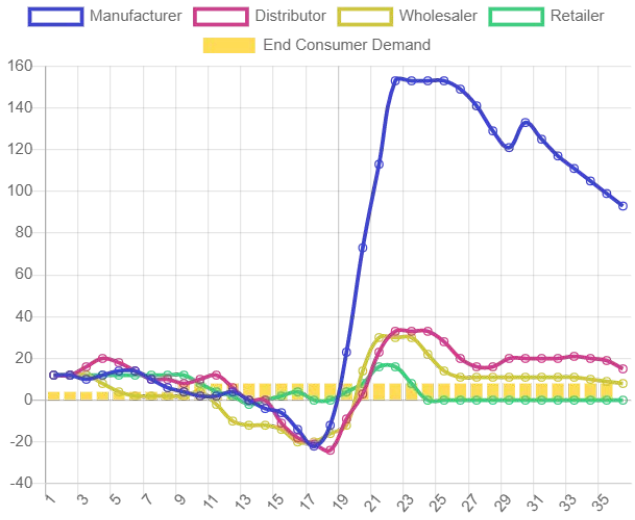
The normal low volatility is going to have the lowest costs, similar to our Game 1 run. The low volatility allows for the greatest prediction of demand, to the point of being a single mean with no variation. Next would be a regular normal distribution. Likewise, the normal high volatility would create the high costs because it's more difficult to predict and many options for its magnitude.

The uniform customer demand (if truly uniform) has higher variability than a normal distribution since it doesn't have a known distribution so is likely to cause issues with the costs since there is no way to model it to know what is coming.

In all scenarios, information from sales and marketing helps forecast demand and adjust orders accordingly. The importance of showing the customer demand in this format versus the time series is that you can get a sense of variation and it is applicable to any scenario, whereas the other format is more useful to determine seasonality or time-based variation.

As you may have realized in the earlier question about mean, the mean (low or high) shouldn't change much about the shape of the graphs but may affect the cost magnitudes only because for instance low mean demand there are less orders at any time in the supply chain. Likewise, high mean with high variability could be completely disastrous for a supply chain to the point of being impossible to manage due to the massive inventory costs.

5. Let’s discuss how to fix the bull-whip effect problem mentioned in the Response to Demand section and often seen in the Stock vs Final Demand graph. The bull-whip effect is where roles alternate between phases of over-stock (above 0) and out of stock (below 0). The amplitude of variations increases as we move up the chain from retailer to manufacturer. We also expect it to increase as we move forward in time, as shown in this example.



a. Which system parameters may have an influence on the Bullwhip effect? Can you imagine changes that would amplify it or eliminate it altogether? Hint: Think both about the beer game and more broadly about real world costs associated with stock and backorder at each role (location, customer-facing).

Longer lead times make supply-chains less reactive to changes of demand. This also increases the tendency to 'secure' stock and order more than needed.

The number of stages in the chain has a negative impact. Each level tries to avoid backorder and secure their own stock, which creates tension in the chain.

Batch sizes and Minimum Order Quantities (MOQ) serve lower prices (thanks to economies of scale). However this greatly reduces the flexibility of the whole supply-chain.

The lack of visibility on each other's stocks/demand make it impossible to anticipate production. When industries master their whole supply-chain's capacity, they can make better stock decisions.

Different costs (inventory and backorder) would certainly influence your strategy and the graphed results. Rather than having a 2:1 cost it could skew you to prefer backorder or stock. You can quickly play an individual version of the game yourself here https://beergame.opexanalytics.com/#/ against 3 AI and change those associated inventory and backorder costs.

Naturally, if backorder costs were higher it would skew the user to having more overstock and vice-versa. This could drastically change the strategy at each role. Also, if you reduced the lead-time, it would allow the orders to better reflect the customer demand, whereas if you increased the lead-time, the orders would barely reflect the downstream customer. You could generate a specific strategy for each of these different setting combinations.

b. Could a different configuration of the Beer supply chain network improve performance? Draw or explain your thoughts.

Reducing the number of stages would be quite beneficial. Some industries choose a 'direct to consumer' strategy, which reduces time-to-market, allows unified IT-systems and access to all the data.

Having alternative sources of supply can reduce risk and improve reactivity. Rather than a linear supply chain, you could easily have a pronged approach.

There might be manufacturers/distributors/wholesalers that cost more but have shorter lead times. The additional product cost might be offset by your ability to react faster to demand and avoid backlogs and overstocks.

A factory having flexible production lines can smooth its productions depending on demand.

In product development, making use of generic components can reduce their variability and obsolescence risk. Industries should try to design products with a late differentiation (ex: using the same bottles for different beer brands).

6. Look at your “Supply Chain Evolution” graph including backorder, stock, order, and cost and the “Stages Evolution” graph that shows each different role’s orders. Remember you can toggle off/on the graph for each role to see the trends more clearly.

Each team will have different variations but certain trends are very typical

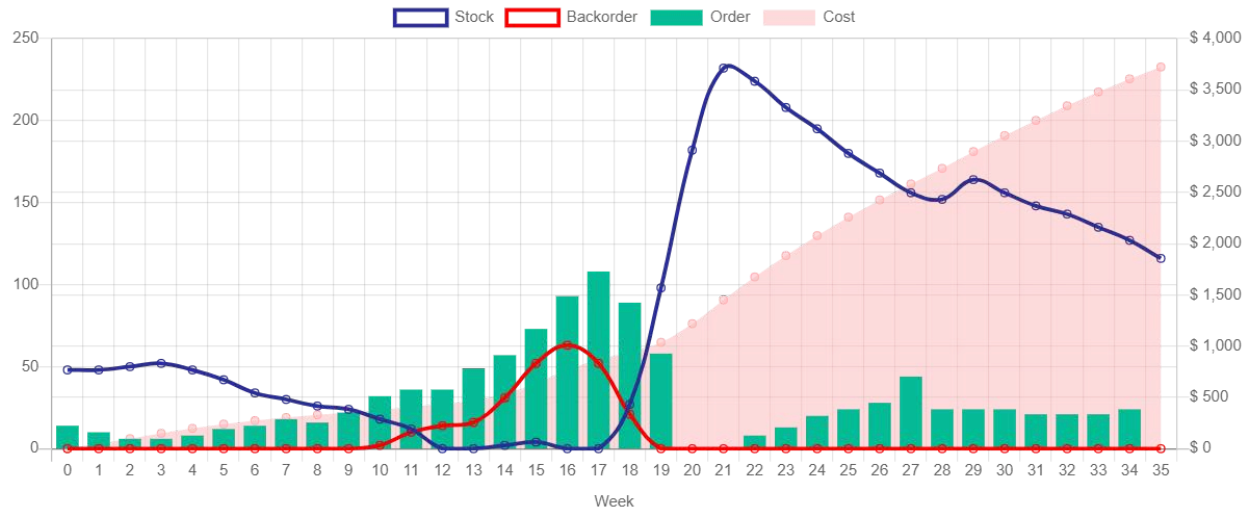
a.

Which week(s) contributed most to the cost? (reminder: the cost shown in the graph is cumulative, not weekly).	Answers will vary by team, but general observations are provided in the solutions below.
Was there a point of no return where due to the lead time it seemed like you couldn’t fix the issue and costs continued to rise?	

Backorders occur when there are decreases in the stock, especially if stock hits zero and is unable to get back up. So since we started with some stock automatically, backorders won't begin till later in the process once those stocks are depleted and not immediately replenished due to the processing time for orders

Stock shortages, which cause backorders, typically follow low order weeks. This can then lead to an increase in ordering to attempt to correct the backlog, but often that action also turns into a spike in cost due to the now large amount of stock. So low orders followed by high backorder, and high orders followed by high stock, are common trends that both contribute to cost spikes.

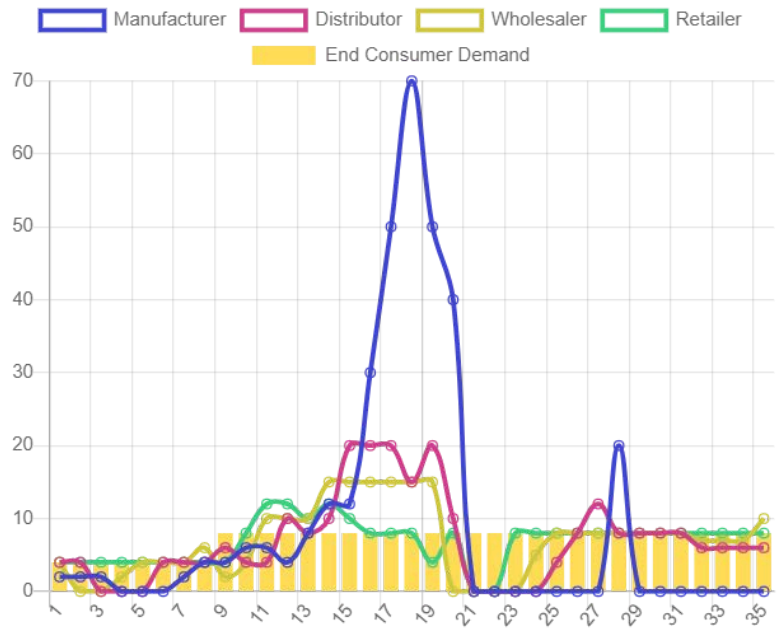
Note if your cost graph is mostly linear or if there were spikes during weeks that got pinched or overbought. In the graph shown here there was clearly a backorder that was then overcompensated for and so our costs initially rose due to backorder and then kept rising due to stock. You can see that the orders did not increase fast enough and there was a delay of those spiking after the backorder spiked. This time lag is present in most people's first attempt at the game.



b. Strategize what different roles will do differently in the second game based on these two graphs. What information could one role share with others to help make the appropriate decision? What cost cutting choices do you want to prioritize?

A common regret is a lack of supplies before the step increases. Better communication throughout the chain will often improve the result since each role will have more information to work with before the orders hit them. You can see in the Order vs Final Demand graph that the retailer's graph matches the closest to the "final consumer demand" graph. The roles further downstream (manufacturer and distributor) have higher variability than the ones upstream (retailer and wholesaler). Downstream rolls frequently place the largest orders as they try to catch up. Communication can bridge this gap.

Both overstock and backlogs add to cost, and even the most practiced supply chain managers can't avoid these costs completely. Trying to minimize either is useful so choosing which one to prioritize generally comes down to how effective you believe your strategy/team will be at one vs the other.



7. (20 minutes) Time to use what you've learned! Use the **Game 2** link from the Google Sheet on Canvas to play again. This time you can communicate and strategize as a team. Try to implement the strategies you discussed above to improve your outcomes.

Remember consumer demand is unpredictable and variable. Don't expect to see the same demand as last time (but the magnitude will still be between 0-20 every week).

Once finished, compare your Game 2 debrief page to Game 1. Were you successful at avoiding the issues that you experienced in Game 1? How do you think you did as a team overall managing the stock and backorder relative to other supply chains?

This will vary for each team, but hopefully everyone saw an improvement with your updated strategies.

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