MIE 578 Supply Chain Logistics

Prof. Ana Muriel

Distribution Network Design Project[1]

Creating hubs: the case of North Suburban Library Systems

Introduction

The North Suburban Library System (NSLS) is a state-funded library system that delivers interlibrary loan items (books, video cassettes, etc.) to its member libraries in the suburbs north of Chicago. Although NSLS counts with 769 member libraries, the 49 public libraries it serves account for 89% of the total demand and are the focus of attention for NSLS management. The system is undergoing a budget crisis due to stagnant state funding, while at the same time experiencing a 35.8% increase in volume in the last year. This has prompted NSLS management to reevaluate operations and explore new options.

Current Operations

Currently, four vans operate from a sorting facility (the depot), which is at the NSLS headquarters in Wheeling, Illinois. Each van follows a delivery route and visits libraries to pick up outgoing items and deliver incoming items. Vehicle capacity is not a problem, but vehicle tour lengths are constrained by travel and library visit times. NSLS spends a significant amount on driver overtime. At the end of the work day, the items that have been picked up are sorted at the depot for delivery to their destination libraries when they are next visited.

Hub System

NSLS would like to provide the greatest possible visit frequency to its members. However, due to budgetary restrictions and rising demand for service from libraries, NSLS is creating "hub" libraries: the vans will visit only a subset of the 49 public libraries, which will act as hubs; the other libraries will be responsible for collecting material from the hubs and delivering material to the hubs. As a result of this change, NSLS will move from four vans to two vans and plan for no driver overtime.

In the hub system, two van routes will connect the hubs and the NSLS headquarters. Access trips will connect the non-hub libraries with hub libraries: When a patron uses interlibrary loan services at a library that is not a hub, either the library staff or the patron must travel to the nearest hub. As demand at non-hub libraries increases, the likelihood of travel increases.

In initial discussions of the development of the hub system, a few librarians have raised concerns about the adverse effect these changes will have on the marginalized communities they serve. Many of their patrons do not have access to transportation to collect their books from the hub

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[1] *Adapted from the case shared by Prof. Karen Smilowitz, Northwestern University*

library. The limited personnel and budget at their particular facilities will make it very hard to provide frequent visits to the hubs and adequate service.

Assignment

You are a team of business analysts from Minutemen Consulting. You have been hired by NSLS to design this new hub system. In particular, NSLS would like you to design a simple solution approach for them and use this approach to determine the hub locations and assignments for NSLS. They want a solution approach that they can re-run as needed when their demand volumes and other parameters change, without the support of Minutemen Consulting.

While the team should analyze the problem as given, where libraries are just distinguished by their locations and demand volumes, management is also requesting recommendations to ensure adequate service to a number of marginalized communities for whom the library services are an essential gateway to knowledge and upward social mobility. There are plans to assess the communities served by each of the libraries and identify which libraries should qualify for increased service. Could the solution approach be adapted to incorporate these requirements later on?

Note, some issues are purposely left vague as they would be in practice. Real projects are muddy: objectives are not fully clear (different stakeholders may have different objectives), system constraints need to be uncovered. As a team, you must make some assumptions about operations. Justify each assumption you make. Be creative!

Your write-up should include:

- Discussion of the problem, including the objective and constraints of the problem and related decisions; you must justify your objective function, constraints, decision variables and parameters
- Discussion of assumptions
- PART 1:
    - Provide a mathematical formulation for the problem of locating hubs; explain your model clearly – show how your formulation matches your problem description
        - You can use the suggestions on Appendix 2 to approximate the two-van constraint when modeling the hub location problem
    - Optimal solution in AMPL or your mathematical programming language of choice
    - Final recommendations for the design of the hub system and clear guidelines on how to reassess and redesign the system when needed.
    - Recommendations to better serve communities in greater need. How could the models change to make sure that the solutions generated will provide appropriate access for these patrons?
- PART 2:
    - Write a mathematical formulation for the problem of visiting the hubs in PART 1, with the two available vans and no driver overtime.
    - Solve the routing problem either through exact optimization or a heuristic approach.

Appendix 1 – Details on Delivery Route Operations

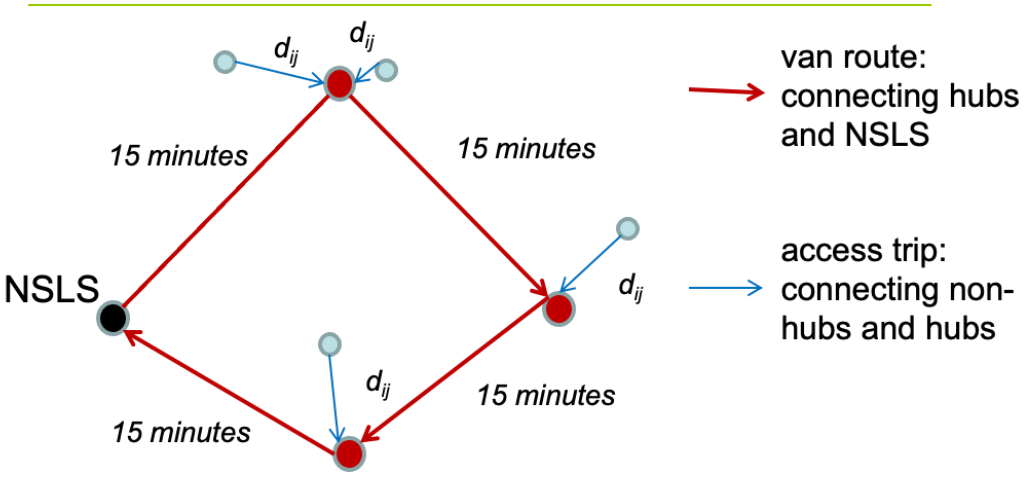
At each library the demand is composed of books lent and books borrowed. Management has aggregated the full volume of total demand for each library into a daily demand figure in the companion data file. Each van will depart from the depot, visit the hub libraries assigned to it, and return to the depot. The stopping time (measured in minutes) necessary to drop-off books borrowed and pick up books lent at a hub library is a function of the full demand the hub serves, which management suggests can be well approximated by the formula:

$$\text{Stop time} = (1/10) * \text{demand served by that hub}$$

Finally, an important constraint to consider is driver shift length. Each driver can spend at most 6 hours making their route, so as to leave time for sorting at the depot.

Appendix 2 – Assumptions Suggested by Management

To make the problem easier when deciding which locations to use as hubs, management is suggesting to simplify the travel time of the two van routes and assume that the travel time between any two nodes (libraries or the depot) is 15 minutes. However, they feel strongly that the actual distances between non-hub libraries and hub libraries be considered when evaluating the proposed solutions, as they are a reflection of the level of service NSLS is providing to each library. They have compiled a distance matrix in the companion data file.



In addition, NSLS management finds it reasonable to consider the driver availability constraint in the aggregate:

$$\text{total travel time of the vans} + \text{stopping time} \leq 2 * 6 \text{ hour driver limit}$$

Once the hub locations have been identified, then accurate vehicle routes using the actual distances can be created for the two vehicles to visit these locations.

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Grading Rubric

Report Presentation 10 points

- Clarity of report/easy to understand
- Organization
- Self-contained
- Good use of Figures and Appendix

Modeling Assumptions 20 points

- Are all the assumptions clearly stated (both those stated in the case study and those the team develops)?
- Are the assumptions reasonable and justified? Pros and cons evaluated?
- Does the team consider the impact of the assumptions on the model results?

Formulation 20 points

- Explanation of terms, decision variables, constraints and objective
- Formulation matches modeling assumptions and goals

Solution Methods 20 points

- Explanation of solution method
- Creativity of solution method
- Ability of solution method to generate high quality solutions in reasonable time

Analysis and Conclusions 30 points

- Appropriate cases are solved and using the formulation and solution method.
- Sensitivity analysis, if appropriate.
- Consideration of the impact of engineering solutions in global, economic, environmental, and societal contexts, showing good understanding of ethical and professional responsibility.
- In this particular project, the needs of marginalized communities are of special interest.
- Conclusions are well supported by the analysis and computational results