Pick-Up Route Optimization Using GIS Network Analysis

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G639 GIS & ENVIRONMENTAL ANALYSIS
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Introduction

Green With Indy, the only curbside compost hauler in the greater Indianapolis area, serves 324 customers in Marion and Hamilton Counties. Offering bi-weekly pickups, this local business collects food waste from households and the collected material is dropped off daily at a facility in south Indy. A single truck and driver handle pickups, typically working five days with shifts ranging from 8 to 14 hours.

What is the problem?

This project aims to optimize Green With Indy's pick-up routes with GIS software. The heuristic algorithms in the software will beused to minimize workdays to a safer and more reasonable 8-hour window.

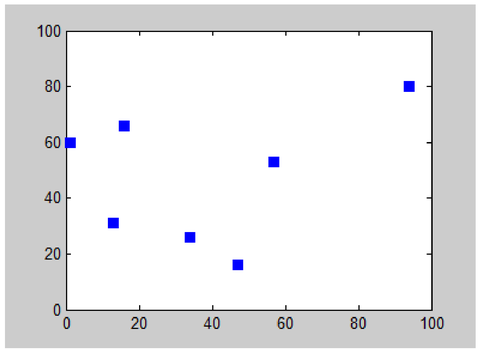
Traveling Salesperson Problem

"The Traveling Salesman Problem… is "the challenge of finding the shortest route visiting each member of a collection of locations and returning to your starting point." (Cook, 2023) The TSP is considered to be an *NP-hard* problem, one of the most difficult mathematical problems known. Although no exact solution to all TSPs has been found, many heuristics have been developed, finding results that are very close to "optimized."

We can easily calculate the number of routes, *r*, for the number of locations, *n*, *w*ith the equation: r= (n-1)!/2

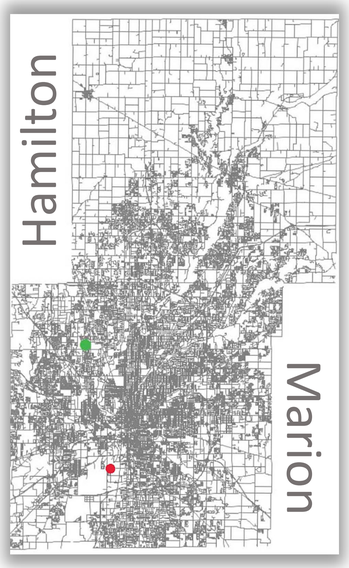
This gives Green With Indy 3.5324034879 × 10^671 possible routes, which is an impossibly large number. Computing solutions for TSP problems involves using heuristic algorithms which will result in an approximation, but in a reasonable time frame. Many have been developed over time. The very simple nearest "neighbor algorithm," for example, builds on any starting point and finds the next closest location until all locations are visited. It may never find the best route, or even a feasible route, but it does find complete routes.

Steps of the Nearest Neighbor Algorithm (Wikipedia, 2023)

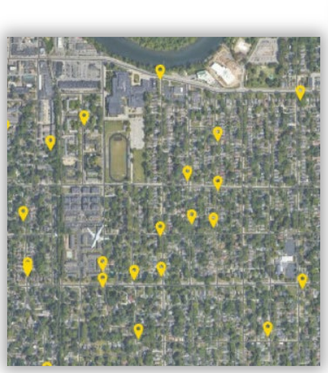


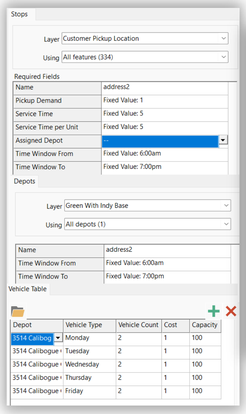
1. Initialize all vertices as unvisited.
2. Select an arbitrary vertex, set it as the current vertex **u**. Mark **u** as visited.
3. Find out the shortest edge connecting the current vertex **u** and an unvisited vertex **v**.
4. Set **v** as the current vertex **u**. Mark **v** as visited.
5. If all the vertices in the domain are visited, then terminate. Else, go to step 3.

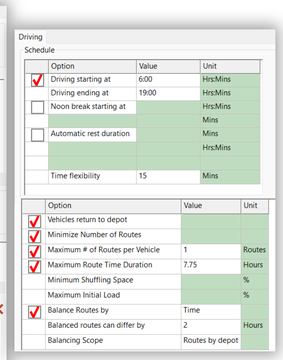
Methods



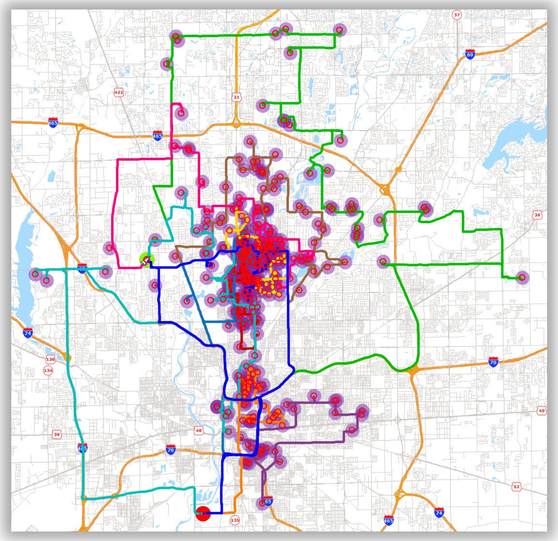
1. The first step is to gather road data and build a network with GIS software. In this case, we used Maptitude form Caliper because it uses a HERE national road dataset that includes one-way and two-way road attributes, which is important when calculating routes though a city such as Indianapolis.
2. Maptitude automatically calculates the network based on drive times between nodes (intersections), but other software, such as TransCAD, builds customized networks based on several user defined variables and establishes a cost matrix for the study area.
3. Once the network is established, customer locations are geocoded based on address and added to the map.
4. Finally, we run the "Routing & Deliveries" tool with the options seen below. Notice there are two "vehicles" per day to calculate bi-weekly:







Optimized Routes With Maptitude:



Route Legend

Monday-1,	36 stops,	43.6 mi,	7 hr 35 min,
Monday-2,	38 stops,	45.5 mi,	8 hr 1 min,
Tuesday-1,	29 stops,	91.2 mi,	8 hr 10 min,
Tuesday-2,	26 stops,	55.8 mi,	6 hr 34 min,
Wednesday-1,	35 stops,	42.4 mi,	7 hr 33 min,
Wednesday-2,	35 stops,	59.0 mi,	8 hr 14 min,
Thursday-1,	35 stops,	62.7 mi,	8 hr 21 min,
Thursday-2,	36 stops,	45.5 mi,	7 hr 41 min,
Friday-1,	28 stops,	70.9 mi,	7 hr 9 min,
Friday-2,	36 stops,	42.2 mi,	7 hr 36 min,

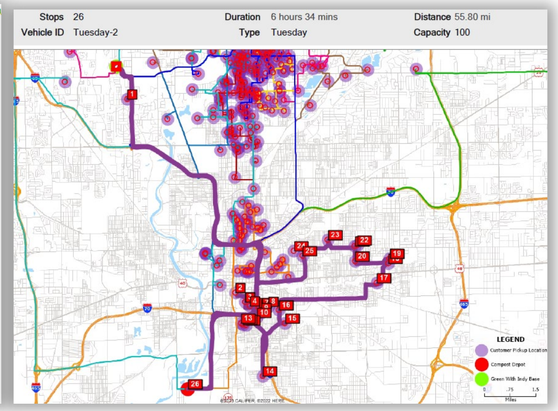
Route optimization with GIS software reduced workdays to under 8 hours in most cases. One day is less than 7 hours.

Results

The software was able to calculate a set of ten separate routes, two for each day of the week. A report map and a table generated for each route to be used in further GIS and GPS applications. Below is a table and route map created for Tuesday-2.

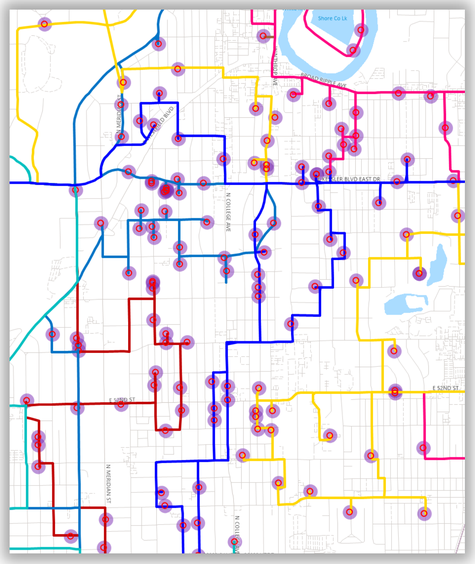
3514 Calibogue Circle Tuesday-2, 26 stops, 55.8 mi, 6 hr 34 min

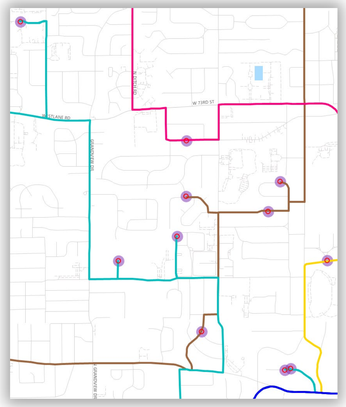
	Depot/Stop	Arr.	Dep.	Break	Dist.
	3514 Calibogue Circle		1-06:00	00:00	0.0 mi
1	5090 Sylvan Rd.	1-06:04	1-06:14	00:00	1.6 mi
2	307 S. Delaware St.	1-06:30	1-06:40	00:00	11.4 mi
3	529 E. Merrill St.	1-06:42	1-06:52	00:00	11.9 mi
4	718 Noble St.	1-06:53	1-07:03	00:00	12.3 mi
5	959 Elm St.	1-07:06	1-07:16	00:00	12.8 mi
6	1034 Elm St.	1-07:17	1-07:27	00:00	12.9 mi
7	1021 Lexington Av	1-07:27	1-07:37	00:00	13.0 mi
8	1305 Hoyt Ave.	1-07:39	1-07:49	00:00	13.3 mi
9	1067 Hosbrook St.	1-07:50	1-08:00	00:00	13.7 mi
10	917 Prospect St.	1-08:02	1-08:12	00:00	14.0 mi
11	519 Parkway Ave.	1-08:14	1-08:24	00:00	14.7 mi
12	426 Parkway Ave.	1-08:25	1-08:35	00:00	14.8 mi
13	345 Orange St.	1-08:35	1-08:45	00:00	14.9 mi
14	2729 Shelby St.	1-09:09	1-09:19	00:00	20.8 mi
15	1905 Orange St.	1-09:24	1-09:34	00:00	22.8 mi
16	822 S. State Ave.	1-09:36	1-09:46	00:00	23.5 mi
17	222 S. Downey Ave.	1-09:55	1-10:05	00:00	27.1 mi
18	5712 E. Michigan St.	1-10:08	1-10:18	00:00	28.0 mi
19	731 N. Audubon Rd.	1-10:20	1-10:30	00:00	28.5 mi
20	603 Wallace Ave.	1-10:33	1-10:43	00:00	29.7 mi
21	1024 Wallace Ave.	1-10:45	1-10:55	00:00	30.1 mi
22	1102 N. Dequincy St.	1-10:56	1-11:06	00:00	30.2 mi
23	1311 N Kealing	1-11:09	1-11:19	00:00	31.5 mi
24	903 N. Beville Ave.	1-11:24	1-11:34	00:00	32.9 mi
25	812 Eastern Ave.	1-11:36	1-11:46	00:00	33.6 mi
26	4 Last Stop	1-12:01	1-12:11	00:00	40.8 mi
	3514 Calibogue Circle	1-12:34	12:35	00:00	55.8 mi



Other Items To Consider

Some locations within the same neighborhood are serviced on different days…





Optimized routes in some areas may seem to be inefficient, but the software calculates stops considering left-hand-turns, traffic signals, one-way streets and current direction of travel. This can seem counterintuitive, but instinct isn't always most efficient.

What happens if we add another vehicle?

Monday,	27 stops,	41.8 mi,	6 hr 18 min,
Tuesday-1,	28 stops,	68.6 mi,	7 hr 34 min,
Tuesday-2,	35 stops,	44.6 mi,	7 hr 36 min,
Tuesday-3,	34 stops,	28.5 mi,	6 hr 58 min,
Tuesday-4,	34 stops,	41.0 mi,	7 hr 39 min,
Wednesday-1,	34 stops,	39.7 mi,	7 hr 36 min,
Wednesday-2,	35 stops,	23.7 mi,	6 hr 59 min,
Thursday-1,	35 stops,	18.5 mi,	6 hr 50 min,
Thursday-2,	35 stops,	19.6 mi,	6 hr 46 min,
Friday,	37 stops,	21.5 mi,	7 hr 11 min,

Even adding one extra vehicle/driver one day a week can have a significant impact on the work day. The table to the left shows routes after adding an extra driver on Tuesdays. This drops half of work days below 7 hours and allows for a Monday and a Friday off every other week for the primary driver.

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