Optimizing the Aberdeen Department of Public Works' pick up services

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Introduction

Aberdeen City, like all municipalities, wants to spend money efficiently. After looking into some projects with the City Government, the Department of Public Works (DPW) seemed to have the greatest potential for savings, given the success of other studies on similar topics (Arribas, Blazquez, & Lamas, 2010). The expenses of running a waste collection service for all residents of Aberdeen City stem primarily from two factors, refueling the low gas-mileage Refuse Collection Vehicles (RCVs), and the maintenance costs that they incur because of continuous daily use. Fuel consumption is split between running the route and the trips to the landfill to offload waste. Unfortunately, the landfill is located in Baltimore County, meaning a significant amount of fuel is expended just transporting the waste. Regulations dictate that the RCVs be empty of waste before they are retired for the day regardless if they are full or partially filled. If a RCV packs out, then another RCV has to finish the route and ultimately go to the landfill, which is highly inefficient and costly. This means there is an opportunity to optimize for both reducing the amount of necessary pack outs and the time spent running the route.

Materials and Methods

A model of Aberdeen City's Trash and Recycling Pick Up Services (TRPUS) was needed before any avenue of cost reduction could be explored. In order to develop a conceptual model of the TRPUS, information on the current practices of Aberdeen's Department of Works was gathered. The Director of the DPW, Mr. Kyle Torster, was interviewed to ensure that the model included all relevant details of how the DPW collects waste, manages crews and routes its RCVs. These details went to create an IDEF0 diagram that would clearly demonstrate the relationship between the internal and external components of the DPW (Figure 1).

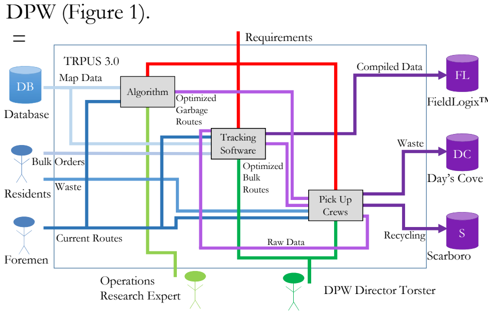

Figure 1: Blue lines are inputs, purple are outputs, red lines are requirements and green lines are external actors on the system.

It was clear from the model that the only element of the TRPUS that this project could manipulate was the routing of the RCVs.

Materials and Methods (cont.)

Optimizing the routes was done through graph theory. Graph theory translates problems into systems of nodes (intersections) and edges (streets), and explores ways of navigating between the nodes while minimizing the weight (time and fuel usage) of the cumulative edges visited on the route. To more accurately develop an algorithm, speed and distance data was gathered, to better optimize the routes through Aberdeen to reduce (1) the landfill trips taken by the RCVs and (2) the overall time and distance that they travel. Edges are defined as a pair of intersections, and these were listed together in a row in Excel along with data for each edge (Table 1). Data such as the number of residences and the distance of each edge was acquired with the use of Google Maps™. The speed limit for each edge was found through the tracking software FieldLogix™ which is installed on every RCV and logs position and time data. Once compiled, all this data was formulated into an algorithm that would perform two kinds of optimization. The first optimization would create a new set of four zones from trash weighting data. Being divided by cumulative trash within each zone and not by geographic region, these zones can be created such that the probability of pack outs are minimized. The second optimization would occur after the creation of these new zones and seek to optimize routes node to node, along every edge, within each zone to reduce the time and consequently the fuel spent traversing them.

Table 1: Sample of data taken from the entire spreadsheet for Aberdeen City.

The "Deen" Cluster		Time (min)	Houses	Speed (mph)	Distance (miles)
Post Rd @ Monroe St	Post Rd @ Center Deen Ave	0.20	0	25	0.05
Post Rd @ Center Deen Ave	Center Deen Ave @ N Deen Alley	5.50	22	25	0.20
Post Rd @ Emmit Ave	S Deen Ave @ Emmit Ave	0.10	0	25	0.05
Post Rd @ Glade Ave	S Deen Ave @ Glade Ave	0.10	0	25	0.05
Center Deen Ave @ N Deen Alley	Center Deen Ave @ West Deen St	0.50	2	25	0.02
Center Deen Ave @ West Deen St	Center Deen Ave @ Allendale Ave	1.50	6	25	0.05
Center Deen Ave @ Allendale Ave	Center Deen Ave @ Bannister Ave	2.50	10	25	0.05
Center Deen Ave @ Bannister Ave	Center Deen Ave @ East Deen St	2.50	10	25	0.05

Results

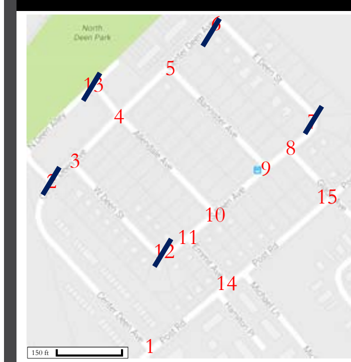

Figure 2: Subset of city data used to validate the algorithm. Intersections are numbered and the redundant ones are struck through.

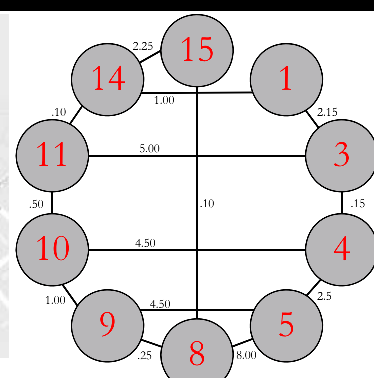

Figure 3: Graphical model of the data segment's intersections. Time along the edges is in minutes.

Results (cont.)

Optimization for time and distance was performed on a small cluster of streets within Aberdeen City to demonstrate the validity of the data. First the intersections were numbered and the redundant ones were removed (Figure 2). Then the nodes and edges were redrawn as a graph with the edges given their weighting in time (Figure 3). Finally the Chinese Postman Problem (Edmonds and Johnson, 1973) was applied to minimize the time to traverse every edge at least once. The result was the most optimal route with respect to time through the cluster, following nodes 1-3-4-5-9-10-4-3-11-14-15-8-9-5-8-9-10-11-14-1. Its time is an estimated 16.1 minutes, as opposed to the 25-30 minute mean time.

Conclusion

The end goal of the project was to devise an algorithm that, with the data collected, could create four new waste collections zones and optimize the routes within them so that they could be pitched to the City Government as an efficient alternative to the zoning and routes currently in use. Unfortunately, the algorithm was never fully coded due to time constraints on the operations research expert who was codifying the algorithm. Despite this shortcoming, there still is data that was gathered on every street in Aberdeen City which might prove useful to City Government in the near future. As new residential areas continue to be built, the City must reevaluate how the current waste zones are laid out to accommodate the new expansion and the data gleaned from this project provides a good jumping off point for an evaluation. Furthermore, it's apparent from this project that it's not practical for a municipality to attempt something like this without any proper operations consulting. Looking to the future one could take the results of this project in a multitude of directions. They could finish the original algorithm, or repeat the processes of this project but instead focus on data about Recycling in Aberdeen City and possibly compare and contrast that data to the waste figures.

References

Arribas, C. A., Blazquez, C. A., & Lamas, A. (2010). Urban solid waste collection system using mathematical modelling and tools of geographic information systems. *Waste Management & Research 28 (4)*, 355–363.

Edmonds, J., & Johnson, E. L. (1973). Matching, Euler tours and the Chinese postman problem. *Mathematical Programming 5*, pp. 88–124.

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