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Supply Chain Network Design: Key Factors for the Retail Industry
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Supply Chain Network Design: Key Factors for the Retail Industry

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Summary:

The objective of this thesis is to identify and evaluate the impact of a set of key performance factors that need to be considered while designing a supply chain network for a retail firm. Specifically, we locate a set of distribution centers that serve a fixed set of retail stores using a p -median location model. We perform a sensitivity analysis to evaluate the robustness of our solution to these factors.



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KEY INSIGHTS

1. Factors, such as, population density, oil prices, demand fluctuations, and operating costs drive network costs.
2. Optimization of a milk-run route involves the identification of the precise store cluster for each distance range.
3. A network design solution should hedge against uncertainties in the external environment by measuring the key metrics on variation of these factors.

Introduction

The importance of supply chain strategy in an organization's overall business strategy has considerably grown over the last few years, with companies' recognizing the vast potential cost savings and high level of responsiveness that can be achieved by designing an effective supply chain network. Supply chain network design involves making a transportation mode choice, supplier profile choice, facility choice, topologies, etc. We will focus particularly in facility location. Specifically, we will focus on the location of distribution centers for a set of retail stores. A key issue that the retail

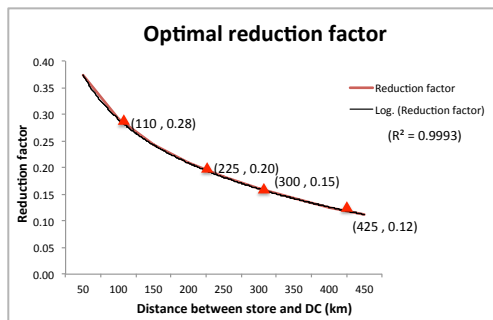
industry faces is to build a network that can effectively serve end customer demand at the lowest cost.

Yet, in doing so, they are faced with a multitude of issues such as, stock outs, excess inventory, and obsolescence. The unpredictability of the network demand and various external variables adds to the complexity of network design for a retail firm. The challenge of locating a facility optimally has been frequently addressed in scientific literature over the last few years. Daskin (2008) in his work developed insights on the drivers of supply chain cost; Menezes (2010) took this work forward to highlight the variables that impact the number of facilities required to serve demand. The model described in his work is central to our work to determine the factors that impact network design. The p -median problem was first introduced by Hakimi (1964). He developed a model that would effectively locate a facility to minimize transportation costs by minimizing the distance between the facility and the demand point. We perform a sensitivity analysis of the factors that impact this location model. We make a comparison between a location set with milk-runs and a location set with direct shipments. We compare the two models based on costs and make

a deep dive sensitivity analysis for both cases from which managerial insights can be drawn.

The milk-run transportation model

The retail firm uses milk-runs in its transportation to serve demand at its retail stores. The inclusion of milk-runs in the transportation model introduces a degree of complexity to the facility location model that is unwanted at least for a first rough evaluation of a problem. Our objective is to keep the model simple and to create a mechanism for approximating the impact of milk-runs on the solution. That helps decision makers to 'easily' find solutions to very complex problem and to get a first cut on costs and network size. Also, by keeping the model simple, it makes easier for decision makers to gain relevant insights. In our approach, we find ways to generate a reduction factor that can be used to adjust the raw direct distance between a distribution center and a store, such that it would reflect the fact that the store is a part of a milk-run cluster. It is a clever way of including milk-runs through adjusting the shortest distance matrix. The figure below depicts the continuous function that would determine the reduction factor for any given distance. The model is also used to generate optimum store clusters for the given distance. We will use these reduced distances in the model to develop insights on the factors mentioned previously.



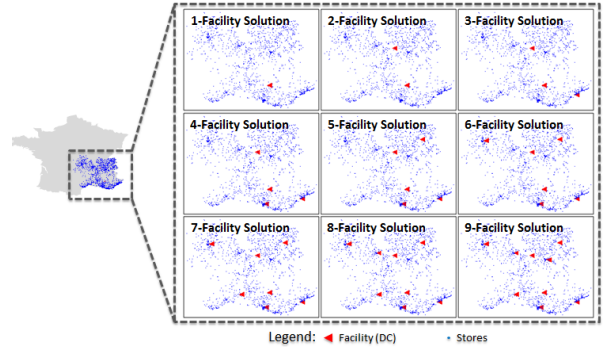
This model neglects constraints that involve caps on maximum distance that can be traveled by a truck, and working hours for a single driver; these factors are specific to a region and need to be considered on a case-by-case basis.

The p -median model

We formulate the p -median model to locate a set of facilities to minimize the demand weighted average distance.

The p -median formulation cannot be solved optimally using solver or any other processing software. The problem scope was too large to be solved optimally, and hence it was solved via a greedy heuristic algorithm.

The greedy heuristic algorithm is an algorithm that follows a sequential process by which each open potential candidate site is evaluated, and the facility site with the greatest impact on the objective function is selected. The greedy heuristic algorithm was run for $p = 1, 2, 3, \dots$, and 10 facilities, and the figure below shows us the 9 optimal solutions among the 10.

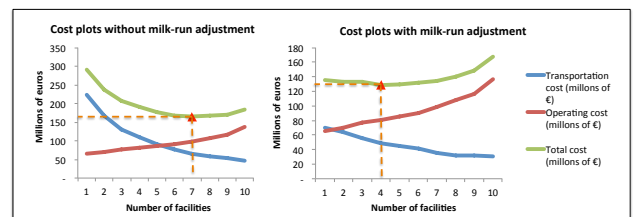


On determining the optimum network structure, compute the network cost for each network structure.

The table below depicts the cost savings by incorporating the various network solutions. We find that the maximum cost savings achieved by assuming a direct shipment transportation model is 31%, and the maximum cost savings achieved by making the milk-run adjustment is 18%. We find that all the solutions obtained in the milk-run adjusted model bring about cost savings; however, the 1-facility solution in the direct shipment model actually leads to a cost increase over the existing network.

*All costs in millions of Euros					
Direct Shipment Cost Structure			*All costs in millions of Euros		
Existing Network Cost	237		Existing Network Cost	156	
Solution	Network Cost	Theoretical cost reduction	Solution	Network Cost	Theoretical cost reduction
1 - Facility	290	-22%	1 - Facility	136	13%
2 - Facility	236	0%	2 - Facility	134	15%
3 - Facility	207	13%	3 - Facility	133	15%
4 - Facility	191	20%	4 - Facility	129	18%
5 - Facility	177	26%	5 - Facility	130	17%
6 - Facility	167	29%	6 - Facility	132	16%
7 - Facility	165	31%	7 - Facility	135	14%
8 - Facility	167	30%	8 - Facility	140	10%
9 - Facility	170	29%	9 - Facility	149	5%
10 - Facility	183	23%	10 - Facility	167	-7%

We consolidated all the solutions and identified that the optimal network configuration for location model without the milk-run adjustment is the 7-facility solution. The optimal network configuration with the milk-run adjustment is the 4-facility solution. (figure below).



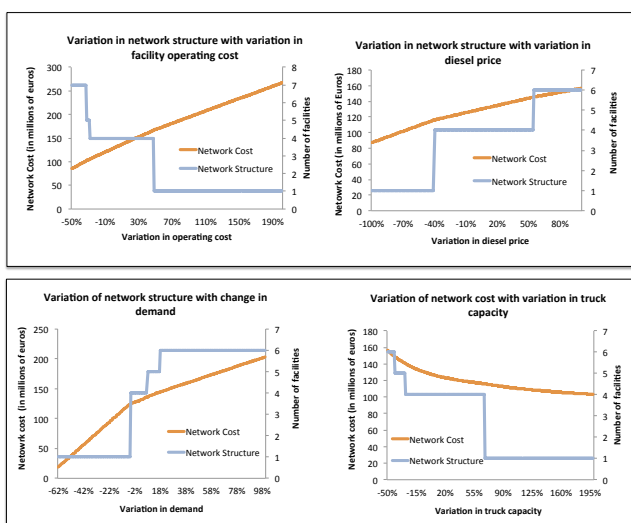
Although we have identified an optimal solution of 4 facilities for location model (milk-run adjusted), we

believe that the incremental costs of moving up to 7 facilities or down to 3 facilities for the company is very small. We think that the choice of moving closer to a 3 facilities or closer to 9 facilities depends much on the supply chain strategy. If the company is looking to be more responsive, focusing more on achieving high service levels, or even switching completely to a brick and mortar channel, it can choose to adopt a solution closer to 9 facilities. However, if the focus is on efficiency, cost competitiveness, or maybe an e-commerce channel, it might make more strategic sense to move towards a 5-facility solution. We think that business strategy should be aligned with network design solution to bring about an overall efficient supply chain. In the next section, we further analyze the variation in the optimal network structure by performing a sensitivity analysis on a few external factors.

Sensitivity Analysis

To gain insights about which of these network structures would be optimum under different operating circumstances, we have identified a few factors from current literature that could have a significant impact on the network structure. We modeled the optimum network structure by quantifying the cost associated with operating the network.

We performed the sensitivity analysis on the factors (operating cost, diesel price, demand variation, and transportation capacity) for the milk-run adjusted model and the traditional model. The figure below shows the result of the sensitivity analysis with the milk-run adjustment.



We find that the optimum network structure in both cases is quite sensitive to a variation in diesel prices. We found that both the models are sensitive to both decreases and increases in demand. We also found

that the model is robust to increases in truck capacity but sensitive to decreases in capacity. We have mapped out the variation in network structures for the different factors. However, it is important to understand the factors that contribute to the variation in the four factors detailed in this section. Factors such as, efficiency of trucks, fuel consumption, and carbon footprint, impact the variation in diesel price. SKU (stock-keeping-unit) proliferation and facility capacity are key drivers of facility operating cost. Government regulations can affect the variation in truck specifications can impact truck capacity, and finally, factors such as, competitor strategy, population density, price structures, and product strategy play a large role in demand variation.

Conclusions

In this work, our main objective was to identify and to perform a sensitivity analysis on the factors that impact on the supply chain network of our sponsor company. We have analyzed the existing network structure of a retail firm and have identified potential factors and key trade-offs that a firm should consider when approaching strategic network design. We developed a milk-run model, which defines the reduction factor and optimal store cluster for a given distance for the retail company. We have presented cost structures of the 10 solution sets with and without the milk-run adaptation and have identified that the 7-facility solution with an overall network cost of 165 million € is the optimum for the p -median model (without milk-run adjustment), and the 4-facility solution with an overall network cost of 129 million € is optimal for the milk-run adjusted model. We have identified 4 factors that impact network design for the sponsor company and have performed a sensitivity analysis on these factors to understand the sensitivity of our solution set to various external factors. We think that the incorporation of the right network design solution or the choice of transportation model (milk-run or direct shipment) depends largely on the business strategy of the company.

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