Home Dialysis Equipment Network Rationalization

Design Team
Mike Dutra, Chris LaColla
Michaela Poulin, Ally Snigur

Design Advisor
Prof. James Benneyan

Sponsor
NxStage Medical Inc.

Abstract
NxStage Medical is a medical device company that develops and distributes home hemodialysis equipment, delivering 1.5 million cases of dialysate to over 6000 patients annually. The company aims to rationalize the cost and service level of its supply chain network for the delivery of dialysate to patients’ homes. The following project optimized NxStage’s home-delivery network using integer programming and explored additional improvements using sensitivity analysis. Important considerations included cost, customer satisfaction, shipment type, and carrier capability. The final solution provided a mathematical model for the selection of services to be offered, by what couriers, and in what geographical markets of the continental U.S. The level of improvement achieved by the final solution was measured through a comparison to baseline measures of the current state of the network.

For more information, please contact j.benneyan@neu.edu.
The Need for Project

NxStage Medical would like to optimize its home delivery costs and provide a higher level of service to its customers for the delivery of monthly replenishment orders of dialysate to patients’ homes. NxStage Medical’s supply chain network for the delivery of dialysate to patients’ homes has not been evaluated in terms of cost and service level since its conception. Given NxStage’s growing patient population and the vital importance of dialysate in hemodialysis, optimizing its home-delivery network has significant implications for NxStage and its patients, both in terms of minimizing the transportation costs of the network and improving service level. Network rationalization is expected to increase patient satisfaction and retention, as well as the accessibility of dialysate (Rep. 2.1).

The Design Project Objectives and Requirements

Design Objectives

The objective of this project was to provide NxStage with a robust mathematical model for redesigning and optimizing its home-delivery network that has the flexibility to support growth and shifts in the company’s ever-changing patient population. The capstone team used integer programming and sensitivity analysis approaches to develop an easily implementable solution that utilizes the company’s current third party logistics providers. The mathematical model determines what services are to be offered, by what couriers, and in what geographical markets of the continental U.S., while the sensitivity analysis helps decision makers explore further improvements.

Design Requirements

The final solution needed to optimize the cost while improving the service level of NxStage’s home-delivery network. To achieve this, the integer programming model required a multi-criteria objective function that minimized transportation costs and the penalty costs associated with poor service levels. The integer programming model also considers couriers’ rates, delivery capabilities, and past performance statistics.

Since NxStage has not had the opportunity to evaluate its network and did not establish a desired level of improvement to be achieved, the overall success of the model was validated through a comparison to baseline measures of the current state of the network (Rep. 3.1). In particular, a significant decrease in the total cost per delivery is expected as a result of employing the optimal solution.
Design Concepts Considered
The capstone team identified two candidate design approaches of which we found the Assignment Approach was the most feasible. Optimizing NxStage’s home-delivery network was a matter of effective assignment, i.e. appropriately assigning couriers to geographic markets based on their pricing structure and delivery capabilities. To determine the best approach to this problem, the capstone team researched several location-allocation models, both discrete and continuous (Rep. 2.2). The following two concepts were the leading candidates.

Location- Allocation Approach
Solution: Use location-allocation modeling approach to determine the locations of optimal forward stocking locations and warehouses based on patient demand and iteratively find the closest existing forward stocking location to assign to a patient population.
Feasibility: Upon formulating delivery cost equations, the team found that not all couriers calculate their delivery costs with respect to distance, which meant that, for some patients, being closer to a courier location did not ensure cheaper delivery. Additionally, using a location-allocation modeling approach was ill-suited for NxStage, as their priority was not to locate new facilities. Finally, this approach would not have produced a dynamic, decision-making tool that would benefit NxStage beyond the completion of this project.

Assignment Approach
Solution: Create an integer programming model to rationalize NxStage’s courier network by optimally assigning a courier to each 3-digit zip code for each product type.
Feasibility: The capstone team chose this approach because it provides NxStage with a concise solution that draws on multiple considerations and allows for sensitivity analysis. Sensitivity analysis is especially valuable, because it allows NxStage to explore the different tradeoffs between cost and service level. This approach is also dynamic enough that NxStage can continue to use the model as a decision-making tool beyond project completion as their supply chain continues to evolve.
Recommended Design Concept

The chosen design concept provided a mathematical model for the selection of services to be offered, by what couriers, and in what geographical markets of the continental U.S.

Design Description

The courier selection tool utilizes a mathematical model to designate which courier is to deliver what type of dialysate to each geographic market of the continental U.S. A robust objective function is defined to optimize the cost and service level of NxStage’s home-delivery network. The function considers the cost to deliver dialysate from the distribution center to courier locations and then from courier locations to patients’ homes. The function also assigns a cost to service level. Data inputs such as pricing structures and service level ratings are defined in Excel and then read into the model. The model is then solved using CPLEX, optimization software (Rep. 4).

Analytical Investigations

The input for the objective function required thorough and extensive data mining (Rep. 3.1). After analyzing six months of shipment data for NxStage’s 6,000 patients, the capstone team was able to capture all network information, such as demand and couriers’ pricing structures. Microsoft MapPoint was used to calculate travel distances from each courier location to all 3-digit zip codes. Additionally, service ratings for each courier were determined through an analysis of customer complaint data, collaboration with NxStage on the weight of importance of different complaint types, and the number of days per week that each courier allows for delivery appointments to be made. Finally, CPLEX was used to calculate the optimal assignment of couriers to 3-digit zip codes and perform sensitivity analysis by examining tradeoffs between service level and cost.

Key Advantages of Recommended Concept

The recommended concept offers a flexible, continuous, and easily implementable solution to optimizing NxStage’s home-delivery network for cost and service level. The model assigns demand to the third party couriers currently employed by NxStage. In doing so, the model yields a final solution with a low cost of implementation. However, although the project focuses specifically on deliveries of dialysate, the objective function has the flexibility to consider additional products, couriers, service criteria, or distribution centers. NxStage can continue to use this optimization tool as the company’s network grows and changes.
Financial Issues

The final solution has a minimal implementation cost, but continuous use of the tool requires an investment in optimization software. As the model considers NxStage’s current resources, the final solution has a minimal implementation cost. Implementation entails reorganizing product shipments to match the assignments designated in the final solution. The cost of reorganization shall be mitigated by the cost savings provided by the optimized network. Continual use of the tool however, requires an investment in the optimization software, CPLEX.

Recommended Improvements

The model can be expanded upon to consider the other shipment types and products that comprise NxStage’s delivery network. The primary focus of this project was the optimization of the network for replenishment order types, which make up approximately 50% of NxStage’s monthly orders (Rep. 3.1). Ideally, the model should be expanded upon to include other order types and product. Further consideration should also be given to alternative couriers not currently employed by NxStage as well as new distribution centers. Sensitivity analysis can be performed to gauge the benefit of such changes.