Laura Reading

617 E. Liberty St, #1

Ann Arbor, MI 48104

reading.lauraj@gmail.com

Minimizing Transportation Costs with Location-Allocation Analysis: An Application to Recycling

ABSTRACT

Ecomaine, a regional non-profit waste management company in Portland, Maine, sought to reduce transportation costs to member communities that transport recycling in 30 square yard collection roll-off containers (known as "silver bullets") to the Ecomaine recycling facility. This study objective was to minimize transportation costs by identifying the minimum number of consolidation locations to serve all silver bullets in fewer than twenty miles and the minimum number of locations to serve all silver bullets in fewer than thirty miles using the location-allocation analysis tool in GIS. The economic benefits of using the new consolidation locations were calculated by determining the net cost savings based on the reduction in distance traveled. The environmental benefits were also calculated by determining the reduction in greenhouse gas emissions based on the reduction in distance traveled.

INTRODUCTION

Ecomaine, a regional non-profit waste management company in Portland, Maine, sought to reduce transportation costs to member communities that transport recycling in 30 square yard collection roll-off containers (known as "silver bullets") to the Ecomaine recycling facility. It is important to reduce transportation costs so that recycling is more cost effective than disposal. Currently, communities haul silver bullets from the collection site directly to Ecomaine and then haul the container back to the collection site. However, the empty weight of the silver bullets is 3.4 metric tonnes so the return trip is inefficient. The silver bullets are designed for collection rather than transport so the contents of multiple silver bullets could be combined in a single trip. By consolidating the contents and reducing the distance travelled of heavy, empty containers, it is theorized that individual communities could reduce transportation costs. In addition, a reduction in total distance travelled can reduce the regional carbon footprint.

Therefore, this study objective was to minimize transportation costs by identifying potential consolidation locations between the 54 silver bullet locations and Ecomaine. Based on the least cost theory of industrial location, which identifies the location of an industry between two resources and a single market where the criterion is minimization of transport cost (Weber 1909), this objective was best achieved with the network analysis location-allocation tool in GIS.

Network analysis is a method of solving network problems, such as transportation problems, using an interconnected set of points and lines that represent possible routes from one location to another (ESRI n.d. a). Location-allocation, a type of network analysis, is the process of finding the best locations for one or more facilities (i.e., consolidation locations) that will service a given set of demand points (i.e., silver bullet locations) and then allocating, or assigning, those points to the facilities (ESRI n.d. b). The locations of the facilities can be based on one of the following variables: the number of facilities, their cost, or the maximum distance from a demand point to a facility.

METHODS

The goal of this study was to identify the minimum number of potential consolidation locations to serve all silver bullets using the following parameters:

- Ecomaine was set as a required facility so that any silver bullet that was closer to Ecomaine than a potential consolidation location would continue to travel directly to Ecomaine;
- The silver bullet locations were set as both demand points and as potential facilities since both uses have similar site requirements and the cost of adapting an existing facility is lower than constructing a new one; and
- A roads layer from the Maine Department of Transportation was used to calculate driving distances between demand points and facilities (MEGIS 2009). Local roads were excluded from the dataset because they may not allow commercial truck travel due to weight limits.

After identifying the minimum number of facilities, the economic benefits of using the new consolidation locations were calculated by determining the net cost savings based on the reduction in distance traveled. The environmental benefits were also calculated by determining the reduction in greenhouse gas emissions based on the reduction in distance traveled.

RESULTS

Location-allocation identified five potential consolidation locations (including Ecomaine) to serve all silver bullets in fewer than 32 kilometers and three potential consolidation locations (including Ecomaine) to serve all silver bullets in fewer than 48 kilometers (Figure 1).

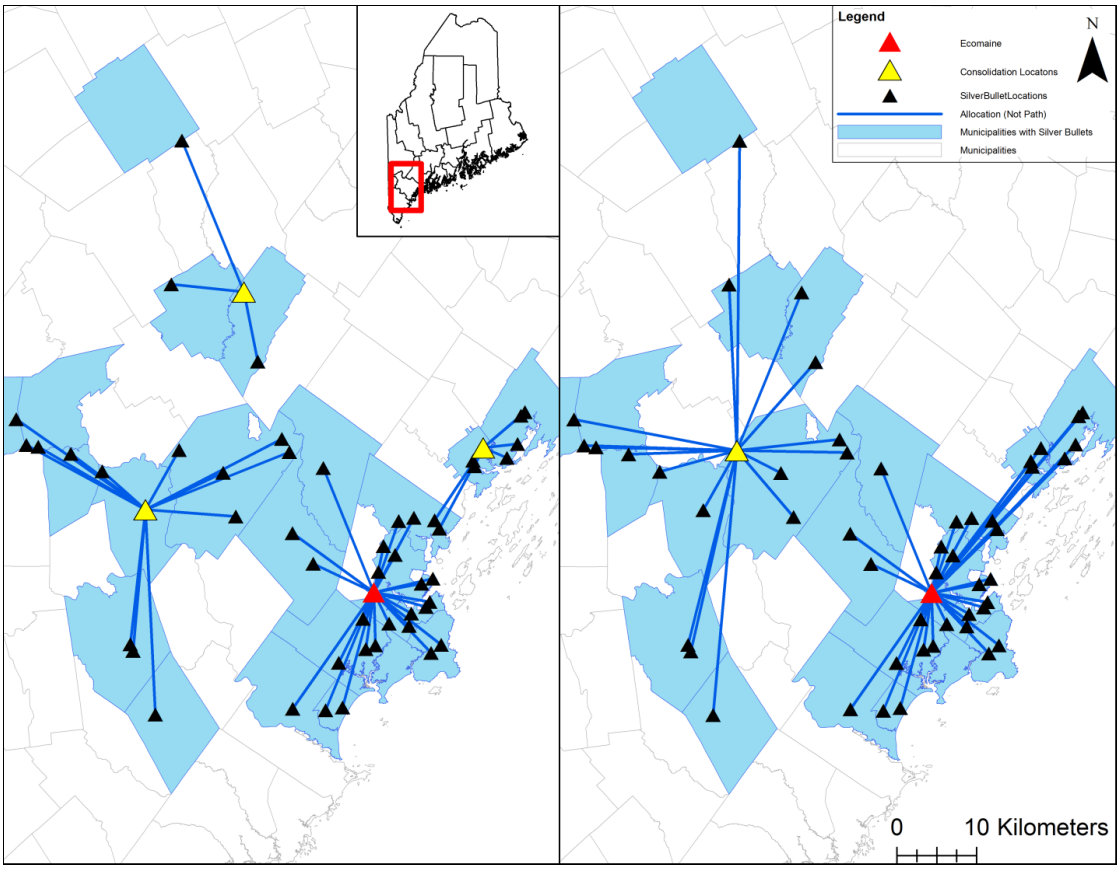

Figure 1. *Left*, Scenario 1, five facilities serve all silver bullets in fewer than 32 km; *right*, Scenario 2, three facilities serve all silver bullets in fewer than 48 km. One consolidation location is not shown in either Scenario because it is an outlier. NOTE: The output shape type of the location-allocation analysis is a straight line that represents the shortest network path between the facility and the demand point. Therefore, **the distances between the facilities and demand points are actual driving distances and not straight-line distances** (ESRI 2010).

In Scenario 1, the reduction in distance traveled was 530 km and in Scenario 2, the reduction in distance traveled was 286 km (Table 1).

	Scenario 1	Scenario 2
Reduction in Distance Traveled (km)	530.7	286.2
Savings to Communities	$3,893.33	$2,218.94
Cost to Ecomaine	$1,068.79	$695.73
Net Savings*	$2,824.54	$1,523.21
Reduction in CO2 Released (million MT)	3.6	1.9

*Assumptions: 1) average cost of transporting a silver bullet (or the consolidated contents of silver bullets) is $5.32 per kilometer (based on available community data); and 2) every silver bullet completes one trip to its assigned consolidation location (or directly to Ecomaine) and then one trip is completed from every consolidation location to Ecomaine (a "complete haul").

Table 1. Comparison of Scenarios 1 and 2.

Ecomaine would incur additional costs in each scenario, though there are substantial net savings. At an average cost of $5.32 per kilometer, a net total of $2,824 would be saved in Scenario 1 and a net total of $1,523 would be saved in Scenario 2 (Table 1). The net savings is calculated based on a "complete haul" of all containers. For example, in Scenario 1, $2,824 would be saved each time every silver bullet completes one trip to its assigned consolidation location (or directly to Ecomaine) and then one trip is completed from every consolidation location to Ecomaine. However, cost savings would be distributed unequally among the twenty-one communities based on the distance between their silver bullet(s) and its assigned consolidation location. As an additional benefit, the reduction in distance traveled would reduce carbon dioxide emissions by 3.6 million metric tons (MT) in Scenario 1 and by 1.9 million MT in Scenario 2 (Table 1).

Based on the average number of trips each silver bullet completes in a year, the annual savings to communities would be $236,135.20 and the annual cost to Ecomaine would be $52,725.90 (Table 2).

Average no. of trips per year of all silver bullets	Savings to communities per year	Cost to Ecomaine per year
2172	$236,135.20	$52,725.90

Table 2. Annual savings to communities and annual costs to Ecomaine.

The annual savings to communities are significantly greater than the annual costs to Ecomaine because at the consolidation location, the contents of seven silver bullets would fill one tractor-trailer, significantly reducing the number of trips from the consolidation location to Ecomaine.

DISCUSSION

Scenario 1 provides the greatest net cost savings but requires five consolidation locations and Ecomaine incurs greater costs than in Scenario 2. Ecomaine incurs lower costs in Scenario 2, which requires only three consolidation locations, but the net cost savings is lower than Scenario 1. It is important to note that this analysis only examined the net cost savings of transportation and did not include infrastructure costs that may be necessary to conduct the consolidation. This study also only looked at loosely packed hauling and did not calculate the potential economic or carbon reduction benefits of using mechanical, stationary compacters. However, this study demonstrated that location-allocation can be a powerful tool to improve the transportation efficiency of regional recycling.

ABOUT THE AUTHOR

Laura Reading recently graduated from the University of Southern Maine with a B.A. in Environmental Planning and Policy and a Certificate in Applied GIS. In the fall she will begin working towards her Master of Urban Planning degree at the University of Michigan.

REFERENCES

ESRI, GIS Dictionary – Network (n.d. a), http://support.esri.com/en/knowledgebase/GISDictionary/term/network

ESRI, GIS Dictionary – Location-Allocation (n.d. b), http://support.esri.com/en/knowledgebase/GISDictionary/term/location%2Dallocation

ESRI, Location-allocation analysis (2010), http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//004700000050000000.htm

Maine Office of GIS (MEGIS), Data Catalog (2009), http://www.maine.gov/megis/catalog/

ReVelle, C. S., and R. W. Swain, R. W., 2010, Central Facilities Location. Geographical Analysis, 2(1), 30-42.

U.S. Environmental Protection Agency (EPA), Emission facts (2005), http://www.epa.gov/oms/climate/420f05001.htm

Weber, A., 1909, Uber den Standort der Industrien. (Tubingen, Germany).