Supply/Distribution Chain Planning at Dartboard Corporation 2.0

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Note: The events of this case take place in January 2015.

Dartboard Corporation

Dartboard Corporation, founded in 1922, is today one of the ten largest retail companies in North America, operating over 1,800 brick-and-mortar stores. Its stores are within reach of customers in every ZIP code in the continental United States. The company's nationwide physical footprint was the focus of several successful advertising campaigns, including the early 1990s slogan "Wherever you are" that pre-dated the World Wide Web and the phenomenon of online retail.

Indeed, online retail has created fundamental challenges for Dartboard over the past decade. The company has experienced a slowdown in the growth of its brick-and-mortar store sales and has ceded market share of the growing online retail business. Dartboard was slow in adjusting its business model to the disruption – and potential opportunity – of online retail enabled by the Web and, more recently, by mobile computing. Dartboard's major shareholders have expressed frustration with the company's inability to establish a larger online presence. In 2014, Dartboard's Board of Directors appointed Mr. Rama Anand as the company's new CEO, with the expectation that he will improve the company's online presence.

New CEO First Impressions

Rama spent his first two months at Dartboard reviewing all aspects of Dartboard's online retail strategy. He sought candid assessments and fresh ideas from key managers in different functional areas and at different levels of the organization. One of the first things Rama noticed at Dartboard was a corporate culture of "fighting fires" – essentially focusing on solving today's problems with insufficient attention on medium-to-long-term planning that would avoid many of these problems if addressed sufficiently in advance. He also observed that the company's decision-making culture was too hierarchical, with an unhealthy reliance on the opinions of a few influential senior managers. These managers are highly experienced in the management of brick-and-mortar stores; however, they are far less knowledgeable about online retail. Rama has also observed that Dartboard's direct competitors are much further ahead in their use of data-driven analytics. He recognized that he must change Dartboard's decision-making culture. In the short term, however, he needs to formulate a practical strategy to address Dartboard's struggling online business.

Northeast Stockouts

One urgent operational problem facing Dartboard is the high frequency of stockouts of items sold through its online channel. These stockouts are hampering the growth of online sales, not only because of lost revenue due to unsatisfied demand, but also because stockouts negatively impact customer satisfaction and future customer engagement. Even when a product appears in stock online, orders of that product are sometimes not delivered to customers on time due to replenishment problems throughout Dartboard's distribution network. Stockouts have been detrimental not only to Dartboard's online business, but also to its brand in general.

The cause of the problem was evident: the network of distribution centers (DCs) supporting the online retail business has become over-capacitated and unable to handle current – let alone future – demand. This problem has become especially severe in the Northeast region of the United States. In Dartboard's logistics network, the Northeast region spans 18 states from Maine in the north to Virginia in the south, and from Michigan, Indiana, and Kentucky in the west, to the Atlantic coast in the east. With a combined population exceeding 100 million, and annual online retail sales exceeding $7 billion in 2014, the Northeast region is served by only three DCs, which were built prior to 2010. Not only is the physical capacity of this distribution network a problem, but transportation costs are also becoming excessive as the DCs continue to serve growing demand dispersed throughout the region. Dartboard incurs the cost of delivering products from DCs to customers, and Dartboard's actual delivery costs generally exceed the fixed order shipping costs it charges its customers.

Dartboard, like many retailers, has made a decision early-on to fulfill online orders through dedicated small e-commerce DCs that operate independently from their traditional larger DCs that serve physical stores. The original rationale was that the operations of a direct-to-consumer e-commerce DC were in many ways distinct from that of a traditional DC. The mix of products carried is typically different. E-commerce DCs need to handle the packing, labeling, and shipping of small order sizes, and they need to do so with a high level of accuracy. E-commerce DCs also need to manage order returns.

With the rise of omni-channel retail, Dartboard is now rethinking the wisdom of operating separate distribution networks. However, it will take at least 2-3 years before they can design and implement the integration of their distribution networks. For now, Dartboard has to continue fulfilling online orders through a dedicated distribution network, but it needs to significantly upgrade the capacity of this network, especially in the Northeast region, to alleviate the stockout problems. Fortunately, a logistics team at Dartboard has just completed a project that identified 17 potential new sites for setting up new e-commerce DCs throughout the Northeast regions, along with a detailed analysis of construction and operational costs of these potential new DCs. It typically takes only 5 months from the time a DC site is chosen for construction to the time it is built and its operations are up and running.

A Consulting Engagement

To expedite this effort, Rama reached out to Ailsa Land, a Partner at the Operations Practice of the consulting firm MCG in early January 2015. Rama knew Ailsa from the time they were pursuing their MBA degrees, and they have worked together on several projects as their career paths crossed. Ailsa's practice at MCG matched perfectly with Dartboard's need to upgrade their online distribution network. Rama contracted MCG to work on this project for three weeks, with the scope limited to the Northeast region and with a planning horizon extending only through to the end of 2017. Ailsa was enthusiastic about the engagement, and especially that it presented MCG the opportunity – if they deliver good results – to later expand the engagement to Dartboard's entire national network, and perhaps also to longer-term redesign and integration of Dartboard's online and physical supply chains.

Ailsa assembled an MCG project team to work on-site with their counterpart Dartboard team at Dartboard headquarters. Given the limited scope and time-sensitivity of the initial engagement, Ailsa charged her team with identifying which combination of the 17 potential DC locations shortlisted by the Dartboard logistics group would best alleviate Dartboard's distribution capacity problem through the end of 2017. The MCG team split the project into two main tasks:

1) <u>Demand forecasting</u>: The first task is to construct a forecast of Dartboard's online demand for each county in the Northeast region on a weekly basis from mid-2015 (when the new DCs would become operational) through to the end of 2017. The MCG team believes that aggregate annual forecasts are not sufficient because retail sales are highly seasonal; and designing the distribution network based on annual averages will almost certainly lead to capacity shortages during peak seasons.
2) <u>DC locations and capacities</u>: The second task is to select from among the 17 potential DC locations (a) which, if any, should be built, (b) the precise physical capacities in square feet [SQF] of the proposed DCs, and (c) which customer orders should be served by the proposed DCs vs. the existing DCs. The key requirement is to have sufficient capacity to eliminate stockouts through to the end of 2017 based on the demand forecast. The objective is to do so in the most economical way—by taking into account the transportation costs as well as the warehouse construction/operation costs.

The MCG team held informational meetings with key Dartboard senior managers and logistics and sales specialists. Ailsa was there on-site during the entire first week of the engagement. Following the meetings, MCG issued the customary information request—for sales, operational, and other pertinent data. The data provided by Dartboard to MCG includes weekly sales data for each county in the Northeast from the beginning of 2012 through to the end of 2014 (see Exhibit 1 for a sample). The Northeast region is comprised of 765 counties (and county equivalents) each identified by a unique Federal Information Processing Series (FIPS) code. The data also includes a summary of the locations, projected costs, and capacities of the potential and existing DCs (see Exhibit 4).

Demand Forecasting

Preliminary analysis of historical sales data by the MCG team has revealed a great deal of variability in weekly sales across counties (spatial variability) and a great deal of variability in county sales across different weeks (temporal variability). Discussions between the MCG and Dartboard teams identified several factors that possibly explain this variability:

i) Spatial variability: Exhibit 2 illustrates the variability in online sales across the 765 counties of the Northeast region. More populous counties clearly exhibit greater sales. Also, counties with higher income per capita tended to exhibit more sales. The MCG team was able to obtain accurate estimates of county-level population and income per capita data from publicly available government sources (census.gov and bea.gov). The team then interpolated this annual data to the weekly level.

ii) Temporal variability: Exhibit 3 illustrates the variability in online sales over time. The charts illustrate the time trends of weekly online sales per capita (total sales volume divided by population) at three levels of geographic aggregation. For a given county, say Suffolk County in Massachusetts, there is a clear upward trend, but also significant variability around the trend. As the level of aggregation increases, the upward trend persists, but also a distinct seasonal pattern emerges within each year. In particular, the last 8 or so weeks of each year (the holiday season) have higher sales volume compared to the other weeks of the year.

Based on the above exploratory analysis, Ailsa's team decided to model weekly sales at the county level as a function of: county population, county income per capita, number of weeks elapsed since beginning of 2012, and the "season" corresponding to a given period.

Upon further reflection the team decided to use county sales per capita (that is, sales divided by population), rather than county sales, as the relevant quantity to forecast as a function of county income per capita and time series patterns. To capture the seasonality component, the team divided the 52 weeks of each year into 13 four-week periods. The team thought that this split would capture annual seasonal trends at a sufficient level of detail.

The final demand modeling task facing the team is to relate the variables together using an appropriate forecasting model and functional form. Here the expertise of the Dartboard sales analysis team shone brightly. The Dartboard team had observed from years of experience that sales volume tends to increase by a given *percentage* from week to week. They also observed that relative changes in income per capita translate to relative changes in sales per capita. This suggested that a simple linear form would not be adequate. And indeed, Dartboard's observations were in synch with MCG's internal online research on retail sales modeling.

The team ultimately settled on the following mathematical model for forecasting demand:

$$log\left(\frac{d_{t,c}}{pop_{t,c}}\right) = a_0 + a_1 log(inc_{t,c}) + b_0 t + \sum_{s=1}^{13} b_i\, u_{t,s}$$

where:

- $d_{t,c}$: denotes the demand in week *t* from county *c,* in dollars;
- $pop_{t,c}$: denotes the population in week *t* of county *c*;
- $inc_{t,c}$: denotes the income per capita in week *t* of county *c* in dollars;
- t : denotes the number of weeks elapsed since the start of year 2012;
- $u_{t,s}$: 1 if week *t* falls in "season" *s* of the year; 0 otherwise*.

In the above model, the dependent variable is the log of sales per capita. The independent variables are log of income per capita, the number of weeks elapsed (the trend component), and the seasonality component. The model coefficients (to be estimated via linear regression) are the 16 values a_0, a_1, b_0 , and b_1 , …, b_{13} . At this point, the team knew exactly what to do next. Following best practice, they would divide the available historical data into a training set and a test set. They would fit the above regression model on the training set and assess its performance on the test set. Most of the MCG team were proficient in business analytics and specifically knew R. This made it easy to quickly go from concept model to model assessment.

From Demand Forecasts to Distribution Capacity

After completing the demand forecasting task, the project soon pivoted to the main task of planning distribution center capacities.

Working with Dartboard's logistics group, MCG reviewed how sales predictions in dollars [$] can be converted into DC space requirements in square feet [SQF]. Products are stored in DCs on standard size pallets. On average, each pallet carries SKUs with a retail sales value of approximately $1,000. Therefore, a sales volume of, say, $500,000 out of a DC corresponds to the flow of approximately 500 pallets through the DC.

The inventory turnover rate of Dartboard's online retail business determines how long, on average, a pallet remains at a DC before it is shipped out. Based on historical records, inventory turnover rate is 8 weeks in a Dartboard DC. It is useful to think of the sales of the next 8 weeks as today's inventory of pallets in Dartboard's DCs.

A standard size pallet measures 48" in length by 40" in width. Therefore, each pallet requires a footprint of 13.33 SQF, which is rounded up to 13.5 SQF to account for placement tolerances.

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* For example, the fifth week of the year (t=5) will have $u_{5,1} = 0$, $u_{5,2} = 1$, $u_{5,3} = 0$, …, $u_{5,13} = 0$. This reduces the summation term in the forecasting model to b_2, the seasonality effect of the second 4-week period of the year.

The size of DCs is measured in SQF of (storage) floor space. Dartboard's e-commerce DCs are standardized to allow five vertical tiers of storage accessible by human- or robot-driven forklifts. Therefore, a 1,200,000 SQF distribution center (which is the largest size DC that Dartboard can build) can store up to 5 * 1,200,000 / 13.5 = 444,444 pallets of inventory.

Dartboard currently operates three DCs in the Northeast region: Providence (1,200,000 SQF), Richmond (1,200,000 SQF), and Youngstown (900,000 SQF). The combined capacity of these three DCs is 1.22 million pallets of inventory. The online sales orders in the last 8 weeks of 2014 were in excess of $1.35 billion (the equivalent of 1.35 million pallets of inventory). It is no wonder that Dartboard has experienced stockouts. (In reality, stockouts start occurring when average demand rates approach, even if they do not strictly exceed, the system's capacity.)

Expansion Possibilities

Faced with significant shortages in its distribution capacity, and unable to upgrade the capacity of its three existing DCs, Dartboard needs to expand its DC footprint in the Northeast region.

Exhibit 4 lists 17 potential sites for new DCs. Once a site is chosen, Dartboard can get a DC up and running there within 5 months. Dartboard uses a simple and economical structural design for its DCs, and can efficiently configure them to any capacity up to 1,200,000 SQF. The simple structural design gives Dartboard flexibility to arrange the layout of its DCs to meet the preferences of its local employees.

Dartboard estimates the costs of constructing and operating its DCs based on a fixed cost component (independent of the facility size) and a variable cost component based on the footprint of the facility. These costs are provided in Exhibit 4. The fixed cost is for land lease or purchase leases, site work, permits and other legal/regulatory costs—and does not really depend on the location. The variable costs, in contrast, vary significantly by county. For example, building a 1,200,000 SQF in Athens, Ohio, costs $133.6 million. These costs are fully amortized over the 2.5-year planning horizon (July 2015 through December 2017).

Optimizing the Distribution Network

On Tuesday of the second week of the consulting engagement, Ailsa and her team held a morning meeting to carefully discuss and agree on some key modeling assumptions.

Ailsa re-iterated that the team needs to produce a concrete recommendation for (a) which, if any, of the 17 potential sites identified in Exhibit 4 should be chosen for the immediate construction of new DCs, (b) the recommended sizes in square feet [SQF] of each of the proposed new DCs, and (c) which customer orders should be served by which DC over the planning horizon (July 2015 to December 2017). On this last point, the team confirmed that county demand should not, in general, be split across different DCs due to various customer service and logistics constraints. A key modeling assumption is therefore that each county must be served by a single DC throughout the planning horizon.

A second important modeling discussion revolved around how to size DCs appropriately. Even with a fixed allocation of counties to DCs, seasonal and time trends in demand imply that the amount of inventory stored in any given DC fluctuates over time. Given the emphasis on eliminating stockouts, and given the 8-week average duration a pallet remains at a DC, the MCG team decided to size each DC to accommodate the peak 8-week period of demand from allocated counties within the planning horizon. This assumption simplifies the computational complexity, and makes it easier to communicate the model to the client. The demand forecast suggests that this peak period will in all likelihood be the last 8 weeks of 2017. Therefore, the team decided to size each new DC just enough to cover this peak demand period.

A third discussion centered on transportation costs. Products are transported from DCs to customers by truck. According to data obtained by the logistics team, a truck holds 20 pallets on average. The average cost per mile is $1.55, which includes driver's salary, diesel fuel, lease and maintenance costs, etc. Thus, transportation costs will be assumed to equal 7.8 cents per pallet per mile. The fact that all customer orders in each county are served by a single DC simplifies the computation of these costs because a county's projected demand can be summed over all 130 weeks of the planning horizon for the purposes of computing transportation costs.

Finally, there was a brief discussion about whether discounting cash flows was necessary. An earlier discussion with Dartboard's finance departments has concluded that such discounting is unnecessary in the context of this project.

At the end of the meeting, Ailsa reviewed the planning timeline facing Dartboard. The Northeast's distribution capacity plan needs to be finalized by the end of the current month (January 2015). Then, construction of new DCs will commence and the DCs will be operational at the beginning of July 2015. If all goes according to plan, Dartboard will hopefully have solved its distribution capacity problems through the end of 2017.

The team will reconvene to proceed with determining that optimal configuration of DCs.

EXHIBITS

Exhibit 1: Sales Data

FIPS.Code	State.Name	County.Name	Latitude	Longitude	Year	Week	Sales [$]
9001	Connecticut	Fairfield County	41.244	-73.363	2012	1	709,767
9001	Connecticut	Fairfield County	41.244	-73.363	2012	2	783,785
9001	Connecticut	Fairfield County	41.244	-73.363	2012	3	588,098
9001	Connecticut	Fairfield County	41.244	-73.363	2012	4	576,305
9001	Connecticut	Fairfield County	41.244	-73.363	2012	5	757,478
9001	Connecticut	Fairfield County	41.244	-73.363	2012	6	686,065
9001	Connecticut	Fairfield County	41.244	-73.363	2012	7	715,862
9001	Connecticut	Fairfield County	41.244	-73.363	2012	8	809,186
9001	Connecticut	Fairfield County	41.244	-73.363	2012	9	868,546
9001	Connecticut	Fairfield County	41.244	-73.363	2012	10	685,889

Exhibit 1a: Extract from the Dartboard_historical.csv file. The file contains weekly sales data for each of the 765 counties and county-equivalents in the Northeast between 2012 and 2014. The above table is a sample of weekly sales for a given county. “FIPS” is the Federal Information Processing Series code for the county. Latitude and Longitude are in degrees. Weeks are numbered consecutively from 1 to 52 within each year.

FIPS.Code	State.Name	County.Name	Latitude	Longitude	Year	Week	Sales [$]
9001	Connecticut	Fairfield County	41.244	-73.363	2012	1	709,767
9003	Connecticut	Hartford County	41.82	-72.718	2012	1	552,666
9005	Connecticut	Litchfield County	41.776	-73.202	2012	1	169,079
9007	Connecticut	Middlesex County	41.447	-72.529	2012	1	114,898
9009	Connecticut	New Haven County	41.33	-72.927	2012	1	546,430
9011	Connecticut	New London County	41.457	-72.127	2012	1	188,069
9013	Connecticut	Tolland County	41.842	-72.308	2012	1	116,260
9015	Connecticut	Windham County	41.836	-72.02	2012	1	99,236
10001	Delaware	Kent County	39.134	-75.448	2012	1	127,444
10003	Delaware	New Castle County	39.573	-75.597	2012	1	469,746

Exhibit 1b: Extract from the Dartboard_historical.csv file. The file contains weekly sales data for each of the 765 counties and county-equivalents in the Northeast between 2012 and 2014. The above table is a sample of county sales for a given week. “FIPS” is the Federal Information Processing Series code for the county. Latitude and Longitude are in degrees. Weeks are numbered consecutively from 1 to 52 within each year.

Exhibit 2: 2014 Online Sales Across Northeast Counties

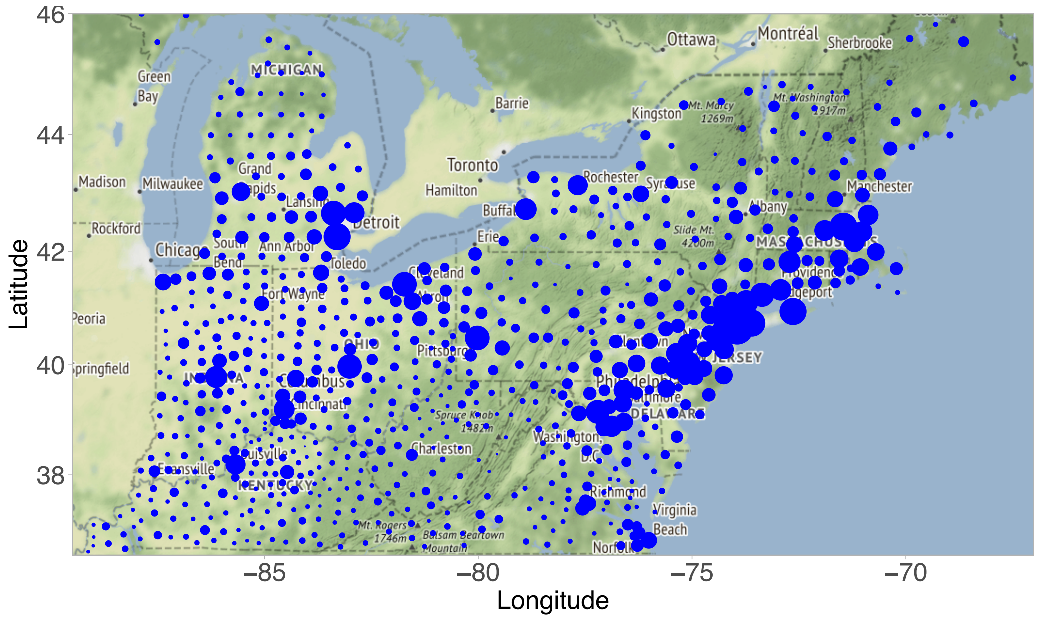

Exhibit 3: A schematic of the variability in 2014 online sales volume across the 765 counties comprising the Northeast region. The area of each circle is proportional to the sales volume (in dollars).

Exhibit 3: Weekly Online Sales per Capita at Three Levels of Geographic Aggregation

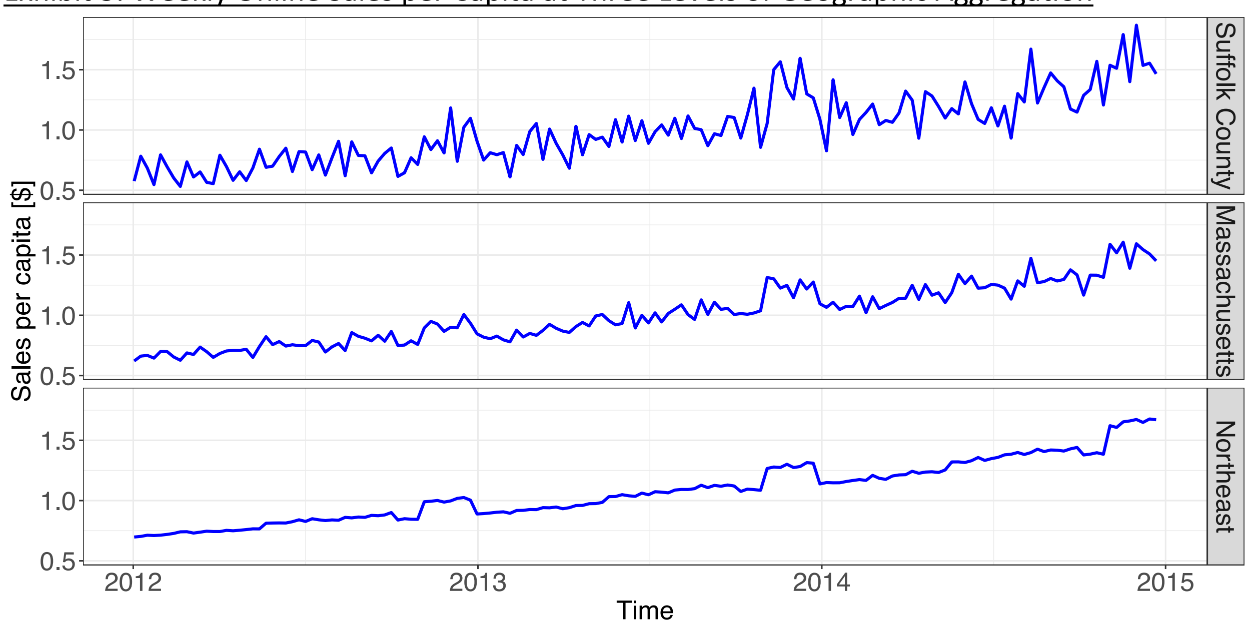

Exhibit 4: Weekly online sales per capita at three levels of geographic aggregation.

<u>Exhibit 4: Current and Potential DC Data</u>

Warehouse Name	Current/ Potential	Latitude	Longitude	Fixed Cost [$]	Variable Cost [$/SQF]	Current Size [SQF]	Max Size [SQF]
Providence	C	41.8	-71.4	0	0	1,200,000	1,200,000
Richmond	C	37.5	-77.4	0	0	1,200,000	1,200,000
Youngstown	C	41.1	-80.6	0	0	900,000	900,000
Athens	P	39.3	-82.2	25,000,000	90.5	-	1,200,000
Baltimore	P	39.3	-76.6	25,000,000	132.0	-	1,200,000
Bangor	P	44.8	-68.7	25,000,000	75.0	-	1,200,000
Buffalo	P	42.9	-78.8	25,000,000	92.2	-	1,200,000
Burlington	P	44.5	-73.1	25,000,000	148.3	-	1,200,000
Chillicothe	P	39.3	-82.9	25,000,000	68.7	-	1,200,000
Dover	P	39.2	-75.6	25,000,000	102.8	-	1,200,000
Kalamazoo	P	42.3	-85.6	25,000,000	74.8	-	1,200,000
Knoxville	P	36.0	-83.9	25,000,000	75.8	-	1,200,000
Laconia	P	43.5	-71.5	25,000,000	118.2	-	1,200,000
Lancaster	P	40.0	-76.3	25,000,000	92.0	-	1,200,000
Norwalk	P	41.1	-73.4	25,000,000	166.5	-	1,200,000
Salem	P	42.5	-70.9	25,000,000	157.0	-	1,200,000
Scranton	P	41.4	-75.6	25,000,000	78.7	-	1,200,000
Syracuse	P	43.0	-76.1	25,000,000	88.0	-	1,200,000
Toledo	P	41.7	-83.6	25,000,000	64.0	-	1,200,000
Worcester	P	42.3	-71.8	25,000,000	101.5	-	1,200,000

Exhibit 2: Warehouse information for current and potential new DCs in the Northeast. Latitude and Longitude are in degrees. “Fixed cost” and “Variable cost” data are estimates for new construction (at potential new sites).

Exhibit 5: Map of Current and Potential Warehouse Locations

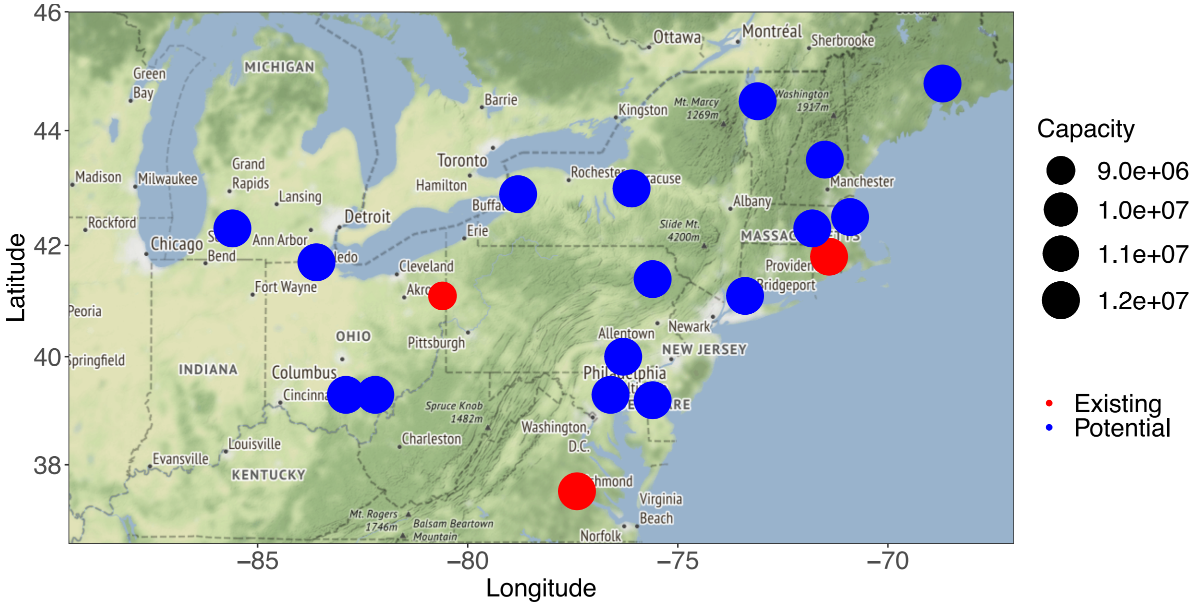

Exhibit 5: Current (in blue) and potential (in red) DC locations in the Northeast.