Where Should You Put Your:
Warehouse, Factory, E-Commerce Facility?
An Optimization Story

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June 2015

Abstract

Most companies make facility location decisions based on convenience (proximity to employees or existing facility), lease or start-up costs or subjective criteria such as liking a certain location. In supply chain management we consider facility location decisions to be one of the most strategic and long-lasting decisions a company can make.

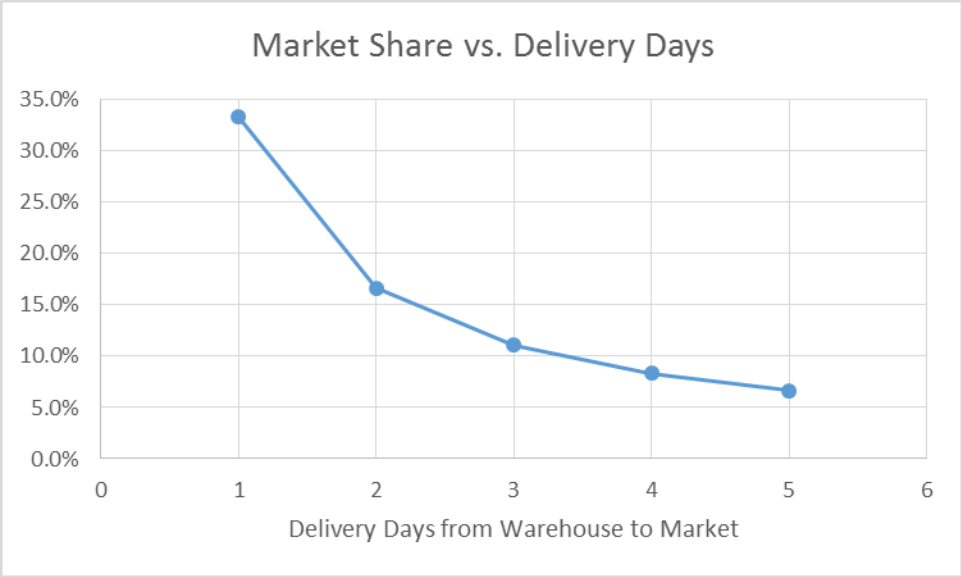
In this case study we demonstrate the benefits of determining the optimal solution based on maximizing sales and minimizing costs. Optimization is an over-used word these days. Many companies (especially software companies) claim to "optimize" when all they are doing is using some known formula. Optimization is a solution-method to determine the true best answer. In our case we use optimization modelling (also-known-as linear programming) to determine the best number, location and size of warehouses to maximize our Client's profit. This quantitative best answer is then combined with qualitative factors to enable this company to make the best decision. The result is getting the most sales with the least cost, or maximizing long-term profits.

Background

Our Client is a leading retailer/e-tailer of specialty sporting good equipment in the USA. They experienced fast growth increasing from three stores in a single market in 2005, to 32 stores spread over 12 markets in 2015. E-commerce is 35% of our Client's sales (with the balance generated by their 32 retail stores). As Amazon has shown, the closer you are to a customer the more likely you are to get their sale. With companies offering free shipping on all e-commerce sales, and the price-comparison capability of the internet, location, or speed of delivery, is becoming the competitive advantage. Therefore, our Client wanted to determine where its e-commerce warehouse(s) should be located. In 2015 they had only one warehouse near where the company was founded in the Midwest.

The Tradeoff: More Sales versus Lower Costs

In 1964 David Huff, a Professor at the University of Texas, developed a facility location formula called the "attraction" model. He proposed that the likelihood of a customer shopping at your store, versus shopping at a competitor's store, is a function of the distance from that store. This "attraction" model is the basis for many companies (Amazon perhaps being the most famous) building e-commerce facilities to be as close as possible to as many customers as possible. An example of this attraction function is shown below in Figure 1. The further away a market is from your facility, the lower your share of the sales in that market.



One way to get close to all of your customers is to open more warehouses, stores or factories, but that can be expensive. (Economies of scale dictate that unit costs get lower as facilities get larger because fixed costs are allocated over more volume.) In addition, sometimes being close to your customers means paying for premium real estate (anyone want to put a warehouse in New York City?).

The key problem you are trying to solve, when locating your warehouse, store or factory is to be as close to as many customers as possible, while minimizing your operating costs, which can broadly be defined as facility operations and shipping. This is the tradeoff… more sales versus lower costs.

Getting the Data

- Market potential
- Market-share by distance function
- Shipping costs and times
- Facility opening and operating costs

The data to optimally determine the locations of your facilities is not very complicated, but it will take time to acquire. The model we developed for our Client (and most facility

location optimization models) required determining the market share potential. If you are trying to maximize your market share, you probably want to maximize it in markets that are the largest. Therefore, you need to have some understanding of what 100% market share equals in sales. While this may seem daunting, if you don't know the market potential, how can you make any plans based on serving a market? Estimates such as the number of potential customers in a market and the sales per customer are a great starting point.

The next step is understanding what effect distance, or delivery time, has on market share. This is presented in the equation below.

Market Share % = 1 / (Delivery Time * Market Share Factor)

As an example, the "market share factor" used in Figure 1 above is three. Given this factor, if our Client has an e-commerce warehouse one day away from a market, we would expect to get 33% of the e-commerce orders originating in this market. Two days away equals 16.5% market share, three days equals 8.25%, and four days equals 4.125%. The "market share factor" is determined by management. We recommend that you run sensitivity analysis on this factor to ensure that you evaluate the highest and lowest possible market share and therefore make fully-informed decisions. Ultimately people, not an optimization model, make the final decision.

You will need to get data from your shipping sources of the distance and cost from each potential site to each customer location. If you have thousands of customers you can summarize your customer-locations into groups, such as metropolitan service areas (MSAs). MSA data is also available from the government census.

The last data needed are facility opening and operating costs. This includes rent, labor, utilities, inventory holding cost and others to represent your ongoing operating costs, and moving, construction, installation, and equipment purchases for your facility opening costs. The costs you gather should represent the operating cost differences throughout the regions in the US.

What is Optimization Modelling?

Optimization modelling (also known as linear programming) is a mathematical solution methodology that short-cuts to the absolute best answer. The problem our Client was evaluating has over 64 million possible solutions. However, the optimization model only had to evaluate about 10,000 choices to find the highest profit warehouse locations and sizes. The model simultaneously maximizes sales and minimizes shipping and facility costs by choosing which warehouses to open, the size of each warehouse and the primary shipping locations for each market (or MSA).

Model Results

Without using the optimization model, our Client was planning to keep their original Midwest warehouse and open a single large warehouse in the Northeast. This seemed logical as the Midwest warehouse served a large number of markets in one to two days. The proposed Northeast warehouse (to be located in eastern Pennsylvania, which is a popular site for distribution centers) would handle the large Northeast and New England markets in one to two days. This solution generated a profit of $6.9 million.

Instead, the optimization model's solution was to open five small warehouses; one in the West, one in the upper Midwest, one in the "Ohio Valley", one in the Mid-Atlantic and one in New England. These five sites increased profit to $8.7 million, a 25% increase! These five sites were more expensive, increasing facilities costs from about $1 million to $1.5 million. However, sales due to the shorter delivery time to most major markets increased by $5 million. In addition the average delivery time across the network was 2.5 days in the baseline design versus 1.95 days in the optimal solution.

To quote the CEO, these results defied common-sense. "Why wouldn't we keep our existing warehouse and add one more equally large warehouse in the Northeast?" Closing the existing warehouse and opening five small facilities in different cities just didn't make sense. However, when there are 64 million possible solutions, common-sense may not be the best decision making tool.

Sensitivity Analysis

When using inputs, such as the market-share earned by being close to a market, or the e-commerce market share due to having retail stores in a market (See Figure 1 above), it is best to conduct sensitivity analysis. In this case we changed the percentages due to these market shares to evaluate best and worst case scenarios.

Decision Support, Not Decision Making

Sensitivity analysis is so important because optimization models are decision support tools, not decision making tools. At the end of this process we didn't expect management to simply implement the model's solution. It takes a combination of qualitative criteria and quantitative answers to make the best decision.

Management decided to leave the original warehouse open but halve its size. Having a warehouse in the same facility as the supply chain, marketing and customer service functions improves access to inventory for multiple purposes. In addition, the "Ohio Valley" location was moved from the recommendation, a secondary market, to one of our Client's top markets, which was only 60 miles away. It was a bit more expensive, and slightly reduced sales, but there are other non-quantifiable factors including ease of flying and the desire to have a warehouse near large markets.

Conclusion

Locating your facility is an important and difficult-to-change decision. It should be done with a blend of qualitative criteria and optimization solutions. Including optimization in the analysis can result in a dramatic difference in company profitability and service to customers.