CAPACITATED VEHICLE ROUTING PROBLEMS WITH HETEROGENEOUS FLEET

BY

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ABSTRACT

This independent study focuses on solving the Capacitated Vehicle Routing Problem for a beverage distributor in Thailand, addressing the challenges posed by heterogeneous fleet vehicles, limited driver working hours, and customer-specific time windows. The study aims to minimize logistics costs by optimizing delivery routes and schedules. The mathematical model formulated in this project considers multiple constraints, such as vehicle capacity, demand at each customer location, and time limitations, and aims to find the optimal routes for a fleet of three types of trucks: small 4-wheelers, big 4-wheelers, and 6-wheelers. The research first applies a mixed-integer linear programming model to small-scale problems to achieve optimal solutions, followed by the development of heuristics for large-scale problems, where exact solutions may not be computationally feasible. The results, derived from data collected from a real beverage distributor's operations in the Eastern part of Thailand, demonstrate the potential of this approach to reduce operational costs and improve logistical efficiency. The study concludes that the proposed methods can effectively manage complexities of heterogeneous fleets, providing a practical solution to the logistics challenges faced by beverage distributors in the region.

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Keywords: Capacitated Vehicle Routing Problem (CVRP), Heterogeneous Fleet, Mixed-Integer Linear Programming (MILP), Heuristic Algorithms, Logistics Optimization, Beverage Distribution

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CHAPTER 1
INTRODUCTION

From Thailand's logistics report 2021, transport costs account earn 6.4% of GDP or 1,044,200,000 baht. The trend line of the transportation cost is higher every year, which may impact the overall GDP. Saving on transportation costs boosts profits, competitiveness, and sustainability by reducing expenses and enhancing pricing attractiveness.

In Thailand, many entrepreneurs have logistics cost problems. Reducing logistics costs brings good benefits; many businesses have problems with logistics costs, and this project is a problem for one beverage distributor.

The Approach of the project is to resolve the capacitated vehicle routing issues with route as well as customer time window limitations for the beverage distributor with a heterogeneous fleet of vehicles

1.1 Problem Statement

The problem is that a beverage distributor has one depot of beverage stores for sending beverage products by using pallets and hand arrangement to the trucks and has 3 types of trucks (small 4 wheels, big 4 wheels, 6 wheels) with a limited driver time limit (8.00 to 17.00) and customer's time limit (specific for each customer)

1.2 Objectives

The objective is to make the route for the trucks within the limited driver and customer time limits.

- Formulate a mathematical model to solve a small problem and reach the optimal solution.
- Develop heuristics for large problems.

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1.3 Overview of Independent Study Report

Chapter 2 contains the papers and articles related to the project problem statement. Chapter 3 describes the working process and method of working on the project. Chapter 4 contains the results after analyzing data with the program. Chapter 5 contains the conclusion.

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CHAPTER 2
REVIEW OF LITERATURE

2.1 Summary of Relevant Research.

To summarize the related paper on the topic of optimizing vehicle routing problems, strategically tackling complexities often sidelined by conventional methodologies. Firouzi et al.. (2018) introduced a robust mathematical programming model, intricately addressing the dynamics of heterogeneous fleets and flexible time windows. Their comprehensive approach resulted in a remarkable $156,000 annual cost reduction in cargo transport operations, showcasing practical viability and significant benefits for stakeholders in logistics and supply chain systems. In a complementary vein, Guo et al. (2021) extended the capacity vehicle routing problem to account for incompatible loading constraints, presenting novel heuristic algorithms that demonstrated prowess in handling complex logistics requirements, especially in scenarios with multiple orders from a single customer. Guezouli and Abdelhamid (2018) innovatively tackled the multi-depot heterogeneous vehicle routing problem with time windows, leveraging bio-inspired genetic algorithm heuristics and clustering algorithms. Their method, validated against benchmark instances, showed promising results, offering efficient solutions within reasonable processing times. Fachini and Armentano (2020) addressed the heterogeneous fixed fleet vehicle routing problem with time windows, deploying logic-based Benders decomposition and achieving proven optimality and competitiveness against established methods across various instances. Furthermore, Yousefikhoshbakht et al. (2014) proposed a bone route algorithm coupled with tabu search to efficiently tackle the Heterogeneous Fixed Fleet Open Vehicle Routing Problem, demonstrating practical efficiency in real-world logistics scenarios. Mutzel et al. (2022) took an innovative approach, considering individualized customer time windows and employing a branch-and-price framework to enhance daily delivery tour planning. Finally, Meliani et al. (2019) contributed a Tabu search algorithm specifically for the Heterogeneous Fleet Vehicle Routing Problem (HFVRP), providing efficient solutions and valuable insights into routing problem-solving techniques. Collectively, these studies showcase diverse methodologies—from mathematical programming models to heuristic algorithms—

highlighting their effectiveness in addressing the intricacies of vehicle routing problems and their potential to significantly enhance operational efficiency in real life logistics and transportation scenarios.

2.2 Vehicle Routing Problems

The literature on vehicle routing problems is generally divided into three main subtypes: First Vehicle Routing Problems with Time Windows, which impose time constraints on deliveries; Second Heterogeneous Fleet Vehicle Routing Problems with Time Windows, and Third Capacitated Vehicle Routing Problems, which deal with optimizing routes for vehicles with limited carrying capacity. These subtypes meet the unique requirements of diverse logistics and transportation situations by addressing a variety of route optimization challenges, such as capacity restrictions, time windows, and vehicle heterogeneity.

2.2.1 Capacitated Vehicle Routing Problems

When a fleet of vehicles is used that is limited in how much it can transport, the vehicle routing problems. The primary challenge is determining the most efficient routes for these cars to serve clients while ensuring that they aren't carrying more than they can manage. Reducing distance or logistical expenses is the aim. The study by Guo, F., Huang, Z., & Huang, W. (2021) is one of the reviewed papers. With restrictions on incompatible loading and the practice of dividing supplies by order for improved truck efficiency, the CVRP problem. To reduce the overall routing and receiving costs, the study also focuses on hybrid heuristic methods and formulates this as an integer programming model.

2.2.2 Vehicle Routing Problems with Time Windows.

Delivering goods to clients within predetermined time constraints is the focus of vehicle routing problems with time windows. The goal on this topic is to minimize the total distance traveled or other associated costs and optimize routes, known as the truck capacity and the time windows, all the while guaranteeing punctual delivery to every customer within their designated time limits. The Firouzi et al. (2018) work addresses a heterogeneous fleet vehicle routing problem that includes flexible time

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windows, permitting both early and late deliveries within predetermined time constraints. This is one of the two reviewed studies. & Mutzel et al.'s article (2022) Their research is centered on a particular on the heterogeneous vehicle routing problem that takes individual client time frames into account.

2.2.3 Heterogeneous Fleet Vehicle Routing Problems with Time Windows.

Heterogeneous Fleet VRP with time windows involves optimizing routes for diverse number of vehicles, each with unique capacities and characteristics, to deliver goods within specified time constraints. Two of the reviewed papers are. Fachini and Armentano present strategies for addressing the time-windowed routing problem of heterogeneous fixed-fleet vehicles. Their method, which uses logic-based bender decomposition, aims to effectively serve a distributed customer base in a predetermined amount of time. Additionally, Guezouli and Abdelhamid's (2018) paper uses a genetic algorithm-based clustering strategy to optimize the many depot heterogeneous VRPs with time windows. They strive to efficiently plan routes that cater to different customer locations across several depots while adhering to set periods. They address a multitude of objectives and criteria, including the variable capacities of vehicles

2.3 Solution approaches

In addressing vehicle routing problems, the solution approach is often divided into two main strategies: the MILP model and Heuristics. The MILP model presents a methodical, exact solution by formulating the problem as a set of linear equations with integer decision variables, aiming for the optimal solution through precise mathematical formulations. Conversely, Heuristics adopt practical, rule-based strategies to swiftly explore solution spaces, offering satisfactory solutions within reasonable timeframes but without guaranteeing optimality. While the MILP model seeks mathematical rigor in obtaining optimal solutions, Heuristics prioritize practical efficiency, making them valuable for complex problems where computational complexity challenges precise solutions.

2.3.1 Mixed integer linear programming model

The Mixed integer linear programming model is used as a mathematical framework to optimize the routing of vehicles. It's a powerful tool that helps find the best routes for vehicles while considering various constraints and objectives.

One of the reviewed papers is the paper by Guo, F., Huang, Z., & Huang, W. (2021). This paper focuses on an integer programming model to minimize total routing and receipt costs, making it relevant to both the MILP and the heuristic categories.

2.3.2 Heuristics

Heuristics are strategies or methods used to find good or near-optimal solutions efficiently, considering the complexities of routing vehicles to serve customers.

Genetic Algorithms: These are inspired by natural selection processes. In VRP, genetic algorithms create a population of potential solutions represented as chromosomes, each denoting a route for vehicles. One of the reviewed papers is

Guezouli and Abdelhamid (2018) address the Multi-Depot Heterogeneous Fleet VRP with Time Windows using a genetic algorithm-based clustering approach. This paper focuses on multi-objective optimization, where a genetic algorithm is employed to explore solutions considering multiple conflicting objectives.

Tabu Search: Tabu search is a local search metaheuristic that iteratively investigates the neighborhoods surrounding existing solutions. In VRP, it iteratively moves toward better solutions by exploring surrounding routes, assessing their quality, and so on. Its use of a memory structure known as a tabu list, which maintains track on previously visited solutions, is what distinguishes it. Among the two publications that were assessed are Yousefikhoshbakht et al. (2014): They tackle the Heterogeneous Fixed Fleet Open VRP using a combined metaheuristic algorithm known as the bone route algorithm, which incorporates tabu search. This algorithm combines different metaheuristic techniques to address the complexities of the problem efficiently. Meliani et al. (2019): This study concentrates on the Heterogeneous Fleet VPR and introduces a dedicated Tabu search heuristic. The approach is to minimize the total costs associated with routing in this problem scenario.

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2.4 Research Gap

Research gaps found in the research of the reviewed paper, such as unanswered questions and unclear context, are divided into two topics

Contextual Gaps: Environmental Considerations: There's a limited exploration of environmentally conscious routing strategies, such as minimizing carbon emissions or integrating alternative-energy vehicles into the routing models.

Dynamic Real-Time Adaptability: Many studies focus on static or predefined scenarios, but there's a lack of research into dynamic routing models that can adapt in real time to changing traffic conditions, unexpected events, or varying customer demands.

Integration of Last-Mile Logistics: Research focusing on integrating last-mile logistics optimization, considering factors like urban congestion, pedestrianized zones, and micro-mobility solutions, could significantly enhance the practical applicability of routing models in urban settings.

Algorithmic Gaps: Hybrid Algorithm Enhancement: While several studies use hybrid approaches (combining heuristics, metaheuristics, and exact methods), there's room to explore more effective combinations or novel hybrid algorithms that leverage the strengths of different techniques.

Machine Learning Integration: A limited exploration of integrating machine learning techniques for predictive modeling, adaptive routing, or decision support systems could enhance the ability of routing algorithms to learn from past experiences and adapt to new scenarios.

Robustness and Scalability: Many algorithms exhibit strong performance in small to medium-sized instances but might lack robustness or scalability for larger and more complex real-world scenarios. There's a need to develop algorithms that maintain efficiency and accuracy as problem sizes increase

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CHAPTER 3
METHOD OF APPROACH

3.1 Mathematical Model

The mathematical Model of this project uses Capacitated Vehicle Routing Problems with a Heterogeneous Fleet Model to solve this problem. The variables, objective function, and constraints of the model are to minimize the total distance of trucks in the Capacitated Vehicle Routing Problem.

For the **variable**, set it as follows:

Sets:

• C set of customers; $C = \{1, 2, \ldots, n\}$

• N set of all nodes (where a depot is represented by node 0); $N = \{0, 1, \ldots, n\}$

• K set of vehicles; $K = \{1, 2, \ldots, m\}$

Parameters:

• n number of customers

• D_i demand of customer i (pallet)

• m number of (heterogeneous) vehicles

• Q_k Capacity of vehicle k (pallet)

• dij distance from node i to node j (km)

• Variables:

• $x_{ijk} = 1$ if vehicle k travels from node i to node j (binary);

otherwise, $x_{ijk} = 0$

• y_{ij} load (weight of cargo) carried by a vehicle when it travels from node i to node j (pallet)

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The objective function of this study is to minimize the total travel distance of the vehicle.

$$Min \sum_{i}\sum_{j}\sum_{k} d_{ij}x_{ijk}$$

The constraint of the model is as follows.

- Each customer must be visited once by only one vehicle (Const 1).

$$\sum_{j}\sum_{k} x_{ijk} = 1 \ \ for\ all\ i$$

- Path-flow constraint. If vehicle k arrives at node i, it must leave from that node (Const 2).

$$\sum_{j} x_{ijk} - \sum_{j} x_{ijk} = 1 \ \ for\ all\ i\ and\ k$$

- Demand and sub-tour elimination constraint. To satisfy the demand of customer i, the reduced cargo of the vehicle after it visits customer i is equal to its demand (Const 3).

$$\sum_{j} y_{ij} - \sum_{j} y_{ij} = D_i \quad for\ all\ i$$

- vehicle capacity constraint. The maximal supply carried by the vehicle (y_{ij}) is limited by Q and x_{ij}. (Const 4).

$$y_{ij} \leq Qx_{ij}; \quad for\ all\ i\ and\ j$$

- Only available vehicles can be dispatched from the depot (Const 5).

$$\sum_{j \in C} x_{0j} \leq m$$

- Binary and non-negativity conditions. (Const 6,7).

$$x_{ijk} \ \in \{0, 1\}\ for\ all\ i\ j\ and\ k$$

$$y_{ij} \geq 0 \ \ for\ all\ i\ and\ j$$

3.2 Data collection

Data collection from real cases of beverage distributor hubs in the Eastern part of Thailand. The following data have been collected. First, Location of Distributor and customers (in Latitude, Longitude) Location of 1 distribution center and customers collected in Latitude, Longitude. Second, Demand data from each customer. Demand of each customer collected in daily demand in each customer. And Number and capacity of trucks for each type of truck. Capacity of trucks collected in units of pallet.

3.3 Spreadsheet Modelling

3.3.1 Calculate Distance matrix

The distance matrix is a matrix to show the distance of one place to another place for this study, which is calculated by using Google Collab python open source routing machine code. The first step to make a distance matrix, is to classify customers by following the company's day route and preparing location data.

	A	B	C	D
1		Location	Latitude	Longitude
2		สิงห์ปราจีน	14.05638	101.38
3		ปังเจริญ	13.89659	101.5854
4		เจ้ปองการสุรา	13.90226	101.5772
5		หน่อยน้ำแข็ง	13.97144	101.5133
6		ลุงเหลือ	13.95757	101.5617
7		ประชาพร	13.9718	101.5117
8		สำรวย	13.97194	101.511
9		ปังง่วนหลี โคกขวาง	13.94956	101.5096
10		ศ.ศุภกิจ	14.14825	101.3172
11		สกุล สระข่อย	13.85528	101.4246
12		ป้าจวน	13.89313	101.4033
13		ขวัญ โคกปีป	13.89235	101.4005
14		ต้นโพธิ์	13.87191	101.4033
15		เอส อาร์ ไทร์	13.85249	101.423
16		แสนเย็น	13.89367	101.403
17		ป.มินิมาร์ท	13.88145	101.4086
18		เลิศลักษณ์การค้า	13.89409	101.404
19		จ่าน้อย	14.06888	101.5817

Figure 3.1 Customer Location Data In Day Route (Route 1)

Using Google Collab Python open-source routing machine code. To generate the Distance Matrix.

```
# file path
f_path = '/content/IS Location_Coordinates MON.xlsx'
input_ws='MON'
```

```
[ ] import requests
    # function to get a distance matrix from OSRM given an input dataframe
    def get_dist_mat(loc_df,orsm_url="http://router.project-osrm.org/table/v1/driving/",orsm_option='distance'):
        if orsm_option=='distance':
          orsm_option_const=1000
        elif orsm_option=='duration':
          orsm_option_const=3600

        # create a long_lat col
        loc_df['long_lat'] = loc_df['Longitude'].astype(str) + ',' + loc_df['Latitude'].astype(str)
        # print(loc_df) # for debugging purpose

        # the list of long-lat pairs
        loc_coord = loc_df['long_lat'].tolist()
        loc_coord = ';'.join(loc_coord)
        # print(loc_coord) # for debugging purpose

        # define additional options for osrm service
        options = '?annotations=' + orsm_option

        # send a request to osrm service and retrieve the returing result
        # print(orsm_url + loc_coord + options) # for debugging purpose
        r = requests.get(orsm_url  + loc_coord + options)
        res = r.json()
        dist_df=pd.DataFrame(res[orsm_option+'s'])
        dist_df=dist_df/orsm_option_const
        return dist_df
```

Figure 3.2 Open-Source Routing Machine Code In Google Collab.

Distance Matrix											
	สิงห์ปราจีน	ปังเจริญ	ป้องการสุ	หน่อยน้ำแข็	ลุงเหลือ	ประชาพร	สำรวย	นหลี โกก	ศ.ศุภกิจ	กุล สระข่อ	ป้าจวน
สิงห์ปราจีน	0	34.4072	32.3207	19.4439	30.1565	19.2645	19.1833	22.3316	14.6163	25.6842	21.0663
ปังเจริญ	34.375	0	2.1621	14.6135	9.5509	14.793	14.8741	11.9807	53.5497	30.3287	25.7108
เจ๊ป้องการสุรา	32.7457	2.0865	0	12.9843	7.9216	13.1637	13.2448	10.3515	51.9204	28.6994	24.0816
หน่อยน้ำแข็ง	19.7615	14.9632	12.8768	0	10.7126	0.1795	0.2606	2.8877	39.6009	21.2051	16.5872
ลุงเหลือ	30.5029	9.8831	7.7967	10.7415	0	10.9209	11.002	8.1087	43.955	26.4566	21.8388
ประชาพร	19.582	15.1427	13.0562	0.1795	10.8921	0	0.0811	3.0672	39.7804	21.3846	16.7667
สำรวย	19.5009	15.2238	13.1373	0.2606	10.9732	0.0811	0	3.1483	39.8615	21.4657	16.8478
ปังง่วนหลี โกกขวาง	24.5218	14.2726	12.1861	4.7603	10.0219	4.9398	5.0209	0	43.6965	20.4755	15.8576
ศ.ศุภกิจ	14.1109	53.8927	51.8063	39.5943	43.9484	39.7738	33.3168	41.8172	0	35.9845	31.3666
สกุล สระข่อย	26.0087	30.707	28.6205	21.177	26.4564	21.3565	21.4376	18.6315	35.9899	0	4.9113
ป้าจวน	21.0974	25.7957	23.7092	16.2657	21.545	16.4452	16.5263	13.7201	31.0786	5.0767	0
ขวัญ โกกปีป	21.3593	26.0576	23.9711	16.5276	21.8069	16.7071	16.7882	13.982	31.3405	5.3386	0.7208
ต้นโพธิ์	24.6567	29.355	27.2685	19.825	25.1043	20.0045	20.0856	17.2794	34.6379	3.9041	3.5593
เอส อาร์ ไทร์	26.2448	30.9432	28.8567	21.4131	26.6925	21.5926	21.6737	18.8676	36.226	0.5986	5.1475
แสนเย็น	21.0513	25.7497	23.6632	16.2196	21.499	16.3991	16.4802	13.6741	31.0325	5.0307	0.4128
ป.มินิมาร์ท	22.536	27.2343	25.1479	17.7043	22.9837	17.8838	17.9649	15.1588	32.5172	3.4727	1.4386
เลิศลักษณ์การค้า	21.118	25.6261	23.5396	16.096	21.3754	16.2755	16.3566	13.5505	31.0992	5.0723	0.4544
จ่าน้อย	24.4211	44.8287	31.8103	19.5983	23.9524	19.7778	19.8589	21.8212	33.7709	40.1386	35.5208

Figure 3.3 Distance Matrix From Open-Source Routing Machine Code.

3.3.2 The model followed by the objective function and constraint.

The diagram shows the constraint that each customer must be visited once by only one vehicle (Const 1). And path-flow constraint. If vehicle k arrives at node i, it must leave from that node (Const 2).

For constraint 1, set $xijk$ binary variable and sum the variable to be 1, and for constraint 2, search $xijk$ of each customer and subtract by the sum of several trucks in each customer must be equal 0.

xij k=1

	สิงห์ปราจีน	ปังเจริญ	ปองการสุ	น่อยน้ำแข	ลุงเหลือ	...	จ่าน้อย	Sum		Const. (1)	Const. (2)	k=1	
สิงห์ปราจีน	0	0	0	0	0		0	1			0	==	0
ปังเจริญ	0	1	0	0	0		0	1	==	1	0	==	0
เจ้ปองการสุรา	0	0	1	0	0		0	1	==	1	0	==	0
หน่อยน้ำแข็ง	0	0	0	0	0		0	1	==	1	0	==	0
ลุงเหลือ	0	0	0	0	1		0	1	==	1	0	==	0
เอส อาร์ ไทร์	0	0	0	0	0		0	1	==	1	0	==	0
แสนเย็น	0	0	0	0	0		0	1	==	1	0	==	0
ป.มินิมาร์ท	0	0	0	0	0		0	1	==	1	0	==	0
เลิศลักษณ์การค้า	0	0	0	0	0		0	1	==	1	0	==	0
...													
จ่าน้อย	0	0	0	0	0		1	1	==	1	0	==	0
	1	1	1	1	1		1						

Figure 3.4 Decision Variable And Constraint (Const 1,2)

The diagram shows the constraint that is the demand constraint to satisfy the demand of customer i; the reduced cargo of the vehicle after it visits customer i is equal to its demand (Const 3).

Constraint 3 is set by the Sum of y_{ij} not below by Q*xijk of every customer.

yij

	สิงห์ปราจีน	ปังเจริญ	ปองการสุ	น่อยน้ำแข	ลุงเหลือ	...	จ่าน้อย	Sum	Const. (3)		
สิงห์ปราจีน	0	0	0	0	0		0	11			
ปังเจริญ	0	0	0	0	0		0	0	0	==	0
เจ้ปองการสุรา	0	0	0	0	0		0	0	0	==	0
หน่อยน้ำแข็ง	0	0	0	0	0		0	2	1	==	1.1
ลุงเหลือ	0	0	0	0	0		0	0	0	==	0
ประชาพร	0	0	0	0	0		0	0	0	==	0
สำรวย	0	0	0	3.1	0		0	3	0	==	0
ปังง่วนหลี โคกขวาง	0	0	0	0	0		0	0	2	==	2
...											
จ่าน้อย	0	0	0	0	0		0	0	0	==	0
	0	0	0	3	0		0				

Figure 3.5 Decision Variable And Constraint (Const 3)

capacity constraint. The maximal supply carried by the vehicle (y_{ij}) is limited by Q and x_{ijk}. (Const 4). The diagram shows multiplies of Q and x_{ijk} for every customer.

Q*xij k=2

	สิงห์ปราจีน	ปังเจริญ	เจ้ปองการสุรา	น่อยน้ำแข็	ลุงเหลือ	...	จ่าน้อย
สิงห์ปราจีน	0	0	0	0	0		0
ปังเจริญ	0	3.5	0	0	0		0
เจ้ปองการสุรา	0	0	3.5	0	0		0
หน่อยน้ำแข็ง	0	0	0	3.5	0		0
ลุงเหลือ	0	0	0	0	3.5		0
ประชาพร	0	0	0	0	0		0
สำรวย	3.5	0	0	0	0		0
ปังง่วนหลี โคกขวาง	0	0	0	0	0		0
...							
จ่าน้อย	0	0	0	0	0		3.5

SUM Q*xij

	สิงห์ปราจีน	ปังเจริญ	เจ้ปองการสุรา	น่อยน้ำแข็	ลุงเหลือ	...	จ่าน้อย
สิงห์ปราจีน	0	0	0	0	0		0
ปังเจริญ	0	12	0	0	0		0
เจ้ปองการสุรา	0	0	12	0	0		0
หน่อยน้ำแข็ง	0	0	0	3.5	0		0
ลุงเหลือ	0	0	0	0	12		0
ประชาพร	0	0	0	0	0		0
สำรวย	3.5	0	0	8.5	0		0
ปังง่วนหลี โคกขวาง	0	0	0	0	0		0
...							
จ่าน้อย	0	0	0	0	0		12

Figure 3.6 Decision Variable And Constraint (Const 4)

available vehicles constraint that only available vehicles can be dispatched from the depot (Const 5) is a binary condition for x_{ij}. This constraint is a constraint for a limited number of vehicles that can be used.

Const. (5)

1	=	1
1	=	1

Figure 3.7 Decision Variable And Constraint (Const 5)

3.3.3 After assigning all constraints, calculate objective function, total distance by sum of all decision variables and distance matrix, and set all constraints in Open Slover.

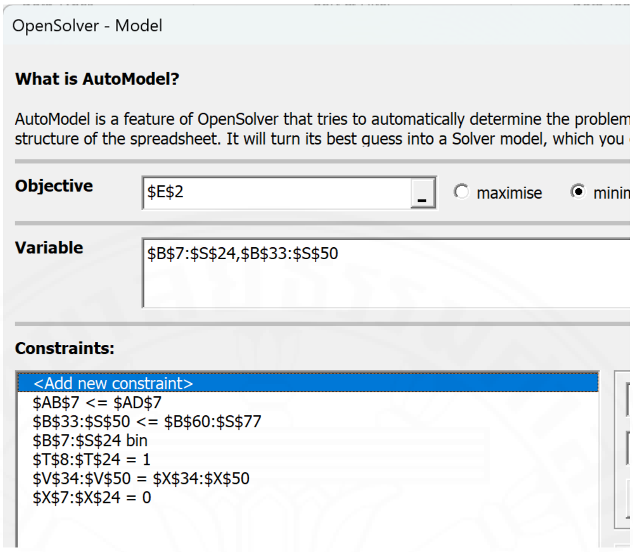

Figure 3.8 Model Setting Up In Open Slover.

3.3.4 After solving the model objective function, make other worksheets to display the results.

Figure 3.9 Route Worksheet Display.

3.3.5 Repeat all of the steps to make the model for 10-20 customers by using the same constraints and model interface

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CHAPTER 4
PROJECT RESULTS

4.1 Case Study Data

- Location of Distributor and customers (in Latitude, Longitude)

  After observing the data location from the distributor and classifying in 6 route

	A	B	C	D
1	Location	Latitude	Longitude	Route
2	สิงห์ปราจีน	14.05638	101.38	Route_1
3	ปังเจริญ	13.89659	101.5854	Route_1
4	เจ้ปองการสุรา	13.90226	101.5772	Route_1
5	หน่อยน้ำแข็ง	13.97144	101.5133	Route_1
6	ลุงเหลือ	13.95757	101.5617	Route_1
7	ประชาพร	13.9718	101.5117	Route_1
8	สำรวย	13.97194	101.511	Route_1
9	ปังง่วนหลี โคกขวาง	13.94956	101.5096	Route_1
10	ศ.ศุภกิจ	14.14825	101.3172	Route_1
11	สกุล สระข่อย	13.85528	101.4246	Route_1
12	ป้าจวน	13.89313	101.4033	Route_1
13	ขวัญ โคกปีป	13.89235	101.4005	Route_1
14	ต้นโพธิ์	13.87191	101.4033	Route_1
15	เอส อาร์ ไทร์	13.85249	101.423	Route_1
16	แสนเย็น	13.89367	101.403	Route_1
17	ป.มินิมาร์ท	13.88145	101.4086	Route_1
18	เลิศลักษณ์การค้า	13.89409	101.404	Route_1
19	จ่าน้อย	14.06888	101.5817	Route_1
20	สิงห์ปราจีน	14.05638	101.38	Route_2
21	ปังเจริญ	13.89659	101.5854	Route_2
22	เจ้ปองการสุรา	13.90226	101.5772	Route_2
23	โชคชัยพานิช	14.05204	101.3678	Route_2
24	แม่บุญโฉม	14.05346	101.3682	Route_2
25	นิวไล้	14.05391	101.3684	Route_2
26	ยี่สุ่น	14.07086	101.3757	Route_2
27	โชคบูรพา	14.07144	101.3761	Route_2
28	ทวีผล ริมน้ำ	14.05206	101.368	Route_2
29	อมรทัต	14.05261	101.3676	Route_2
30	วรรณทิพย์	14.05421	101.3743	Route_2
31	โรงน้ำแข็งจรัญ	14.05545	101.3758	Route_2
32	จรูญ เป็งฮะ	14.07025	101.3741	Route_2
33	ทวีผล หาดยาง	13.99458	101.4442	Route_2
34	ร้านค้าท่าประชุม	13.97098	101.515	Route_2
35	เจริญเภสัช	14.07169	101.3743	Route_2
36	ตี๋ ท่าประชุม	13.97172	101.5118	Route_2

Figure 4.1 Location Of Distributor And Customers (in Latitude, Longitude)

Built the display of each route on Google Maps. By using the function, we built a saved map with the Location coordinates of the Distributor and customers (in Latitude and longitude)

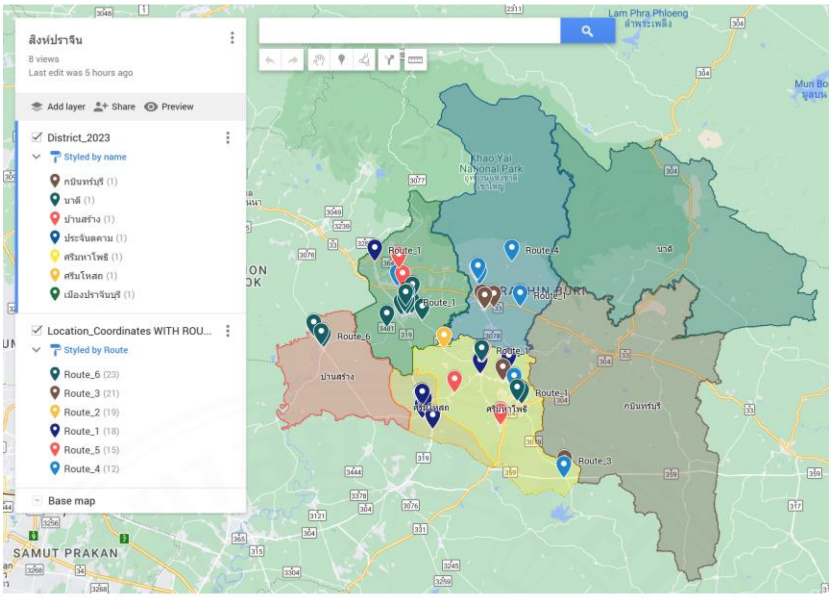

Figure 4.2 Location Of Distributor And Customers Setting Display In Google Maps.

- Demand data from each customer.

  After collecting demand data from the distributor, the demand data in each category of product and collect vehicle and route data. Then, calculate the sum of all the orders in units of pallets.

	A	B	C	D	E	F	G	H	I	J	K	L
1			Number of box in 1 pallet		90	150	126	70	90	150	126	70
2	D/M/YY	ร้าน	รถ	Pallet	เบียร์สิงห์ ข	เบียร์สิงห์ ก	เบียร์สิงห์ ก	เบียร์สิงห์ ข	เบียร์ลีโอ ข	เบียร์ลีโอ ก	เบียร์ลีโอ ก	เบียร์ลีโอ ข
3	1/3/2023	เจ้ปอง	6ล้อ	8.119047619	150		36		303	120	126	
4	1/3/2023	เจ้ปอง	6ล้อ	6.666666667					600			
5	1/3/2023	ส.ศุภกิจ	6ล้อ	6.042857143	50		10		301	40		
6	1/3/2023	จ่าน้อย	6ล้อ	7.666666667					600			
7	1/3/2023	ตี๋	6ล้อ	8.571428571	150		30		600			
8	1/3/2023	วรรณทีพย์	4ล้อ	0.744047619								
9	1/3/2023	จรัญ	4ล้อ	0.535714286								
10	1/3/2023	ไอศรีมทอด	4ล้อ	0.111111111					10			
11	1/3/2023	จรัญ	4ล้อ	0.535714286								
12	1/3/2023	อมรทัต	4ล้อ	0.498015873					10			
13	1/3/2023	แสนเย็น	6ล้อ	6.342063492	30				431	10	30	
14	1/3/2023	ป.มินิมาร์ท	6ล้อ	3.344444444					301			
15	1/3/2023	ต้นโพธิ	6ล้อ	2.666666667	20				200	30		
16	1/3/2023	สกุล	6ล้อ	1.091269841	10				40			
17	1/3/2023	ตี๋	6ล้อ	7.003968254	50				500			
18	1/3/2023	ต้นคุณ	4ล้อ	0.222222222	8				12			
19	1/3/2023	ทวีผลริมน้ำ	4ล้อ	1.339285714								
20	1/3/2023	จรูญ	4ล้อใหญ่	2.085714286	50				100		50	
21	1/3/2023	เจริญ	4ล้อใหญ่	5.710714286	50		5		350	20	20	
22	1/4/2023	กิมฮะจั๊ว	ไม่ส่ง	7								
23	1/4/2023	เจ้ปอง	6ล้อ	7.938095238	150		30		453			
24	1/4/2023	เจ้ปอง	6ล้อ	7					450			
25	1/4/2023	big c ศรี	6ล้อ	1.500396825					40	20		
26	1/4/2023	หน่อย	4ล้อใหญ่	2.895238095	15				165		20	
27	1/4/2023	สามารถ	6ล้อ	7.201984127	30				501			

Figure 4.3 Demand Of Each Customer.

4.2 Best Found Results from Model

After building the model, objective function and constraint. The results of the model ($xijk$) are shown in a binary variable.

xij k=1

	สิงห์ปราจีน	ปังเจริญ	เจ้ปองการสุรา	น่อยน้ำแข็	ลุงเหลือ	...	จ่าน้อย	Sum		Const. (1)	Const. (2)	k=1	
สิงห์ปราจีน	0	0	0	0	0		0	1			0	==	0
ปังเจริญ	0	1	0	0	0		0	1	==	1	0	==	0
เจ้ปองการสุรา	0	0	1	0	0		0	1	==	1	0	==	0
หน่อยน้ำแข็ง	0	0	0	0	0		0	1	==	1	0	==	0
ลุงเหลือ	0	0	0	0	1		0	1	==	1	0	==	0
เอส อาร์ ไทร์	0	0	0	0	0		0	1	==	1	0	==	0
แสนเย็น	0	0	0	0	0		0	1	==	1	0	==	0
ป.มินิมาร์ท	0	0	0	0	0		0	1	==	1	0	==	0
เลิศลักษณ์การค้า	0	0	0	0	0		0	1	==	1	0	==	0
...													
จ่าน้อย	0	0	0	0	0		1	1	==	1	0	==	0
	1	1	1	1	1		1						

Xijk K=2

	สิงห์ปราจีน	ปังเจริญ	เจ้ปองการสุรา	น่อยน้ำแข็	ลุงเหลือ		จ่าน้อย	Sum			Const. (2)	k=2	
สิงห์ปราจีน	0	0	0	0	0		0	1			0	==	0
ปังเจริญ	0	1	0	0	0		0	1	==	1	0	==	0
เจ้ปองการสุรา	0	0	1	0	0		0	1	==	1	0	==	0
หน่อยน้ำแข็ง	0	0	0	1	0		0	1	==	1	0	==	0
ลุงเหลือ	0	0	0	0	1		0	1	==	1	0	==	0
ประชาพร	0	0	0	0	0		0	1	==	1	0	==	0
สำรวย	1	0	0	0	0		0	1	==	1	0	==	0
ปังง่วนหลี โคกขวาง	0	0	0	0	0		0	1	==	1	0	==	0
ศ.ศุภกิจ	0	0	0	0	0		0	1	==	1	0	==	0
...													
สกุล สระข่อย	0	0	0	0	0		0	1	==	1	0	==	0
เลิศลักษณ์การค้า	0	0	0	0	0		0	1	==	1	0	==	0
จ่าน้อย	0	0	0	0	0		1	1	==	1	0	==	0
	1	1	1	1	1		1						

Figure 4.4 Optimization Model Of The Project

The results interface from a worksheet in Excel. Shows Results from the origin to customers in each route. all of the customers are divided into each route for delivery. Every model can serve the demand of each customer sufficiently.

		สิงห์ปราจีน	ปังเจริญ	เจ้ปองการสุรา	หน่อยน้ำแข็ง	...	ขวัญ โคกปีป	ตันโพธิ์	จ่าน้อย
1	สิงห์ปราจีน	0	1	1	1		0	1	1
2	ปังเจริญ	1	0	0	0		0	0	0
3	เจ้ปองการสุรา	0	0	0	0		0	0	0
4	หน่อยน้ำแข็ง	1	0	0	0		0	0	0
5	ลุงเหลือ	1	0	0	0		0	0	0
6	ประชาพร	1	0	0	0		0	0	0
7	สำรวย	0	0	0	0		0	0	0
8	ปังง่วนหลี โคกขวาง	0	0	0	0		0	0	0
9	ศ.ศุภกิจ	1	0	0	0		0	0	0
10	สกุล สระข่อย	0	0	0	0		0	0	0
11	ป้าจวน	0	0	0	0		1	0	0
12	ขวัญ โคกปีป	1	0	0	0		0	0	0
13	ตันโพธิ์	0	0	0	0		0	0	0
14	เอส อาร์ ไทร์	1	0	0	0		0	0	0
15	แสนเย็น	1	0	0	0		0	0	0
16	ป.มินิมาร์ท	0	0	0	0		0	0	0
17	เลิศลักษณ์การค้า	0	0	0	0		0	0	0
18	จ่าน้อย	0	0	0	0		0	0	0
		สิงห์ปราจีน	ปังเจริญ	เจ้ปองการสุรา	หน่อยน้ำแข็ง		ขวัญ โคกปีป	ตันโพธิ์	จ่าน้อย

Route 1	Route 2	Route 3	...	Route 11	Route 12
สิงห์ปราจีน	สิงห์ปราจีน	สิงห์ปราจีน		สิงห์ปราจีน	สิงห์ปราจีน
ปังเจริญ	เจ้ปองการสุรา	หน่อยน้ำแข็ง			
สิงห์ปราจีน	ปังง่วนหลี โคกขวาง	สิงห์ปราจีน			
	ประชาพร	ปังเจริญ			
	สิงห์ปราจีน	สิงห์ปราจีน			
1	3	2		0	0
18					

Figure 4.5 The Display Worksheet In Excel.

CHAPTER 5

PROJECT CONCLUSION

The objective of this project is to make the route for the trucks on the limited driver time limit and customer's time limit. Also, I am trying to formulate a mathematical model to solve small problems to optimal solutions. And develop heuristics for large problems.

After collecting the data and analyzing it by using the Excel Open-solver, the results from the project can solve the problem belonging to the project's objective. The model can solve the Heterogeneous fleet VRP with demand constraints from customers.

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