

Introduction

In past weeks, we have explored the specific types of engineering. From environmental engineering to industrial engineering, each type of engineering has its own unique challenges. However, what is needed for all types of engineering is a quality final product. To do this, there are many required steps. The first step is designing the product, then planning the manufacturing process, and lastly maintaining the supply chain. Each of these three steps has several other small steps that are necessary to ensure the supply chain is running properly. This is where engineering management comes in. *Engineering management* is the practice of ensuring a quality final end product by managing the engineering design process. Engineering managers are involved throughout the whole engineering process, from brainstorming what materials will be used to designing and maintaining the manufacturing process. Once the product is designed and manufactured the *supply chain engineers* get involved. A supply chain engineer's job is to figure out the quickest and most efficient way to manufacture and deliver a product to a consumer. Another aspect of a supply chain engineer's job is cost management.

The Institute of Industrial and Systems Engineers (IISE) gives the following definition of a supply chain:

“Supply chain management (SCM) is the oversight of materials, information, and finances as they move in a process from supplier to manufacturer to wholesaler to retailer to consumer. Supply chain management involves coordinating and integrating these flows both within and among companies. It is said that the ultimate goal of any effective supply chain management system is to reduce inventory (with the assumption that products are available when needed).”

Fundamentally, engineering management is managing a supply chain from the initial idea all the way to manufacturing and delivering the product to consumers.

For more information about supply chain management, see [this video](#)

Northeastern Connections

Faculty Connection



This week we are highlighting [Ozlem Ergun](#), professor in the Mechanical and Industrial Engineering Department and organization advisor for [INFORMS](#)! Mirroring this week's topic, her research focuses on the management of large-scale networks and supply chain design, along with humanitarian logistics and resilience. Her work has been applied in critical systems like transportation, healthcare, and pharmaceuticals. Ergun has worked with numerous social impact organizations including the CDC and FEMA to respond to emergencies around the world. More recently, she has begun college [research initiatives with COVID-19](#). Ergun is partnering with the state's Executive Office of Elder Affairs (EOEA), which helps to match qualified workers to nursing facilities or assisted living centers. Her lab developed an algorithm to optimize matching along with an online portal to coordinate the influx of applicant information, matching it to a list of staffing needs automatically. This is a perfect example of engineering management, since the process requires developing of the algorithm, acquisition of data, and ensuring it is functioning properly and creating appropriate matches. Her team continues to maintain the supply chain by responding to daily urgent requests for facilities and staff, as the demand for workers is rising each hour.

Student Connection



[Nandika Vasanthmurali](#) is a recent graduate with a Bachelors of Technology in Chemical Engineering. Being a chemical engineer, she is familiar with processing methodologies of converting raw materials into finished products. She chose to pursue an additional degree (Masters in Engineering Management) to learn about management leadership techniques and business concepts. Vasanthmurali specializes in Supply Chain Management - she is learning analytical tools and techniques to manage the operation of a company from purchasing raw material to production and delivery of finished goods to the customer. She hopes to work in a pharmaceutical company in the future.

Currently, she is one of the committee members of the Programs Department of Northeastern's [American Society for Engineering Management](#) (ASEM) chapter. ASEM organizes events to bring in industry experts to discuss prominent issues and solutions in manufacturing,

process improvement, supply chain, data analytics. They conduct workshops to help students gain knowledge about the skills, certifications, and software. This academic year, ASEM had a few exciting industry visits to Dell EMC and Boston Harbour to learn about their supply chain strategy and logistics.

In addition, she has participated in events organized by Northeastern's [Supply Chain Management Club](#), which focuses solely on supply chain. They have weekly events covering all sectors of industries ranging from medical, electrical, transportation/logistics and focusing on companies like Johnson & Johnson, Insulet, Bose, UPS, and Raytheon. These clubs have provided a great opportunity to interact with professionals from the US and learn a lot about the US workforce. Being an international student, the whole learning experience at Northeastern University has been exceptionally great as Vasanthmurali gets to work and meet students with such varied backgrounds and experiences on projects and research.

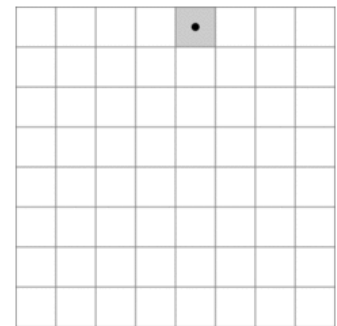
Outside of the classroom, students can become more involved with engineering management and supply chain related organizations, such as [INFORMS](#) and [CoE Graduate Embassadors](#). The Northeastern student chapter of INFORMS provides the opportunity for collaborative learning, professional advancement, and teamwork. Students with various business, engineering, and science backgrounds work with faculty to develop seminars and discussion groups focusing on the methods and applications of Operations Research and Management Science and ways to improve operational processes. Additionally, the Northeastern College of Engineering Grad Student Ambassadors provide prospective and admitted students with a chance to connect and engage with individuals representing different programs and engineering interests.



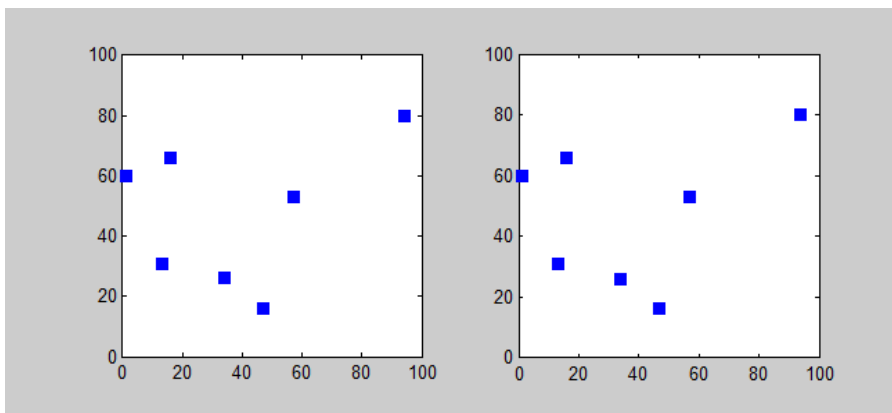
Do Now

Engineering Management often deals with logistics: the flow of things between various points in a system. When you are connecting various points in your system, you usually want to connect points as efficiently as possible, i.e. with the least distance between each point. For example, you might be managing an electrical grid and need to determine the best way to connect different houses with the shortest amount of electrical cables. Or, you might work for Amazon and be tasked with how to efficiently distribute various goods from Northern Kentucky Airport, the primary hub airport for Amazon Air.

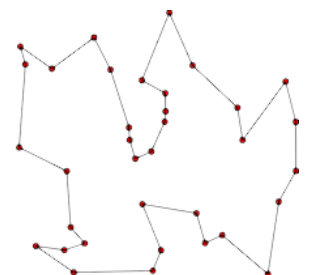
One such way to solve these tasks is by looking at math problems and their solutions. In the Knight's Tour, the Knight, from the game of Chess, must travel to each square exactly once (a solution on right). In the Icosian Game, developed by William Rowan Hamilton, the objective is to find a Hamiltonian path, i.e. a path that visits each point in exactly once. You can try the game [online here \(solution\)](#). There's a variety of ways to solve these problems, although these methods are quite complex and often cannot be simply explained.



One method to solve these problems is via "brute force," i.e. trying every single possibility and selecting the best method. This works well when there are few points in the system, but becomes increasingly time-consuming as the number of points increases. For example, the image below shows a brute force search for the shortest distance between 7 cities.



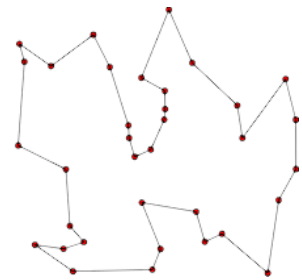
An 8x8 Knight's Tour board has 4×10^{51} possible move sequences, making it (with current computer technology level), impossible to solve. However, the problem can be solved via other methods. One such way to tackle this problem is by "dividing and conquering" - splitting the problem into smaller pieces and then putting it back together again. Another method is to create an



artificial intelligence/neural networks to solve the problem. This is a high-level programming challenge, which is a bit too complex to explain here. If you want to learn more about neural networks, you can watch [this neural network learning how to play Mario Kart](#).

Another math problem applicable to engineering management, particularly supply chains, is the [Traveling salesman problem](#) [TSP], which asks: "Given a list of cities and the distances between each pair of cities, what is the shortest possible route that visits each city and returns to the origin city?" We can use similar problem-solving methods to solve this, such as brute force searches or even modeling an ant colony traveling between its nest and food sources.

For our Do Now activity, we will be tackling a problem similar to the TSP, where we start at a point and travel to a variety of cities. Unlike the TSP, we will not be traveling back to our starting point. The real world equivalent for this problem is a company sending its product to customers in different parts of the country, trying to minimize the cost of transportation (by shortening the total distance traveled).



Objective: Find the shortest possible path (in miles) that visits every city at least once. You must start in Boston, MA, but may end at any city you want. Travel between cities must be in straight line distances, as if you are flying from one point to another. However, you do not need to select the airport in each city, and can instead measure from the placemark dot for that city.

Instructions:

1. Open the problem in Google MyMaps (GMM) ([Link Here](#)). Alternatively, you can use [this KML file](#) to open the problem in Google Earth Pro (GEP) ([free download here](#))
2. GMM: If you aren't already, sign into a Gmail account (top right "Sign In")
3. GMM: Click the three vertical dots at the top of the screen and select "Copy Map"



4. GMM/GEP: In your map, use the ruler tool to measure distances between points. For GMM, double click to end your current path.

Questions:

1. What is the shortest possible path to visit all points? How did you get to your answer?
2. If you could remove one city, which would you remove (goal still to have the shortest path)?
3. If we wanted to start AND end our path in Boston, what would our new best path look like?
4. So far we have been traveling between cities in straight lines (as if we were flying there). If we instead

needed to travel via roads, do you think your sequence (i.e. the order in which you visit each city) would change? Why or why not?

Activity

Root Beer Distribution Game

Overview:

The purpose of this game is to demonstrate the complexity of managing a supply chain. To play the game, players create the game board from the schematic at the end of this newsletter (Use a large table or the floor), which represents the supply chain for root beer. Each player then represents a specific part of the supply chain by placing orders from the previous player in the supply chain to keep their current inventory stocked to supply the next player in the supply chain.



Supplies:

- ~80-100 Coins/Poker chips/Plastic game chips/Cut pieces of paper (These represent root beer cases)
- 4 Players
- 4 pads of sticky notes/slips of paper
- Painters Tape/Masking Tape/Printer Paper
- 4 Pens/Pencils
- 1 6-sided dice or a random number generator app

Objectives:

The overall objective is to meet the consumer demand and spend as little money as possible as a team

Game Terminology:

- **Retailer:** This is the part of the supply chain that directly sells the root beer to the consumer. Examples of a retailer could be a grocery store or convenience store.
- **Wholesaler:** This is the part of the supply chain that sells the root beer to the retailer.
- **Distributor:** This is the part of the supply chain that sells the root beer to the wholesaler.
- **Factory:** This is the part of the supply chain that makes the root beer, and then sells it to the distributor.

- **Raw Materials:** These are the materials (or ingredients) that are required to make the root beer. Examples could include food coloring, sugar, or water.
- **Consumer Demand:** This is the amount of root beer that people want to buy from the retailer. For example, if on one day 10 people enter a grocery store to buy 10 cases of root beer, the consumer demand for that day is 10. If the next day 5 people enter a grocery store to buy 5 cases of root beer, the consumer demand for that day is 5. Demand changes depending on the habits of the consumer.
- **Inventory:** This is the total amount of root beer that each step in the supply chain has available to sell to the next step in the supply chain.
- **Shipping Delay:** Shipping takes time. If a retailer is out of root beer and they need more to meet the consumer demand, they can order more from the wholesaler; however, it will not be instantaneous. Generally, they will have to wait days or even weeks to receive a new shipment. The shipping delay boxes in the game represent this real world factor.
- **Manufacturing Delay:** Just like shipping, manufacturing a product also takes time. If the factory does not have enough root beer to adequately supply the distributor, they can make more, but it will take time. The manufacturing delay boxes in the game represent this factor.
- **Backorder:** A backorder is an order placed by the next step in the supply chain that the current step in the supply chain has insufficient inventory to meet. For example, if the Retailer needs 10 cases of root beer, but the wholesaler only has 8 cases of root beer in their inventory, there is now a backorder of 2 cases of rootbeer ($10 - 2 = 8$). Backorders should be avoided because they are costly.

Setup:

1. Using the game board schematic at the end of this newsletter, create each box using either painters/masking tape or pieces of paper on a large table or on the floor (See example at end of newsletter)
2. Place 12 “root beer cases” each in the Retailer, Wholesaler, Distributor, and Factory Boxes
3. Place 4 “root beer cases” in each of the shipping delay boxes
4. Place the remaining “root beer cases” in the Raw Materials box

5. Take 7 Sticky Notes and write the number “4” on each one. Then place one sticky note (faced down) in the Production Request boxes, and then place one (faced down) in each of the Incoming Orders and Orders Placed boxes
6. Assign each player the role of Retailer, Wholesaler, Distributor, or Factory (Each player should be seated in front of their respective inventory boxes).

Instructions:

The game consists of 20 “turns.” After each turn, each player will document their inventory, backorders, and orders placed. Once the game is finished, these values will be used to generate a final cost. The team’s goal is to minimize the final cost!

Playing a “Turn”:

1. The Retailer rolls the dice. They then slide the number of root beer cases (determined by the dice roll) to the orders sold to customers box.
2. Each player then slides all of the root beer cases in each shipping delay and production delay boxes one box over (following the arrows).
3. The Wholesaler, Distributor, and Factory look at the sticky note in their incoming orders box, and slide the needed amount of root beer cases from their inventory box to the next shipping delay box
4. The Wholesaler, Distributor, and Factory then slide the sticky note in their orders placed box to their incoming orders box.
5. The factory checks their production requests box, and slides the needed amount of root beer cases from the raw materials box to their first production delay box.
6. The Retailer, Wholesaler, and Distributor then write down the number of root beer cases they would like to order for their inventory on a sticky note (without showing any of the other players) and then place it face-down in their orders placed box. CHOOSE THIS NUMBER WISELY! Remember that you want to have enough root beer to meet the need of the next level up in the supply chain, but do not want to create backorders from the level in the supply chain below you!
7. On the worksheet, fill out the number of root beer cases in your inventory, the number of backorders you have (if you are the wholesaler and the retailer ordered 10 cases, but

you only had 8, you would have a backorder of 2 ($10 - 8 = 2$), and the number of cases you ordered from the next lower step in the supply chain.

8. Repeat steps 1-7 20 times (each turn represents a week)
9. Use the worksheet to add up total costs for each player
10. Once the game is finished, add up the total costs from each player to get a final team cost

Scoring Backorders: If you end up with a back order for one turn, you must attempt to fulfill the backorder on the next turn. For instance, let's say you have a backorder of 2 at the end of one turn. For the next turn, if the player above you in the supply chain orders 10 cases, you will need to try to supply 12 cases ($10 + 2 = 12$). If you have 12 cases during this turn in your inventory, then you can fulfill the order and the backorder, which would bring your backorder at the end of that turn to 0. If you only have 5 cases, then your backorder would grow to 7.

[Here is a helpful video explaining each step of the game](#)

(NOTE: A dice is used in our version of the game, instead of “weekly order cards.”)

Share Your Results

We'd love to know how the activity and/or the “do now” turned out! What worked and what didn't work? Please share with us something you learned and/or send us pictures of your shortest path! Email us at stem@northeastern.edu.

Related links/Extensions

- [Supply Chain Example: Coca Cola](#)
- [Supply Chain Example: Lemonade Stand](#)
- [How the Supply Chain Saves Lives](#)
- Games on Engineering Management/Supply Chain
 - [Production Line](#)
 - [The Project Management Game](#)
 - [Supply Chain Management Game](#)
- [Covid-19: Why Are Supply Chains Breaking Down: Interview with NU Professor](#)
- [America Revealed, Food Nation](#)
- [Resilient Food Systems](#)
- [Extension Activity: Research a Supply Chain](#)



Team Name (Root Beer Brand): _____

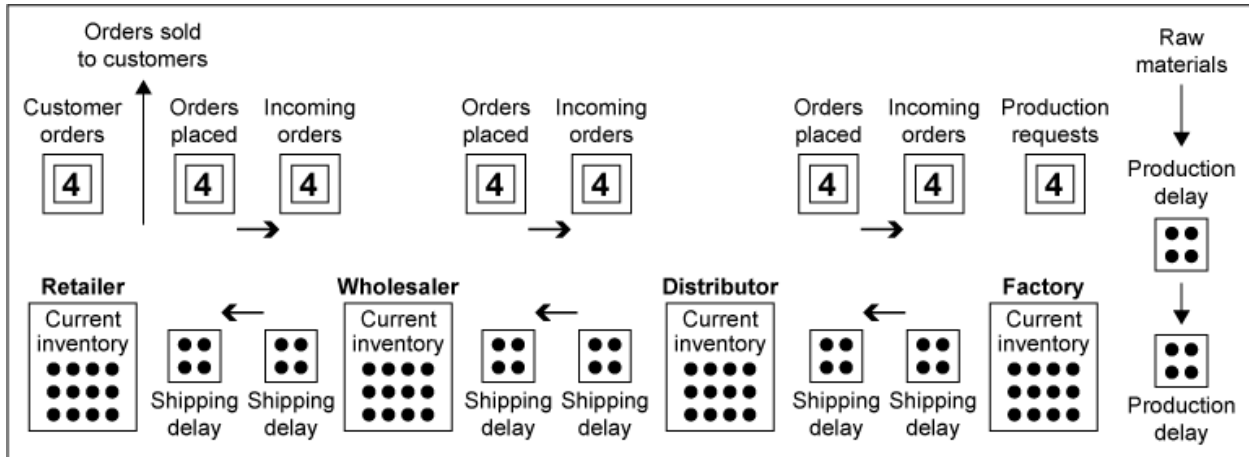
Position: Retailer Wholesaler Distributor Factory

Week	Inventory	Backorders	Order Placed (Factory: Production Requests)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

SUM: Inventory: _____ Backorders: _____

Total Inventory x \$0.50 + Total Backorders x \$1.00 = Total Cost \$_____

Root Beer Distribution Game: Game Board Schematic



Homemade Root Beer Distribution Game Board Made with Notebook Paper

