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TGIS 415

Final Paper:

Optimizing Garbage Collection Routes in Tacoma

Literature Review

Municipal Solid Waste (MSW) is a necessary part of any civilization and dates back to the Roman Empire. They break the waste stream down into main systems and sub-systems; however it is important that all aspects should be analyzed as they are all interconnected. Several models were used to determine the sustainability of the MSW system because this is one of the most important things we must deal with as a society. Waste production is up from any other time in the past and disposing and storing is becoming more expensive and hard to find suitable places (Pires et al. 2011). In 1990 more than 80% of waste collection in the US is done by private companies (Lin and Koa 2008). A sustainable MSW system is one in which costs and pollution emissions are both minimized. Factors that are used to determine an effective system are compactness, road network integrity, collection cost, and regional proximity. Effective route planning can minimize differences among sub regions and minimize costs for collection (Chen and Lin 2008).

Residential garbage accounts for most of the refuge in any municipal waste stream. Route optimization is the primary way in which a MSW system can cut cost while reducing pollution emissions. In Tacoma the waste is taken to a local transfer facility and then bulked for transport to the permanent landfill. A study found that that local transport of waste has minimized carbon and fuel impacts than that of large scale transport (Bastin and Longden 2009). The emissions of greenhouse gases emitted from collection practices increased from 1.4% to 12.5% of all activities, some of this is the advancement of other practices and some is the ineffective routes and old emission controls on collection vehicles (Agar et al. 2007). There is a strong correlation between emissions with both fuel consumption and travel distance. The shorter the distance and the less fuel is consumed the less emission will be associated with the collection and delivery of municipal solid waste (Apaydin and Gonullu 2008). GIS has shown in Trabzon that routes can be decreased by at least 20% and could be decreased by as much as 30% (Apaydin et al. 2004). The collection and transportation may account for more than 60% of overall budget and by optimizing routes it is fair to expect at least a 20% savings in cost as savings were estimated between 20-40% using GIS software (Jovicic et al. 2010).

Planning Process

I began this project by sitting down with my professor, Mathew Kelley, to discuss the potential topics in which he expressed to me that the Office of Sustainability was interested in having the garbage collection routes optimized for the city of Tacoma. It was suspected that there was a considerable amount of backtracking by the trucks and that this could be minimized by using a computer program such as GIS. In class, during winter quarter, we began by brainstormed ideas as a whole group and as small groups. We sat down and work-shopped the project for potential data and tools to be used in the project twice as a whole group and weekly in our small groups.

I then sat down with several members of the community to discuss their potential outlook on the project. As a small group we set the major steps needed to complete the project. These were the digitization of current routes, the creating the service areas for those routes, and creating optimized routes. The last step in the planning process was in creating a project workflow. This was done using Gliffy.com in which each step was plotted in a flow-diagram with the inputs, intermediate data, and outputs from each process laid-out from beginning to end as seen in figure 1 (see appendix).

Methods and Implementation

I started the project by collecting parcel data, street data, and maps of the current city of Tacoma's garbage collection areas. The residential parcels were selected using the field calculator based on the land class use field. The selected parcels were then exported to create a polygon feature class of just residential parcels. The parcels were then turned into points using the polygon to point tool. The MSW transfer station (city dump) parcel was selected using the select by attribute tool and exported to create a permanent feature as a point.

The service areas were digitized using the editor tool. The boundary of each day's service area was drawn in to create polygons along the streets that are designated by the city on their website as seen in figure 2 (see appendix). These polygons were then used to select the parcel points that are contained within the boundaries using the clip tool. The parcel points and the service area were labeled based on the day in which the city collects the garbage.

Three layers were then added to maps, one map for each day of the week, which were streets, parcel points, and the city dump point. The street layer was converted into a network using the create network tool. This layer was created for each day of the week in a separate map. I then used the Create Routing Problem tool to create optimized routes for each day based on drive time and distance. The parcel point layers were selected as locations in the routing problem layer. The city dump point was loaded into the routing problem as the depot. I then created routes, as trucks, in which I set the parameters for each route to pick up the collection locations from earlier. Each route was set to have a maximum amount of pick-ups, which was equal to the total number of collection points for the day divided by the total number of routes. The solve tool in network analysis was used to allow GIS to figure out the optimized routes based on the number of trucks and the maximum pick-ups per route. Each day of the week was set up and run as a whole in accordance with the city of Tacoma's determination of collection except for Monday. Monday was split into two equal sections based on the division for the recycling and yard waste collections due to an unexpected problem for which the analysis failed several times. The two halves were set up and run with the same parameters as the whole days from above, then the data was calculated together in order to have one set of data for the day instead of two.

A second analysis was performed for the collections in the Monday section of the city. As was done above the section was split between the two halves and then the data was computed together. The same vehicle routing problem tool was used for the analysis but with some parameters changed in order to create a model for determining the most efficient routes for an actual workday collection route. In this analysis the depot, city dump, was loaded into the vehicle routing problem tool the same way as above except that there was a fifteen minute service time to unload the truck at the end of the run. Orders (collection points) were loaded in with a service time of 15 seconds per collection location. The routes were set up with a time limit of 220 minutes per route to simulate a four hour run with twenty minutes for the driver to take a break during the run and a maximum number of pickups of 700 which exceeds any amount that can be reached in 220 minutes by any one truck. The solve tool was then used to run the analysis as was done in the first analysis.

The output data from the first and second analysis was then calculated to find annual driving distances of the average truck. The first analysis had a weekly and a Monday average but the second only had a Monday average. The average weekly and daily mileages of each were then multiplied accordingly to create annual mileage averages. These averages were then input into an online Carbon calculator using .9 miles per gallon to figure out the average Carbon Dioxide emissions per truck for each (CFC).

Results

The first analysis output a set of optimized routes for each day of the week as a polyline. The output polyline was accompanied with set of step by step directions to follow in order to perform the route that the GIS program found to be the shortest for both drive time and drive distance as a fleet. The individual routes were determined and the collection points were assigned to each route in a particular order as can be seen on the sample map 1 (see appendix). The attribute table for each day's routes were updated to include the number of collections, distance, and drive time to name a few, in which the stats were calculate and seen below.

Day	**Minimum Distance(mi.)**	**Maximum Distance(mi.)**	**Mean Distance(mi.)**	**Total Distance(mi.)**	**Average Collections/route**
Monday	14.55	29.09	20.04	561.10	415.7

Tuesday	17.18	42.92	29.49	825.71	410.5
Wednesday	17.70	30.65	24.81	694.69	443.8
Thursday	16.92	33.58	19.97	559.07	451.9
Friday	14.69	29.85	20.06	561.55	492.5

The weekly average for each route was 22.87 miles twice a day for a total of 45.74 miles per day. The average truck commutes 11,892.4 miles per year which accounts for 157.88 metric tons of Carbon Dioxide emissions per year.

The second analysis output routes in the form of polylines for the day of Monday. The polyline was also accompanied with a set of step by step directions and updates to the attribute tables. There were 21 total routes with 11 being on one half and 10 on the other. The minimum distance travelled on Monday was 17.44 miles, a maximum distance of 27.79 miles, and an average distance was 24.32 miles per route. The first half of the day had 11 routes with a minimum of 127 collections, a maximum of 615 collections, and an average of 532.7 collections. The second half of the day had a minimum of 381 collections, a maximum of 652 collections, and an average of 577.8 collections. The average truck would commute 2528.84 miles per year, on Monday, and would emit 27.98 metric tons of Carbon Dioxide.

The last part of this project was to compare the Monday portion of the first analysis with the second analysis. The total distance was reduced from 561.1 miles in the first analysis to 510.6 miles as a fleet in the second. The number of trucks was reduced from 14 in the first to 11 in the second and the total number of routes was reduced from 28 to 21 which is a 25% reduction. The amount of Carbon Dioxide emitted increased from 23.06 metric tons/year to 27.98 metric tons/year per truck (on Mondays) from the first to the second respectively, but the total emissions were reduced from 322.84 metric tons/year to 293.79 metric tons/year for each truck which is a 10% reduction.

Critical Analysis

The results from this project were in line with the research that was done prior to the beginning of the analysis. The results however are subject to ground tests to be sure that such a route can actually be performed as certain parameters and limitations were set based on the available data. The optimized routes for this analysis are based on drive time and distance, which according to a study in Turkey would not be the best parameters to maximize fuel efficiency in hilly terrains such as Tacoma. In this project Carbon emissions were calculated based on estimated fuel consumption and mileage driven. This study concluded that empty trucks use less fuel going up and down hills and therefore trucks should collect on the hills before collecting the flat areas with a heavier load to maximize fuel efficiency (Tavares et al. 2009). Because of Tacoma's hills the fuel efficiency may have been improved if slope of the roadway and amount (weight) had been figured in as a parameter for fuel consumption. I wanted to incorporate this into another analysis but time constraints and the limited knowledge of the tools prevented me from being able to perform this portion of the analysis.

During the analysis there were always collections that were not serviced by any route for that particular day. I found that there were some small breaks in the road layer that would not allow the collection truck to make its way onto that part of the road network, thus isolating the collection points in that region from being collected. In other portions of the city these breaks would be circumvented but would change the overall route and thus make the route less efficient by adding distance. The streets layer that I used was provided in a lab in which elevations were available for the network tool to create the road network; however the streets had been clipped to the city boundary in a way that some access or important streets along the edges were missing. This made some parcels inaccessible from within the city boundary that would have been accessible from streets that border the arbitrary city line. One street in particular, Orchard Street, is a main road that runs almost the entire west side of south Tacoma and was missing from the road network. This street is an important road for access to edge parcels along with making routing to south Tacoma faster with less distance than using the center of the city.

The class readings conclude that an analysis is only as good as the data used and the GIS user's perception of important data to be used. Every project is subjective in that the GIS user decides what information to use or not use and therefore influences the project to fulfill their idea of how the project should go. The municipal solid waste collection in Tacoma is a service provided to the citizens and should be treated as such. In this project I looked at the collection from an efficiency standpoint and in no way took into account the customer's needs or wants. Pavlovskaya among others were read during this quarter which argued that participatory GIS should be used when decisions are being made that affect a community. I would agree that this project would be best if the community had some input into certain aspects of the collection system such as where they would like to place their garbage cans for pick-up. I could not conceive how to do this for a project of this scale, but if I were to do this project for the city it would be important to way the customer's wants with the needs of the city to be efficient. I in no way limited the routes to streets and/or alleys. I let GIS determine the best placement of the collection point. The routes for this project were set up to include every parcel zoned residential, both developed and vacant, which would allow collection points to be added or dropped without changing the overall route. As with other projects in our class some of the data may be wrong or not updated which was evident in Christina's project. She was looking for vacant parcels for community gardens but found that one of her vacant parcels was not vacant upon physically checking the site.

Overall I was very pleased with the way in which the project turned out, however I realize that the second analysis is not completely accurate. The drive time data is an approximation based on the data available. The service time per stop is the doubling of actual service time to alleviate excess drive time between stops as there was no way to account for acceleration and deceleration between stops. There are no signals, such as stop signs and traffic lights, or other vehicles to impede the truck from always travelling at the marked speed limits. Because of these issues and others that may not be mentioned here the analysis and maps that are created from the analysis are a perception of what could be real and not reality itself. The average person looking at the map or data from the results may be led to believe that this is real which is a concept well described in class reading. I chose to display two routes that would cover the same area for comparison but left off many things that did not seem important to the story being told. There is no reference to the other routes and all other collection points are lumped together even if they are not serviced by any route. It is through these little decisions that in some ways our maps lye and the power we have as a map maker to influence the perception of what is real.

References

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Appendix

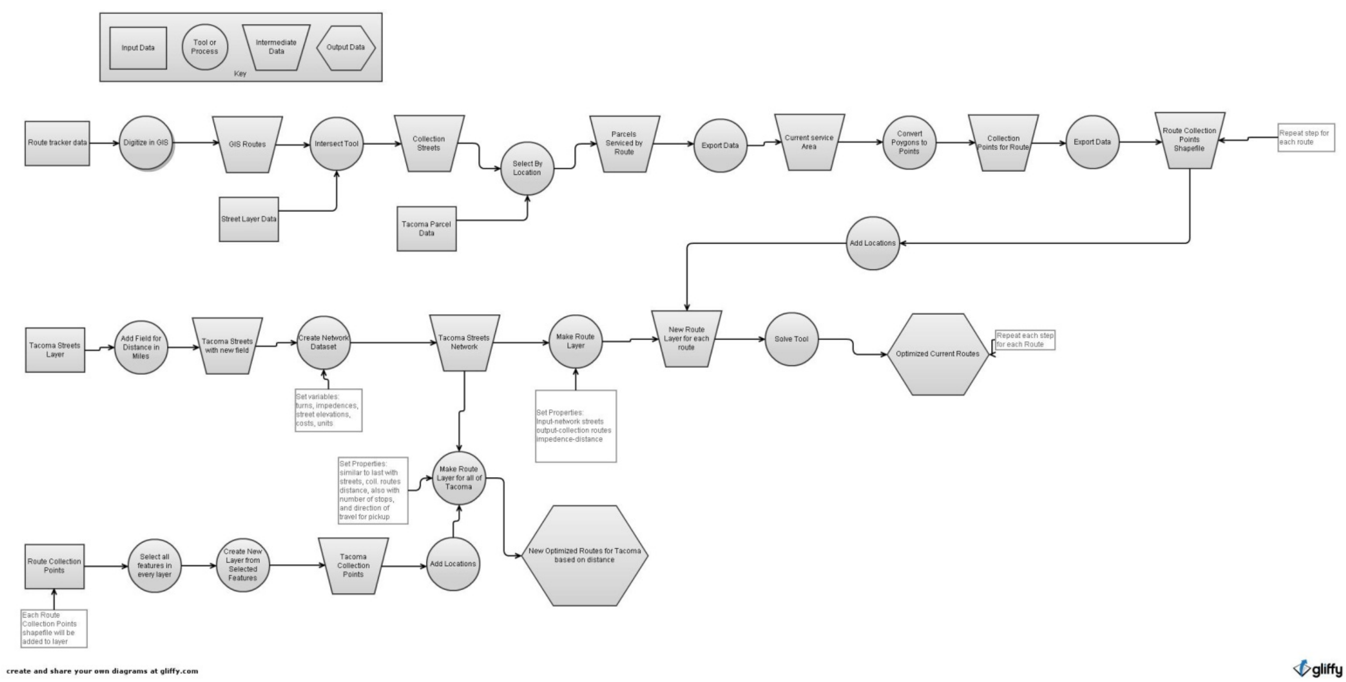


Figure 1. Workflow designed to be a step by step project plan

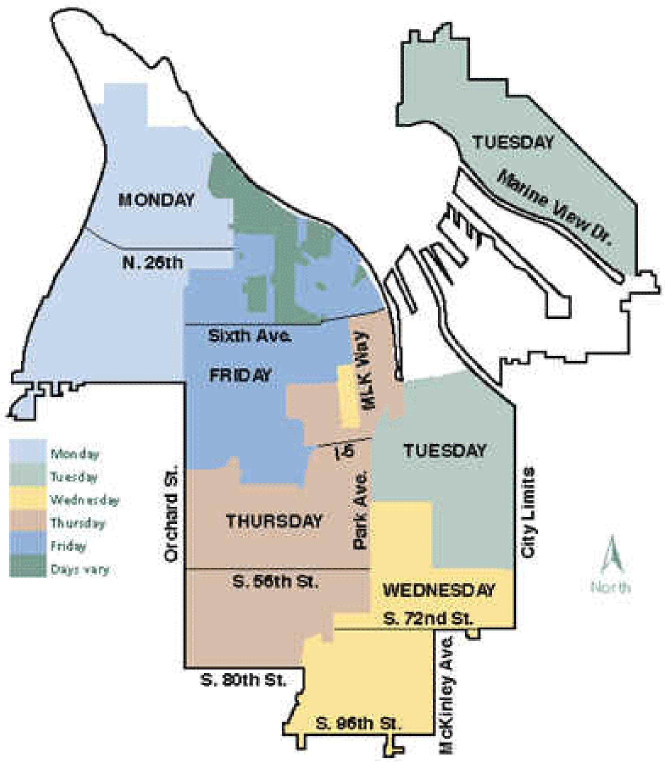
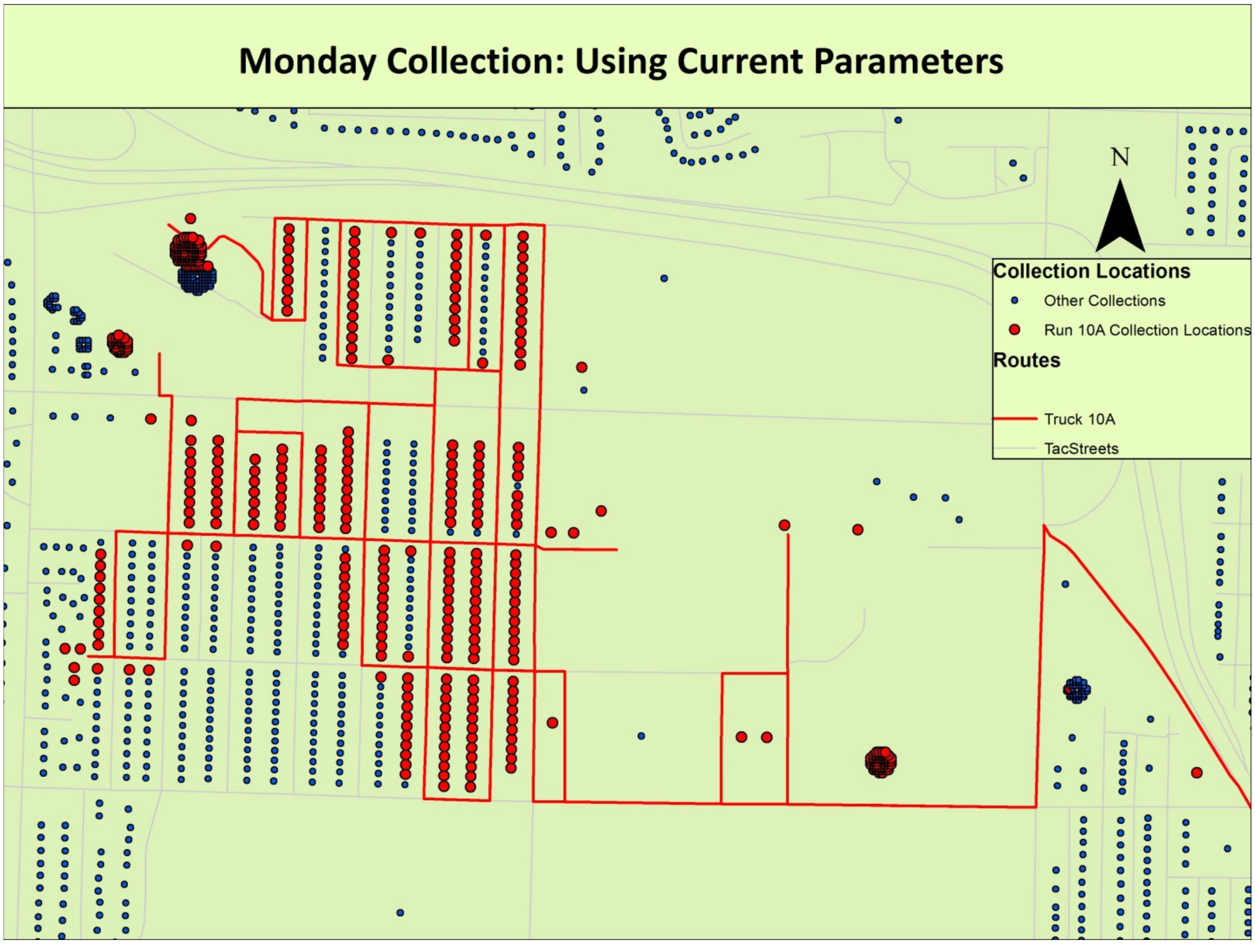
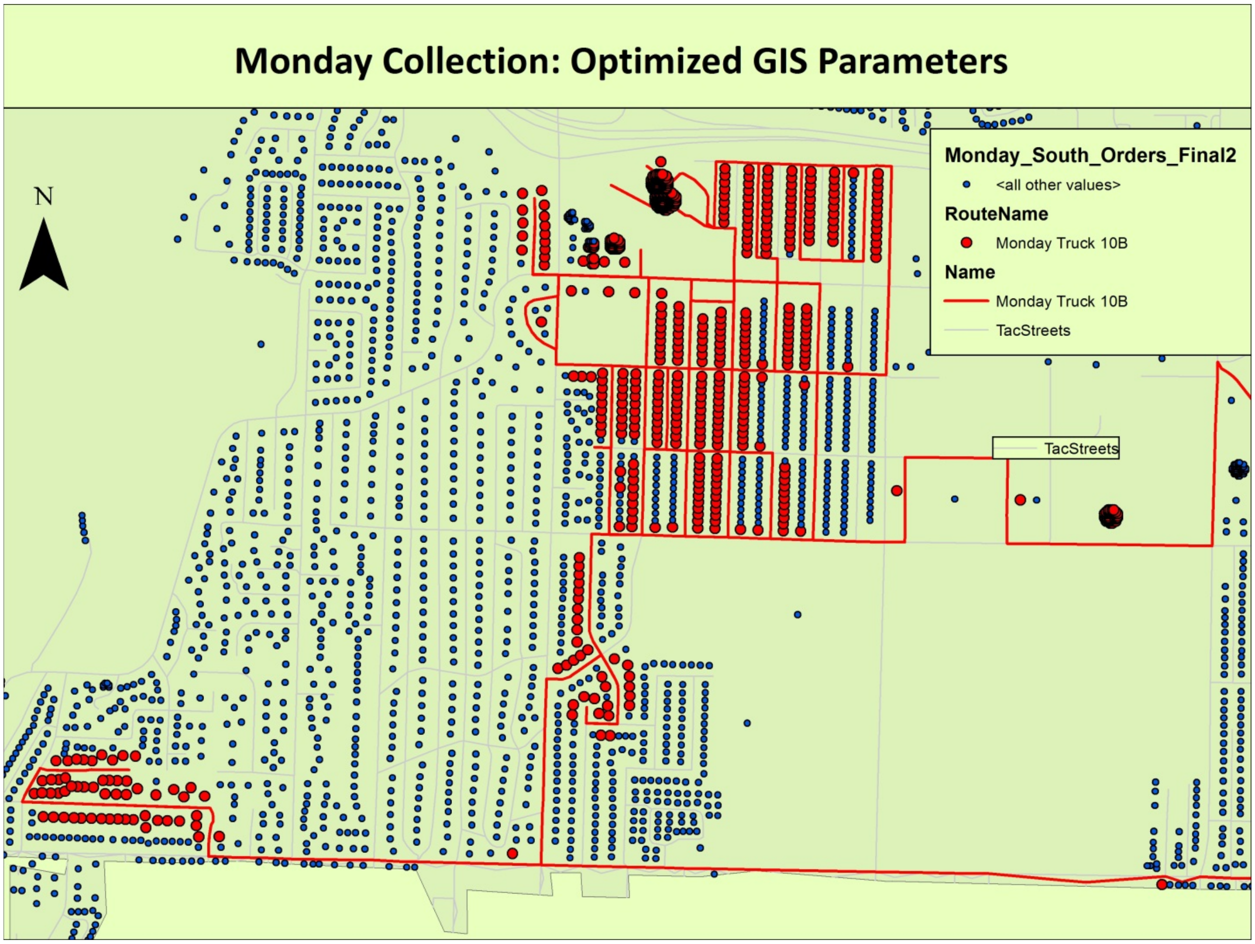


Figure 2. City of Tacoma residential MSW collection days.



Map 1. This map depicts a sample route with collection points produced from the first analysis.



Map 2. This map depicts one route and collection points produced during the second analysis.