Exploring Supply Chain Co-location: Implications on Cost, Speed-to-Market, and Sustainability

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Abstract

With today's highly competitive business world, companies are therefore more than ever interested in figuring how to fine-tune their supply chain networks so that they are able to reduce costs, quicken their responsiveness, and also achieve their sustainability goals. This study explores the suitability of supply chain co-location strategy, particularly the supplier park model, in addressing the supply chain inefficiencies for ABC Corporation, a global food and beverage company. By comparing the baseline scenario of the company's current geographically dispersed network with a future state scenario implementing the supplier park model, the study quantifies the impact of co-location on three key metrics: cost reduction, quicker speed-to-market, and higher environmental sustainability. The overall results show that the supplier park model can lead to a decrease by 45% in overall costs, a decrease by 30% in the speed-to-market lead time, and a drop by 80% in the Scope 3 emissions due to transportation. This project pinpoints the necessity of transportation planning and inventory optimization for supply chain network design and provides ABC Corporation with actionable recommendations for the implementation of supply chain co-location strategy. This study contributes to the field of supply chain management by demonstrating the potential of co-location strategies to drive significant improvements in efficiency, responsiveness, and sustainability, pushing the boundaries of supply chain network design.

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- *Nilay Kumar*

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- *Oscar L. Nieto Michelis*

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1. Introduction

This chapter describes the context of our capstone project that is aimed at evaluating the impact of supply chain co-location strategies for the sponsoring company – ABC Corporation, which is one of the leading food and beverage companies in the world.

We start the chapter by articulating ABC Corporation's motivation to explore this study, which is primarily due to their widely distributed supply chain network. The chapter illustrates the unique problem statement of ABC Corporation - to analyze the implications and impacts of co-locating supply chain nodes (suppliers, manufacturing plants and distribution centers) on the total cost, speed to the market, and scope 3 carbon emissions (environmental impact). As a next step, we put forward the hypothesis that a "production campus" concept of a centralized network model can assist in mitigating these challenges. The key objectives and the overall action plan are addressed in the final part of this chapter.

The ABC Corporation can achieve a considerable decrease in the cost of its supply chain and enhance its speed to market, as well as significantly reduce its environmental footprint, by adopting the recommendations from this project. The strategy of co-location could help the company to optimize its operations, thereby making collaboration among the supply chain partners more effective and place the company ahead of other competitors in the food and beverage market.

1.1 Motivation

The supply chains of the mass-produced products are hardly ever straightforward. They depend on various suppliers and distribution centers (DCs) with different geographic locations and these often incur persistent inefficiencies.

When the supplier's and the distribution center's locations are widely scattered, their lead times are usually extended, making it hard to coordinate them efficiently enough to ensure a continuous supply of goods. Additionally, if any of the suppliers run into trouble and are not able to meet a delivery, the whole production process might be interrupted. As a result, many firms maintain excess inventory across their network to eliminate this possibility (Chaturvedi & Martínez-de-Albéniz, 2016), which, in turn, increases the inefficiencies in the network. Intuitively, one can easily conclude that transportation costs are also distance-dependent, thus, it is always desirable to reduce the distance between the suppliers and the production site and between the production site and the distribution centers as much as possible. If these issues are not dealt with, the company that is experiencing the problems will be subject to increases in cost on a daily basis because of inefficiencies within its supply chain nodes. Finally, consumers are now more concerned about the environmental sustainability of the products they buy, use and eat, giving enough reasons to the companies to innovate their supply chain operations better than what the consumers are expecting (Bar Am et al., 2023).

This is the situation that the sponsor company, namely ABC Corporation, a major global brand in the food and beverage industry, is facing. ABC Corporation's supply chain strategy is centred on delivering high-quality products to its customers, and reducing the network costs and environmental impacts involved in the process. The company regularly invests in its supply chain and innovates in order to react quickly to their customer's demand, shorten their lead time, and manage their inventory effectively. Nevertheless, one of the main obstacles that will hinder these goals is the company's complex supply chain network, which involves suppliers and distribution centers far away from the beverage manufacturing plants. Not only does it take more time to supply products but it makes the system less efficient by keeping higher inventory to cover for the long lead times, and using more fuel that pollutes the environment through higher transport fuel consumption.

1.2 Problem Statement

Through a strong pledge to cut their carbon footprint by half until 2030, and to maintain the profitability by the help of constant improvements and innovations in their supply chains, the company wanted to test new concepts for the revamping of their beverage supply chain network in the USA.

In order to achieve these goals, ABC Corporation would like to conduct an analysis of the effect and implications of co-location of their beverage supply chain nodes (suppliers, manufacturing plants, and distribution centers) on the overall cost, speed-to-market, and Scope 3 carbon emissions (environmental impact).

This capstone project intends to address ABC Corporation's key objectives by answering the following research questions:

1. What is the current state of the supply chain network of ABC Corporation for the selected set of beverage products and what are the most important inefficiencies in terms of costs, speed-to-market and Scope 3 carbon emissions?

2. What is the importance of co-location strategies, like the creation of a "production campus" that groups together all the suppliers and distribution centers very close to the production site, for the supply chain performance of ABC Corporation (costs, speed-to-market lead time, and Scope 3 carbon emissions)?

3. What gains might be achieved as a result of adopting a co-location strategy in terms of lower transportation costs and inventory holding costs as well as faster speed-to-market lead time and lower Scope 3 carbon emissions, especially in transportation?

4. What are the critical determinants that can impede or restrict ABC Corporation in its co-location strategy?

1.3 Hypothesis

We hypothesize that the creation of a 'production campus', which would have all the parts of the supply chain of ABC Corporation at one location, could help to alleviate the problems in the supply chain of the company and would also bring some other benefits. These anticipated benefits, which will be explored and validated through our analysis, are ranked in order of the organization's priorities as follows:

1. Reduced network costs (transportation costs, and inventory holding costs) that follow from the reduction of distances between the suppliers, production site and distribution points and decreasing the network inventory.

2. Shorter speed-to-market lead time for their beverages products through the reduction of inventory days and lead times for purchase of its components and distribution of finished goods.

3. Reduced carbon footprint, since fuel consumption is reduced among logistics partners involved in procurement of components and distribution of finished goods because of close proximity of supply chain nodes.

1.4 Project Goals

The main objective of the project is the creation of a quantitative model for ABC Corporation which compares the baseline scenario of their current supply chain network against the future state scenarios involving the co-location of their suppliers and distribution centers. Such model will guide them in determining the consequences of co-locating all the parts of their beverage supply chain on the key areas such as cost-saving, inventory reduction, carbon emissions, lead time to market as well as working capital. We aim to deliver a comprehensive supply chain network assessment to ABC Corporation and provide insights on how co-location of suppliers and distribution centers would generate value within their organization against their current performance metrics and their future goals.

1.5 Project Action Plan

Our project plan consisted of six main steps which showed how we completed this capstone project (see Figure 1-1, Project Action Plan).

1. Develop problem statement and define the scope for the project in collaboration with ABC Corporation.

2. Gather ABC Corporation's current supply chain network data, clean it up and then use descriptive analysis to summarize the existing supply chain.

3. Depict the initial supply chain network using Value Stream Mapping (VSM) techniques.

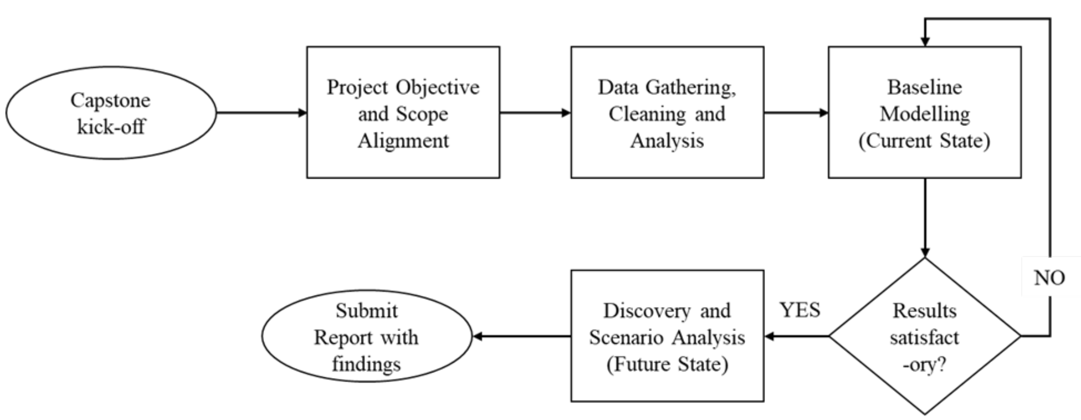
4. Construct a quantitative model for the assessment of co-location strategies on vital supply chain metrics.

5. Perform an in-depth evaluation of the co-location scenario, considering advantages, challenges, and implementation issues.

6. Develop and summarize the findings from the exploration of co-location strategy, make conclusions based on data analysis and insights, give recommendations for further areas of exploration and prepare the final report.

Figure 1-1

Project Action Plan



2. State of the Practice

In this chapter, we review the existing literature and practices that are relevant to our capstone project which is to evaluate the effectiveness of co-location strategies for ABC Corporation's supply chain network. In order to design a reliable approach for assessing the advantages and disadvantages of spatial proximity of suppliers, manufacturing plants, and distribution centers, we focus on four key areas.

First, we look at co-location approaches in the supply chain, especially in the automotive industry, to understand successful implementations of supplier parks and other co-location models and lessons learned from them. Next, we focus on cost savings through network design, by looking into the literature of network optimization, and the effect of facility location on different cost components. Then, we study value stream mapping (VSM) as a tool for describing complex supply chain systems, which enables us to visualize and quantify the possible improvements in lead time and inventory levels. Lastly, we learn how to calculate the Scope 3 carbon emissions from transportation to incorporate sustainability metrics to our co-location assessment.

These areas are very relevant to our project as they give us insights on the tools and methods of assessing the impact of co-location on supply chain performance considering factors such as cost efficiency, lead time reduction and estimate of Scope 3 emissions. The knowledge obtained from this literature review will guide our data collection, model development and scenario analysis, thus supporting us to provide data-driven recommendations to ABC Corporation.

2.1 Co-location Phenomenon in Supply Chains

The concept or idea of co-locating different supply chain nodes, particularly suppliers, first appeared in 1992. Seat originated the phrase "supplier park" at the time, by becoming the first to formally name a co-located industrial area next to its assembly factory in Abrera (Spain) as a "supplier park." Ever since then, the strategy of co-location has been adopted by many automotive organizations. Similar “supplier parks” were created in Europe (e.g., Bratislava, VW; Cologne, Ford); Brazil (e.g., Curitiba, Renault); and also in North America (e.g., Chicago, Ford). A supplier park can be developed in one of two ways: close to brownfield sites (existing car assembly plants) or adjacent to greenfield sites (newly created plants) (Reichhart & Holweg, 2006).

The majority of co-located units can be classified as local dedicated units (LDUs) (Gullander & Larsson, 2000) or local assembly units (LAUs) (Millington et al., 1998), , manufacturing sites that are operated by a large vendor exclusively for a single customer only. This spatial closeness allows them to reduce their total inventory and even consider a just-in-time (JIT) arrangement with their supplier, which will end up eliminating their major safety stock.

Consequently, potential line stoppages because of the unreliable delivery from suppliers which are more likely to occur over long distances were less likely to happen in this case. In addition, the co-location of suppliers not only reduces the transportation costs for components, but also renders additional benefits (Millington et al., 1998). Lastly, it is expected that being close to one another brings not only tangible advantages but also intangible ones. For instance, it can lead to higher face-to-face contact, better problem resolution and more mutual understanding (Frigant & Lung, 2002), yet it is not clear to what degree this is a deciding factor in the location choices (Larsson, 2002; Sako, 2003).

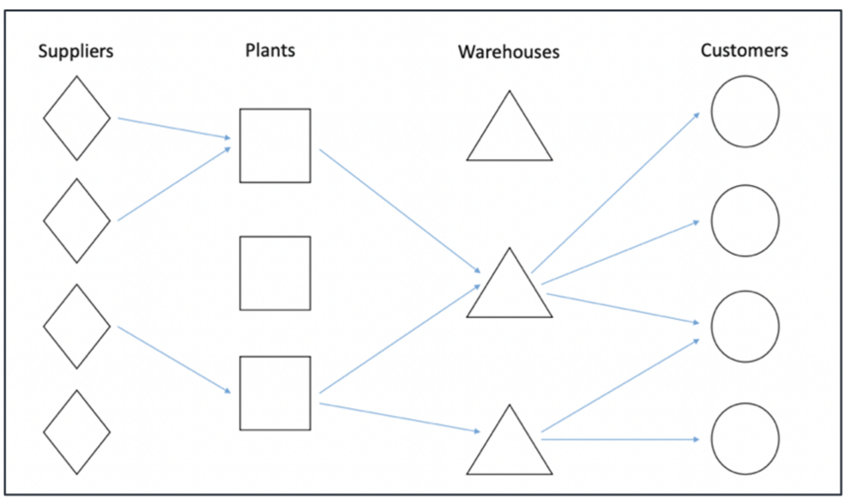
2.2 Cost Savings by Network Design

Savings in costs through changes in the supply chain network have been extensively studied in the literature. The reason is quite intuitive: oftentimes, even small changes in the interactions of the components of the networks provide great potential to reduce the costs of an operation. Despite the existence of deeply complex logistics networks, the literature usually considers four main elements (called nodes) that interact with each other in a conventional network (Figure 2-1): suppliers, production plants, warehouses, and end customers.

In a conventional network, distributors are responsible for supplying production plants, which in turn manufacture the final product and send it to warehouses for distribution to end customers. Each of these nodes has the potential to be optimized to generate cost savings, for example, through the geographical relocation of nodes or efficient inventory management to minimize holding costs.

Figure 2-1

Conventional supply chain network



Note: From *Network Design with Applications to Transportation and Logistics* by Crainic et al., 2021.

The main goal of an efficient supply chain network is to maximize performance and minimize the cost at the same time (Ketchen Jr et al., 2008). One of the key tools in measuring costs for a supply chain network is the total relevant cost equation. In this study, we will be analyzing all the different parts of the cost equation and simulate the impact of lead-time reduction approaches (co-location) on the total costs in order to recommend the optimal future state scenario.

$$\text{Total Cost} = 365DC_p + C_t\left(\frac{365D}{Q}\right) + C_e\left(\frac{Q}{2} + k\sigma_{DL} + DL\right) \tag{2.1}$$

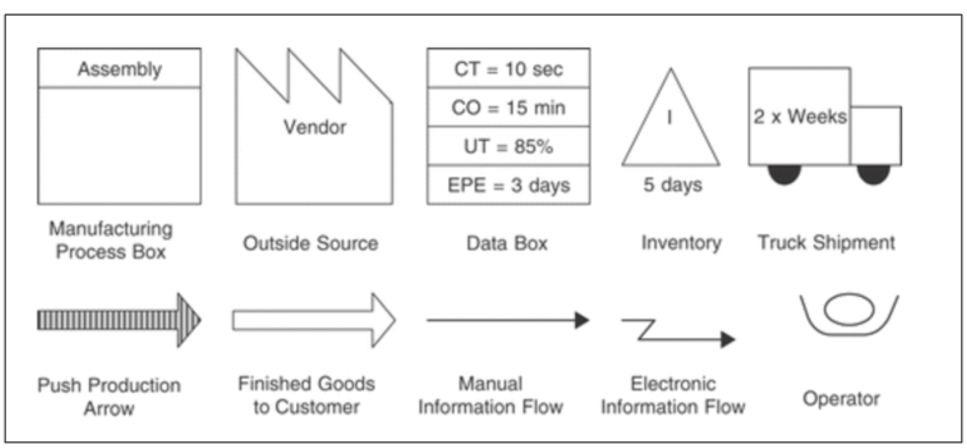
In the above equation 2.1, D equals daily demand, C_p equals purchase cost, C_t equals order cost, C_e equals holding cost, Q equals order quantity, L equals lead time, k equals k-factor and σ_{DL} equals demand deviation over lead-time.

2.3 Visualizing Network Inventory and Speed-to-Market Lead Time

To analyze the complex supply chains a common practice is to apply Value Stream Mapping which is a method that is based on the decomposition of a system into its elements in order to make a clear picture of the role of each element in the overall movement of materials and finished goods. This methodology has several advantages, such as ease of interpreting the information and the ability to understand how the system changes if only one of the parts is modified. Figure 2-2 is an example of the main components for developing a Value Stream Map (VSM).

Figure 2-2

Main components of a value stream map



Note: From "A New Value Stream Mapping Approach for Complex Production Systems" by Braglia et al., 2006, International Journal of Production Research, Volume 44, Number 18-19, p.3929–3952.

The geometric shapes, in this case, represent steps in the production process, while the different types of arrows are connectors between the processes and explain the role of each component in the big picture of the system. By using this type of methodology, the role of each component becomes clear, and in this way, each part can be modified while understanding how it affects the overall outcome of the system.

For this project, we will use Value Stream Mapping as the main technique to define Company ABC's baseline supply chain network, consisting of parameters such as on-hand inventory, lead times, shipment frequencies, and product flows. The details are described in Chapter 3 Methodology under Figure 3-4.

2.4 Estimating Carbon Emissions

In the last few years, the carbon emissions released into the atmosphere which are harmful to the Earth have been increasingly the subject of media attention. In the context of supply chains this is especially relevant as information from various agencies shows that at some instances more than 90% of carbon emissions from organizations are from their supply chains (CDP, 2021), with land transportation accounting for the majority, 65%, of the freight emissions (Forum, 2023).

In the context of this project, we are looking at the greenhouse gas emissions from land-based transportation, focusing on trucks in particular. Zubair et al. (2023) discovered that the conventional literature utilizes two common approaches for measuring the emissions of a transportation unit. The first is based on the type of vehicle and the average speed at which it travels. The second considers the distance traveled as the main emissions indicator.

Although a combination of both is undoubtedly the most comprehensive approach, in practice, it is difficult to use this method because information about the type of transportation can vary considerably over time or may not even be available. This is common in companies that outsource transportation to other companies and therefore do not have consistency in the type or model of vehicle used throughout their supply chain.

In situations where information on vehicle speed and type is restricted, it is usual practice to use the second technique and compute emissions based on the distance traveled by transportation vehicles and the weight of items transported throughout the supply chain. This way, emissions would be calculated as shown below.

$$\text{CO}_2 \text{ emissions} = \text{Mass of Goods} \times \text{Distance Traveled} \times \text{Emission Factor} \tag{2.2}$$

Note: From "Methods For The Calculation of CO_2 Emissions in Logistics Activities" by Zadek and Schulz, 2010, Advanced Manufacturing and Sustainable Logistics: 8th International Heinz Nixdorf Symposium, IHNS 2010, Paderborn, Germany, p.263–268.

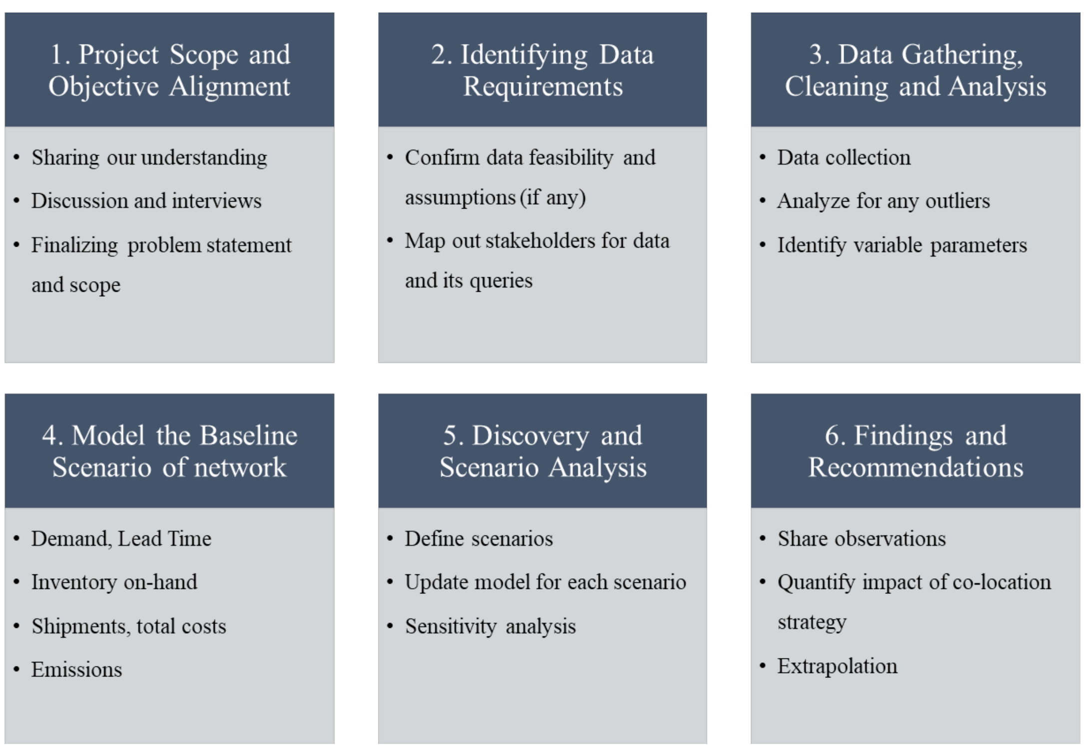
Emission factors are usually expressed in kilograms of carbon dioxide equivalent per tonne-kilometer (noted, kg CO_2e/ t.km). Tonne-kilometer is a unit of measure representing one metric ton of goods transported over 1 kilometer.

3. Methodology

Following extensive discussions with the sponsoring company and a review of research publications relevant to our objectives, we decided to address our problem statement — assessing the impact of a co-location strategy on cost, inventory, speed-to-market, and carbon footprint — in six distinct stages or phases, as outlined in Figure 3-1.

Figure 3-1

Methodology Stages



3.1 Project Scope and Objective Alignment

The scope of this project focused on evaluating the impact of co-locating ABC Corporation's beverage supply chain nodes, specifically suppliers, manufacturing plants, and distribution centers, on three key metrics: cost, speed-to-market, and Scope 3 carbon emissions (environmental impact). The project covered a selected set of 17 SKUs, four suppliers, two distribution centers, and one production plant within ABC Corporation's beverage supply chain network in the United States.

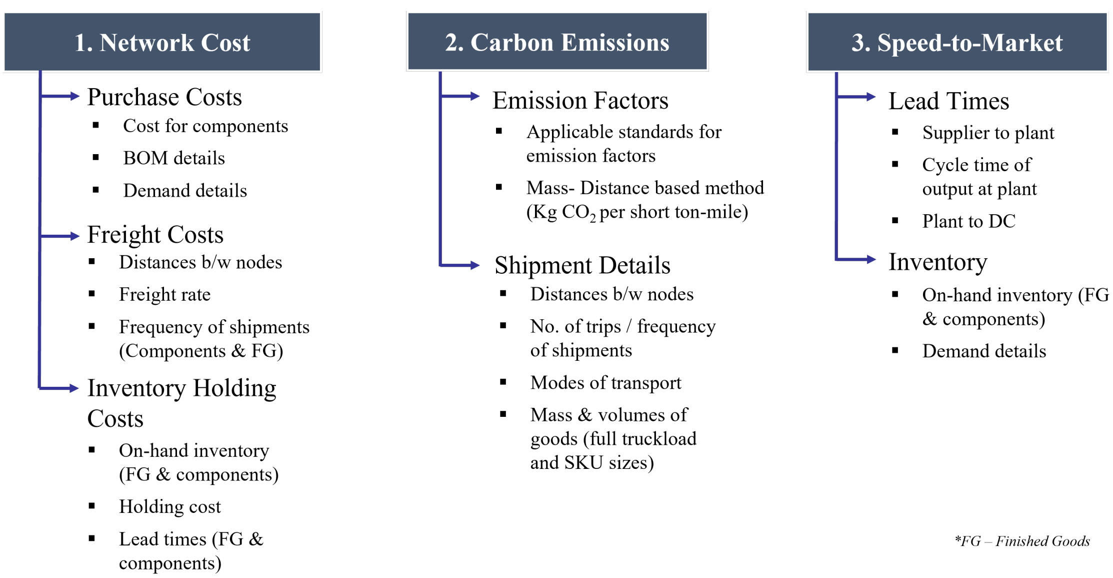
To ensure the project scope remains focused and achievable, periodic discussions and interviews were conducted with key stakeholders from ABC Corporation to refine the scope and align it with the company's priorities and data availability.

3.2 Identifying Data Requirements

After establishing the project's scope, data identification and the acquisition of datasets from the company were initiated. Our focus areas were: Cost, Scope 3 CO_2 emissions, and Speed-to-market lead time, as illustrated in Figure 3-2.

Figure 3-2

Data Requirements



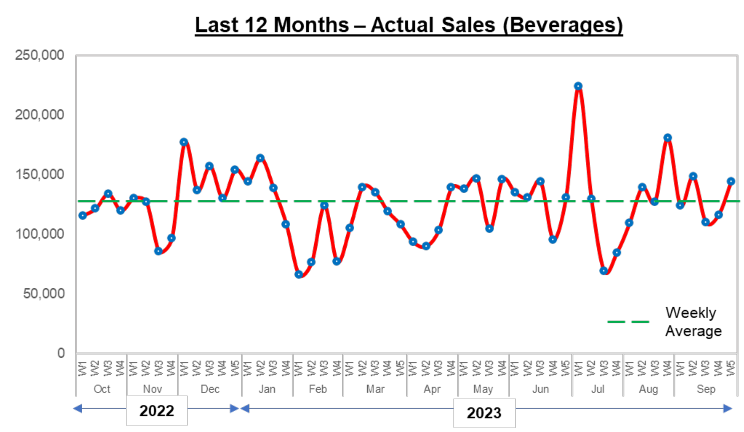
3.3 Data Collection and Analysis

After collecting all relevant data and executing the feasibility checks and cleaning procedures (including outlier checks), the focus shifted to modeling the baseline scenario of the supply chain network within our defined scope. To achieve a more precise and realistic evaluation of ABC Corporation's current supply chain state, we decided to utilize a dataset spanning 12 months from October 2022 to September 2023. The time frame was selected to encompass a whole year of demand and supply cycle, which is important for correctly showing the company's usual business operations. Through analyzing a full year of data, we made certain that our baseline model was capable of accounting for seasonal variations as well as other factors which may have an impact on supply chain performance.

For validating this decision, we ran a descriptive analysis of the annual demand data that showed a normal distribution (see Figure 3-3). This finding also showed that we chose the 12 month period correctly, as it showed that this period was normal to the ABC Corporation's standard operating conditions without any significant anomaly or interruption. The sponsor company also agreed with this choice, which is the evidence that the data selected are relevant for the capstone project.

Figure 3-3

Descriptive Analysis - Annual Demand



Descriptive Analysis

- Mean (Weekly) – 114,137 Units
- Median (50%) – 118,439 Units
- Standard Deviation (Std. Dev.) – 21,363 Units
- Coefficient of Variation (COV) – 0.18
  (Indicating relatively low volatility)
- Minimum – 62,084 Units
- Maximum – 203,872 Units

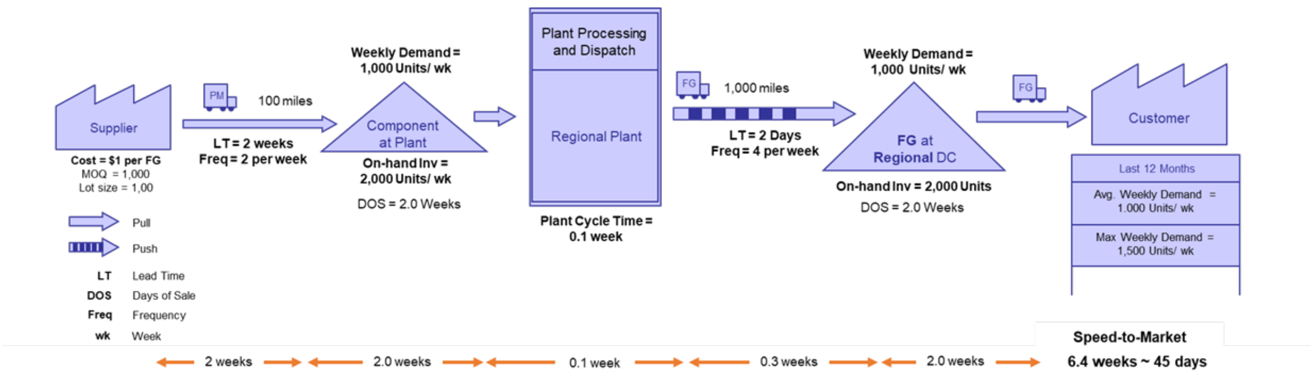
✓ **Normally Distributed**

3.4 Baseline Network Modelling

To build a baseline for their existing supply chain network, we chose the Value Stream Mapping (VSM) technique. As mentioned in Section 2.3 and depicted in Figure 3-4, this approach creates a visual depiction of the entire supply chain network, including inventories (waste) and lead times.

Figure 3-4

Sample Value Stream Map Using Sample Values



Note: This figure depicts a sample value stream created using dummy data to illustrate how it visually captures the end-to-end supply chain network.

By collecting data on demand (for finished goods), inventory (for finished goods and its components), lead times (ordering components and shipment of finished goods), shipments (frequency, truckload, and type of transportation), and different cost components as per Equation 3.1 (purchase costs, holding costs, and freight costs), we defined the total relevant cost equation for ABC Corporation's baseline network along with the equation for speed-to-market lead time:

$$\text{Total Costs} = \text{Purchasing Costs} + \text{Inventory Holding Costs} + \text{Freight Costs} \tag{3.1}$$

1. Purchasing costs equal the cost of purchasing any component from the suppliers.

2. Inventory holding costs equal the holding costs for the component storage at the

plant and finished goods (FG) storage at the distribution center.

3. Freight costs are the charges incurred when transporting components from the supplier to the factory and finished goods from the production to the distribution center. In the case of our sponsored company, all transportation is handled by third-party logistics (3PL).

$$\begin{aligned}\text{Speed-to-market lead time (LT)} = {} & \text{Component order LT} \\ & + \text{Component inventory at plant (days)} \\ & + \text{Plant cycle time} \\ & + \text{Finished goods (FG) shipment LT} \\ & + \text{FG inventory at DC (days)}\end{aligned} \tag{3.2}$$

For estimating the impact of the co-location strategy on the total carbon emissions of the supply chain network, we focused only on the emissions of their transportation network. As we established from the scope of the project that co-location would only change the distances between each node in the supply chain network, only the travel distance would be considered as a variable in future state scenarios. In other words, our evaluation of different scenarios only changes the emissions in terms of the distance traveled by their trucks.

We used the mass-distance-based method discussed in Section 2.4 that calculates carbon emissions as the product of mass, distance, and carbon-equivalent intensity factors for transportation. We decided to leverage Company ABC's current practice of using carbon-equivalent intensity factors derived from the Global Logistics Emissions Council (GLEC) (Smart Freight Centre, 2023), which is seen as a global standard. The distances for shipments are obtained using the Google Maps API. Finally, the weight of each shipment is obtained as part of the datasets provided by the company.

3.5 Future Scenario Analysis

After the baselines for each area of focus (costs, speed-to-market, and Scope 3 emissions from transportation) were identified, the next step is to define future scenarios to evaluate the effect of co-locating the different supply chain nodes. The scenarios below were created together with the main stakeholders from ABC Corporation:

1. Supplier Park Model: The co-location of both suppliers and distribution centers in close proximity with the production facility.

2. Milk Run Co-operative Model: Co-locating suppliers and distribution centers in the same city or county with the manufacturing plant.

For each scenario, we used the data from the Section 3.3 and then used different analytical methods to calculate the expected changes in costs, inventory levels, lead times and carbon emissions.These methods included:

1. Transportation cost analysis: We applied the revised distances between supply chain nodes and the corresponding freight rates to project the estimated reduction in transportation expenses.

2. Inventory analysis: We use inventory modelling methods, including the Continuous Review model for safety stock and order quantity calculations, to determine the possible inventory reduction and holding cost.

3. Lead time analysis: We calculated the lead time improvements with the shortened distances and easing processes ensured by co-location while taking all factors into account – like transportation time, handling time, and some more coordination and communication improvements.

4. Carbon emissions analysis: We took the Scope 3 carbon emission mitigation potential into account using the revised distances and the relevant emission factors mentioned in Section 3.4.

The results of future scenario analysis were compared with the baseline values to quantify the benefits and trade-offs of each co-location strategy. Such findings were the foundation of our recommendations to ABC Corporation which will be discussed in Section 5.5. Additionally, we validated our findings with the subject matter experts from ABC Corporation to achieve the alignment on feasibility and practicality of the scenarios.

3.6 Findings and Recommendations

Once we finalized our assessment of every scenario and extracted the vital trade-offs, we showed the primary insights of our findings and and its impact — indicating pros and cons of the co-location strategy for the company's supply chain and environmental sustainability objectives.

In addition, we also put forth the limitations of our study and areas for future research that may supplement our findings. Furthermore, we focused on how our project contributes to the discipline of supply chain management and how our research was at the forefront of the design of supply chain networks.

4. Results

In this chapter, we present the results of our study, which addresses three different network scenarios for the supply chain co-location of ABC Corporation. Firstly, we create the baseline scenario by producing the current state of the company operations and its key metrics, such the speed-to-market time, total relevant costs, and Scope 3 carbon emissions from transportation. Next, the three scenarios are evaluated, namely, the Baseline Scenario Model, the Supplier Park Scenario Model, and the Milk Run Co-operative Model. For each scenario, we outline the main attributes and design considerations, and give a complete breakdown of the effect on costs, lead times, and carbon emissions, in contrast to the baseline. The outcomes illustrate the positive aspects of co-location in terms of cutting down on costs, improving the speed-to-market and boosting environmental sustainability.

4.1 Scenario #1 - Baseline Scenario

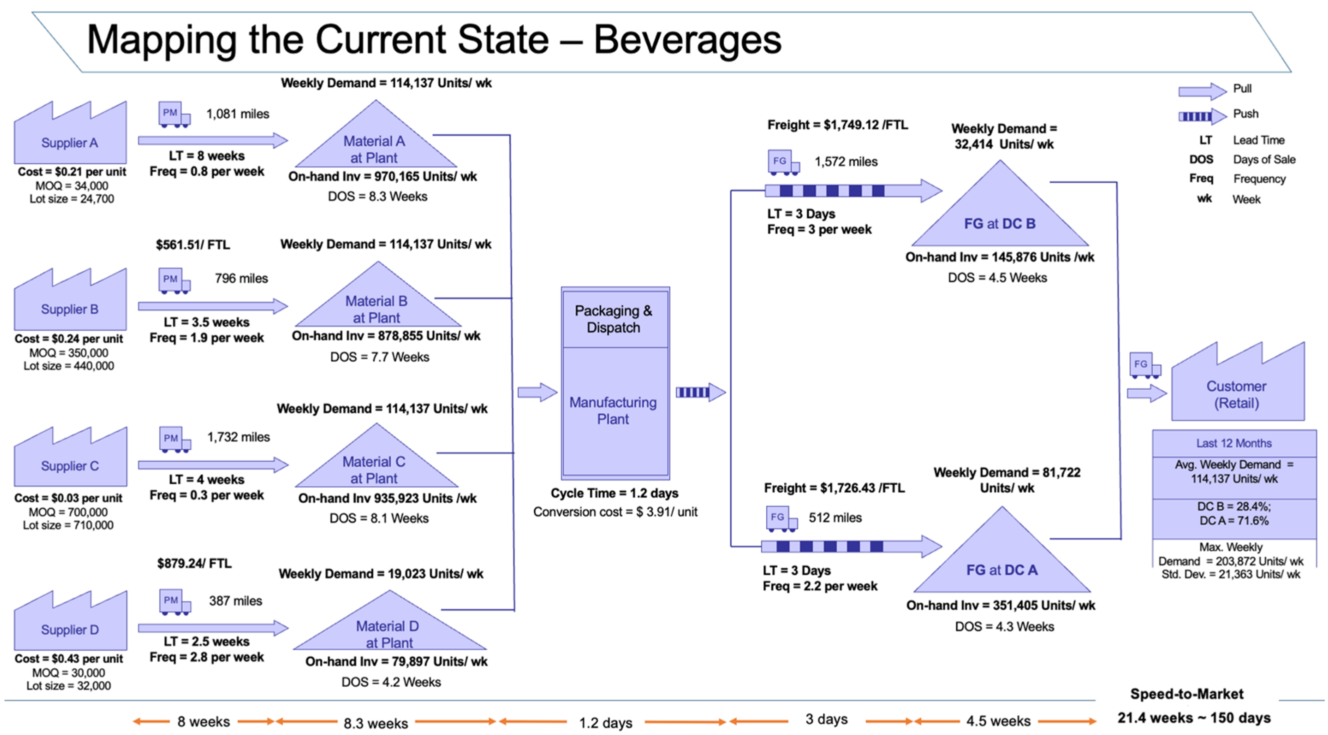
In order to get a baseline for assessing the effectiveness of co-location strategies, we firstly analyzed the current state of supply chain network of the sponsoring company.

In mapping each segment of the supply chain, we worked closely together with company experts in inventory management (finished goods supply planning and materials planning), demand planning, finance, innovation, and sustainability, as described in Section 3.4. This was a key interaction that was essential in detailing the costs and lead times for their supply chain operations. The information that was collected for the scope of this project included 17 SKUs, four suppliers, two distribution centers and one production plant. The supply chain process consists of five steps, the first one being suppliers sending materials to the plant. These materials are processed in the production facility and shipped to the distribution centers, and eventually to the point of sale.

Each item is shipped by a separate supplier with the fastest lead times being 2.5 weeks and the slowest being 8 weeks. The plant has an average cycle time of 1.2 days to produce one batch (the minimum order quantity) of the products, and once it is completed, the product takes approximately three days on average to reach the distribution centers. From there, it takes an additional 4.5 weeks on average to be sent to the final customers and points of sale. Adding up all these components, we can see that the total speed-to-market time is 21.4 weeks (approximately 150 days). This can be seen more clearly in Figure 4-1.

Figure 4-1

Mapping the current state – Baseline scenario

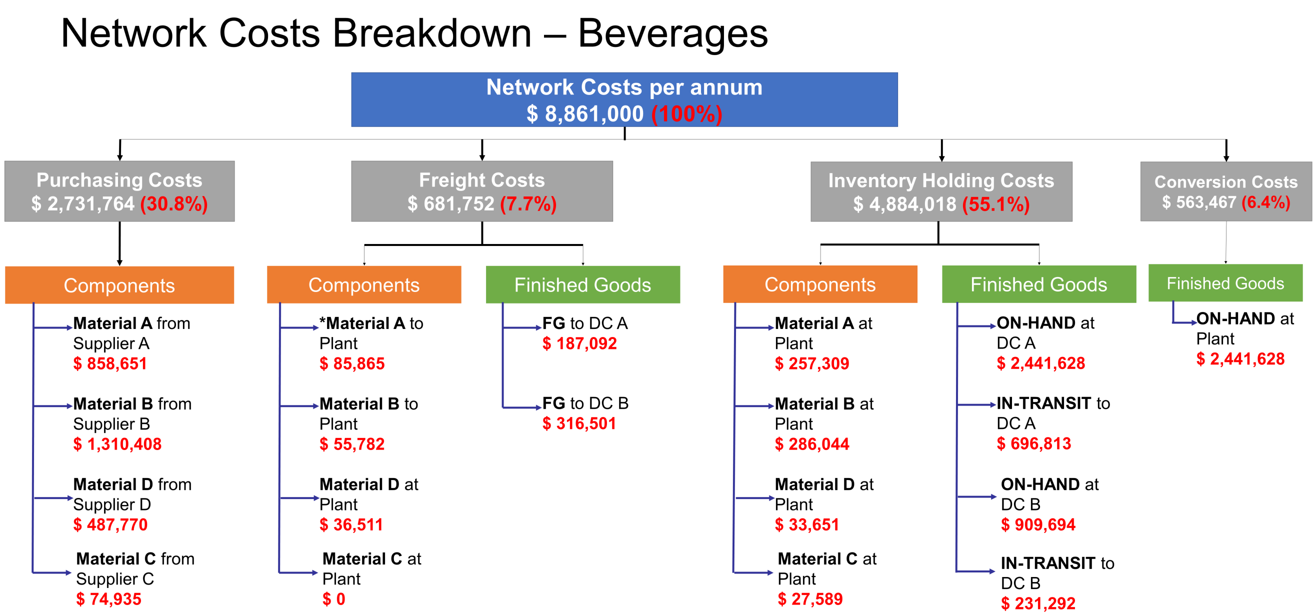


Regarding the total relevant costs, as explained in Section 3.4 Methodology, we segmented the components into four main categories: purchasing costs, conversion costs, freight costs, and inventory holding costs. Since the first two are independent of supply chain network design (the first being material costs and the second being costs associated with the manufacturing process), these costs are assumed to be fixed and unaffected in any of the scenarios we evaluate. In total, both represent approximately 37% of the total costs. The remaining 63% consists of freight costs and inventory holding costs, which, being dependant on the lead time and distance between supply chain nodes, can be reduced through a co-location strategy, and will surely change as we evaluate different scenarios.

For the baseline scenario, the company's costs for this network amount to $8,861,000. The details can be seen more clearly in Figure 4-2.

Figure 4-2

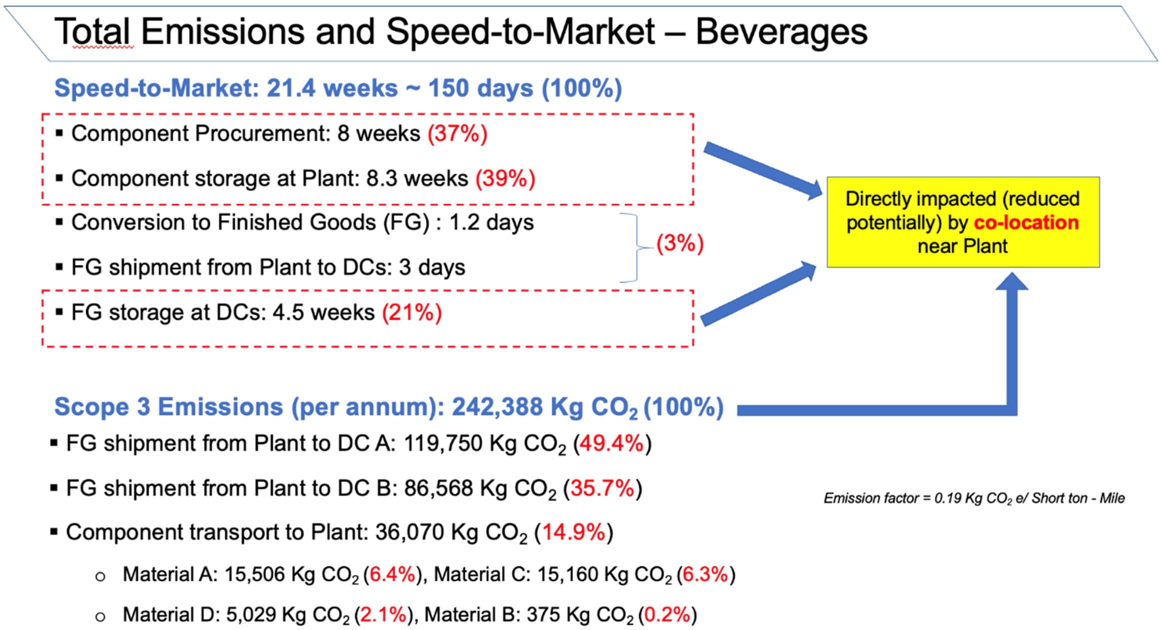
Network Costs Breakdown – Baseline scenario



Finally, for the calculation of Scope 3 carbon emissions from transportation, we considered the distances of the current operation and used the CO_2 emission factor per short ton-mile to calculate emissions. Because network co-location will alter the distances traveled by trucks, in our evaluation scenarios, we observed how these emissions are reduced based on the changes in distances. For the baseline scenario, we have a total annual emission of 242,388 kg of CO_2 for this part of the company's operation. It is important to note that around 85% of the Scope 3 CO_2 emissions in this baseline scenario come from the transportation of finished goods. The details of the emissions can be seen in Figure 4-3.

Figure 4-3

Speed-to-Market and Scope 3 Emissions Breakdown – Baseline scenario



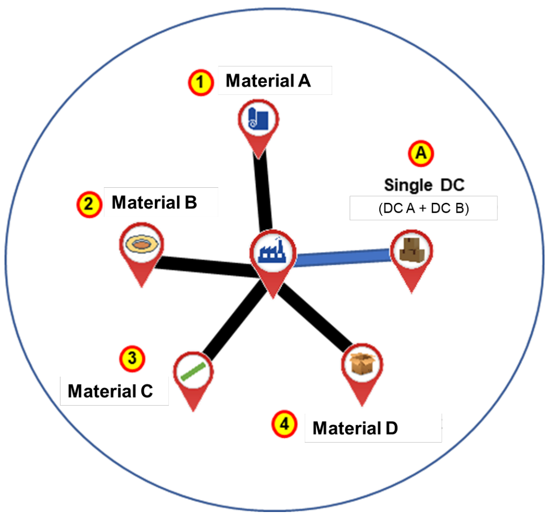
4.2 Scenario #2 - Supplier Park Model

The name "Supplier Park", as discussed in Section 2.1, comes from the operating strategy of automotive companies. Managing the high number of parts/ components required for manufacturing automobiles is a challenging task. To ensure that the manufacturers get the best quality spare parts with optimal price and highest efficiency, they came up with the idea of locating their suppliers close to their manufacturing facility. Instead of waiting for long lead times of components and not being able to resolve issues faster, they now have the advantage of faster order replenishment and speedy resolution of any issues with the parts. This also helps them minimize their inventories thereby optimizing their costs.

Co-location implies locating different nodes of a supply chain close to each other. In this particular scenario, we are designing a network where all the nodes in the supply chain (suppliers, manufacturing plant, and distribution centers) are located right next to each other in a large integrated campus/ facility, as illustrated in Figure 4-4.

Figure 4-4

Proposed Network for Future Scenario – Supplier Park Model



Below are some of the key features and design considerations for this scenario that we have incorporated into our calculations:

1. Sponsoring company will have all its suppliers located next to its manufacturing facility as part of a large complex.

    (a) As illustrated in Figure 4-4, since the suppliers will be very near to the plant, very minimal freight logistics would be required. Instead of trucks, specialized vehicles or conveyors can also be used.

    (b) A JIT (Just-In-Time) operating model could be utilized, which will minimize the safety stock.

2. By implementing a co-location strategy and the synergies developed from that strategy, the transportation and receiving portion of lead time will be optimized (approximately 1 week).

3. Current lot sizes and Minimum Order Quantities (MOQs) from suppliers have been incorporated for calculating order quantities under inventory replenishment model.

4. Continuous review model was applied for calculating target inventory norms.

5. Sponsoring company will combine its current distribution centers (DCs) into a single DC that will have the combined capacity of both of the original DCs.

By incorporating these design elements into our calculations, we were able to arrive at the final values for costs (purchasing, freight, inventory holding, and conversion), speed-to-market, and Scope 3 emissions and the percentage change as compared to the baseline scenario in Table 4.1.

Table 4.1

Scenario #2 values for Costs, Speed-to-Market, Scope 3 Carbon Emissions

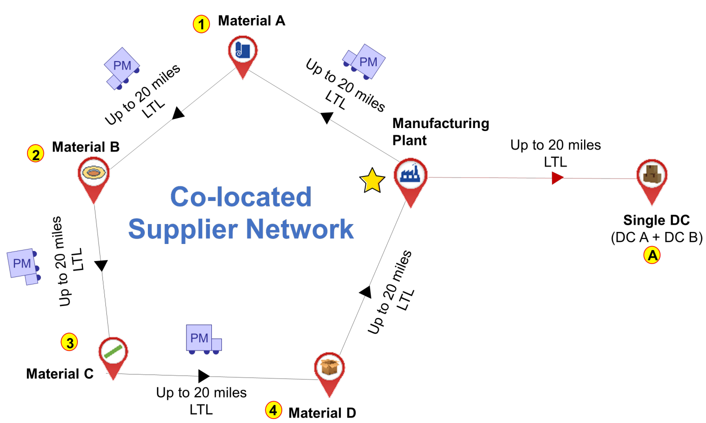
Category	Description	Unit	Value	% change vs baseline	Rationale
Costs	Purchasing Costs	$	2,731,764	None	Co-location has no impact on price of procuring components
	Freight Costs	$	157,015	77% less	Reduced freight costs due to shorter distances between each node
	Inventory Holding Costs	$	1,384,483	72% less	Lower inventory/ buffer requirement due to reduced lead times
	Conversion Costs	$	563,467	None	Co-location has no impact on cost of converting components into finished goods
	Total	**$**	**4,836,729**	**45% less**	
Speed-to-Market	Procurement of components	Weeks	7.0	11% less	Reduced lead time due to proximity between suppliers and manufacturing plant
	Storage of components	Weeks	6.0	28% less	Lower inventory/ buffer requirement due to reduced lead times
	Conversion to finished goods (FGs)	Weeks	0.03	None	Co-location has no impact on cycle time of converting components into finished goods
	FG Shipment from Plant to DC	Weeks	0.21	50% less	Reduced lead time due to proximity between manufacturing plant and DC
	FG Storage at DC	Weeks	1.8	60% less	Lower inventory/ buffer requirement due to reduced lead times
	Total	**Weeks**	**15.0**	**30% less**	
Scope 3 Carbon Emissions	Shipment of components	Kg CO_2	262	82% less	Reduced emissions due to lesser distances being travelled by trucks
	Shipment of FGs	Kg CO2	4,313	80% less	Note: this is only considering the shipments from plant to DC. The impact on shipments from DC to stores is outside our scope.

4.3 Scenario #3 - Milk Run Co-operative Model

The name 'Milk Run' comes from the distribution operating model of milk manufacturing companies. Due to the perishable nature of milk, consumers wanted to purchase fresh milk almost daily at the start of their day. Instead of servicing each customer one after the other, they came up with the strategy of delivering milk to all customers using a single vehicle operating on an optimized route covering as many customers in the agreed time period. In this particular scenario, we are designing a network where all the nodes in the supply chain (suppliers, manufacturing plant, and distribution centers) are within the same city, county, or district, as illustrated in Figure 4-5.

Figure 4-5

Proposed Network for Future Scenario – Milk Run Co-operative Model



Listed below are the major features and design considerations for this scenario that we have factored into our computations:

1. Sponsoring company will have a dedicated fleet of trucks or specialized vehicles for procurement of the components of its products using the milk-run model. By having a dedicated fleet of vehicles, the sponsoring company can exercise a greater degree of control over the specialized nature of operations in this scenario versus relying on a 3PL. However, the tradeoff would be initial investment in acquiring the vehicles that get added as fixed capacity to the network, as opposed to variable nature of capacity in case of using 3PLs.

(a) As illustrated in Figure 4-4, one truck will start its journey from the manufacturing plant and cover each of the suppliers one by one in a single route before returning to the plant.

(b) This model will lead to less than 100% utilization of a truck (less than truckload), and we have considered that in our calculations.

2. By implementing this strategy and the synergies developed from it, the transportation and receiving lead time will be optimized (approximately 0.5 week).

3. Continuous review model was applied for calculating target inventory norms and sponsoring company will combine its current distribution centers (DCs) into a single warehouse.

Table 4.2

Scenario #3 values for Costs, Speed-to-Market, Scope 3 Carbon Emissions

Category	Description	Unit	Value	% change vs baseline	Rationale
Costs	Purchasing Costs	$	2,731,764	None	Co-location has no impact on price of procuring components
	Freight Costs	$	259,416	62% less	Reduced freight costs due to shorter distances between nodes, but slightly higher than Supplier Park model due to milk run routes
	Inventory Holding Costs	$	1,928,387	61% less	Lower inventory/buffer requirement due to reduced lead times, but slightly higher than Supplier Park model
	Conversion Costs	$	563,467	None	Co-location has no impact on cost of converting components into finished goods
	Total	**$**	**5,483,034**	**30% less**	
Speed-to-Market	Procurement of components	Weeks	7.5	6% less	Reduced lead time due to proximity between suppliers and manufacturing plant, but slightly longer than Supplier Park model
	Storage of components	Weeks	6.8	18% less	Lower inventory/buffer requirement due to reduced lead times, but slightly higher than Supplier Park model
	Conversion to finished goods (FGs)	Weeks	0.03	None	Co-location has no impact on cycle time of converting components into finished goods
	FG Shipment from Plant to DC	Weeks	0.29	33% less	Reduced lead time due to proximity between manufacturing plant and DC, but slightly longer than Supplier Park model
	FG Storage at DC	Weeks	2.7	40% less	Lower inventory/buffer requirement due to reduced lead times, but slightly higher than Supplier Park model
	Total	**Weeks**	**17.3**	**19% less**	
Scope 3 Carbon Emissions	Shipment of components	Kg CO_2	480	67% less	Reduced emissions due to shorter distances being traveled by trucks, but slightly higher than Supplier Park model
	Shipment of FGs	Kg CO2	6,038	72% less	Note: this is only considering the shipments from plant to DC. The impact on shipments from DC to stores is outside our scope.

While the Milk Run Co-operative Model is better than the baseline scenario, it should also be noted that it has some drawbacks compared to the Supplier Park Model, where the nodes are located next to each other. The following results table (Table 4.2) shows the Milk Run model results in terms of costs, speed-to-market, and Scope 3 carbon emissions which are compared with the baseline scenario and the Supplier Park Model.

These results emphasize the need to take into account the design features and geographic location when co-location strategies are being evaluated. The Milk Run Model is better than the baseline model in terms of costs, lead time and emissions but the Supplier Park Model, with its adjacent location of nodes, provides the biggest improvements in these factors.

5. Discussion

By comparing the baseline scenario with the future state scenario, we have quantified the impact of co-location on key performance metrics such as costs, speed-to-market, and Scope 3 carbon emissions.

5.1 Significance of Findings

Our analysis reveals that the Supplier Park Model can drive substantial improvements in ABC Corporation's beverage supply chain network. The future state scenario outcomes clearly demonstrate decreases in total costs, speed-to-market lead times and Scope 3 carbon emissions from transportation (Table 4.1). The co-location strategy, which minimizes the distances between supply chain nodes, inventory levels and transportation routes, is the driving engine of these improvements.

The next section will focus on the key insights gained from the analysis, which will be shown by connecting the dots between the co-location strategy and cost reduction, speed-to-market improvement and Scope 3 carbon emissions reduction. In addition, we will also provide a list of actionable recommendations that ABC Company can consider in order to carry out this co-localization strategy and ensure its long-term prosperity.

5.2 Cost Reduction and Inventory Optimization

An important revelation from our analysis is the huge cost saving possibility that the Supplier Park Model offers. The future state scenario reduced the total costs by 45% as shown in Table 4.1. This cost decrease is mainly because of the 77% reduction in freight costs and the 72% reduction in inventory holding costs. This being the case, transportation and inventory management should be in focus when designing supply chain network strategies.

The shorter distances between supply chain nodes of the Supplier Park Model allows for more efficient transportation routes, hence lower freight costs. In addition to this, the proximity of suppliers to the production plant results in lower inventory levels and shorter lead times which are the major factors for the reduction in inventory holding costs.

5.3 Speed-to-Market Improvement and Agility

The other significant insight from our analysis is the marked reduction in speed-to-market time. The Supplier Park Model converts the total lead time from 21.4 weeks (150 days) to 15 weeks, which implies a 30% reduction (Table 4.1). The main reason for this improvement is the 11% decrease in component procurement lead time and the 28% decrease in component storage time at the plant.

The co-location of suppliers, distribution centers and the manufacturing plant makes it possible to reduce the order-to-receive lead time. The company is able to be more agile in such a way that it reacts fast to market demands and customer requirements. Decreasing the speed-to-market time helps the company obtain a competitive edge and increase customer satisfaction.

5.4 Environmental Sustainability and Scope 3 emissions

The Supplier Park Model not only delivers cost and speed-to-market benefits, but also provides an important contribution to ABC Corporation's environmental sustainability objectives. The study we conducted shows that there was a reduction of 80% in the Scope 3 carbon emissions from transportation (Table 4.1) under the future state scenario. This decrease is a direct result of the reduction of distances between supply chain nodes which in turn minimizes the environmental impact of transportation activities.

Currently, the four components being procured from suppliers are 387 miles, 796 miles, 1081 miles, and 1732 miles away from the manufacturing plant. And, the two distribution centers are 512 miles and 1572 miles away from the manufacturing plant. Under the co-location scenario, the distance between each of these supply chain nodes (suppliers, manufacturing plant, and distribution center) would be very minimal (less than 1 mile) owing to the close proximity of the nodes by design, thereby significantly reducing the distance to be travelled by any vehicle for the flow of goods or materials.

5.5 Recommendations for ABC Corporation

Given the results obtained from our study, we suggest that ABC Corporation strongly considers implementing the Supplier Park Model as long-term strategy for the given set of beverage products, or for any greenfield expansion plans. For a seamless change over to this co-located supply chain network, we recommend the following steps:

1. Comprehensively evaluate the supplier network to identify the crucial suppliers and components that are most appropriate for a co-location. Concentrate on suppliers who offer high-value, strategic parts that are fundamental in the product's quality, innovation, and competitiveness.

2. Evaluate the feasibility of co-locating the identified key suppliers by taking into account their relocation willingness, financial stability, and partnership potential over the long term. Co-location usually goes along with high degree of cooperation and trust between the company and its suppliers, so it's necessary to assess the strength and maturity of the existing connections.

3. Prepare a comprehensive business case that will highlight the potential advantages and costs of the Supplier Park Model implementation for the chosen suppliers and components. This should include a financial analysis in detail as well as a risk assessment and an implementation roadmap.

4. Interact with the identified key suppliers and propose the co-location option, evaluate their readiness to be involved in the initiative. Address any concerns or limitations they might have and share ideas on the ways to design a win-win partnership.

5. Perform a feasibility study to determine potential sites for the integrated campus, taking into account the factors of land availability, infrastructure, proximity to major markets, and specific needs of the chosen suppliers.

6. Create a comprehensive implementation plan that encompasses timeframes, resources, and responsibilities for the Supplier Park Model execution. This must encompass milestones, KPIs, and contingency plans to cushion against the risks and attain a seamless process.

7. Plan in advance for a complete systems integration with the suppliers enabling a seamless flow of information between both parties through a collaborative planning data infrastructure setup.

8. Set up a reliable governance framework and communication scheme so that all stakeholders of the co-location project may collaborate, make decisions, and solve problems efficiently. This should consist of periodic performance reviews, continuous improvement efforts, and knowledge-sharing channels to create an innovation and performance culture.

5.6 General Recommendations and Applicability

While our analysis focused on ABC Corporation's specific beverage supply chain network, the insights gained from this study can be valuable for other companies facing similar challenges. The Supplier Park Model can be particularly beneficial for organizations with complex supply chains, high inventory levels, and significant transportation costs. However, the applicability of these recommendations may be limited by factors such as industry dynamics, product characteristics, and geographical constraints.

5.7 Limitations and Future Research

It is critical to acknowledge the limitations of our study and highlight the areas that require further research which will be useful for the company's strategic planning and decision-making processes.

The knowledge of the limitations of our research will help the sponsoring company to anticipate the possible constraints in the process of implementation of the co-location strategy. Moreover, by identifying the areas for further research, the company will be able to grasp the intricacies of supply chain co-location dynamics, thus unraveling fresh approaches to improve the efficiency and resilience of their supply chain network.

1. **Minimum Order Quantities (MOQs) and lot sizes**: Our design considerations were tied with the current contractual terms of the sponsor company with suppliers. The next phase of research could look into the ways in which reducing MOQs and lot sizes through co-location could be mutually beneficial, while examining the downsides of the higher purchase prices.

2. **Material A lead time**: The long lead time of material A can compromise the full potential of co-location in terms of speed-to-market. Further research might be done to investigate the process improvements and innovations that could lead to shorter lead time and, therefore, more benefits of co-location.

3. **Electric Vehicle (EV) fleet integration**: In the course of the research we examined the traditional 3PL systems (Section 3.4), however, the future research can analyse the impact of integrating an EV fleet for short-distance transportation under the co-location model. This would accelerate the achievement of sustainability goals but could also result in an increase in freight costs and will require an initial investment.

4. **Scope 3 emissions beyond the DC**: We have been focusing our effort on emissions reduction between the suppliers and the plant, and between the plant and DCs. In the future, another research could be done on the final delivery leg from DCs to final nodes of the network for a complete picture of how co-location model affects the environmental sustainability.

5. **Data granularity and sensitivity**: Future research could include more detailed

data on transportation modes, emission factors, and demand curves in order to improve the accuracy and conduct the sensitivity analyses.

6. **Expanding product and network scope**: In our research we concentrated on a narrow range of beverages and a limited network. Future research into the scalability and generalizability of the co-location model may be studied further by expanding it to other product lines, facilities and regions.

7. **Estimating return on potential investments**: This study clearly showcases the benefits and value generated for the sponsoring company by implementing co-location strategies. However, due to the limitations of scope and time availability for generating the insights, our study does not include a financial analysis for implementing co-location strategies. We recommend that the sponsoring company should base their future decisions by computing key financial metrics such as Payback period or IRR (Internal Rate of Return) to compare the potential savings against the estimated investments in PPE (property, plant, and equipments), and other capital/operating expenses.

6. Conclusion

Our capstone project's focus was the supply chain inefficiencies experienced by ABC Corporation arising from their geographically distributed supply chain network. The supplier park model as a co-location strategy was considered to be one of the best ways to achieve their goals of reducing costs, improving speed-to-market, and enhancing environmental sustainability.

By means of detailed data analysis and modeling, we compared ABC Corporation's current beverage supply chain network with the Supplier Park Model scenario as the future state. The data analysis showed that this strategy would enable significant improvements under three main metrics — costs, speed-to-market, and transportation-related carbon footprint. Given the results of our research, we strongly recommend ABC Corporation to implement the supplier park model for its selected beverage products. However, we also accept the shortcomings of our study and propose several areas for future research.

The main contributions of our research include the quantification of the effect of a supply chain co-location strategy on the company's key supply chain metrics and a methodology for the determination of the feasibility and benefits of the co-location strategy. Additionally, the study could be expanded by developing an optimization model that explores co-location in detail or a simulation model that considers various scenarios for comprehensive analysis.

In a nutshell, our project gives a clear picture of the actionable recommendations which will help the ABC Corporation to improve their efficiency and decrease the costs of their supply chain network by the co-location strategy. Through the adoption of co-location strategies and dealing with the identified challenges, the company will be able to remain cost effective, speedy to the market, and environmentally sustainable in the long-run. Our study forms the basis for future investigations of co-location models for different supply chain environments and their contribution to the emergence of more resilient, agile and sustainable supply chains.

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