Route Optimization with ArcGIS on Waste Management in Hong Kong

Braundt Lau

Erasmus Mundus Master of Geospatial Technologies
University of Jaume I, 12071 Castellón, Spain

Abstract

With the increasing trend of Smart City initiatives in Hong Kong, industries such as Waste Management has also turned its head to analytical tools to increase its competitive edge and efficiency. In this project, multi-day optimized schedules are created with Vehicle Route Problem (VRP) of ArcGIS Network Analyst based on real-life parameters such as collection frequency and route renewals. The insights brought by VRP could bring manpower and cost cut of 70%, and additional benefits related to CO2 emissions, employee wellbeing and vehicle maintenance which could be further applied to other industries.

Keywords: Location Analytics, Network Analyst, Multi-day Vehicle Routing Problem

1 INTRODUCTION

Brought by the Smart Cities initiatives implemented in the city, there has been increasing attention on digitalizing city operations in order to extract the data and insights thus increasing the efficiency, quality and competitiveness of city services.

The Waste Management Industry has been one with long history and the operations remains hugely manual. There are over 20,000 government owned solid waste bins all over Hong Kong, locating at corners of the streets, in the middle of a busy pedestrian walk, inside schools and outside private housing estates. In order to provide a nourishing environment and public health wellbeing to the world-class city, these bins are carefully monitored and maintained by specialized Waste Management Businesses. Firstly the waste collection route will be planned and reviewed for cost effective analysis, then the collection is carried out based on the schedule. The solid waste is collected by trucks, and then transported to transfer stations (for storage and compression) and finally sent to local landfills.

The original planning process of waste collection route involved enquiring individual distance on map engines, numbering of bins and calculations, which is time consuming and involved a lot of human errors. Furthermore, in order to plan for a waste collection schedule, which is a logistics problem involves complex constraints and rules, the use of GIS in waste management arises and is the best suited analytical software that takes account the locational element in the analysis.

2 METHODOLOGY AND DATA

In this project, the Vehicle Routing Problem (VRP) in ArcGIS Network Analyst was used. The VRP analysis is commonly used to find the best routes for a fleet of vehicles to service orders and minimize the overall cost. The analysis has the ability to incorporate Truck and Route specific parameters because numerous options are available, such as providing breaks for drivers, allowing route renewals for depot visits and matching capacities of trucks to pick-up quantities, etc. In particular, Specialties is the major parameter to determine the temporal feature i.e. day of week or month with is critical for this analysis.

The VRP is also a powerful tool to model road specific parameters with road datasets unique to Hong Kong. In Hong Kong, the Intelligent Road Network (IRN) includes traffic directions, turning restrictions at junctions, limits such as speed, height and weight, and other road traffic data. With these data a highly sophisticated road network could be built and modelled with high accuracy.

3 CASE STUDY AREA

Table 1. Subset of the total 179 waste bins in Study Area

BinID	Solid Waste (tonnes)	Collection Time (mins)	Collection Frequency (per week)	Specialty	Time Start	Time End
1	0.32	1.6	1	All	6:00:00	22:00:00
2	0.54	2.7	2	Mon-Thurs Fri-Sun	18:00:00	21:30:00
3	2.02	10.1	3	Mon-Wed Thurs-Fri Sat-Sun	6:00:00	22:00:00

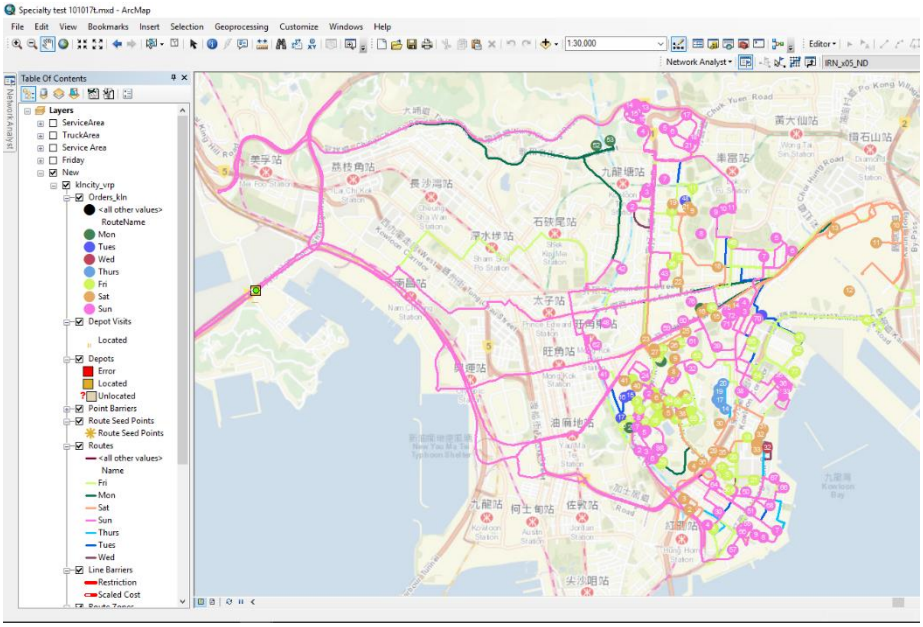
The data and business practice is based on the real situation of a waste management company of the city, it has a total number of 179 bins to manage every day in the selected region. As seen in Table 1, the collection frequency of bins varies from once a week, twice a week or three times per week which is influenced by historic solid waste weight. Furthermore, the bins are located at places which are only open to collection at a specific time of day, eg. Bin 2 only allows collection at night time.

In additional to the bin and vehicle parameters, a common waste collection mechanism which is transferring the collected waste to a central waste transfer station to empty the truck for the next operation is considered, which is modelled with the parameter Route Renewal.

4 RESULTS AND DISCUSSION

In a classic VRP, only simple parameters of a complex real-life logistics problem could be modelled, such as routing of a fleet on a single day. While in this project, since Specialty could be assigned for each route and order, the frequency of the specific bin is included in the calculation.

The geographic representation of the weekly scheduling is presented at Figure 1. It could be seen that orders of the same route are clustered, for example pink is at the north and yellow is at the south. Although errors in routing did occur, such as the results are routed to another district, it was caused by errors in the road network therefore was adjusted in the next attempt by adding Route Zones to the analysis.



Routes

ObjectID	Name	StartTime	EndTime	OrderCount	RenewalCount	TotalDistance
1	Mon-Day	10/11/2017 6:19:28 AM	10/11/2017 3:13:51 PM	59	4	135.398312
2	Thurs-Day	10/11/2017 6:08:52 AM	10/11/2017 2:59:40 PM	58	4	131.802957
3	Sat-Day	10/11/2017 6:00:00 AM	10/11/2017 2:44:17 PM	63	4	141.22516
4	Wed-Day	10/11/2017 6:00:00 AM	10/11/2017 1:52:25 PM	36	4	120.402151
6	Fri-Day	10/11/2017 7:54:11 AM	10/11/2017 4:52:39 PM	60	4	145.125449
7	Tues-Day	10/11/2017 6:16:37 AM	10/11/2017 12:00:00 PM	16	2	78.370821
8	Sun-Day	10/11/2017 6:06:38 AM	10/11/2017 3:04:43 PM	54	4	133.655204
9	Wed-Night	10/11/2017 6:32:07 PM	10/11/2017 8:12:51 PM	17	0	29.392131
10	Fri-Night	10/11/2017 6:32:50 PM	10/11/2017 10:30:57 PM	20	2	72.406638

Figure 1. Multi-day VRP Results

Another refinement in the analysis was the large number of orders presented in one single route, eg. the Friday route where the driver had to work for 10 hours straight. Therefore the day could be split into 2 routes, specifying a day and a night route in order to service the orders which could only be serviced during the night.

Table 2. Comparison table of schedule before and after VRP

	Without VRP	With VRP
Number of Truck per day	5 Day A-E 2 Night F-G	1 Day (1) Night
Total Distance Travel per day	Day: 270 (avg per route: 54) Night: 80 (avg: 40)	Day: 120 (avg per route: 120) Night: 50 (avg: 50)
Total Refuse Collected per day	Day: avg 25 tonnes Night: avg 12.5 tonnes	Day: avg 37 tonnes Night: avg 15 tonnes
Average Work Time	Day: 7am to 4pm (9 hrs) Night: 5pm to 9pm (4 hrs)	Day: 6 am to 2 pm (8 hrs with 1 hour break) Night: 6pm to 9pm (3 hrs)

A comparison table is created based on the original schedule provided by the waste management company and schedule modelled by the VRP. The number of trucks could be reduced from 7 a day to 1 or 2 per day depending on the schedule. This could substantially cut time and operation costs by 70%, such as manpower, trucks, fuel cost and carbon emission, thus greatly benefitting the company.

5 CONCLUSION

In this paper, the possibility of extending the capability of VRP to multi-day scheduling is explored and given very positive results. While the data collection and preparation could be time consuming, the usage of VRP remains largely user-friendly comparing to other schedule methods that requires mathematical modelling.

This method has a optimistic outlook of commercialization in the market since there will be an increase demand on analytical tools for logistics scheduling, and the increasingly digitize operations workflows for companies due to Smart Cities initiatives. Replicating the model on a web application and sharing VRP models online will be a desirable future development on the project.

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