Effectively Teaching Supply Chain Logistics

By way of the anyLogistix simulator

Ed Lindoo, Ph.D.
3333 Regis Blvd.
Denver, CO 80221-1099
303-964-6358
elindoo@regis.edu

Abstract

Supply chains involve complex, multi-tiered networks of suppliers, manufacturers, distributors, and retailers. In fact, these supply chains are networks where organizations collaborate to convert raw materials into finished products and deliver them to customers. Effective supply chain management (SCM) integrates material, information, and financial flows, optimizing resources from suppliers to customers. Strategic decisions in SCM include locating distribution centers and designing service networks, while tactical issues cover inventory and transportation planning. Operative concerns address production scheduling and vehicle routing. Distribution and logistics management are vital in fulfilling customer demands, managing inventory, and controlling shipments. Distribution centers consolidate products for efficient dispatch to final destinations and can be self-managed or operated by third-party logistics providers.

The costs of building and operating distribution centers vary widely, influenced by factors like size and location. To enhance SCM education, tools like anyLogistix enable students to simulate and analyze supply chain dynamics, focusing on key performance indicators (KPIs) to measure operational, customer, and financial performance. Simulation, combined with optimization, offers powerful insights into supply chain design and management, addressing the need for experiential learning in SCM. In this paper we present the complexities of teaching supply chain logistics and how the anyLogistix free simulator can be used in the classroom to facilitate this.

Keywords: *Supply-chain management, anyLogistix, Sustainability, Teaching Supply-chain Logistics, Supply-chain capabilities.*

Introduction

When we think of supply chains, we often envision the end-to-end process involving tier 1, tier 2, and tier 3 suppliers. However, this perspective overlooks the intricate details involved in creating and maintaining a supply chain. Whether we aim to teach these complexities in a specialized supply chain course or provide an overview in a Management Information Systems (MIS) or management course, having a tool to assist professors would be beneficial. Before delving into such tools, let's first discuss the general concept of supply chains.

Ivanov (2024) describes a supply chain as "a network of organizations and processes where enterprises, including suppliers, manufacturers, distributors, and retailers, cooperate and coordinate along the value chain." This collaboration is essential for acquiring raw materials, converting them into products, and delivering these products to customers. Supply chain management (SCM) evolution requires the integration and coordination of material, information, and financial flows across departments and enterprises. The aim is to utilize supply chain resources most efficiently along the value chain, from raw material suppliers to customers. Supply chain management (SCM) integrates production and logistics processes at various levels to achieve this goal.

Strategic issues encompass decision making in the form of size and location of distribution centers or manufacturing plants, the structure of service networks, and the overall design of the supply chain. On the other hand, tactical issues involve inventory planning, transportation and production while operative issues address vehicle routing, production scheduling and control, as well as inventory control. (Ivanov, 2024).

In the realm of supply chain management, the roles of distribution and logistics management are crucial. Experts in this field are instrumental in meeting customer demands, handling inventory orders, managing the flow of incoming and outgoing shipments, cutting costs, optimizing time, and achieving organizational goals. Distribution is a primary logistics activity that significantly influences business competitiveness. The main logistics concern is the efficient transfer of goods from the manufacturer to the point of consumption in a cost-effective manner while providing acceptable service to the consumer (Sutapa, Wuller, & Cahyono, 2020).

What Are Distribution Centers?

Distribution centers function as hubs where companies consolidate large volumes of diverse products into a single location. From there, warehouse and distribution teams dispatch orders in smaller quantities to nearby destinations. These shipments might include Less-Than-Truckload (LTL) or Full-Truckload (FTL) loads, or they might involve individual trucks. For instance, a grocery store chain may utilize a local distribution center where large shipments of cereal and frozen waffles are received. The teams at this central location process the inbound inventory, store it, and eventually send out smaller quantities of each SKU, along with other items like bread and granola bars, to stock the breakfast aisles of individual stores (Whiting, 2023).

Luther (2022) highlighted that distribution centers are logistics facilities where finished goods are stored prior to being picked and packed to fulfill customer orders. Distribution centers can be viewed as specialized, strategically located warehouses that are essential in the supply chain, fulfilling customer needs.

Distribution centers can be operated and managed in several ways based on a company's needs and organizational structure. While some retailers opt to construct and oversee their own distribution facilities, others choose to collaborate with third-party logistics (3PL) providers. According to Luther (2022), certain businesses even center their entire operations around functioning as specialized distribution hubs, catering to other companies, such as wholesale food distributors serving restaurants and the hospitality industry.

Hydraroll (2023) explains that a distribution center functions differently from a warehouse, although the terms are sometimes used interchangeably. While a warehouse stores products for extended periods, a distribution center typically holds items for a shorter duration and experiences a higher turnover rate. Distribution centers are often located near the end customer to ensure quick and efficient delivery. These centers offer additional services such as picking and packing, packaging, and product mixing. Because they provide more services than standard warehouses, distribution centers rely heavily on advanced technology to manage their operations efficiently.

Alexander (2018) explains that distribution structures involve the spatial organization of freight transport and storage systems used to move goods from production to consumption locations. These layout decisions are vital for companies as they strike a balance between maintaining high customer service standards and managing logistics costs effectively. With globalization, new international trade and transport flows have emerged, creating significant logistics challenges in managing long-distance movements. To ensure products reach the right location, at the right time, in the right condition, and at the right price, companies like shippers and Logistics Service Providers (LSPs) must develop effective distribution structures. This often involves optimizing the use of transport and distribution centers. Goods can be distributed directly to customers or through one or more intermediate storage points. Centralized structures may include a single distribution center (DC) location.

Yang and Sheng (2023) emphasized that the primary role of a distribution center within a logistics system is to allocate goods based on customer demands. Acting as an intermediary between suppliers and customers, the distribution center's location significantly influences the distribution distance and logistics mode, thereby impacting the system's operational efficiency. Furthermore, once established, the location of a logistics center is typically fixed and challenging to alter.

Luther (2022) explained that in any industry, suppliers or manufacturers typically send their products directly to distribution centers, where they are received and stored. When a customer order is placed, employees handle the fulfillment process by picking, packing, and shipping the appropriate items. An alternative method is cross-docking, where fast-moving inbound freight is immediately transferred to outbound docks, bypassing storage and speeding up delivery. Nike exemplifies this approach with over 50 distribution centers worldwide, allowing the company to sell directly to consumers, wholesalers, and retailers. In the U.S., Nike's largest distribution center is a 2.8 million-square-foot facility in Tennessee, featuring 33 miles of conveyor belts, 73 outbound doors, and 96 receiving spurs.

Opening a distribution center can be expensive initially, but the long-term benefits often surpass the upfront costs. Distribution centers are designed to optimize efficiency in receiving, storing, packing, and distributing goods. This efficiency translates to lower inventory carrying costs, reduced risk of stockouts, and improved customer satisfaction due to quicker fulfillment times. However, the costs associated with building and operating a distribution center vary, especially depending on whether a company runs its own center or uses a third-party service.

The cost of constructing a distribution center varies based on factors like its size, location, and type of building. For example, building a facility in states like California or New York is generally more expensive compared to Alabama. Large corporations with significant distribution needs might invest millions solely in construction. Other expenses include permits, planning, materials, engineering, security systems, legal fees, and taxes. Operating costs involve expenses related to handling products, including labor and equipment for receiving, storing, picking, and shipping, as well as fuel and electricity for operating this equipment. Maintenance costs are also significant. Storage costs cover inventory carrying expenses, administrative costs like clerical and IT-related expenses, supplies, insurance, office expenses, general management, and variable labor costs (Luther, 2022).

Wang and Zhang's research indicates that over 60% of companies use big data to optimize picking routes and automate replenishment. Traditional analysis methods fall short in supporting rapid decision-making. This highlights the effectiveness of big data technology in enhancing decision-making processes and driving significant improvements in supply chain logistics services (Wang and Zhang, 2022).

Teaching Supply Chain Management:

Angolia and Pagliari (2018) discovered that employers expect new hires to understand organizational functions and possess basic knowledge of business processes and technology. Their research highlighted a gap in student learning outcomes, showing a lack of awareness and expertise in SCM technologies and software. They also noted that students often struggle with real-world situations requiring multidisciplinary understanding. An integrated enterprise software curriculum, which exposes students to the interdependencies of internal business systems and processes, can address this gap. This underscores the need for both theoretical knowledge and practical skills in complex systems like logistics and SCM. This paper argues that including commercial software as a key component of skills-based learning outcomes better prepares graduates for industry roles. Effective pedagogy combining foundational principles with experiential learning enhances graduates' readiness for the workforce.

Angolia and Pagliari (2018) observed that logistics courses in higher education have shifted from a narrow focus on transportation to a broader, process-oriented approach that integrates the management of materials, finances, and information. Today, a successful logistics system is characterized not just by minimal costs but by overall cost-effectiveness, ensuring inventory availability at the right time and place to meet customer demands. While textbooks and case studies provide foundational knowledge through lectures, they fall short in illustrating the strategic, overarching aspects of logistics and supply chain management (SCM). With SCM becoming a critical corporate function in the 1990s, there has been an increasing demand for experiential learning in the classroom to better engage students and cater to various learning styles.

Liu (2017) found that providing motivational instruction to maintain student interest and enhance learning effectiveness is challenging. Traditional education methods often rely on textbooks, handouts, and slides. However, for practical fields like supply chain and logistics management, these conventional approaches may be less effective, as traditional lectures can be disengaging for both newcomers and experienced employees. These methods often fail to cover practical materials and do not sufficiently stimulate students' desire to learn, resulting in lower learning efficacy. To address these issues, integrating gaming with education has emerged as a valuable supplement for logistics education.

Where do we start with teaching this?

We could start with a list of cities and coordinates (Lat/Long) and then use some crazy formula as provided by Yang and Sheng (2023).

Longitude and latitude coordinates of provincial capital city

No.	City	(U_i°N , V_i°E)
1	Beijing	(39.905°, 116.405°)
2	Tianjin	(39.126°, 117.190°)
3	Shijiazhuang	(38.045°, 114.502°)
4	Taiyuan	(37.857°, 112.549°)
5	Hohhot	(40.841°, 111.752°)
6	Shenyang	(41.797°, 123.429°)
7	Changchun	(43.887°, 125.325°)
8	Harbin	(45.757°, 126.642°)
9	Shanghai	(31.232°, 121.473°)
10	Nanjing	(32.042°, 118.767°)
11	Hangzhou	(30.287°, 120.154°)
12	Hefei	(31.861°, 117.283°)
13	Fuzhou	(26.075°, 119.306°)
14	Nanchang	(28.676°, 115.892°)
15	Jinan	(36.676°, 117.001°)
16	Zhengzhou	(34.758°, 113.665°)
17	Wuhan	(30.584°, 114.299°)
18	Changsha	(28.194°, 112.982°)
19	Guangzhou	(23.125°, 113.281°)
20	Nanning	(22.824°, 108.320°)
21	Haikou	(20.044°, 110.200°)
22	Chongqing	(29.533°, 106.505°)
23	Chengdu	(30.659°, 104.066°)
24	Guiyang	(26.578°, 106.713°)
25	Kunming	(25.041°, 102.712°)
26	Lhasa	(29.644°, 91.115°)
27	Xi'an	(34.263°, 108.948°)
28	Lanzhou	(36.061°, 103.834°)
29	Xining	(36.617°, 101.778°)
30	Yinchuan	(38.486°, 106.232°)
31	Urumqi	(43.827°, 87.617°)

Yang and Sheng (2023).

$$\begin{aligned}\Delta_\delta &= \frac{1}{\Lambda_\delta}\\ \Lambda_\delta &= \sum_{i\in N}\sum_{j\in M_i} E\left[\omega_i\right]\cdot f\left(d_{ij}+E[\eta_{ij}]\right)\cdot \mu_{ij}\\ &\quad - \sum_{i\in N}\sum_{j\in M_i} E\left[F_{ij}\right]\\ &\quad - M\sum_{i\in N}\min\left\{\left(\sum_{j\in M_i}\mu_{ij}\right)-1, 0\right\}\end{aligned} \tag{13}$$

Yang and Sheng (2023).

But we'll probably lose half to three-fourths of the class. Instead, we'll take another approach.

We can begin by discussing the Centre of Gravity (CoG) technique, which is used to determine the optimal location for a distribution point to minimize distribution costs. According to Sutapa (2020), the primary goal of this method is to identify a location that is cost-efficient for moving goods or services from existing points. The initial step in finding the CoG involves determining the total demand in each region. The CoG calculation is then performed for each resulting cluster.

Agglomerative Hierarchical Clustering (AHC) is a hierarchical clustering method that starts with individual data points as single clusters and repeatedly merges the two closest clusters until all points are clustered. AHC includes three techniques: single linkage (min), complete linkage (max), and group average. In this study, single linkage is chosen because it merges clusters based on the minimum distance between two different clusters, making it effective for minimizing distribution costs.

Blok (2019) highlighted that operating costs are a major concern in logistics, with transportation costs being a significant contributor. These transportation costs consist of both fixed and variable components, where the variable costs fluctuate based on the distance traveled. To illustrate this concept in a classroom setting, a professor might present the following assignment to students:

"Locate the delivery locations on a map and look up the expected shipping volume to each location. The shipping volume can be of units of your choice. If you're doing deliveries of the same materials to each you can simply use unit volume. If the loads vary in size you may want to use total weight shipped or the sum of units x weight over all shipments." (Block, 2019).

*"Using a grid assign an X and Y coordinate to each location. Calculate the sums for Total Shipments, X value **

*Shipments for each location, Y value * Shipments for each location, The X value for the Center Point = Sum(X value * Shipments) / Sum of Shipments, In this example 435,000 / 66,000. 5. The Y value for the Center Point = Sum(Y value * Shipments) / Sum of all Shipments here 590,000 / 66,000*" (Block, 2019).

This surely will prove challenging. Instead, let's explore the use of simulation in supply chain management (SCM) education. Ivanov (2024) explained that SCM courses are often enhanced by decision-support software like anyLogistix to demonstrate the application of quantitative methods in practice. Universities can integrate the anyLogistix simulator into their SCM, operations, and logistics courses. anyLogistix is a user-friendly tool designed for both students and professionals to address a wide range of SCM challenges. By minimizing technical complexity, anyLogistix enables students to concentrate on management decision analysis and utilize key performance indicators (KPIs) to measure and make decisions based on operational, customer, and financial performance.

When we think of supply chains, we must consider several critical elements:

- Facility Location Planning
- Center-of-Gravity Method for Single and Multiple Locations
- Network Optimization using Mixed-Linear Programming
- Capacity Planning of Distribution Centers
- Inventory Control Policies and Ordering Rules
- Sourcing Policies (Single and Multiple Sourcing)
- Transportation Policies (Full Truckload/FTL and Less-Than-Load/LTL)
- Batching in Transportation, Production, and Sales
- Bullwhip Effect and Ripple Effect Analysis in the Supply Chain (Ivanov, 2024)

But we must also consider:

- Optimal Locations: Where are the best locations for our warehouses, distribution centers, and production sites?
- Replenishment, Sourcing, and Transportation Policies: What are the best policies for replenishment, sourcing, and transportation?
- Supply Chain Robustness: How robust is our supply chain?
- Inventory Policy Changes: What will happen if we change our inventory policy?
- Distribution Center Capacity: What will happen if we increase a distribution center's capacity?
- Demand Fluctuations: What will happen if demand changes?
- Product Line Expansion: What will happen if we add a new product?
- Out-of-Stock Costs: What does an out-of-stock event cost? (Ivanov, 2024)

As Ivanov (2024) explained, optimization aims to find the best solution for operations or supply chain problems by representing choices as decision variables and seeking values that maximize or minimize objective functions within given constraints. This method determines the optimal solution by considering various limits on decision choices. An optimization model consists of three main components:

an objective function, a constraint system, and a set of decision variables and input parameters.

Ivanov (2024) highlights a significant drawback of optimization: the challenge of developing models that are detailed enough to capture complexity and uncertainty, yet simple enough to solve. Most optimization models are deterministic and static, while supply chain and operations problems are inherently dynamic, with interdependent parameters and variables that resist simplification.

In contrast, simulation mimics the dynamic behavior of one system using another. By altering the parameters of the simulated supply chain, you can gain insights into the real supply chain's dynamics. Instead of deriving a mathematical solution, simulation allows for experimentation with system parameters to observe outcomes. Additionally, simulation offers the advantage of visualizing processes and structures.

However, since simulation relies on the "what happens if...?" approach, it raises concerns about the extremity, completeness, and consistency of its results. Despite these challenges, simulation remains a powerful tool for evaluating the performance of supply chain designs created using optimization models. Combining optimization with simulation offers a promising method for assisting supply chain and operations managers, and it can also be highly effective in educational settings.

There is a generalized concern about meeting customer demand, especially as it becomes characterized by highly personalized products and shorter delivery times. To address this, Andres (2024) argues that both academics and practitioners should focus on optimizing the logistics system by making it more reliable, flexible, agile, and resilient to unforeseen natural disasters and man-made catastrophes.

To achieve this, logistics must evolve to incorporate new solutions aligned with the industry 5.0 trend, which emphasizes increased human interaction, enhanced supply chain resilience, and sustainable principles. This evolution involves the application of emerging technologies that can capture and process vast amounts of data, enabling informed decision-making and responsive actions. These advancements are crucial for the successful adoption of Industry 5.0 in logistics.

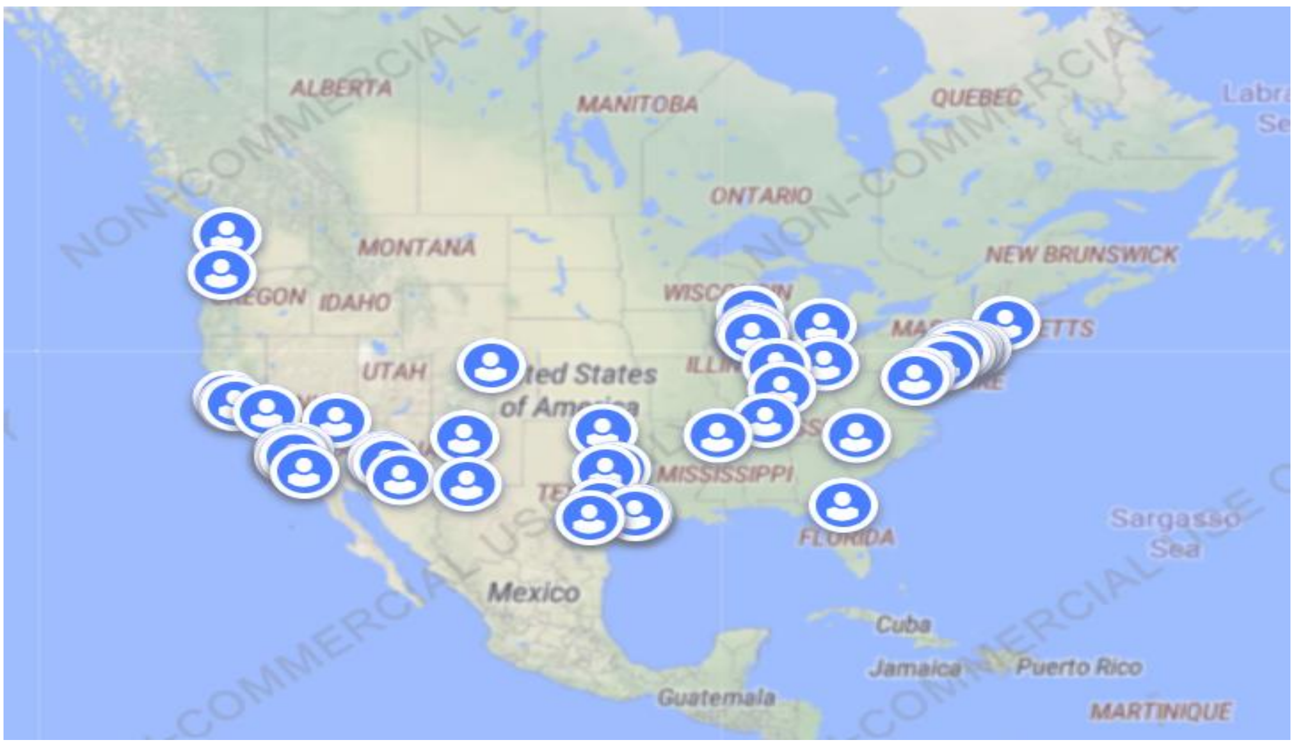
Using anyLogistix in the classroom

We won't go into details here as to how to install the software, however it's very straightforward and will work on a PC or MAC. By going to https://www.anylogistix.com/ you can download and use for free the simulator which comes with a very detailed book by Dr. Dmitry Ivanov along with examples and exercises. One of the first exercises we can try a Greenfield analysis (GFA).

Within the exercise we are provided a table of 52 customers:

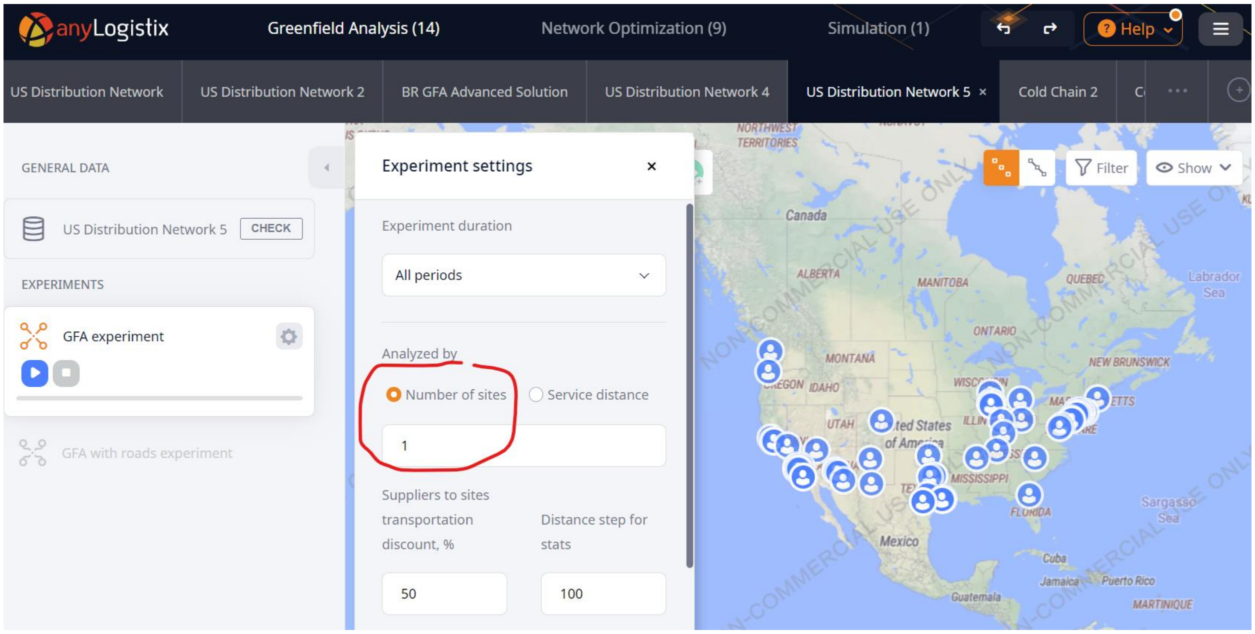
Table 1: Customer demand **Customer**	**Product**	**Parameters**	**Expected lead time**
New York City 1	Lighting	Quantity=8.0;Period, days=5.0;	30
Philadelphia 2	Gardening equipment	Quantity=20.0;Period, days=5.0;	30
Dallas 1	Large home appliances	Quantity=12.0;Period, days=5.0;	30

Here we show only 3 customers to consolidate space while providing a view of the table. There are a number of other parameters that are built into an import file. After importing we can visually see where these customers are located:



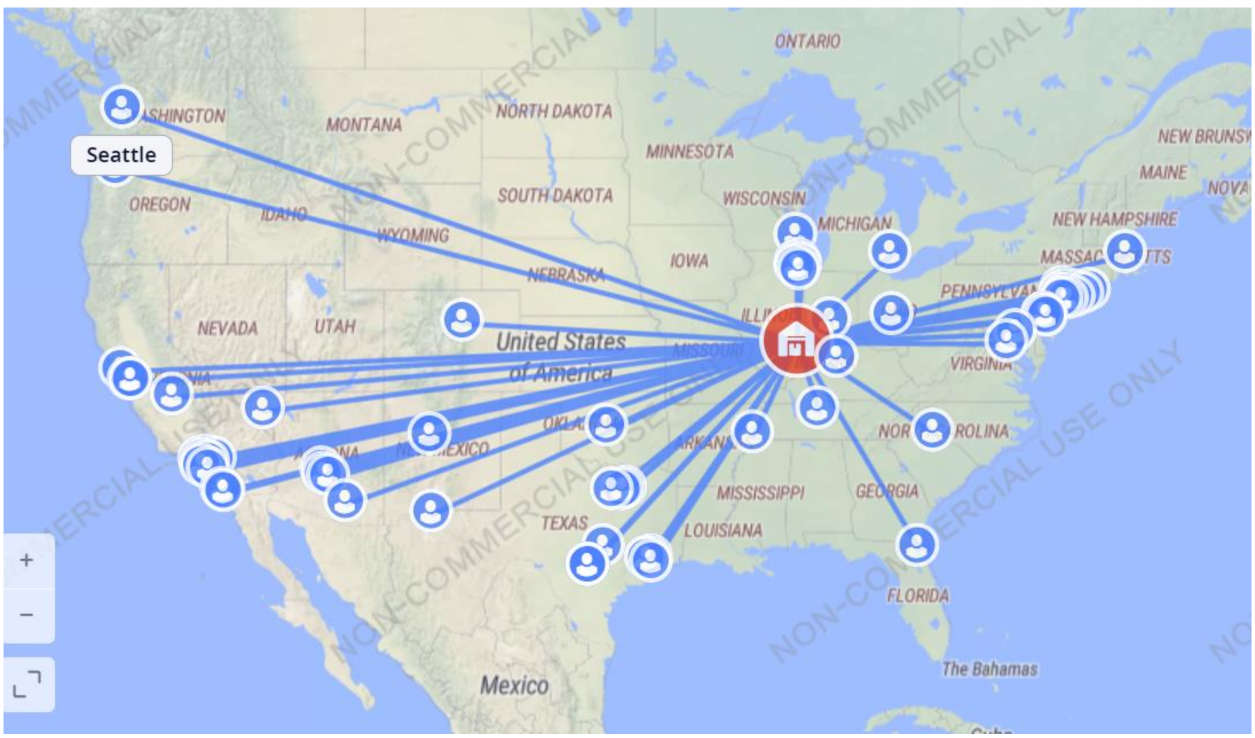
These "customers" are not the typical consumer, instead they are wholesales who will be selling to their local consumers. The question now posed is "where do we put DCs and how many to best optimize profits?"

We can now run a number of green field analysis to determine the answer to this question. Let's start with just one DC.



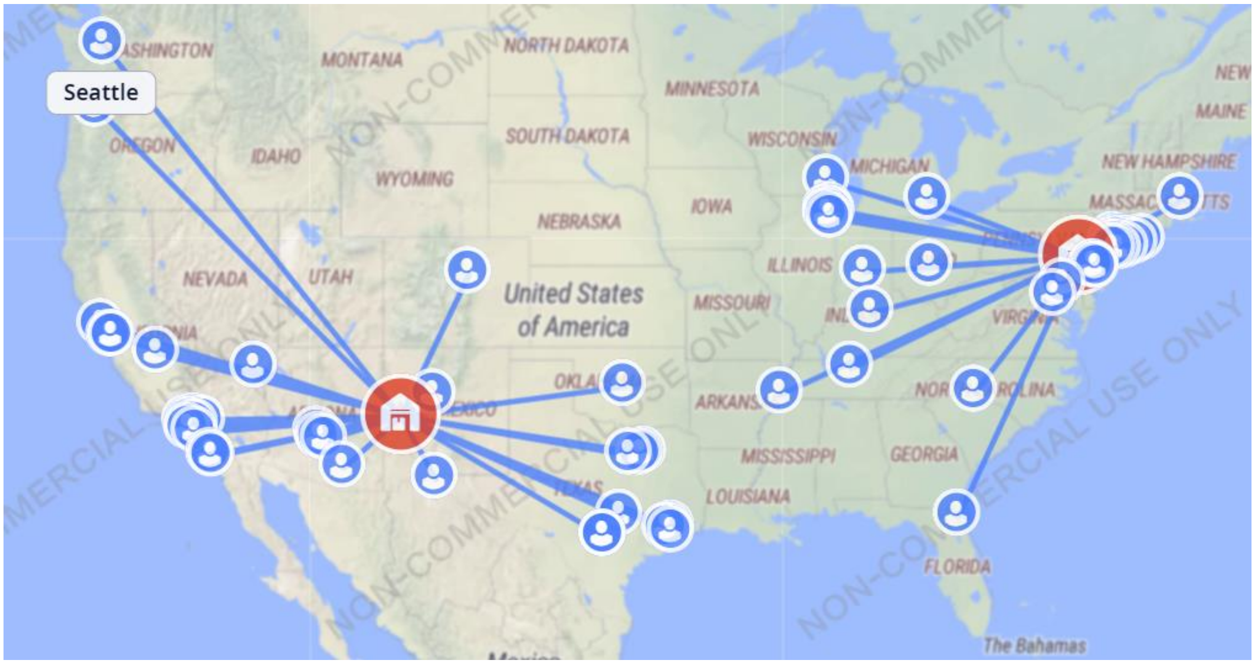
We simply set number of sites to one and run the experiment.

No doubt it would be somewhere in the middle of the country.



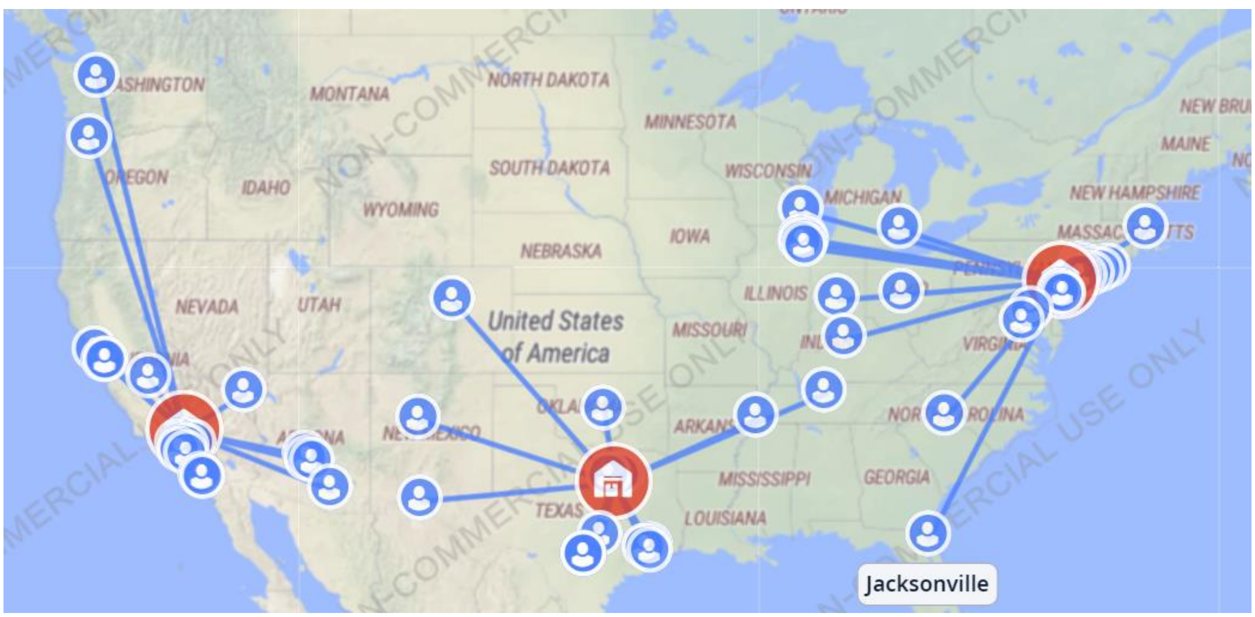
Visually we can see that some of the distances from the DC to the customer are quite long. Obviously this will mean increased costs. But what are our overall costs for this scenario given the parameters and demand of these 52 customers? We can easily go to the Product Flows table and add up the flow costs, in this case one DC with these customers costs $98,816,750.

OK, but what if we were to put in 2 DC's? Let's rerun the experiment with these parameters. DC locations have shifted dramatically:



The flow cost of this 2 DC scenario is at $52,994,085 which is a significant reduction in costs. Even if we consider $15 million per year to maintain a DC, there is still quite a saving. But let's move on and try 3 DCs.

Again, cost has been reduced to just $36,011,956

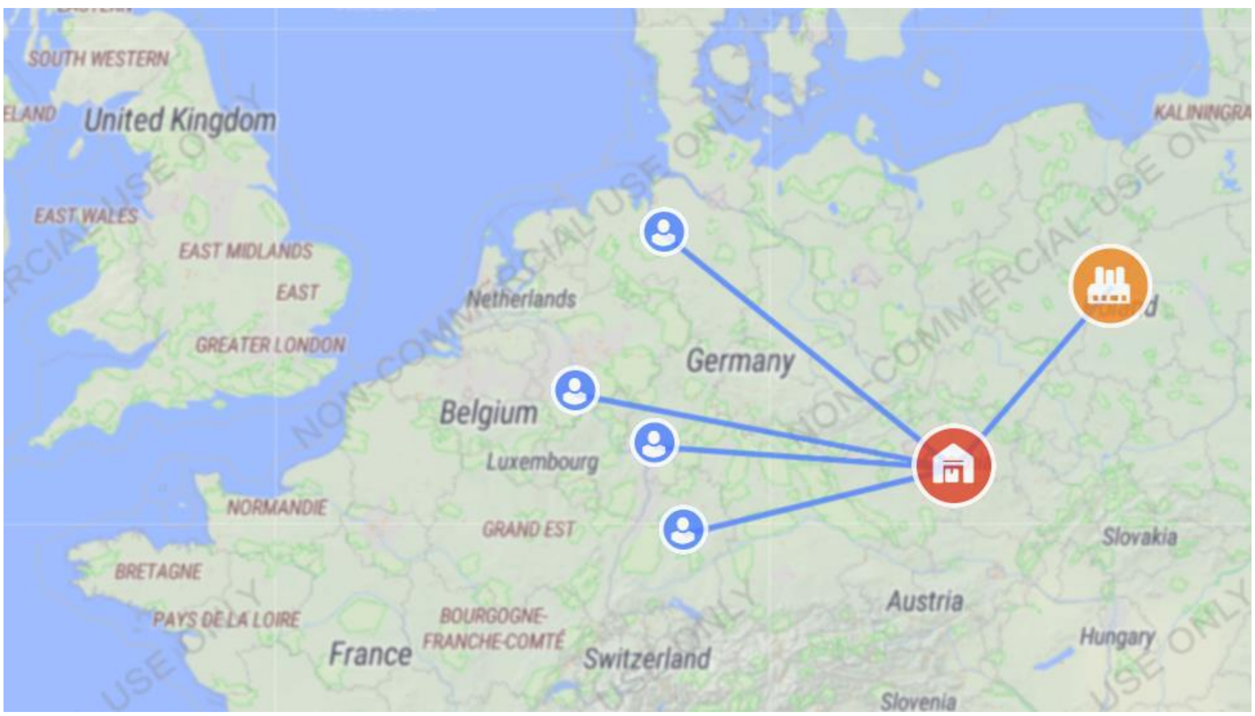


Taking it one step further, we try 4 DCs which reduces our overall costs to $25,323,416 but when we factor in the $15 million per year to maintain a DC, in the end we have found that a 3 DC scenario in this case is the best option. Overall, this is a fun yet somewhat challenging assignment for students who have never been exposed to supply chain logistics.

Let’s try another experiment, this time with Network Optimization (NO). With a production facility established in Nuremberg Germany producing 250 bikes each day, the Polarbear bike company recently received an offer from a Polish production factory to rent a DC in the Czech Republic at a reasonable price. The same company also wants to offer them rental of a factory in Warsaw, Poland, even though they already have one factory in Germany. Polarbear must now decide which SC design is more profitable:

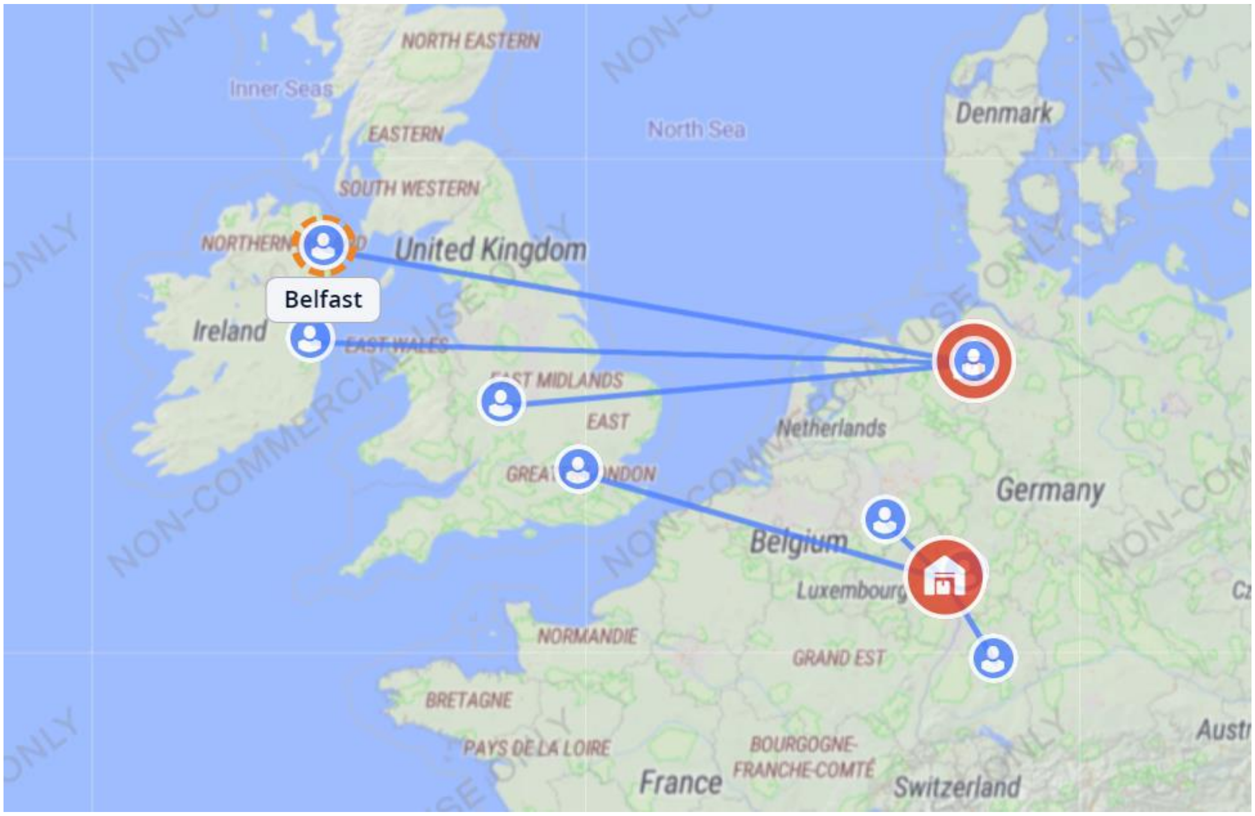
- Option 1: DC in Germany and Factory in Germany
- Option 2: DC in Germany and Factory in Poland
- Option 3: DC in Czech Republic and Factory in Poland
- Option 4: DC in Czech Republic and Factory in Germany

anylogistix can help us figure this out. To define the two-stage NO problem (transport between factories and DCs and between DCs and customers) from a mathematical perspective, several parameters must be input as data. Sample data has been provided by anylogistix for this experiment so there is nothing for us to add. We now import the data file and run Network Optimization Experiment and run it with the Demand variation type “95-100%”.



We can see that the Factory in Poland and DC in Czech Republic is our best option. We can also drill down to find that total revenue in this configuration is $44,500,820 and that total profit is $26,256,744. Now we can throw the students a bit of a curveball by telling them that we have just gained access to the UK and Ireland with four new customers in London, Birmingham, Dublin and Belfast. How does this change our supply chain for best optimization?

We can see that with 2 DCs, our cost flows are $10,463,388 but with only 1 DC those flows increase to $18,610,897. Keeping in mind that DCs cost $15 million per year to maintain it would cost $33,610,897 per year for one DC versus $40,463,388 with a supply chain of two DCs. We have only touched the surface of what the anylogistix simulator can do but this is a demonstration of how it used in a number of our courses.



Conclusion

Our research demonstrates that supply chains are complex, multi-tiered networks involving suppliers, manufacturers, distributors, and retailers. These networks facilitate collaboration among organizations to convert raw materials into finished products and deliver them to customers. Effective supply chain management (SCM) integrates material, information, and financial flows, optimizing resources throughout the value chain. Strategic decisions in SCM involve locating distribution centers and designing service networks, while tactical issues encompass inventory and transportation planning. Operational concerns include production scheduling and vehicle routing. Distribution and logistics management are crucial for meeting customer demands, managing inventory, and controlling shipments. Distribution centers, which consolidate products for efficient dispatch to final destinations, can be self-managed or operated by third-party logistics providers.

Given the complexities of supply chains, particularly in logistics, we recommend incorporating the anyLogistix simulator in SCM or related courses. This tool enables students to simulate and analyze supply chain dynamics, focusing on key performance indicators (KPIs) to measure operational, customer, and financial performance. By combining simulation with optimization, anyLogistix provides valuable insights into supply chain design and management, fulfilling the need for experiential learning in SCM.

References

Alexander T., C. Onstein & Lóránt A. Tavasszy, & Dick A. van Damme. Factors determining distribution structure decisions in logistics: a literature review and research agenda. Pages 243-260. Published online: 06 Apr 2018 https://doi.org/10.1080/01441647.2018.1459929

Angolia, M., Pagliari, L. (2018), Experiential learning for logistics and supply chain management using an SAP ERP software simulation. Decision Sciences Journal of Innovative Education, Volume 16 Number 2, April 2018

Andres, B., and Diaz-Madronero, M., and Soares, A., and Poler, R. (2024) Enabling technologies to support supply chain logistics 5.0, IEEE Access 28 March 2024.

Blok, P. (2019), Center of gravity technique for locating a distribution center. https://ofienterprises.com/center-of-gravity-technique-for-locating-a-distribution-center/

Hydraroll, J. (2023). A Complete guide to warehouse logistics. https://www.joloda.com/news/a-complete-guide-to-warehouse-logistics/

Ivanov D. (2024). Supply chain simulation and optimization with anyLogistix. 6th, updated edition, Berlin School of Economics and Law. https://www.anylogistix.com/

Liu, C. (2017) Using a video game to teach supply chain and logistics management, Interactive Learning Environments, 25:8, https://doi.org/10.1080/10494820.2016.1242503

Luther, D. (2022). Distribution centers explained. https://www.netsuite.com/portal/resource/articles/inventory-management/distribution-centers.shtml

Sutapa, N., Wullur, M, and Cahyono, T. (2020) Determining the number and Location of warehouses to minimize logistics costs of business to consumer (B2C) distribution, https://doi.org/10.1051/shsconf/20207601012

Wang, X., and Zhang, D. (2022) Research on the impact of Big Data on the development of supply chain logistics management, https://doi.org/10.1051/e3sconf/202125101039

Whiting, G. (2023). How distribution centers work for today's supply chains. Red Stag Fulfillment, Knoxville, TN. https://redstagfulfillment.com/how-distribution-centers-work/

Yang, Y. and Sheng. Y. (2023). Location problem of logistics center under uncertain environment. Journal of Intelligent & Fuzzy Systems 44 (2023) 815–825. DOI:10.3233/JIFS-220885