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LOG950 Logistics

Analysing the application of Vehicle Routing Problem (VRP) in the Distribution of a Brewery: A case study.

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Number of pages including this page: 92

Molde, May 2018

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Preface

This dissertation is the final work of our studies in Operation Management, MSc in Logistics at Molde University College, Specialized University in Logistics. It was conducted from the middle of November 2017 to the end of May 2018.

First of all, we want to express our gratitude to our supervisor: Øyvind Halskau, Høgskolen i Molde. During our thesis, he provided so many remarks and suggestions helping us to finish our thesis smoothly.

Our next appreciation goes to the management and staff of Guinness Ghana Breweries Limited (GGBL) and the Advantage Route to Consumer (ARTC) department for their support during the period we spent with them. Most especially to Frantz Cann and Daniel Awli of the logistics department.

In summary, we appreciate the help from all the people mentioned above and thank them again for all the things they have done to support the thesis from the bottom of our hearts.

Summary

Distribution is an important activity in any supply chain and the need to explore a smooth and cost-effective way of doing it is always welcome by any organization. This is the same in the brewery industry where a lot distribution is done to satisfy the ever-growing customer needs. Vehicle Routing Problem is a method that can be used to ensure the smooth and cost-effective way of distribution and therefore, when the idea was presented to the GGBL logistics team, they welcomed the idea to find a way to improve the current operation of their ARTC team. The aim of this thesis was to find out the current cost and routing being used being used by the ARTC team. Also, the number of vehicles being used and a scientific way of improving their cost and travel time through VRP. In this thesis, we present the use of an Asymmetric Capacitated Vehicle Routing Problem with Pick-up and Delivery(VRPPD), an Asymmetric Capacitated Vehicle Routing Problem with Pick-up and Delivery and Time Windows (VRPPDTW) and a sweep algorithm using a sample of 25 customers. The results obtained from the data used suggested that a combination of optimal solutions from the VRPPDTW and VRPPD was the best among the rest. The results had to be combined because AMPL could not compute a result for the 25 customers, hence, the customers had to be divided between 17 key customers with VRPPDTW and 8 regular customers with VRPPD. This gave a travel time reduction of 5.97% and cost reduction of 50% in comparison to the current routing being used by the ARTC department now.

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List of abbreviations

VRP	Vehicle routing problem
TSP	Travelling salesman problem
GGBL	Guinness Ghana Breweries Limited
ARTC	Advantage Route to Consumer
CVRPs	Capacitated vehicle routing problems
GA	Genetic algorithm
ACO	Ant colony optimization
SVRP	Stochastic vehicle routing problem
CVRPSD	Capacited vehicle routing problem with stochatistic demand
DVRP	Dynamic vehicle routing problem
RTDS	Real-time decision system
RTDPs	Real-time decision problems
1-M-1 SVPDP	One-to-many-to-one single vehicle pickup and delivery problems
VRPSPD	VRP with simultaneous pickup and delivery
VRM	Vehicle routing model
DARP	Dial-a-ride problem
ACVRP	Asymmetric Capacitated Vehicle Routing Problem
ARTC	Advantage Route to Consumer
KD	Key distributors
3PL	Third party logistics
AMPL	Algebraic Mathematical Programming Language
VRPPDTW	VRP with Pickup and Delivery and Time Windows
VRPTW	VRP with Time Windows
LP	Linear Programming
VRPPDSTW	VRP with simultaneous pickup and delivery problem with time windows
GHS	Ghana cedis

1 INTRODUCTION

1.1 Introduction to the vehicle routing problem (VRP)

VRP plays an important role in distribution management and is one of the most widely researched problems among combinatorial optimization problems. It is a generalisation of travelling salesman problem (TSP) and m-TSP, thus this problem is more difficult to solve than TSP and m-TSP. VRP could be used to solve the problem of designing the optimal routes or minimizing the number of needed vehicles from one or several depots to a set of scattered customers. Each vehicle has a certain capacity, which is not allowed to be exceeded. Besides, each customer has a certain demand needed to be satisfied and each of them should be visited exactly once. In addition, every vehicle has to leave and return to the depot. The objective is aimed to minimize the total cost and obtaining the optimal route while fulfilling all the customers' demands.

1.1.1 Customers

In a VRP case, the depot is given as the starting node, and all customers have known demands that need to be satisfied. Besides, each customer should be visited exactly once. In some particular cases, the information about service time of vehicle at each customer (node) is vital to know. Basically, the service time of the vehicle at the customers end has a great impact on the number of customers, which could be serviced on a route. This because, if the service time is too long, the amount of time remaining to serve other customers is reduce, making it difficult to serve a lot of customers. In addition, the time windows of customers, especially in the retail industry, is becoming more and more unusual. This is especially the case in Ghana where people's perception of time is relatively flexible. It will be a strict constraint for designing the routes and it will lead to increasing the substantial cost to meet the time requirements of customers.

1.1.2 Cost (Money, Distance, Time)

A view on the involved cost is necessary for researchers, who want to decide the number of vehicles used in the route. Therefore, the information about the cost of the vehicles used should be known. Usually, the cost of using a vehicle is consisted of two parts: one is fixed cost, and the other part is variable cost. The fixed cost can be the salary of drivers or the cost of buying/ leasing the vehicle. The variable cost could be measured in terms of money, distance or time with respect to the actual use. If the distance is used to measure the variable cost, then the cost matrix could be symmetric. If the time or money is used to estimate the variable cost of vehicle, then cost matrix could be asymmetric, such as in the toll road case. As for the latter situation, both fixed cost and variable cost are different from one kind of vehicle to another.

1.1.3 Demand

Time horizon is involved in the customer's demands. Using the same demand unit for all customers is convenient to operate, measure and compare. When there are several demand units shown in the case, the researchers should consider whether using the same demand unit is convenient or different demand units are better. Typically, the dimension of units for the demand of VRP will be tons, litres, containers etc. It is common in the VRP to compact different items into one type of unit. Basically, the main rule of the VRP is the demand of customers should be fulfilled during the time horizon without stock out.

1.1.4 Vehicle

There are different modes of transportation, like cars/ trucks, rail, ferry, ships or airplanes. Each of them has its pros and cons, therefore, one should be cautious when selecting the mode of transportation. To some extent, there is a trend that more than one mode of transportation is used to complement each other, rather than using one mode (inter-modal transportation). As for only one type of vehicle, it could be divided into homogeneous and heterogeneous fleet of vehicles. Homogeneous fleet of vehicles are identical and all the vehicles in the fleet could be seen as equal. However, heterogeneous fleet of vehicles means the vehicles in the fleet are not identical and different vehicles in the fleet have different parameters. The information about the capacity of vehicle is necessary to know before researching the VRP. Besides, the main rule for the vehicle is that the capacity of vehicle should not be violated.

1.2 Research Objectives/Questions

The thesis is about the application of VRP in the distribution of a brewery to ascertain how much cost minimization can be achieved. The brewery to be observed, Guinness Ghana Breweries Limited (GGBL), has two plants/depots but the thesis will be focused on one, because that depot is responsible for the direct distribution to retailers. We will look into the number of customers used for the thesis, the number of vehicles to be used and the objective of the thesis.

Information obtained from the company suggests the use of an Asymmetric Capacitated Vehicle Routing Problem with Pick-up and Delivery and Time windows (also considering service times).

1.2.1 Number of Customers

GGBL has an estimated 7000 retailers in the country (www.oxfordbusinessgroup.com), of which around over 1000 are estimated to be in the capital, Accra, and some of these retailers are going to be used as the thesis population.

As from the field interview of the former head of Advantage Route to Consumer (ARTC) project, Daniel Awli. ARTC has a current active customer base of over 200 customers, which they have divided into three categories as shown as following:

Key Accounts: These are high value customers such as luxury hotels.

Off Trade: Shopping Malls (Shoprite, Palace Mall, Euromart)

Wholesalers: These are the usual Wholesalers.

A sample of 25 customers will be drawn from the population of customer base from ARTC project, with the purpose of observing the level of improvement in terms of cost minimization that can be achieved using our model, and this will be done using a cluster sampling technique.

1.2.2 Vehicles

GGBL uses 3 to 4.5 tonne trucks with estimated space of 26 cbm to 39.5 cbm. The number of vehicles to be used for routing will be deduced from the information provided by the company. An ACVRP is being used in this research to identify; the number of vehicles, the routes to be used, and how much distance can be minimized in comparison to what they are achieving currently.

Our thesis will be concentrated on the homogeneous fleet of vehicles available.

1.2.3 The Objective (minimization of Cost / Distance)

VRP according to researchers like Laporte G. (1992) and Toth and Vigo (2002) are aimed at minimizing cost, in terms of money, time or distance travelled. The thesis is no different in that regard, as we hope to minimize the costs associated with the distribution activities of GGBL. Cost in terms of the distance travelled in the distribution activities. This objective is to be met by first answering the following questions;

- The current cost of the distribution activity
- The routes to use in the distribution activity
- The number of vehicles to be used in distributing products
- The amount of cost savings to be made when using the new routes in comparison to past cost data.

1.3 Structure of the thesis

The main part of the paper is designed into 10 parts. In the following chapter, a literature review has been written to discuss the history of routing problems. In chapter 3, detailed information of the researched company is introduced. Chapter 4 covers the description of the data collection. In chapter 5, we present two mathematical models for solving the VRPPD with the homogeneous vehicle fleet and for solving the VRP with simultaneous Pickup & delivery problem and time windows, and the relevant algorithms might be used are introduced as well. Chapter 6 provides the findings from the computational experiment results obtained by using the methods in chapter 5. Next, a result analysis is discussed in chapter 7. Further, the conclusion of the paper is made in the chapter 8. Finally, reference list is given in chapter 9 and the appendix with the relevant work and additional information is provided in chapter 10.

2 LITERATURE REVIEW

2.1 Review part on the vehicle routing problem

2.1.1 Deterministic VRP

The VRP is first mentioned by Dantzig and Ramser (1959) around 60 years ago. Their paper was focused on solving a real-world problem, in which they needed to find an optimum delivery routes of trucks from a gasoline terminal to the gas stations. Meanwhile, they provided the first procedure of linear programming formulation and the approach of algorithm in order to obtain the optimal solution. Further, they concluded the formulation they proposed is not just to reduce the total cost (in terms of the total mileage), but also to reduce the cost of calculation considerably by replacing daily plan of the truck dispatching.

Few years later, Clarke and Wright (1964) first claimed the new greedy heuristic (Clarke and Wright algorithm) based on the Dantzig-Ramser work. This algorithm is used to solve the capacitated vehicle routing problems (CVRPs) without the restricition on the number of vehicles, and the 'savings cost' was introduced, where the largest saving was applied to merge two generated routes.

Levin (1971) formulated the integer linear programming with binary variables for solving the fleet routing and scheduling problems in the VRPs. They concluded that their approach could be applied to solve large-sized VRPs.

Gillett & Miller (1974) named the method of algorithm as sweep algorithm, which could be traced back to the work of Wren (1971), Wren and Holliday (1972) for solving the CVRPs. In their research, sweep algorithm was applied to solve medium-sized and large-sized CVRPs with constraints on vehicle load and distance.

Laporte G. (1992) defines VRP as a problem where the optimal delivery or collection routes are designed from one or several depots to a number of cities or customers scattered within a geographical location and is subject to some side constraints. In his article, he illustrates the use of exact and appropriate algorithms in solving various VRPs. More importantly to the thesis, he uses a three-index vehicle flow formulation developed by Fisher & Jaikumar (1981) with capacity constraints, time windows and no stopping time.

He also mentions heuristics algorithms such as Clark and wright algorithm (1964), sweep algorithm (Wren, 1971; Wren and Holliday, 1972; Gillett and Miller, 1974), Christofides-Mingozzi-Toth's two-phase algorithm (1979) and Tabu search algorithm (Cordeau et al., 2002). All these heuristics algorithms can be used as an improvement method for cases where an exact solution cannot be obtained. Laporte (1992) concludes by reaffirming the importance of VRP in distribution and that there are several versions of problem and exact or heuristic algorithms to be used in solving them, although exact algorithms can only solve relatively small problems. And heuristics algorithms tend to provide satisfactory results. He also draws attention to tabu search which can be researched to provide better improvement to solutions.

Toth and Vigo (2002) proposed an exact algorithm based on the branch and bound algorithm for the VRP. They dedicated the difference between symmetric CVRP and asymmetric CVRP. They concluded that the size of VRPs increases dramatically by applying their algorithms for the VRPs, the dimension of the largest instances solved increases from 25 to over 100 customers. They found that even in the asymmetric cost matrix, branch and bound still performs well with respect to the exact algorithm.

With the development of the capability and availability of the computer, the researches on the VRPs sped up from 1990s. More complex search approaches were developed and tested on real-life instances. Researchers introduced metaheuristics, such as simulated annealing, tabu search, genetic algorithm etc., for solving larger sized problems of the VRP.

Osman (1993) developed a hybird heuristic combined with simulated annealing and tabu search heuristic for the basic VRPs with certain customers and a single depot. Further, this algorithm was used to compare with descent algorithm and tabu search heuristic. Additionally, the authors investigated the performances of those algorithms from the aspects of computing time and solution quality in VRPs, which is restricted by distance and vehicle capacity. Meanwhile, those algorithms were tested on 17 benchmark instances from the literature and 9 randomly created instances. Finally, they concluded that compared to the previous reported literature, this hybird heuristic made significant improvement on needed vehicles and total travelling distance.

Gendreau, Hertz and Laporte (1994) presented a tabu search heuristic for the basic VRPs, which was restricted by the vehicle capacity and route length. In their study, a generalized insertion heuristic was developed to remove a node from the current route and reinserted the node into another route iteratively, with the purpose of obtaining a neighbour-sequenced route. Furthermore, this algorithm was experimented on 14 benchmarks from the work of Christofides, Mingozzi and Toth (1979), in which the problem size fluctuated from 50 to 199 except the depot node. They pointed out that this algorithm usually produces the best-known solutions and outperforms the best-existing approach.

Baker and Ayechew (2003) presented a genetic algorithm (GA) for solving the simple VRP with a single depot and known demands. Further, the developed heuristic was tested on 14 instances of VRPs from the study of Beasley (1990). Meanwhile, they summarized that GA performed well in the experiments. Besides, GA made a large improvements by incorporating with neighbourhood heuristic, and the results showed that this hybird heuristic is competitive even with tabu search and simulated annealing approach from the aspect of computating time and solution quality.

Baker and Carreto (2003) developed a greedy randomized adaptive search algorithm for solving the VRPs with known demands and a single depot. The highlights of this article was that the authors designed a visually interactive system for performing mordern heuristics with a high speed, which allows users to combine human insights, intuition and knowledge with the computer techniques. Further, this approach provided a considerable flexibility, allowing people to take control over the decision of the final solution.

Bell and McMullen (2004) modified the initial ant colony optimization (ACO) algorithm for solving the VRP with muti-routes. This algorithm was tested on the three instances with different customers based on the previous work Christofides, Mingozzi and Toth (1979). They concluded that as for the small-sized problem, ACO algorithm performs well in finding the results within 1% of the known optimal solution. In addition, in terms of the large-scaled problem, mutiple ACOs were designed as a competitive solution technique. Besides, they summarized that good solutions are often influenced by the list size of candidates and the approach for choosing the list.

Kytöjoki, et al. (2007) developed a two-phase variable neighbourhood search heuristic for solving large-sized real-life CVRPs with known demands and homogenerous vehicle fleet. In this research, the objective aimed to find out the least-cost solution under the constraints of vehicle capacity. Besides, a implementation technique was applied to accelerate the speed of proposed approach and reduce the memory usage of the computer. Further, this heuristic was tested on 32 large-sized benchmarks from the literatures Golden, et al. (1998) and Li, Golden and Wasil (2005), as well as 20 new large-scaled instances. They concluded that this developed algorithm is fast, competitive and could be applied to find good results for CVRPs with problem size up to 2000 in the reasonable computing time of computer.

2.1.2 Stochastic vehicle routing problem (SVRP)

Tillman (1969) first mentioned the capacited vehicle routing problem with stochatistic demand (CVRPSD) in 1969. In his article, He proposed a heuristic approach for solving a multi-point variant of CVRP with Poisson distribution requirements. Additionally, the algorithm for the pick-up of the products was basically same as for the delivery of the products. Furthermore, as for the difficult problem, this approach was practical as well that could provide "near optimal" solutions.

Cook and Russell (1978) studied on the SVRP. In this article, a GPSS simulation was applied to evaluate the developed heuristic on stochastic travel times for solving the vehicle dispatching problem with time constraints, stochastic demands of customers, and travel times. In their study, the objective function aimed to minimize the total travel time without violating the vehicle capacities and sequencing restrictions. Further, their method was tested on the real-life instance with 163 vertices per day.

Golden and Yee (1979) presented an effective heuristic solution program based on the assumptation that customers' demands can be modeled with other appropriate probability distributions instead of Possion distribution, with purpose to solve VRPSD problems. Besides, the analysis results were offered by the authors to discuss the various relationships between the design parameters. Further, a framework for performing the pertubation analysis was provided as well. Finally, they concentrated on developing a more flexible model related to the requirements.

Yee and Golden (1980) concentrated on deciding the operational strategies based on the assumptation that the vehicle routes are certain. In other words, their paper were learning that under what circumstances should the dirivers return to the central warehouse in purpose to supplement their supply? In order to solve this kind of problem, they presented a dynamic programming recursion, and proved the optimal solution is a fairly simple form. In addition, a relevant algorithm was designed, which was tested on an instance to illustrate this proposed strategy.

Laporte, Louveaux and Mercure (1989) provided exact models for solving a series of stochastic location-routing problems. These problems include locating a warehouse within a set of potential locations simultaneously, determining the fleet size, and designing a set of routes through a set of randomly supplied customers. In the first stage, initial plans with regard to the location of the warehouse, the fleet size and the planned route must be made without knowing the actual supply situation, so the total supply of one route may exceed the capacity of the vehicle. And the second phase made improvements on the plans decided in the first stage: the vehicle could return to the warehouse and clear the goods for further delivery, however, this behavior will create punishment costs. Finally, integer linear programs were applied to model those problems in order to solve to optimally.

Bertsimas, Jaillet and Odoni (1990), Laporte and Louveaux (1990), Bastian and Rinnooy Kan (1992) studied on resource version with respect to the nature and formulations of the SVRP. Dror and Trudeau (1986), Dror, Laporte and Trudeau (1989), Bouzaiene-Ayari and Dror (1993), and Yang, Mathur and Ballou (2000) stated their heuristics for solving the SVRPs in their papers separately.

Bianchi, et al. (2004) provided several metaheuristic approaches for solving the SVRP. In their study, the objective is that minimizes the total travelling distances of the vehicle. Further, an effective approximation was applied to improve the performance of the algorithms due to computationally demanding of the objective function. In addition, they stated that the length of the previous tour is a good choice as a quick approximation used in the local research for analyzing several metaheuristics.

A new exact algorithm was developed for dealing with the CVRPSD in the work of Christiansen and Lysgaard (2007). In this model, it took into account the cost banlace between exceeding the capacity of vehicle and completing the route with vacant space. What’s more, CVRPSD can be expressed as a set partitioning problem and showed that dynamic programming schemes can be applied to solve the corresponding column generation sub-problems. Besides, this algorithm was used to solve an instance with 60 customers and 16 routes successfully. Finally, the final result showed that this proposed algorithm supplements the L-shape approach quite well and enables to solve a wider range of problems. According to the computational results, they concluded that compared with the known-exisitng effective heuristics, their metaheuristics provided better solutions and are applied to deal with the problem as two relevant deterministic problems.

2.1.3 Dynamic vehicle routing problem (DVRP)

Psaraftis (1995) focused on the DVRP within a broder area of the vehicle routing. Due to the rapid development of computer technologies, the further study on opening interesting directions of the DVRP was possible. The authors identified the design for methodologies and algorithms, which maybe important in a future exploring work of the DVRP.

Teodorović and Pavković (1996) presented a model for solving the VRPs with uncertain demands of the customers. Next, sweep algorithm, the rules of fuzzy algorithm and the fuzzy logic were applied to build up this model. Meanwhile, this model was tested on lots of different instances. Finally, the authors summarized that this proposed algorithm could be used for solving large-scale problems within a reasonable computing time.

In the paper proposed by Séguin, et al. (1997), they claimed that real-time decision system (RTDS) usually includes random (stochastic) as well as dynamic components. They mentioned that real-time decision problems (RTDPs) are playing an increasingly significant role in the economy, because the advancement of communications and information technology enables real-time information to be quickly obtained and processed. Besides, they concluded that RTDS has a wild application prospect in the field, such as transportation, military and tele-communication etc.. Furthermore, compared with a problem without the same resource constraints, different approaches are needed for solving the RTDPs.

Tan and Tang (2001) proposed a hybrid Fuzzy-Taguchi approach for solving a real-life instance of the vehicle dispatching problem with muti-workcenters and one warehouse, which aims to develop a new dispatching system for a fleet of computer-guided vehicles in the complex manufacturing facility. Further, this new approach was tested on a hypothetical facility from previous literature. They used the results obtained from the hybrid Fuzzy-Taguchi approach to compare with other earlier proposed methods, and found that this approach could be used to solve the well-known NP-complete scheduling problem effectively.

Gomes and Zuben (2003) developed a neuro-fuzzy approach for solving a multi-criteria optimization problems. In this algorithm, a policy of penalties and rewards, a neuron inhibition strategy, insertion and pruning as well as the characteristics of the input space were taken into consideration. Further, they developed a fuzzy interface system for obtaining the mutiple objectives by implementing decision process. Additionally, this appraoch was tested on a number of numerical simulations. And tabu search heuristic was applied to improve the initial solution. They concluded that, this new approach could generate good solutions effectively.

He and Xu (2005) proposed a genetic algorithm for solving the VRPs with uncertain customer demands and a singe depot. The objective of this programming model aimed to minimize the total travelling time without violating the constraints of vehicle capacity and of arrival time. Further, this new approach was tested on a real-life instance for solving a medical waste collection of VRP. Finally, they proved that the proposed approach is useful for offering good results of the VRPs with uncertain demands.

Lin (2008) successfully established a searching mechanism based on genetic algorithm in order to obtain the optiaml combination of the transport parameters for vehicle scheduling. In this paper, the authors considered the DVRPs as from five attributes: space utility, service satisfaction, waiting time, delay time and transportation distance. Further, the dispatchers could get several feasible solutions by changing the weights in the objective function. Therefore, it is easier to solve complex logistics scheduling problem, that is, to meet mutiple objectives under constraints. They concluded that in practical applications, the genetic algorithm is a promising and effective method for improving transport efficiency.

2.2 Review part on the VRPPD

Gribkovskaia and Laporte (2008) made the definition of one-to-many-to-one single vehicle pickup and delivery problems (1-M-1 SVPDP), in which pickup demands and delivery needs of the customers are satisfied by the depot-based vehicle starting from the depot and ending at the depot. In their research, they divided 1-M-1 SVPDP into two parts based on the variants of this problem: one is SVPDP with single demands, and the other is SVPDP with combined demands. Therefore, VRP could be contributed to 1-M-1 SVPDP with combined demands. Next, the corresponding algorithms were proposed and summarized by the authors as well. In the conclusion, the authors mentioned it is hard to solve those problems. Thus, heuristics are often the practical approach for solutions rather than the available exact algorithms.

2.2.1 The algorithms developed for the VRPPD

Dethloff (2001) devoted to reverse logistics and vehicle routing problems with simultaneous pickup and delivery (VRPSPD) due to the rising issuse of environmental protection. In their work, a mathematical model and an insertion-based heurisrics of VRPSPD containing four different criteria were proposed in the body of the text. They summarized that the algorithm they proposed performs well in real-life problem and they implied that the initial solutions got by this approach could be improved by applying local search approach in the future.

Gribkovskaia, Halskau and Myklebost (2001) proposed an algorithm to find the lasso solution for solving single vehicle or muti-vehicles pickup and delivery problem with combined demands. According to the results in the tests, they found that introducing lasso could provide a better result compared with the only cycle-based solutions. Besides, the routes were more flexible solved by the lasso solutions from the aspects of changing customers' demands and free space on vehicles.

Angelelli and Mansini (2002) stated the problem of single depot network transportation, in which a homogeneous vehicle fleet is used to provide services to a set of customers. The pickups, demands and delivery needs of customers are required to be carry out simutaneously within a demanded time window. What is more, a branch and bound method was developed for solving this problem. The objective of this problem aims to minimize the total cost in terms of the overall distances travelled by the vehicle fleet. Computational results were retrieved from known benchmark instances based on Solomon benchmark problems for VRP with Time Windows (VRPTW). They found that the CPU operating time is not relevant with the number of subproblems as for any value of parameter α.

Wasner and Z.apfel (2004) developed a model capable of deciding the optimal network as from the number and locations of hubs and depots, the assigned service boundaries and the routes between the depots (hubs) and the customers. In their research, they emphasized the importance of a generalized hub location and vehicle routing model (VRM) as for the optimal design of the complex, depot and hub transportation networks for a package service provider. They concluded that the location planning problem entends the diversities of the existing location theory. Further, they summarized the approach of algorithms is a way to solve the parcel delivery problem in the case study.

Nagy and Salhi (2005) proposed an approach, which could be used to find the solution of the relevant VRP and modify this solution to be feasible for the VRPPD. Heuristic routines learned from the approaches of VRP contributed to the modifications, which aim to reduce the infeasibilities of the solutions. Next, the concepts of weak and strong feasibility were introduced to solve the VRPPD. Besides, several improvement approaches are developed in this study as well. They concluded that, the proposed heuristic performs well in terms of getting good quality results in short running time for VRPPD with particular problem size, which contains one to five depots and 50 to 249 customers.

Tang and Galvão (2006) developed a tabu search algorithm for the VRPSPD problems. In this approach, inter-route adjacent solutions are obtained from three types of movements and alternative intra-route are retrieved by applying a 2-opt procedure. 87 test problems were used to evaluate their algorithm between 50 and 400 clients in computational results. They concluded that crossover movement produced better results in relatively small clients' size, while combined movements performed better in the big problem size, partly same as the Dethloff problems (crossover movements perform better no matter the size of customers). Further, they surmarized that the tabu heuristic they proposed makes an improvement on the former heuristics for the same problem.

Gribkovskaia et al. (2007) proposed a mixed integer programming model and relative heuristics of SVRPPD, in which customer points may be visited once or twice by the vehicles. Classical construction, improvement heuristics as well as the tabu search approach were mentioned in their research. In addition, those approaches were tested on 17 instances with the problem size from 16 to 101 customers. Meanwhile, they concluded that non-Hamiltonian usually performs the best among the solutions created by the heuristics discussed in the article. Furthermore, when the general solution contains up to two customers visited twice, which is helpful to generate the designed model and algorithms.

Hoff, et al. (2009) considered two solutions of routes according to two different situations: one generates lasso solution, in which one or several customers are visited twice (delivery first, pickup second) while other customers get simultaneous service. The authors developed a tabu search algorithm for solving this problem. The other one creates the general solution retrieved from Hamiltonian routes on an extended graph by duplicating each customer. They summarized that, the general solution does the best performance in terms of cost without considering the computing time. Further, the best lasso solution obtained within the given computational time usually performs better than the best general solution with the same given time.

2.2.2 The applications of VRPPD

Dethloff (2001) considered a reverse process of beverage distribution in addition to the forward distribution process. In the reverse distribution process, re-usable goods or commodities will be transported back along the reverse direction of the delivery.

Wasner and Zäpfel (2004) conducted a real case study of VRPPD based on the application of a mid-scale parcel delivery service in Austria, in which ten depots and one hub are included in the pickup and delivery transportation network in order to operate 24-hour delivery service without interruption.

Tang and Galvão (2006) developed tabu search heuristic for handling VRPSPD. Their research devoted to solving the problems in the beverage distribution, where drinks should be delivered to the customers, and recyclable bottles or cans need to be picked up at the corresponding customers and taken back to the depot.

Privé et al. (2006) described and solved a real life case of VRPSPD, which involves the distribution of soft drinks and the pickup re-usable empty bottles or cans at the corresponding customer locations. The base of the company was located in the Quebec city area serving about 500 customers. In this article, a mathematic model was built, in which the objective function is the minimization of the distribution cost, minus the revenue created by collecting the recyclable containers. Further, three heuristics and one procedure of improvement were proposed by authors for this problem. They concluded that, 23% cost distance reduction were made in the real-life case based on the test of the real-life case and 10 arbitrary generated instances.

Gribkovskaia et al. (2007) defined the single vehicle routing problem with pickups and deliveries as SVRPPD on a graph, in which customer points have the pickup demands and delivery loads needed. In this article, authors described an application in the distribution between the gas station and offshore oil.

2.3 Review part on the VRPPDTW

In this section, a literature review for the static version and dynamic version is done separately to show the development of the VRPPDTW.

2.3.1 The deterministic VRPPDTW

In terms of static VRPPDTW, it assumes that all the information is given before the planning horizon. In other words, transportation requests are provided by the customers one or several days in advance, and it usually happens in the dial-a-ride problem (DARP) for the elderly and the disabled, which aims to deliver those people to their destination with the least-cost vehicle route. So far, A large work have done for solving the static VRPPDTW problems.

Psaraftis (1980) separated the dial-a-ride problem (DARP) with the single vehicle and immediate requests into two parts: one part focused on the static case of this problem, and the other part focused on the dynamic case of the same problem. In the former part, the writer proposed the fisrt exact approach based on the dynamic programming for solving the DARP. The objective function aims to minimize the weighted combination of the total time taken by the single vehicle to serve all customers and of the total ‘dissatisfaction’ from all customers while wating for the vehicle. In the latter part, they applied the same approach proposed in the static part. And the algorithm is capable of considering the requests from customers when the requests occur. The disadvantages of this algorithm is only considering the known requests without anticipating the requests from the new customers. Furthermore, it could be applied to sovle small problem sizes up to 10 customers.

Sexton and Bodin (1985a,b) presented a mathematic programming formulation based on the Benders’ decomposition procedure for solving one single vehicle problems. The objective function is to minimize the total inconvenience of all customers while waiting for the service. A mixed binary non-linear formulation was applied for solving the routing (sequencing) component and scheduling component separately. What’s more, they presented a heuristic algorithm used to find an initial route and another heuristic algorithm developed to improve the route. Lastly, they obtained the final solution by integrating both of the algorithms.

Sexton and Choi (1986) applied Benders’ decomposition procedure for solving one single vehicle routing and scheduling problem with soft time windows. They proposed a two-phase procedures of routing and scheduling with relevant algorithms. Besides, the objective functon aims to minimize the weighted combination of the service time for all the customers and of the penalty as a result of missing the service to customers within the given time windows. In the formulation, they applied the dynamic programming to obtain the exact solution by considering the time windows, vehicle capacity and precedence constraints as well. Further, their approach could be used to solve problem size up to 18 customers.

Dumas, Desrosiers and Soumis (1991) presented a exact algorithm for solving the VRPPDTW problems. They applied a column generation scheme with a constrained shortest path as the sub-problem. This approach performs well for solving VRPPDTW with a single vehicle restricted by capacity constraint, in which the problem size is up to 55 customers. Meanwhile, this approach could be extended to solve the VRPPDTW with mutiple-vehicle.

In addition, they mentioned to develop an algorithm based on their approach for solving muti-vehicle problems, but it was not completed.

Ioachim, et al. (1995) applied a new approximate method based on column generation as well as for solving the VRPPDTW with mitiple-vehicle. In order to solve much larger problems by this approach, they enhanced their optimal algorithm from three ways. For one thing, the lists of adjacent transportation requests were used to design the initial network. For another, the procedure of specialized initialization was proposed to reduce the processing time. what's more, this algorithm was designed for catering to capacity with mutiple-dimensions. Lastly, a heuristic was used to reduce the size of the network, which has little influence on the solution quality. After those steps implemented, this appraoch was capable of solving more than 2400 requests.

Desrosiers, et al. (1995) focused on optimal methods for routing time-constrained problems and scheduling. They revealed that, the column generation is sensitive to the tightness of time windows and capacity limitations. If these constraints are loose, the performance of this approach would not be good.

Borndörfer, et al. (1997) conducted the telebus program, which was used to solve the DARP for disabled people in Berlin. The purpose of their study was to allocate the daily transportation requests to 100 mini-buses with a minimum operation costs. Next, they proposed a set-partitioning approach for solving the bus scheduling problem. Further, a branch-and-cut algorithm was introduced for the solution obtained by the set-partitioning approach. They summarized that, it could be used to solve a vehicle scheduling problem with this case size.

Researchers developed the heuristic algorithms for solving larger sized problems in reality, because the exact algorithm can only handle small-scale problems. Such heuristics are not seeking for the optimal solutions, instead those algorithms are providing a way to obtain the near-optimal solutions within a quick computation time.

Potvin and Rousseau (1992) mentioned a heuristic algorithm based on the constraint-directed search conducted among all the feasible solutions. In this approach, New customers were inserted into the evolving routes at each step. Further, each new solution of routes is qualified in terms of the satisfication of the stated limitations and preferences. Besides, this approach could be applied for the problem size with 100 requests.

Van der Bruggen, Lenstra and Schuur (1993) proposed a local search algorithm with two phase procedures: the first procedure aims to find out a feasible solution, starting with an infeasible solution out of the time windows and reducing the infeasibility at each iteration.

In the second phase, the feasible solution from the former step will be improved continuously by minimizing the objective of total duration of route. Further, a variable-depth search based on arc-exchange procedures with seven variants was used in both phases. What’s more, an alternative algorithm based on simulated annealing was developed with the purpose to avoid the infeasible solution. Further, this approach was tested for solving the DARP with 38 and 50 customers.

Gélinas, et al. (1995) proposed a branch and bound algorithm with a set of partitioning model derieved from the column generation for solving the VRPPDTW. In this algorithm, the authors branch on the resource variables, as like the time window of the customers, the capacity of the vehicles, instead of branching on the flow variables. They concluded that, the algorithm they developed had advantages on solving a set of instances, in which the customer size is up to 100.

Toth and Vigo (1997) tried to solve the handicapped transportation problems happening in the urban area of Bologna. In their study, a parrel insertion heuristic algorithm was proposed to obtain good solutions quickly from the discussed problem. Further, they presented a tabu search heuristic with threshold in purpose to improve the initial solution received from the insertion heuristic. Besides, their method was capable of solving DARP with 312 requests.

Nanry and Barnes (2000) conducted the first application of reactive tabu search to the VRPPDTW. They emphasized the importance on the dominance of the procedence and coupling constraints in the development of search algorithm, which is one of the major factors to evaluate the efficiency of the reactive tabu search for VRPPDTW. In addition, this approach was qualified to solve problem instances with 100 requests.

Cordeau and Laporte (2003) described a classic tabu search for solving the DARP with muti-vehicles. Further, a neighborhood heuristic procedure was proposed for adjusting the visit time of customers in the solution, with the purpose to find the optimal vehicle’s route in terms of time duration and travelling time. Meanwhile, this method could be modified to solve VRPTW with multi-depots or handle VRPTW with various types of the vehicle. In this case, this approach was applied to solve maximum 295 requests.

2.3.2 The Dynamic VRPPDTW

As for the dynamic VRPPDTW, the data of the problem is not known completely before making plans for the problem in advance. Therefore, it is impossible for the decision maker to solve the entire problem promptly due to the imcomplete and uncertain information. Such problem could be found in many real-life cases, such as the delivery of fossil fuel or the delivery of natural gas. Until now, researchers have done lots of study and work on the dynamic VRPPDTW, while is less studied than the static VRPPDTW.

Psaraftis (1983) considered the dynamic single-vehicle DARP based on the previous work Psaraftis (1980). In their study, the requests from the customers happen dynamically and future requests could not be predicted. The main difference between those two algorithms is using forward recursion to replace the backward recursion. In this article, the author assumed all customers with known demands are used to avoid the infeasible results. In addtion, the procedure of checking the infeasibility was developed to identify the infeasible instances. However, the problem of their approach is that infeasibility would happen if the algorithm runs slowly and the requests arrives quickly, because a planned solution should always be available before the arrival of the next request.

Madsen, Ravn and Rygaard (1995) developed a fast and flexible heuristic algorithm stemming from the insertion heuristics for solving the DARP with time windows, multi-capacities, multi-objectives. Further, their study was applied by the Copenhagen Fire-Fighting service to schedule elders and handicapped persons with approximate 50000 requests every year. Meanwhile, this algorithm was used in a dynamic environment in order to schedule online. This case is a rare case study among the study of the DARP, which is designed in a dynamic environment. In their research, the algorithm was used by the authors to solve the problem with 300 cutomers and 24 vehicles.

Shen, et al. (1995) focused on simplifying the work of a dispatcher by designing an expert consulting system based on a neural network in one courier service company. In the system, interactive-graphic features were integrated and one learning module was developed to assist the dispatcher as well. In the real-time dispatching practice, the dispatcher has half hour for a pickup and one and a half hours for a delivery after receiving the transportation requests. Besides, this system was tested by the authors to solve the problem size with 140 transportation requests, 12 vehicles and a 6-hour service period.

Benyahia and Potvin (1998) presented a genetic programming algorithm for solving the vehicle dispatching problem in which real-time transportation requests are allocated to the moving vehicles. Next, A utility function was formulated based on the attribute description of the current situation and the incoming transportaion requests, and focused on approximating the decisions for the dispatcher. Further, the authors tested this method on the same real-life instances as the previous literature.

Mitrović-Minić, Krishnamurti and Laporte (2004) described the double-horizon based heuristic for solving the dynamic VRPPDTW as for the courier companies. In their study, different goals are attributed to two different time horizons (one is short term and the other is long term). The goal in the short term was concentrated on reducing the total travelling distance. Whereas the goal in the long term was focusing on remaining the flexibility of routes that enables to better react on the future requests. Furthermore, this algorithm was tested on the instance with 100 requests, 500 requests and 1000 requests respectively.

Gendreau, et al. (2006) presented the procedure of neighbourhood search (particularly tabu search) heuristic for finding the optimal solution in the dynamic VRPPD with soft time windows. Further, ejection chains were exploited for designing the structure of neighbourhood search. In the first case, an adaptive memory (a pool of routes is associated with the best visited solution) was introduced for diversifying the solutions of an instance with 24 requests every hour and over 6-hours period. In the second case with 33 requests every hour and over 4-hours period, a decomposition procedure was applied to decompose the problem into smaller sub-problems, with the purpose of intensifying the search. They proved that, the adaptive descent (a heuristic based on the adaptive memory inplemented in the first case) and tabu search, both of them could be used to solve the complex dynamic environment.

3.0 CASE DESCRIPTION

This thesis is based on a case study, and the company to be analysed is a brewery located in Ghana, West Africa. GGBL has agreed to allow us to use data from the company to ascertain how much cost savings (in terms of distance minimization) can be made using an Asymmetric Capacitated Vehicle Routing Problem (ACVRP).

A meeting with the head of Planning and Logistics at GGBL, Frantz Cann, was arranged to probe more into the object of the thesis and upon further explanation, he introduced us to the former head of the ARTC project, Daniel Awli, who was the focus of most of the questions relevant to the thesis. The interviews with the head of the planning and logistics departments and the former head of the ARTC project, got us direct and useful information from the company, which gave us an assurance of the authenticity of all information obtained thus far.

3.1 Size

GGBL is a subsidiary of Diageo PLC, a leading drinks producer in the world with well-known brands such as Johnnie Walker, Baileys and Smirnoff. GGBL is a total beverage business in Ghana producing a range of products, from beer, stouts, non-alcoholic to spirit. GGBL is a company listed on the Ghana Stock exchange, and the only beverage company in the country to have done that. They have two production sites, one in the national capital Accra and the other in Kumasi, the second largest city in the country. GGBL employs over 1200 employees between the two sites (www.guinnessghana.com), one in Kumasi and the other in Accra, the capital of Ghana. GGBL has over 14 products, some of which are not produced in Ghana. GGBL produces 14 of its products in Ghana and some other Diageo PLC products are imported. The number of products under each category are as follows;

- Beer and Stouts: Guinness Foreign Extra Stout, Ruut Extra, Guinness Africa Special, Star Lager, Gulder Lager, Smirnoff Ice, Smirnoff Double Black and Orijin Lager.
- Non-alcoholic Beverages: Alvaro, Malta Guinness, Amstel Malta, and Orijin Non-Alcoholic.
- Spirits and Bitters: Gilbeys, and Orijin Bitters

Production is mostly done in Kumasi and distribution to key distributors (KD) are done from there as well. The plant in Accra is used mainly for distribution, both to the KD and Retailers across the city. And this is the main focus of our master's thesis. Distribution to retailers is a new channel developed by the company over the last 2 years and this channel is the focus of our study.

3.2 Money

Reuter (2017) reports that GGBL made $135.62 million in sales in the 2016/17 accounting year from all brands. (www.reuter.com). Cost of distribution for the company takes up to 60% of the company's revenue and our objective is to reduce this cost. The amount is estimated to be $81.37 million. Our objective is to analyse how much cost saving can be achieved using an exact or heuristic approach for their routing activities in the ARTC department.

3.3 ARTC department

As from the interview with Daniel, the former head of ARTC department, he emphasized on the work that the ARTC did, which was to satisfy special retailers (such as hotels, restaurants, shopping centres, etc.). Those customers' demands, and satisfactions were of a top priority to GGBL.

3.3.1 Organizational structure of the ARTC Department

The ARTC Department is made up of an inventory officer, an operations manager, a depot manager and a systems and administrations manager.

Inventory Manager – The inventory manager is responsible for the level of inventory at the depot and ensure that stocks are always available for customer deliveries.

Operations Manager – The operations manager in responsible for the daily activities in the warehouse, in terms of forklift availability, truck and driver availability.

Depot Manager – The depot manager is responsible for all activities at the depot, as such all the other managers are accountable to him. The depot manager is also responsible for the routing of customer orders and trying to minimize the total cost of the delivery.

Systems/Administrations Manager – The systems manager is responsible for the consolidation of customer orders to confirm quantities and help with routing.

3.3.2 Number of Deliveries per day

The average number of deliveries of ARTC project made per day is 50 orders.

3.3.3 Order Processing

Customer orders of ARTC are processed a day before deliveries are to be made. According to Daniel, the preferred number of day for this is supposed to be two (2) days, but changes had to be made to accommodate customer delays. As mentioned earlier, time in Ghana is relatively flexible, hence customers do not feel the urgency to follow deadlines, as such GGBL has to accommodate them.

3.3.4 Current Routing

Routing of ARTC is done based on the orders received and the location of the customers. The depot manager then does the routing manually based on those orders.

3.3.5 Payment Method

Customers of ARTC are given credit time to pay for orders. Key accounts have a 30-day period of credit, Off Trade and Wholesalers have a 14-day period of credit.

3.4 Number of vehicles

GGBL uses third party logistics (3PL) companies when shipping to Key Distributors (KDs). They have approximately 11 3PL's that provide these services. Figure 1 below illustrates the way products are delivered to the KDs. The KDs use their own fleet to distribute to their retailers. These retailers are different from the ones served by the ARTC department. KDs are served by GGBL one after the other since KD orders are very large and is mostly a full truckload consisting of between 1728 to 1764 cases of products.

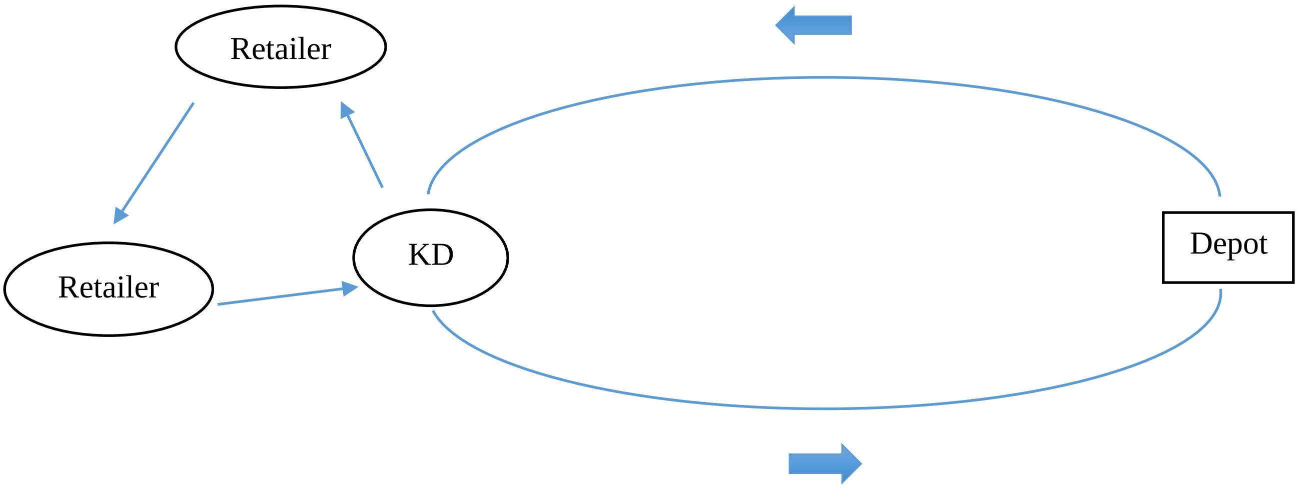

Figure 1: Normal Distribution Routing

In the case of their direct distribution to the retailers, GGBL has its own fleet of vehicles for that activity.

There are approximately 8 vehicles available to the logistics department for this activity. Since the ARTC department does not serve KDs, there are no KDs in their daily routing.

As for the ARTC project, it uses four (4) vehicles on daily deliveries and has four (4) 3PL vehicles they hire when the need arises. Besides, ARTC uses a homogeneous fleet with a capacity of 500 cases each and the 3PLs uses a homogeneous fleet with a capacity of 800 cases. According to Daniel, the company sometimes overloaded their vehicles if they feel the need to.

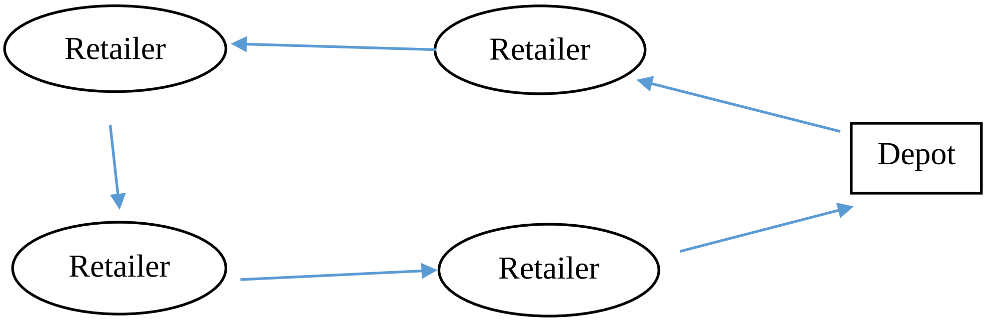

Figure 2: Direct to Retailers Routing

3.5 Supply Chain of GGBL

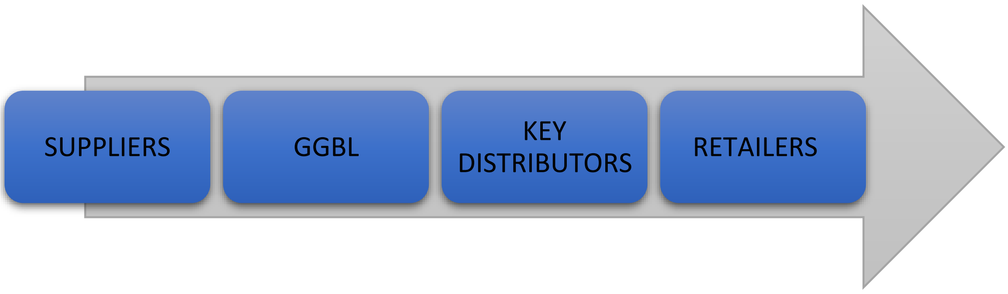

Figure 3: Normal Distribution Channel

3.5.1 Normal Distribution Channel

The normal distribution channel of GGBL is a four (4) step system that ends with the customer. The steps as displayed above in Figure 3 are: Suppliers, GGBL, KDs, Retailers and End Users.

Suppliers: GGBL has 14 different brands of products, and that number of products require a lot of suppliers to keep production going. GGBL has suppliers from abroad and locally to ensure that continued production of their brands.

GGBL: The company uses third party logistics providers to send ordered products from the production floor directly to their KDs. This is done through a direct route (as illustrated in Figure 1 above) and does not require much requisite skill level to do it. All that is required is to apportion a truck to an order and it returns with empty bottles if there is any. Thus, this is not the focus of our thesis.

Key Distributors: These are first point of contact from the production floor unto the market. These KDs are companies that sell GGBL products to retailers. GGBL has two categories of KDs, namely; credit KDs and cash KDs. Credit KDs are those that are given a period within which to pay back purchases made from GGBL and cash KDs are those that have to make payment before products are sold to them.

Retailers: Retailers are the closest to the customers and this give GGBL to aim sales promotions towards them to ensure the customers get to experience the different brands of GGBL.

End Users: These are the end users of GGBL's products and are the most important actors in the supply chain, although they were not indicated in our figure above. The market determines what product is produced since GGBL tries to respond to the end customers' needs all the time.

Figure 4: Direct to Retailers Distribution Channel

3.5.2 Direct to Retailers Distribution Channel

As mentioned earlier, this channel is the focus of our study, as such more attention is paid to this channel in terms of routing. Having explained suppliers and end users, we will be explaining the activities that are different with GGBL and the Retailers this time.

GGBL: This channel requires GGBL to act as a depot as such the ARTC was created to serve that purpose. ARTC is responsible for serving a part of GGBL's retailers who are not served by the KDs.

Retailers: As mentioned earlier, these retailers are not served by the KDs, and this is because they have special needs that ARTC are required to be able to meet.

3.6 Competition

GGBL is the only total beverage producer in the country but they have some competition in some aspects of the beverage production industry. The main competitors on the various categories are outlined below:

- Beer and Stout: The main competitor in Ghana in this category is Accra Breweries Limited, a company that has its only manufacturing plant in Accra. They produce 5 types of beer in total and has 30% market share in the country and GGBL has 70% market share (www.just-drinks.com, www.ratebeer.com).
- Non - Alcoholic Beverages: The main competitor in this category is Coca-Cola Bottling Company Limited which has its production plant in Tema. They have 5 products in this category (gipcghana.com).
- Spirits and Bitters: Kasapreko Ghana Limited in the main competitor in this category and has two production plants across the country. They have 14 brands in total, some of which are direct competitors of GGBL's brand and others that can act as substitutes to the customers (kasapreko.com).

3.7 Map of Ghana

Figure 5: A map of Ghana showing its major cities

The diagram above shows a map of Ghana and major cities in the country. Ghana is divided into 10 regions and has its capital as Accra in the Greater Accra Region. The second largest city in the country is Kumasi, and GGBL has plants in both cities. In Norway, there is an amount of money that is placed on certain bottles to motivate buyers to return the bottles for a refund. Such a system is not in place in Ghana, hence the number of bottles that are returned to the brewery is always lesser than the amount that was shipped out. This presents a problem for the breweries because they have to constantly invest in acquiring new bottles for production.

4 DATA COLLECTION

4.1 The main sources of data

The data required for this thesis as mentioned earlier is obtained from the ARTC department of GGBL. There were two main sources of data acquired from GGBL, namely; interview and secondary data.

4.1.1 Interview

As mentioned earlier, an interview was done with the Head of the Planning and Logistics departments of GGBL, Frantz Cann and the former head of the ARTC department, Daniel Awli. These interviews gave as an insight into the daily activities of the ARTC department and the GGBL logistics department.

Frantz made it clear that all data to be given to us would require approval from the corporate team of the breweries to ensure that trade secrets were not shared without the right scrutiny.

Daniel gave us more detailed information about the ARTC department. And provided us with historical data of the routing done by the company.

4.1.2 Secondary Data

Secondary data for the thesis was obtained from two sources; one was from past routing done by the ARTC and the second was the use of Google map to calculate accurate distances for our distance matrix used for the Algebraic Mathematical Programming Language (AMPL) model.

4.2 The field data

4.2.1 Customers' demands with pick-up and delivery (not considering the TW)

One central depot located in Accra delivers the demanded beverage products to different customers, collects the recyclable bottles or cans at the corresponding customers and takes back to the depot every day. According to the collected data, in one day, 18 customers located around the depot are visited with corresponding deliveries and pick-ups. The demand of deliveries and pick-ups is shown as the following table 1:

Table 1: The demand of VRPPD from 18 customers

Customers	***Delivery***	***Pick-up***
1	170	145
2	80	60
3	60	100
4	40	35
5	70	50
6	100	85
7	80	80
8	85	70
9	70	68
10	50	46
11	90	90
12	120	100
13	80	64
14	45	44
15	40	38
16	30	30
17	40	40
18	50	50
Total	**1300**	**1195**

Table 2: The demand of VRPPD from 25 customers

Customers	***Orders (Cases)***	***Pick Up (Cases)***
1	200	180
2	300	280
3	100	80
4	85	70
5	112	100
6	90	90
7	80	64
8	50	50
9	65	65
10	120	100
11	6	6
12	40	10
13	8	6
14	50	30
15	60	55
16	480	400
17	40	38
18	97	100
19	175	150

20	220	150
21	50	32
22	15	5
23	130	85
24	490	355
25	345	305
Total	***3408***	***2806***

4.2.2 Customers' demands with pick-up and delivery (considering the TW)

Table 3: The demand of VRPPDTW from 17 customers

Customers	Orders (Cases)	Pick Up (Cases)	Start Time TW	End Time TW
1	200	180		
2	300	280		
3	100	80	12:00	14:00
4	85	70		
5	112	100		
6	90	90		
7	80	64		
8	50	50		
9	120	100	13:00	14:00
10	6	6		
11	8	6		
12	50	30	09:00	10:30
13	60	55		
14	40	38		
15	97	100	10:00	14:00
16	220	150		
17	15	5		
Total	**1633**	**1404**		

Table 4: The demand of VRPPDTW from 25 customers

	Customers	Orders (Cases)	Pick Up (Cases)	Start Time TW	End Time TW
1	**ALISA HOTEL**	200	180		
2	**Honeysuke Pub & Restaurant**	300	280		
3	**KHI GH (Movenpick)**	100	80	12:00	14:00
4	**M. HOSPITALITY LIMITED**	85	70		
5	**PALOMA HOTEL LIMITED**	112	100		
6	**Plus 233 JAZZ BAR AND GRILL (Travic F**	90	90		
7	**SHAKAZULU LTD (SHAKAZULU WINE A**	80	64		
8	**Yasmina Restaurant**	50	50		
9	**Afrikiko Leisure Centre**	120	100	13:00	14:00
10	**ROBI COLORS ENTERPRISE**	6	6		
11	**Airport west Hospitality (African R**	8	6		
12	**NUSUBON VENTURES**	50	30	09:00	10:30
13	**Mckays Bar & Restaurant**	60	55		
14	**Firefly Ltd**	40	38		
15	**El-Lizzy Ent (Lizzy Spot)**	97	100	10:00	14:00
16	**PURPLE PUB**	220	150		
17	**MENGRACE ENT (KEIVINS AKAD)**	15	5		
18	**Mum's Corner Enterprise**	65	65		
19	**Tang Palace Hotel**	40	10		
20	**Yoo Mart Limited - Graphic Road Del**	480	400		
21	**Justitet Enterprise**	175	150		
22	**Ladystaff Ventures**	50	32		
23	**SHOPRITE ACHIMOTA**	130	85		
24	**SHOPRITE GHANA (PTY) LIMITED**	490	355		
25	**GAME DISCOUNT WORLD (GHANA) LT**	345	305		
	Total	**3408**	**2806**		

5 METHODOLOGY

The type of research will be a quantitative research based on a case study of Guinness Ghana Breweries Limited, a beverage producing company in Ghana, West Africa. Quantitative research places emphasis on counting and measuring, and since the thesis will be to identify how many vehicles to be used and which routes will be used in serving these customers under the constraints of vehicle capacity, there will be the need to measure how these variables are accounted for.

In order to achieve the above goals, a three-index model for VRPPDTW is introduced, which is a generalization of the VRPTW. VRPPDTW is applied by adding pickup and delivery constraints in this case to incorporate the characteristics of VRPTW. As from the pickup (resp. delivery) aspect, the VRPTW is a particular case of the VRPPDTW where all the vehicles have a common origin starting from the depot and a common destination ending at the depot.

After the introduction of the exact model, this optimization approach is extended further, with the purpose of getting the optimal routes based on a mathematical model.

In addition, a relative heuristic will be introduced following the optimization approach for solving the instances which could not be solved by the optimization approach.

The departments we will be working with is the logistics department of the company, which comprises transport and operation, and most of the data will be taken from daily records entered by the employees in the department.

5.1 Linear Programming (LP) model for VRP

5.1.1 The Linear Programming (LP) model of VRPPD (Model 1)

In VRPPD problem, each pickup and delivery stop need to be visited one and only one time without exceeding the vehicle capacity. A characteristic of this problem is that, it ties the pickup stops and the corresponding delivery stop on the same vehicle routes and gives the visit priority on vehicles among the pickup stops and the related delivery stops. Furthermore, as for the depot, the initial pickup load of the vehicle and the last delivery load at the depot is zero.

Base on the work of Gribkovskaia and Halskau (2016). VRPPD problem is denoted as an undirected graph $G = (N, A)$, where N is the set of nodes denoted as $\{0, \ldots, n\}$ and A is the set of arcs defined as $\{(i, j): i, j \in N, i \neq j\}$. Node 0 represents the depot and the other nodes correspond as the customers. In this model, all the vehicles are considered as homogeneous, and all the vehicles have the same capacity C. All arcs (i, j) are used to denote the travel distance c_{ij}. Additionally, vehicles have a pickup tasks p_i at each customer nodes taking back to the depot, meanwhile, customers may have the delivery needs d_i, which is delivered from the depot.

The notation for VRPPD model
N – set of nodes
A – set of arcs

Variables:

X_{ij} – binary variable, if the value is 1, it means the arc (i,j) is used; if the value is 0, otherwise.$\forall(i,j) \in A$

u_{ij} - the pickup load of vehicle along arc (i, j). $\forall(i,j) \in A$

v_{ij} - the load of vehicle along arc (i, j). $\forall(i,j) \in A$

Parameters:

c_{ij} – travel time between node i and node j. $\forall(i,j) \in A$

p_i – pickup amount at node i. $\forall i \in N$

d_i – delivery amount at node i. $\forall i \in N$

C – capacity of vehicle

The model of VRPPD for homogeneous vehicle fleet

(1) Minimize $\sum_{(i,j)\in A} c_{ij} * X_{ij}$

(2) Subject to $\sum_{(0,i)\in A} X_{0i} = \sum_{(i,0)\in A} X_{i0}$

(3) $\sum_{(i,j)\in A} X_{ij} = 1,\ \forall i \in N\backslash\{0\}$

(4) $\sum_{(i,j)\in A} X_{ij} = \sum_{(j,i)\in A} X_{ji}\ ,\ \forall i\ \in N$

(5) $u_{0i} = 0,, \forall i \in N$

(6) $u_{ij} \geq p_i * X_{ij},\ \forall(i,j) \in A$

(7) $\sum_{(i,j)\in A} u_{ij} - \sum_{(j,i)\in A} u_{ji} = p_i,\ \forall i \in N\backslash\{0\}$

(8) $v_{i0} = 0,, \forall i \in N$

(9) $v_{ij} \geq d_j * X_{ij},\ \forall(i,j) \in A$

(10) $\sum_{(j,i)\in A} v_{ji} - \sum_{(i,j)\in A} v_{ij} = d_i,\ \forall i \in N$

(11) $u_{ij} + v_{ij} \leq C * X_{ij},\ \forall(i,j) \in A$

(12) $X_{ij} \in \{0,1\}, (i,j) \in A$

(13) $u_{ij}, v_{ij} \geq 0, (i,j) \in A$

The objective function (1) expresses this model aims to minimize the total travelling distance.

Constraint (2) is the restriction on the vehicle, it means that the number of vehicle starting from the depot should be the same as the number of vehicle returning to the depot. Next, Constraint (3) indicates that each customer should be visited one and exactly one time.

Constraint (4) guarantees the connectivity of each vehicle route. To do some extensions, if the vehicle visits one node, then this vehicle must leave from this node as well.

Constraint (5) shows the initial pickup load of the vehicle at the depot is zero.

In constraint (6), when arc (i, j) is used ($X_{ij} = 1$), this equation guarantees the lower bound of pickup load is at least p_i. And when arc (*i*, *j*) is not used ($X_{ij} = 0$), this equation is no longer active.

Next, as for the pickup node, constraint (7) presents the outflow of pickup node minus the inflow of that node is equal to the pickup amount at that node, in other words, it guarantees the balance of inflow and outflow of pickup load of each node. Constraint (8) ensures that there is no delivery load when each vehicle returns to the depot. In constraint (9), if arc (i, j) is used ($X_{ij} = 1$), it guarantees the lower bound of delivery load of node *i* is equal or greater than the delivery load of next node j (d_j). And if arc (i, j) is not used ($X_{ij} = 0$), this equation is no longer active. Further, as for the delivery node, constraint (10) indicates the inflow of delivery node minus the outflow of that node is the same as the delivery amount at that node, which guarantees the balance of inflow and outflow of delivery load of each node.

Constraint (11) assures the capacity should not be violated considering the total amount of the pickup load and delivery load on the vehicle.

Constraint (12) imposes the binary restriction on the variable X_{ij}.

Lastly, constraint (13) restricts variables u_{ij} and v_{ij} as non-negative.

5.1.2 LP model for VRPPDSTW (Model 2)

As for the VRPPDTW, the following mathematical formulation is presented based on the paper proposed by Mingyong and Erbao (2010), who focused on solving the vehicle routing problem with simultaneous pickup and delivery problem with time windows (VRPPDSTW).

In VRPPDSTW problems, *G* = (*N*, *A*) denotes the directed graph in this model, where *N* represents a set of customers scattered on the transport network and *A* is the set of arcs showing all the possible connections between depot and nodes and between nodes to nodes. All arcs (i, j) are used in the denotation of the travel time t_{ij}. Each customer has the delivery operation of certain goods (*di*) and the pick-up operation of returning materials (*Pi*) to the depot at each node, and both of opertions need to be conducted once. Further, a fleet of identical vehicles with certain capacities (Q) is used to serve the customers. The amount of goods that each vehicle carries when leaves the depot is equal to the total amount it must deliver to the served customers, and the amount of recycle materials that each vehicle returns to the depot is equal to the total amount it pickup from the served customers. Besides, each customer has a special time windows, which means each vehicle should visit customers within the time windows [a_i, b_i]. The lower bound a_i means the earliest time window of customer, and the upper bound b_i means the latest time window of customer. The acceptable duration of the node traversed by a vehicle is denoted as $T = [a_i, b_i]$, representing the time window of each customer, where a_i is the earliest service time and b_i is the latest service time of each customer i. If the vehicle visits customer $i \in N$, it should do jobs within the time window $[a_i, b_i]$ when the service time t_i starts, which represents the time takes for the vehicle to load and unload cargos. Therefore, the total route time of the vehicle is equal to the summation of travel time, waiting time and service time. Additionally, it is worth mentioning that the vehicle k is allowed to arrive and wait before the earliest time a_i of customer $i \in N$, and the waiting time is not penalized. However, it is prohibited to start service after the latest time b_i. What's more, each valid pickup and delivery route represents a feasible solution starting from the depot and ending at the depot, in which customers are visited at most one time. Moreover, the total load of the vehicle is not allowed to exceed the capacity of the vehicle. The aim of this mathematical model is to minimize the total travelling time of the tours visited by the vehicles.

The notation for VRPPDTW model
N – set of nodes including depot
N_1 – set of nodes except depot
A – set of arcs
V – set of vehicles

Variables:
X_{ijk} – binary variable, if the value is 1, it means the arc (i, j) is traversed by vehicle k; if the value is 0, otherwise. $i \neq j$
Z_{ij} - the amount of delivery to customers after node i and transported in the arc (i, j), $\forall (i, j) \in A$

Y_{ij} - the pickup amount from customers up to customer i and transported in the arc (i, j), $\forall(i,j) \in A$

W_{ik} - arrival time of vehicle k at node i, $\forall i \in N, k \in V$

Parameters:

E – start of the time horizon

L – end of the time horizon

a_i – start of the time window at node i. $\forall i \in N$

b_i – end of the time window at node i. $\forall i \in N$

s_i – service time at node i. $\forall i \in N$

t_{ij} – travel time between node i and node j. $\forall(i,j) \in A$

d_i – delivery amount at node i. $\forall i \in N$

p_i – pickup amount at node i. $\forall i \in N$

C – capacity of vehicle

M – a big number to help control time variable. $\forall i \in C, j \in C$

k - the maximum number of needed vehicle

The model of VRPPDTW

(1) Minimize $\sum_{k\in V}\sum_{i\in N}\sum_{j\in N} t_{ij} * X_{ijk}$

(2) Subject to $\sum_{k\in V}\sum_{i\in N} X_{ijk} = 1,\ \forall j \in N_1$

(3) $\sum_{i\in N} X_{ijk} = \sum_{i\in N} X_{j,i,k},\ \forall j \in N, k \in V$

(4) $\sum_{j\in N_1} X_{0jk} \leq 1,\ \forall k \in V$

(5) $\sum_{i\in N} Y_{ji} - \sum_{i\in N} Y_{ij} = p_j,\ \forall j \in N_1$

(6) $\sum_{i\in N} Z_{ij} - \sum_{i\in N} Z_{ji} = d_j,\ \forall j \in N_1$

(7) $Y_{ij} + Z_{ij} \leq C * \sum_{k\in V} X_{ijk}, \forall i \in N, j \in N$

(8) $W_{ik} + s_i + t_{ij} - W_{jk} \leq M * (1 - X_{ijk}), \forall i \in N, j \in N, k \in V$

(9) $a_i * \sum_{i\in N}\sum_{j\in N} X_{ijk} \leq W_{ik} \leq b_i * \sum_{i\in N}\sum_{j\in N} X_{ijk}, \forall k \in V$

(10) $E \leq W_{i,k} \leq L, \forall k \in V$

(11) $W_{0k} = E,\ \forall k \in V$

(12) $X_{ijk}\ binary, \forall k \in V, (i,j) \in A$

(13) $X_{ijk}, Y_{ij}, Z_{ij} \geq 0, \forall k \in V, (i,j) \in A$

The objective function (1) expresses the minimization of the total cost, which is measured in terms of the total travelling time traversed by the fleet consisting of all vehicles. Given that $N = \{0, \dots, n\}$, where n represents the number of customers, and $\{0\}$ represents the depot used as the starting node and ending node of each vehicle.

Constraint (2) restricts that each customer should be visited one and exactly one time by vehicle k.

Constraint (3) means the corresponding served customers should be visited by the same vehicle. To be specific, if one particular vehicle visits one node, then this vehicle must leave from this node to guarantee the flow balance.

Constraint (4) defines that at most vehicles are used to serve all the customers.

Constraint (5) - (6) guarantees the flow equation for delivery and pickup demands of the customers separately.

Constraint (7) ensures that the total load of the vehicle is not allowed to exceed the capacity of the vehicle.

In constraint (8), *M* is an arbitrarily large number. If the vehicle *k* is selected to traverse from arc (*i*,*j*), $X_{ijk} = 1$, the equation means the arrival time of vehicle k at node j shall be equal or greater than the arrival time of vehicle k at node i, plus the service time at node i, plus the travelling time from node i to node j, which is always established under the assumption. On the other hand, if the vehicle *k* is not going to travel from arc (*i*,*j*), $X_{ijk} = 0$. In this equation, the right-hand side value will be a large number, which means the inequality is no longer active.

Constraint (9) indicates all the vehicles k should arrive the given time windows of pickup and delivery nodes, which allow the vehicle to arrive and wait before the given time and the waiting time is not penalized.

Constraint (10) indicates all the vehicles k should do the delivery and pickup operations within the time horizon.

Nevertheless, constraint (11) shows that the starting time of each vehicle from the depot should be equal to the beginning of time horizon.

Constraint (12) imposes binary restriction on variable X_{ijk}.

Finally, non-negativity restrictions are imposed on variable X_{ijk}, Y_{ij}, Z_{ij} by constraint (13).

5.2 The optimization approach

For one thing, the exact model proposed above will be programmed in CPLEX. For another, the distance matrix or time matrix between various locations (including the depot) is obtained by inputting the locations into Google map manually. Further, the distance matrix or time matrix with other relevant data are input into the optimization software CPLEX to complement the *.dat file. Finally, the optimal solution of routes will be generated in the *.sol file by executing *.run file of the CPLEX in accordance with the criteria of Time Window.

5.3 Some heuristic algorithms

Many of TSP heuristics could be adapted to VRP situation, in which several vehicles start from the beginning node (depot) and end at the depot as well with respect to the vehicle capacity. Laporte (1992) claims that heuristic algorithms of VRP could be derived from the algorithms of TSP. The algorithms of TSP, such as: nearest neighbour algorithm, insertion algorithm and tour improvement algorithm, all of them could be used on the VRP with slight modifications. The main difference between TSP and VRP is: in the TSP algorithms, many of them could choose the starting node freely. However, this criterion will be different in the VRP situation. The starting node is set as the depot, therefore, the number of feasible solutions obtained from the algorithm will be reduced.

In this section, we will take a brief introduction on four classic algorithms for VRP.

5.3.1 The Clark and Wright algorithm

Clark and Wright proposed this algorithm in 1964, the heuristic is one of earliest algorithm designed to solve the routing problem and originally designs for several vehicles. This algorithm in the TSP case is the exact same as in the VRP except that the saving value in the VRP has to be obtained from the corresponding given depot node.

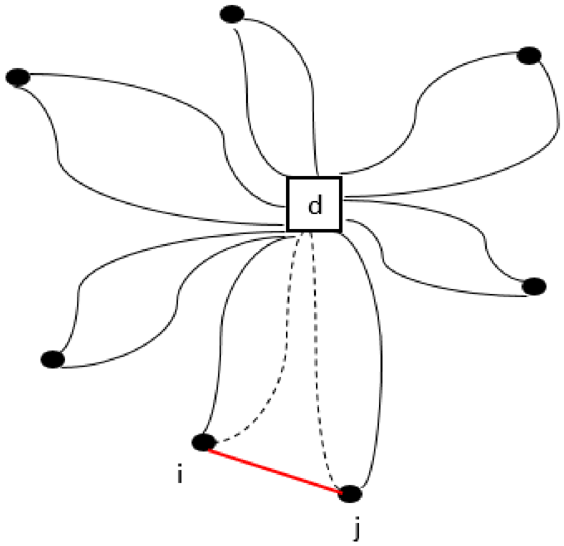

Figure 6: The Clark and Wright algorithm

Step 1: define the depot node as d, then calculate the saving values for all pairs of nodes except depot by the equation $S_{ij} = c_{dj} + c_{id} - c_{ij}$, and make the saving matrix.

Step 2: sort the saving values in a decreasing order.

Step 3: if the S_{ij} >=0, connect two nodes with the greatest saving value from the decreasing order at step 2. Keep doing this by selecting the saving value as big as possible from the decreasing order. However, it should be noticed that sub cycle should be avoided, or the degree of nodes exceeds 2 should be avoided as well. Repeat the above procedure until all the nodes (except depot) have been attached to the path. Then add the depot node *d* with degree 1 at the beginning and end of the path.

Cordeau et al. (2002) claims that this algorithm gets high scores on simplicity and speed and has a medium performance on accuracy. Besides, it is easy to code due to no parameters composed in this algorithm. However, the worst feature of this algorithm is the lack of flexibility. Researchers, such as: Gaskell (1967), Yellow (1970) and Paessens (1988) have proposed several variants of this algorithm.

5.3.2 Sweep algorithm

The sweep algorithm source from the work for the CVRP, which proposed by Wren and Carr (1971) and Wren and Holliday (1972). Gillett and Miller (1974) gave the name to this algorithm and made a great contribution to this method.

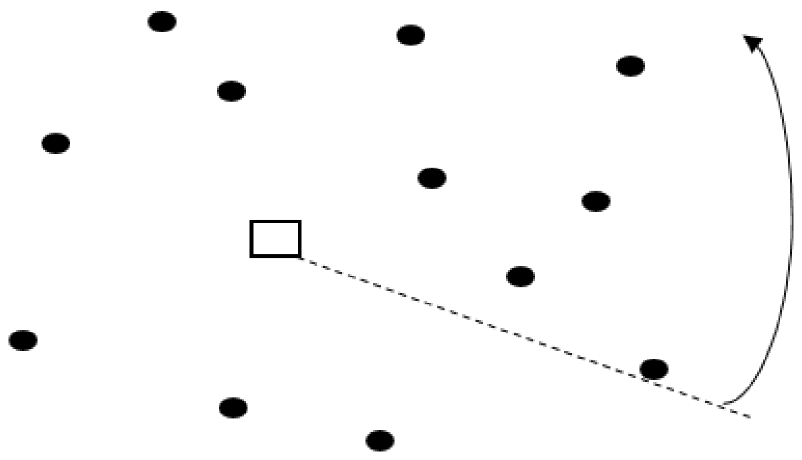

Figure 7: Sweep algorithm

Step 1: the depot is set as the starting node. Place an arrow from the depot to the one of the customer nodes.

Step 2: do the clockwise or counter-clockwise movement and write down the sequence as the arrow sweeps over the nodes. Assign the new node to the vehicle as long as under the capacity of vehicle. Once the vehicle is fully loaded or the capacity of vehicle is violated, then the vehicle should return to the depot.

Step 3: restart the arrow from the last un-routed node out of the previous route, do the same direction movement. The procedure is repeated until all customer nodes are covered by the sweeping arrow.

Cordeau et al. (2002) reports that this algorithm has good performance with the simplicity, while sweep algorithm is inferior to the Clark and Wright algorithm on accuracy and speed.

Meanwhile, this method is inflexible as Clark and Wright algorithm. The author emphasize that this method is unsuitable to the city instances, in which the street layout set with a grid.

5.3.3 The Adaptive Memory Procedure

Rochat and Taillard (1995) developed the concept of adaptive memory procedure. It is one method of metaheuristic and Cordeau et al. (2002) claims it as one of the most creative ideas putting forward for the metaheuristic.

Step 1: define several solutions as S_1 S_2 S_3... S_K with score δ_1 δ_2 δ_3... δ_K. Initially $\delta_1 = \delta_2 = \delta_3 = \ldots = \delta_K = 1$.

Step 2: at every iteration, choose a solution i with probability =

$$P_j = \delta_i / \sum_{i=1}^{R} \delta_i$$

If the solution of route improves the current solution, then increase its score by 1 (for example).

If it improves the best-known solution, then increase its score by 2 (for example).

Step 3: when there is no improvement from all the solutions, then stop.

One of the advantages of this method is that it generates a pool of high quality solutions by using a heuristic, in which new candidates will be updated dynamically and low quality of candidates will be removed from the pool. This method is flexible since it could be merged with other heuristics and it can be adapted to other contexts easily. Nevertheless, it requires sophisticated algorithm to perform the idea. Otherwise, it may not work so well. Meanwhile, the computation time will be increased by applying the adaptive memory procedure. What's more, basic computer skills are needed when coding the adaptive memory procedure.

5.3.4 Fisher & Jaikumar heuristic for VRP

F & J heuristic performs the assignment part of VRP first: where customers assigned to which vehicles will be decided, when the capacity of vehicle and demands of customers are considered. Then, the routing problem will be solved sequentially, in which sequence of route should be decided when the relative customers are taken into consideration. A specific customer is chosen for each vehicle, it has to be visited by this vehicle, and is named as seed-node (i*). Besides, the number of seed-nodes is exactly same as the number of vehicles.

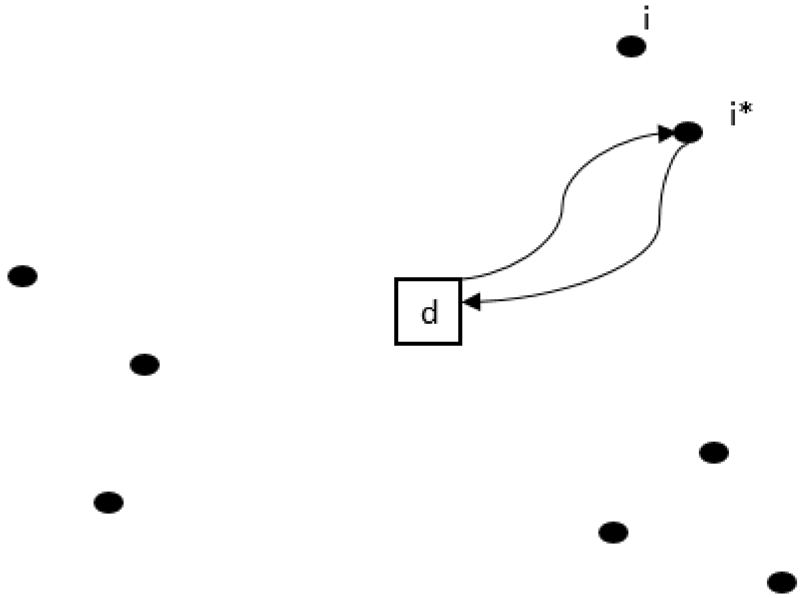

Figure 8: Fisher & Jaikumar heuristic

Step 1: define the decision variable as y_{ik}. If y_{ik} = 1, it means vehicle k is used to serve customer i; 0, otherwise.

Step 2: Calculate the added cost by the equation: $a_{ik} = c_{i*,i} + c_{d,i} - c_{d,i*}$ for each vehicle and all the customers.

Step 3: Construct the model to minimize the added costs, which is subject to the restrictions that each customer is visited exactly one time and the load of vehicle should be under the capacity.

The output of the model is each vehicle is assigned to the seed node and relative customers are assigned to the seed node as well under the capacity of vehicle. For each vehicle, then solve the TSP from the depot to the customers which have been assigned to this vehicle.

6 FINDINGS

This thesis gave us an opportunity to have an insight on how one of the best breweries in Ghana operates in terms of their logistics and their transportation (routing). Although the initial stages turned out to be a little challenging, the data required was obtained.

6.1 Routing

The initial understanding of the problem depicted that, there were 50 customers to be served at once, but this was not the case. And this was because, although GGBL could receive an average of 50 orders per day, many of these orders belonged to the same customers. And this was because, orders for the different brands of GGBL's products for a single customer did not come together as a single order. For example, an order for spirits to customer A and an order for beer from customer A could be made into two different orders. This reduced the number of customers we had to work with by 50%.

Also, we noted that the model for the time window could not solve to optimality customers more than 17 customers when using AMPL.

We start with applying "Sweep" to a set of 18 customers. The result is shown in figure 9 (page 43). The reference for this sweep algorithm can be found as appendix F (page 76) in the appendix.

We then solved the same problem to optimality using model 1 on AMPL. The result is shown in figure 10 (page 44).

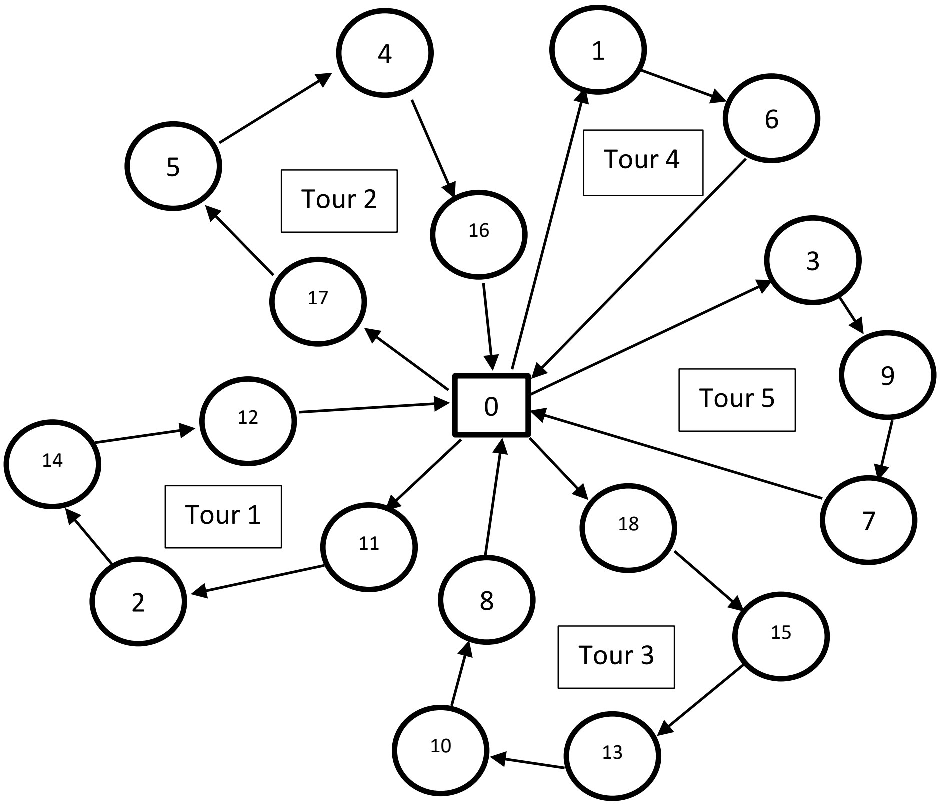

Figure 9: Sweep Algorithm for 18 customers

The results obtained from the heuristic indicated a total travel time of 442 minutes.

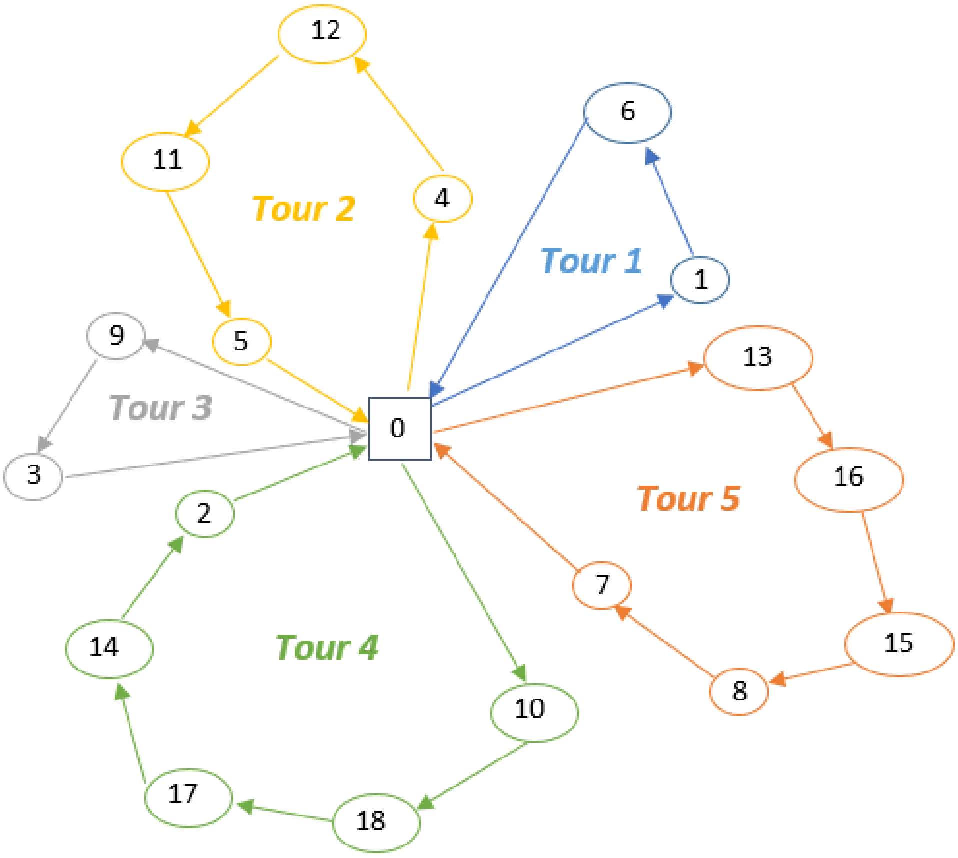

Figure 10: Optimal Solution from AMPL for 18 customers (without TW)

This result obtained from using model 1 and AMPL indicated a total travel time of 374 minutes. The computation time for this problem was approximately 2 minutes.

As can be seen, the optimal solution is 68 minutes better than the sweep solution, or to put it in another way:

Sweep is: $\frac{442-374}{374} * 100 = 18.18\%$ worse than the optimal solution.

The sweep algorithm was also used on 25 customers as seen in figure 11 (page 45) below, to make a comparison between the results, the combined solution obtained through AMPL on 17 key customers with time windows and the 8 remaining customers without time windows, and the routing done by GGBL on these customers. The reference for the sweep algorithm can be found as appendix G (page 77) in the appendix.

We again applied “Sweep” to a set of 25 customers. The result is shown in figure 11 (p 45).

We then solved the same problem using a combination of models 1 and 2 on AMPL. The result is shown in figure 12 (page 46).

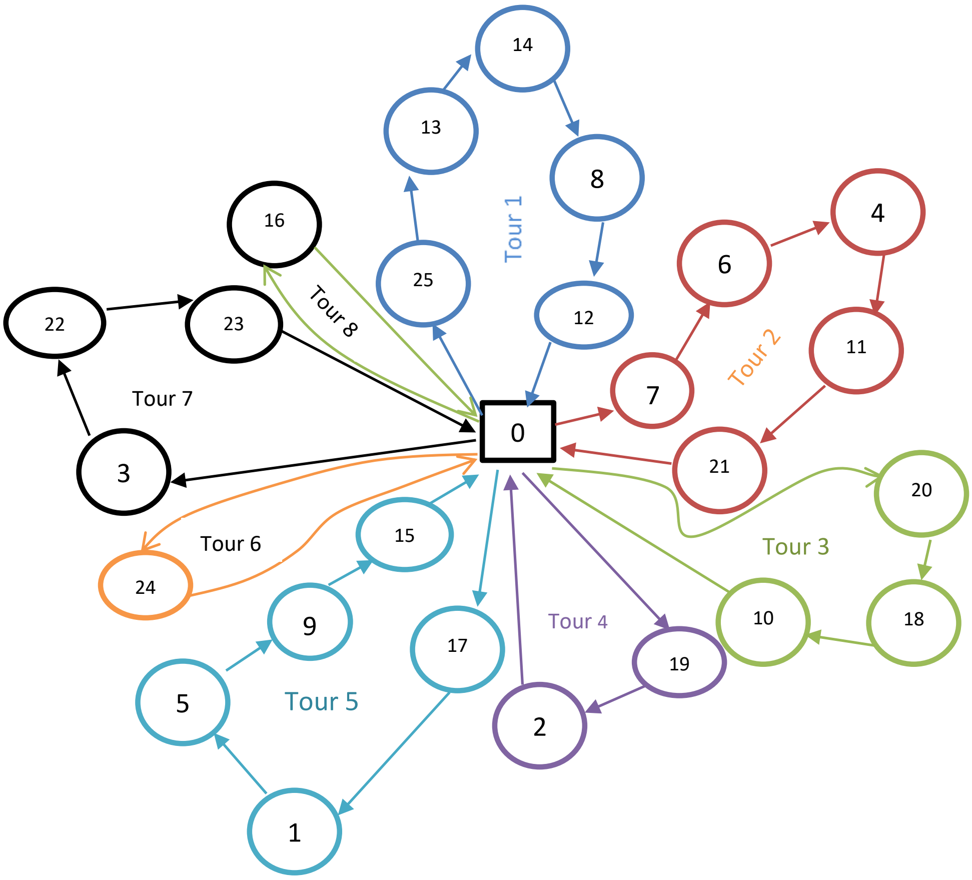

Figure 11: Sweep Algorithm for 25 customers

The results obtained from the sweep algorithm was 638 minutes of total travel time.

Figure 12 below shows the solution obtained using AMPL for the first set of key customers and the second set of customers not considered key customers and combining the two routes to make one solution. This gave us a travel time of 586 minutes. The improvement from sweep in figure 11 (page 45) will be 52 minutes or $\frac{638-586}{586} * 100 = 8.87\%$ worse than the solution obtained from AMPL.

The computation time for the first 17 key customers was 91 minutes and that 8 remaining customers were 2 seconds.

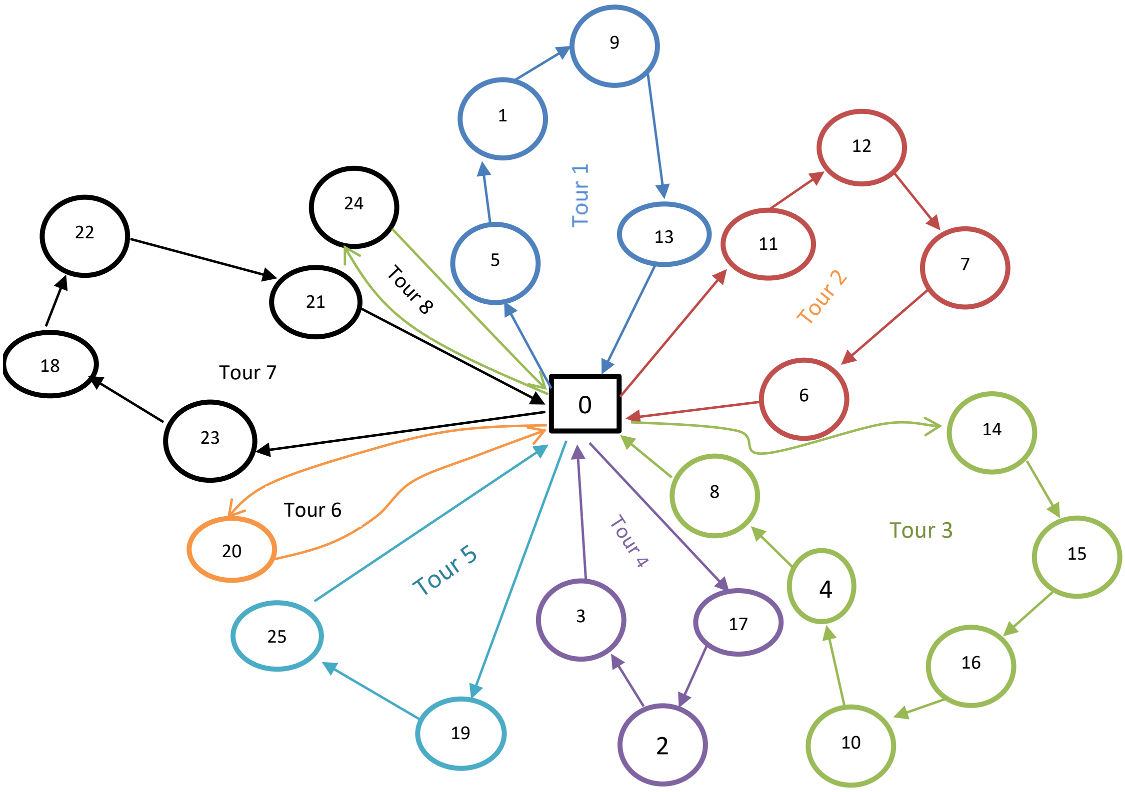

Figure 12: Solution from AMPL for 25 customers (with TW)

The solution shown by figure 13 (page 47) below is the current manual routing done by GGBL. Their approach to routing gave a total time used of 621 minutes. Comparing this manual solution with our best solution, one can see that the improvement in travelling time is 35 minutes, that is $\frac{35}{586} * 100 = 5.97\%$ worse than our solution.

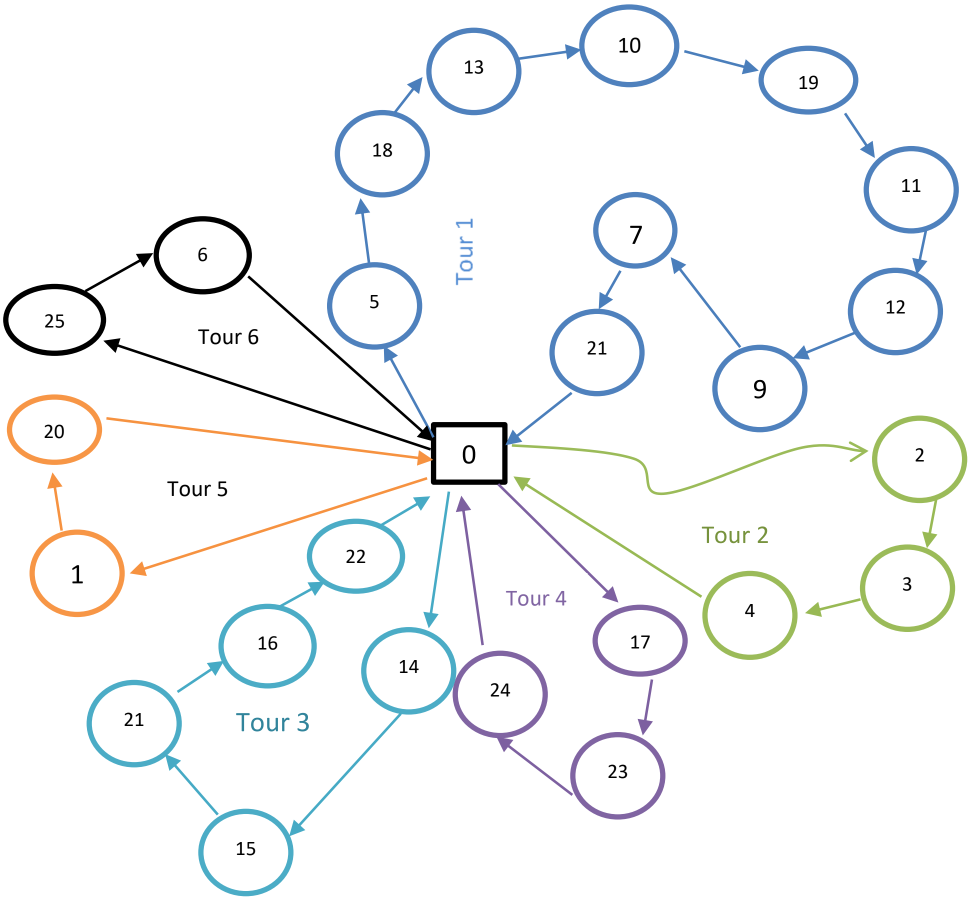

Figure 13: Current Manual Routing done by GGBL for 25 customers

6.2 Cost

In terms of cost to GGBL, the ARTC department operates for 6 days in the week starting from Monday and ending on Saturday and works on holidays too. The company's cost per day as shown in appendix H (page 78) was 5747.11 Ghana cedis (GHS). This equates to GHS 1821833.87 in annual cost to GGBL. The annual cost was calculated based on 316 days in a year since the only days the ARTC department does not work is Sundays, and they work on holidays.

On the other hand, our solution eliminated the use of these 3PL vehicles and improved the use of the company fleet by making them make two trips daily. This gave a daily cost of GHS 2829.73 as shown in appendix I (page 79). This equates to an annual cost of GHS 897024.41 which is 50.77% better than GGBL's current cost.

7 DISCUSSIONS

7.1 Routing

The first data we received from the company was used as a platform to test our model and compare it to the sweep algorithm to ascertain which is better. This is the product of the 18 customer tests done in figure 9 (page 43) and 10 (page 44). And since the first data did not include time windows, we were able to use the VRPPD (model 1, page 31) to test this.

The AMPL solution gave us a result of 374 minutes which provided us with a lower bound to the problem. A lower bound meant that we could not obtain a solution lower than that result, hence, the sweep algorithm could not provide anything lower than that. The sweep algorithm then gave a result of 442 minutes, which meant that the optimal solution was 68 minutes better than the sweep algorithm.

The next set of data received from the company involved 25 customers, with 4 of the customers having time windows and this time they provided as with the service time per customer. All customers had different service times due to their locations. Some customers are located in areas like shopping malls which has a lot of shops and requires trucks to wait their turn to get access to their customers and others have locations that are easy to access. But since the service time was the same across all results, we saw the need to concentrate on the travel time to identify improvements. We then used the model 2 (page 33) to compute this data but could not receive a result due to the number of customers being handled by the model at a time. After a few trials with different number of customers, we discovered that AMPL could not provide an optimal solution for more than 17 customers. Hence, we had to rely on a different approach to obtain our answer. As 15 of the customers were considered key account customers, we decided to compute an optimal solution with those key customers and complete the solution by adding the remaining customers. We also notice that 2 of the non-key customers had time windows as such we included them in our computation for the key customers to ensure that those time windows are adhered to. Hence, a total of 17 key customers were used in our computation. The next step was then to use model 1 (page 31) to compute the 8 remaining customers and combine the results to obtain a complete result. This gave us a travel time of 583 minutes.

The sweep algorithm was then used on the same number of customers to compare the results and the algorithm gave us a total travel time of 638 minutes. This result meant the results that sweep was 8.87% worse than the results obtained from combining the two solutions from AMPL.

We then compared them to the current routing of GGBL, which had a travel time of 621 minutes for the same 25 customers. This meant that the current routing of GGBL was 5.97% worse than our method which is a product of the AMPL solutions combined, and $\frac{17}{621} * 100 = 2.74\%$ better than the sweep algorithm which was 17 minutes higher than GGBL's travel time.

7.2 Cost

GGBL categorises its ARTC cost in the following categories: Warehouse cost, People cost, Transport cost, Miscellaneous and Security. This is shown in appendix H (page 78) and appendix I (page 79). In each of these categories there are cost components that increases the overall cost of the company. Our result from the combined AMPL solutions gives a total cost savings of 50.77% of the current GGBL routing.

7.2.1 Warehouse Cost

The components of the warehouse cost that GGBL is concerned with are the stock handling and forklift costs, which was not improved because the same amount of stock was going to be handled by the depot between our results and GGBL's current routing.

7.2.2 People Cost

The cost of the staff being used for the operations is between the handlers of stock and phone credits being used to call handlers and drivers. This cost would be increased in our results since one of the drivers might have to work a bit extra. This will cause the cause the workers rate to go up by 12%.

7.2.3 Transport Cost

The transport cost had a lot of components but the two we focused on were the fuel and 3PL vehicles. The fuel cost of our routing was increase by 23.64% in comparison to that of GGBLs, but this is because the vehicles will be used for two trips instead of one trip as seen in the GGBL routing. And the cost is now double that of the old routing because the overall distance being travelled by the vehicles has been reduced by 51.57%.

The 3PL vehicles cost was then reduced by 100% because GGBL will using their own fleet now.

7.2.4 Miscellaneous Cost

This cost is based various repair works, maintenance of vehicles and depot items being used in the operations. Minor attention was drawn to this, but we anticipated an increase in this cost by 100% due to the extent to which the GGBL vehicles are going to be used.

The route plan for the current routing of the company can be seen in appendix J (page 80) whereas our proposed route plan can be found in appendix K (page 81).

8 CONCLUSIONS

In concluding, this thesis gave us a look at how many factors had to be taken into consideration when computing a real-world situation of the VRP and how decisions from the company can affect the effectiveness of the study. A lot of challenges were faced and any milestone we achieved was well celebrated because it was difficult to achieve them.

8.1 Research summary

The purpose of our thesis was about analysing how much improvement in terms of cost could be made with the application of VRP in the distribution operations of a brewery. The case study was a company in Ghana called GGBL and the department to be observed was the ARTC department which was involved in the routing and serving of retailers in Accra, the capital town of Ghana.

The thesis was about comparing the results of the current routing of the company with two other result, which were the results we would get from the mathematical model and a heuristic of our choosing. The heuristic we used is the sweep algorithm. Data was then gathered, and the same data was used on all three methods to be able to have a more objective look at the results. A comparison of the cost structure of the current routing of the company was also done with that of the results obtained from the best of the other two methods.

The results obtained from the three methods implied that the best of the three was the mathematical model, followed by the sweep algorithm and lastly the current routing of the company. The mathematical model was able to minimize the company’s total travel time by 5.97% whereas the sweep algorithm increased travelling time by 2.74%.

The cost of the routing was then compared between the current routing of the company and that of the results from the mathematical model. And we realised a cost saving of 50% if the result is implemented.

The research analyses a department in the company which has the potential to become an example to the other departments of the company. This is because the cost reduction observed by this thesis can be made in other departments of the company to help minimize the organisations total cost. And if the company would explore this suggestion, it would realize a lot of improvement.

8.2 Managerial implications

The implementation of our results would bring an improvement to the operations of GGBL. Their manual routing system is doing a good job for them now but compared to our scientific approach to their operations, they fall short on cost minimization. The management of GGBL may be able to reduce their cost by at least 50%.

GGBL’s vehicle travel time would also be reduced by 5.97% if they adopt our approach. They will also not need to employ the services of third party logistics company for their transport operations.

8.3 Limitations of the study

The limitations we faced in this thesis ranged from minor to major ones, and this was to be expected since it was a case study. Some of the major limitations are as follows;

1. Late Data Receipt: The data being used for the study was received only three (3) weeks towards the deadline of the submission of the final work. This meant all computation had to be done and interpreted within a short period of time.

2. Restriction on Data: The company placed high level restriction on which data we could have access to and how much data they would let us have.

3. Approval Period for data sharing: It took at least a month to gain access to each requested data. This was due to the long approval process the company had to go through to provide us with the data. This meant all data we had access to was requested at least a month in advance. Making it difficult to work very fast and smoothly.

Some of the minor limitations we faced were the following:

1. Cost: Cost of travelling and expenses spent in going to Ghana was not cheap. And this was a little straining on a student's budget.

2. Available time: This was mainly due to the delay of data to be received from the company. And this made it difficult to explore all aspects of the thesis like we wanted.

8.4 Suggestions for the future work

We recommend further studies in the other parts of the company's operations, most especially the operations of the logistics department in terms of transportation. Further studies can be done on the Key Distributors to know how their routing is done to serve their retailers. This will help reduce cost through the supply chain as a whole.

Also, there is an opportunity to use metaheuristics to enhance the results further. This is possible due to the ever-expanding applications of metaheuristics in the VRP.

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10 APPENDIX

Appendix A: Distance Matrix

		DISTANCE (Km)																									
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
0		-	11.6	12.8	12.8	15.3	9.6	10.3	9.6	11.7	11.7	13.3	9.9	11	5.2	12.4	12.6	12.8	1.7	10.8	10.1	11.8	13.1	15.8	1.7	13.4	11.2
1	**ALISA HOTEL**	11.2	-	1.8	2.9	4.3	2.3	4.5	4.7	5.8	1.9	4.1	10.7	8.7	9.4	2.4	2.6	2.7	12.3	1.2	6.5	6	3.1	5.7	12	3.4	10
2	**Honeysuke Pub & Restaurant**	11.8	3.7	-	3.9	2.5	3.3	3.7	6.3	5	1.9	2.6	9	7.3	10.2	0.55	0.75	0.9	13.4	4.2	5.1	7.1	1.3	3.9	13.4	1.5	8.6
3	**KHI GH (Movenpick)**	10.5	3.2	4.2	-	6.7	4.1	6.2	7.2	8.1	3.9	7.5	11	9.3	8.7	4.3	4.8	5	11.4	2.4	7.1	4.7	5.3	6.2	11.3	4.3	10.6
4	**M. HOSPITALITY LIMITED**	13.4	5.8	2.9	6	-	5.4	5.1	7	5.6	3.9	0.6	9.1	7.5	11	2.7	2.6	2	13.6	6.3	5.3	9.1	3.1	2.5	13.6	3.1	9.8
5	**PALOMA HOTEL LIMITED**	8.8	1.5	2.7	4.5	5.2	-	4.7	5.6	6.6	2.7	5.1	11.5	7.1	6.4	3.4	3.6	3.8	9.1	0.95	4.9	4.1	4.1	6.8	9	4.4	9.4
6	**Plus 233 JAZZ BAR AND GRILL (Travi**	9.6	5.3	3.4	5.2	4.6	4.6	-	3.2	3.2	2.3	3.8	6.1	4.5	7.9	4	4.2	4.4	10.6	5.4	2.2	8.3	4.7	8.6	10.5	5	5.7
7	**SHAKAZULU LTD (SHAKAZULU WINE**	7.8	4.7	5.3	6.9	6.5	5.1	2.7	-	3	4.1	5.7	3.7	2.4	6.1	5.9	6.6	6.8	8.7	5.3	1	8.8	7.2	10.5	8.7	7.1	6.1
8	**Yasmina Restaurant**	11.4	6	4.5	6.9	5.1	7	2.6	3	-	3.9	4.3	4.1	2.4	9.8	5.1	4.7	4.9	12.8	6.6	2.6	10.7	5.2	9.2	12.4	6.1	3.2
9	**Afrikiko Leisure Centre**	10.5	2.4	1.2	3	3.5	2.3	2.4	4.1	4	-	3.7	7.5	5.4	8.8	1.8	2	2.1	11.5	3.3	3.2	6.1	2.5	5.2	11.4	2.8	6.8
10	**ROBI COLORS ENTERPRISE**	12.4	5.4	2.6	5.6	0.6	5	3.8	5.7	4.3	3.6	-	8.9	7.2	10.7	2.6	2.5	2.7	13.3	5.9	5	8.7	3	3.1	13.3	3	7.6
11	**Airport west Hospitality (African R**	10.8	7	6.3	8.1	7.4	7.6	4	3.4	2	5.1	6.5	-	1.1	7.9	6.8	7	7.7	11.8	7.5	3.3	11.2	8.1	11.5	11.8	7.8	4.8
12	**NUSUBON VENTURES**	8.5	6.1	6.9	8.7	8.1	6.7	4.6	2.4	2.7	5.8	7.3	3.4	-	6.9	7.5	8.2	7.8	9.9	6.6	2.5	10.2	8.7	10.2	9.5	8.5	5.4
13	**Mckays Bar & Restaurant**	1.9	9.3	9.9	11.5	11.1	7.9	7.3	6.6	8.9	8.7	10.3	7.8	7.9	-	10.5	11.2	12.1	2.8	9.9	6.5	10.3	11.2	13.2	2.8	11.5	11.5
14	**Firefly Ltd**	12.1	4	1.2	3.2	2.4	3.6	4.1	6.6	5.8	2.6	2.5	9.8	7.2	11.4	-	0.45	0.8	14.4	4.5	5.7	7.4	0.75	3.8	14	0.8	11.2
15	**El-Lizzy Ent (Lizzy Spot)**	12	3.9	1.1	4.1	2.3	3.5	3.9	6.5	5.7	2	2.4	9	7.8	11.2	0.45	-	0.65	14.3	4.4	5.6	7.2	0.5	3.7	13.8	0.85	8
16	**PURPLE PUB**	13.6	5.5	2.7	5.7	2.1	5.1	5.5	8.1	6.4	3.6	2.7	11.3	9.4	12.8	2.4	2.3	-	15.9	6	7.2	8.8	2	3	15.4	2.1	11.6
17	**MENGRACE ENT (KEIVINS AKAD)**	2.9	11.5	11.9	12.3	13.3	8.8	9.4	8.8	11	10.9	14.5	10.3	10.1	4.7	12.8	13	13.1	-	10	9	11.2	13.5	16.1	1.3	13.8	11.1
18	**Mum's Corner Enterprise**	9.7	1.4	2.6	4.4	4.8	2.1	5.1	5.3	6.3	2.4	4.8	8.7	6.6	8	3.1	3.3	3.5	10.7	-	4.4	5.9	3.8	6.5	10.6	4.1	9.1
19	**Tang Palace Hotel**	7.8	3.8	4.4	6	5.6	4.2	1.7	1	2.5	3.2	4.8	4.3	2.5	6.1	5	5.7	5.9	8.7	4.3	-	7.9	6.2	7.7	8.7	6	5.3
20	**Yoo Mart Limited - Graphic Road De**	10	4.8	6	2.9	8.2	4.7	7.7	8.7	9.3	5.8	8.2	12.3	10.2	8.3	6.5	6.7	6.9	11.5	4	8	-	7.2	9.9	10.9	7.5	17
21	**Justitet Enterprise**	12.5	4.4	1.6	4.6	2.8	4	4.4	7	5.8	2.6	2.9	10.2	8.3	11.7	0.8	0.5	1.2	14.8	4.9	6.1	7.7	-	3.1	14.3	0.7	11.6
22	**Ladystaff Ventures**	14.6	6.5	3.7	6.7	3.2	6.1	6.6	9.1	9.9	4.7	3.8	12.3	10.4	13.9	3.5	3.3	2.7	16.9	7.1	8.2	9.9	3.2	-	16.5	3.3	12.6
23	**SHOPRITE ACHIMOTA**	2.5	13.6	14	14.1	15.4	10.9	11.5	10.9	13.6	13	16.3	12.4	12.2	6.5	14.6	14.8	14.9	3	12.1	10.8	13	15.3	18	-	15.6	13
24	**SHOPRITE GHANA (PTY) LIMITED**	13.1	4.2	1.6	3.6	2.8	4	5.4	7	5.3	2.5	2.9	10.4	8.3	11.9	0.8	1.2	1.2	14.8	4.9	6.1	7.7	0.7	3.7	14.3	-	11.6
25	**GAME DISCOUNT WORLD (GHANA)**	10.3	9.2	8.5	10.3	9.2	14.4	6.2	5.4	4.8	8	8.4	2.3	3.4	7.9	8.9	8.8	8.9	11	10.6	6	14.8	9.3	11.3	10.5	9.3	-

Appendix B: Travelling time matrix

		TIME (mins)(without Service Time)																									
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
0		-	30	29	33	35	27	28	26	33	35	41	27	28	19	36	37	36	10	34	31	32	39	43	8	40	31
1	**ALISA HOTEL**	24	-	6	8	11	8	9	11	13	7	12	30	25	35	8	10	14	47	6	19	15	7	13	48	12	31
2	**Honeysuke Pub & Restaurant**	26	9	-	8	5	6	10	13	10	5	6	16	15	24	2	2	2	31	9	10	11	4	7	29	6	15
3	**KHI GH (Movenpick)**	23	8	9	-	14	12	14	16	15	8	14	19	17	20	11	10	9	29	7	13	11	12	14	28	13	18
4	**M. HOSPITALITY LIMITED**	27	12	6	11	-	9	12	15	10	9	2	18	15	24	6	5	4	31	12	11	14	8	7	29	9	14
5	**PALOMA HOTEL LIMITED**	21	6	5	9	11	-	11	13	13	11	17	25	20	16	12	13	12	25	5	15	8	15	18	24	16	24
6	**Plus 233 JAZZ BAR AND GRILL (Travi**	21	12	8	11	11	10	-	9	7	8	12	18	14	20	13	15	14	29	15	8	23	17	18	26	18	15
7	**SHAKAZULU LTD (SHAKAZULU WINE**	17	11	13	15	16	12	8	-	9	14	17	10	8	14	21	22	20	23	15	5	25	24	24	21	24	16
8	**Yasmina Restaurant**	19	14	9	13	11	13	6	8	-	13	14	10	11	18	17	20	18	29	20	11	28	22	20	28	20	6
9	**Afrikiko Leisure Centre**	24	6	3	5	9	6	9	11	17	-	9	15	12	18	6	6	5	25	7	7	10	8	11	24	10	14
10	**ROBI COLORS ENTERPRISE**	28	13	7	11	2	12	11	16	17	9	-	17	16	21	7	7	6	30	12	11	15	9	9	29	10	15
11	**Airport west Hospitality (African R**	20	16	11	14	14	20	13	11	8	10	15	-	2	16	17	17	17	30	14	8	24	20	22	30	20	9
12	**NUSUBON VENTURES**	21	14	14	16	16	18	14	8	11	12	17	9	-	19	17	18	17	26	13	6	19	20	24	26	21	10
13	**Mckays Bar & Restaurant**	7	19	21	22	22	26	24	20	23	18	22	15	13	-	38	37	38	9	19	17	31	39	45	8	41	21
14	**Firefly Ltd**	44	12	4	8	7	15	14	19	22	7	7	29	18	23	-	4	4	34	11	20	20	5	10	32	5	20
15	**El-Lizzy Ent (Lizzy Spot)**	42	10	3	8	6	13	12	18	22	6	6	28	17	22	3	-	2	31	10	18	18	2	8	30	7	18
16	**PURPLE PUB**	45	10	4	10	4	15	14	19	26	7	6	34	18	24	6	5	-	34	14	20	20	6	6	34	8	18
17	**MENGRACE ENT (KEIVINS AKAD)**	11	27	25	26	29	33	34	28	33	25	30	23	21	18	40	42	41	-	23	24	35	41	45	5	44	28
18	**Mum's Corner Enterprise**	25	5	5	8	10	9	14	16	24	5	9	17	14	16	6	6	6	23	-	11	11	8	12	22	10	16
19	**Tang Palace Hotel**	17	9	11	13	13	12	9	4	13	8	13	12	7	13	15	16	15	25	10	-	17	18	20	26	19	15
20	**Yoo Mart Limited - Graphic Road De**	34	10	10	9	16	15	21	23	35	10	15	29	21	18	17	18	17	28	7	20	-	20	23	27	21	30
21	**Justitet Enterprise**	45	12	5	10	8	15	14	19	25	8	8	30	19	24	4	2	4	33	12	20	21	-	9	32	4	20
22	**Ladystaff Ventures**	46	13	7	12	6	17	16	21	26	9	8	32	20	29	8	7	5	37	22	21	22	9	-	35	11	22
23	**SHOPRITE ACHIMOTA**	13	30	26	28	29	37	38	29	33	27	31	29	21	22	43	44	42	7	13	31	38	46	47	-	46	30
24	**SHOPRITE GHANA (PTY) LIMITED**	46	13	8	10	10	18	17	25	31	9	10	32	21	26	5	5	7	39	20	21	23	4	10	39	-	25
25	**GAME DISCOUNT WORLD (GHANA)**	25	23	16	18	18	30	20	16	13	15	18	7	7	11	24	23	23	21	19	14	33	26	23	19	30	-

Appendix C: Ampl language for VRP with Pick-up & Delivery (With 18 Pick-Ups)

.mod file

```
param n>=0; #number of customer
set Edges:={i in 0..n, j in 0..n: i<>j}; #the set of edges for the nodes
param travel_time {Edges}; # the travel time from node i to node j
param demand {i in 1..n}; #the demand of each node i
param capacity; # the capacity of vehicle
param pickup {i in 1..n};# the amount need to be picked

var X{Edges} binary; #1 if the edge from node i to node j is going to be used; 0 otherwise
var Load_pickup {i in 0..n, j in 0..n: i<>j}>=0, <=capacity;  #pickup load of vehicle along the arc from node i to node j
var Load_delivery {i in 0..n, j in 0..n: i<>j}>=0, <=capacity; #delivery load of vehicle along the arc from node i to node j

minimize Total_travel_time: sum {(i,j) in Edges} travel_time[i,j]*X[i,j];
#the target is minimizing the total travel cost, as the edge between node i and j is used, then it will generate cost.

subject to start_end: sum {(0,j) in Edges}X[0,j]=sum {(i,0) in Edges}X[i,0];
#the amount of vehicles departuring from depot will be same as the number of vehicels coming back to depot

subject to requirement_customer{i in 1..n}: sum {(i,j) in Edges} X[i,j]=1;
#one node is only allowed to connect another node one and only one time

subject to route_continuity {i in 1..n}: sum{(i,j) in Edges} X[i,j] = sum{(j,i) in Edges}X[j,i];
#the inflow into the node i will be exactly same as the the outflow from the node i

subject to depot_pickup {j in 1..n}: Load_pickup[0,j]=0;
# the amount of pickup at the depot will be 0
```

```
subject to requirement_pickup {i in 1..n, j in 1..n: i<>j}:
Load_pickup[i,j]>=pickup[i]*X[i,j];
#if the arc between node i and node j is not used, no pickup along the arc; otherwise, the
pickup on the latter node j will be greater or equal to the former one (the load of pickup is
increasing along the route)

subject to balance_pickup {i in 1..n}: sum{(i,j) in Edges}Load_pickup[i,j]-sum{(j,i) in
Edges}Load_pickup[j,i]=pickup[i];
#the amount of pickup at the node i is exactly same as the outflow of pickup from node i to
node j minus the inflow from the previous node j to node i

subject to depot_delivery {i in 1..n}:Load_delivery[i,0]=0;
#the amount of delivery at the depot will be 0

subject to requirement_delivery {i in 1..n, j in 1..n: i<>j}:
Load_delivery[i,j]>=demand[i]*X[i,j];
# 1 if the amount of delivery carried by the vehicle will no less than the demand of node i;
otherwise, no delivery will exist on the arc between node i to node j

subject to balance_delivery {i in 1..n}: sum{(j,i) in Edges}Load_delivery[j,i]-sum{(i,j) in
Edges}Load_delivery[i,j]=demand[i];
#the amount of delivery at the node i is exactly same as the inflow of delivery from
previous node j to node i minus the outflow from node i to the latter node j



subject to Capacity {(i,j)in Edges}: Load_delivery[i,j] + Load_pickup[i,j] <= capacity *
X[i,j];
#the pickup and delivery should not exceed the capacity of vehicle
```

****.dat file***

```
param n =18;
```

```
param travel_time :     0       1       2       3       4       5       6       7       8       9
        10      11      12      13      14      15      16      17      18:=
          0     .       30      55      27      27      41      29      33      35      27
        28      42      47      26      48      33      31      46      33
          1     24      .       42      7       18      20      6       8       11      8       9
        21      25      11      30      14      12      28      13
          2     35      39      .       34      21      23      32      34      34      35
        29      23      27      29      35      27      24      31      26
          3     21      6       34      .       9       19      5       9       11      1
        11      19      23      13      25      14      14      21      12
          4     18      16      25      12      .       10      14      16      15      16      9
        10      13      8       18      7       5       14      6
          5     20      22      25      20      7       .       18      20      21      20
        13      4       7       13      15      12      9       11      11
          6     26      9       33      6       17      18      .       8       5       6
        10      19      19      13      19      11      12      16      10
          7     23      8       37      12      21      22      9       .       14      12
        14      22      25      16      27      16      16      24      15
          8     27      12      33      9       16      18      6       11      .       9
        12      19      18      15      17      11      15      14      10
          9     21      6       34      1       18      19      5       9       11      .
        11      20      23      13      25      14      13      22      13
         10     21      12      29      11      12      14      8       11      11      10      .
        14      18      9       20      9       9       16      7
         11     20      21      25      20      6       3       17      20      20      20
        14      .       8       13      17      12      9       14      11
         12     24      26      30      25      11      7       20      24      20      25
        19      8       .       19      16      14      14      12      13
         13     17      11      29      12      9       14      13      15      16      12      8
        14      18      .       20      10      5       17      9
         14     29      27      24      23      15      14      21      26      20      25
        21      18      16      21      .       15      18      4       14
         15     22      15      26      13      8       12      11      15      13      14      8
        11      14      10      15      .       7       11      2
```

```
       16   19     12     25     13     9      10     13     16     16     12     8
    11      14     5      18     7      .      14     6
       17   26     24     27     20     12     11     17     22     16     21
    16      14     12     16     4      11     13     .      10
       18   19     14     24     12     7      9      9      13     11     13     6
    9       12     8      13     1      5      9      .;


param demand:= 1 200 2 150 3 240   4 100   5 150   6 300   7 100   8 85    9 112   10 90
        11 120 12 120 13 80   14 95   15 70   16 160 17 90   18 50;
param pickup := 1 180 2 100 3 240   4 95    5 140   6 280   7 80    8 70    9 100   10 90
        11 90   12 100 13 64   14 85   15 60   16 155 17 80   18 50;



param capacity:=500;
```

***.run file**

```
option solver cplex;
model VRPPD(18pickups).mod;
data VRPPD(18pickups).dat;
solve;
option omit_zero_rows 1;
option omit_zero_cols ;
display Total_travel_time > VRPPD(18pickups).sol;
display X,Load_pickup,Load_delivery > VRPPD(18pickups).sol;
display _total_solve_elapsed_time > VRPPD(18pickups).sol;
```

***.sol file**

```
Total_travel_time = 374

:      X Load_pickup Load_delivery    :=
0  1    1       0          500
0  4    1       0          490
0  9    1       0          352
```

```
0  10   1       0         475
0  13   1       0         495
1  6    1     180          300
2  0    1     405            0
3  0    1     340            0
4  12   1      95          390
5  0    1     425            0
6  0    1     460            0
7  0    1     429            0
8  7    1     349          100
9  3    1     100          240
10 18   1      90          385
11 5    1     285          150
12 11   1     195          270
13 16   1      64          415
14 2    1     305          150
15 8    1     279          185
16 15   1     219          255
17 14   1     220          245
18 17   1     140          335
;

_total_solve_elapsed_time = 17.437
```

Appendix D: Ampl language for VRP with Pick-up & Delivery (With 25 Pick-Ups)

***.sol file**

```
Total_travel_time = 512

:       X Load_pickup Load_delivery    :=
0  6    1       0         485
0  13   1       0         490
```

```
0  16   1       0         480
0  20   1       0         481
0  22   1       0         487
0  23   1       0         495
0  24   1       0         490
1  0    1     416           0
2  0    1     430           0
3  19   1      85          372
4  11   1      252          126
5  1    1     236          200
6  8    1      90         395
7  0    1     332           0
8  25   1      140          345
9  2    1     150          300
10 5    1      136          312
11 12   1      258          120
12 7    1      268           80
13 14   1        6          482
14 10   1       36          432
15 0    1      428           0
16 0    1      400           0
17 15   1      373           60
18 17   1      335          100
19 18   1      235          197
20 21   1      150          261
21 4    1      182          211
22 3    1        5         472
23 9    1       85          365
24 0    1      355           0
25 0    1      445           0
;

_total_solve_elapsed_time = 141.829
```

Appendix E: Ampl language for VRP with simultaneous Pick-up & Delivery and time window (with 17 Key customers)

.mod file

```
param n >= 0; #number of sales point, where 0 is a depot
set ARCS := {i in 0..n+1, j in 0..n+1: i<>j}; #set of arcs

param t_time{ARCS} >= 0; #travel time between nodes
param c_distance{ARCS} >= 0; #travel distance between nodes
param d_delivery{i in 0..n+1} >= 0; #delivery demand at node i
param p_pickup {i in 0..n+1} >= 0; #pickup demand at node i
param C_capacity >= 0; #capacity of the vehicle
param s_service{ i in 0..n+1} >= 0; #service time at node i
param a{ i in 1..n }; #start of tw at node i
param b{ i in 1..n }; #end of tw at node i
param E; #start of time horizon
param L; #end of time horizon
param M; # a big number
param K; #total number of vehicles
param Length; #maximum distance constraint
set VECH := {i in 1..K}; #set of vehicles

var X{(i,j) in ARCS, VECH} binary; #1 if (i,j) is travelled by the vehicle l, if is zero, then otherwise
var W{0..n+1, VECH} integer >= 0, <=L; #time of beginning service at task at node i by vehicle k
var Z{ARCS} integer >= 0, <=C_capacity; #integer value representing the amount of delivery to customers after node i and transported in the arc (i, j)
var Y{ARCS} integer >= 0, <=C_capacity; #integer value representing the pickup amount from customers up to customer i and transported in the arc (i, j)

minimize Total_distance: sum{(i,j) in ARCS, k in VECH} c_distance[i,j]*X[i,j,k];

subject to Visit {j in 1..n}:sum{(i,j) in ARCS, k in VECH} X[i,j,k] = 1;#each point visited
```

```
subject to Same_vehicle {j in 1..n, k in VECH}: sum {(i,j) in ARCS} X[i,j,k]= sum {(j,i) in ARCS} X[j,i,k]; #the corresponding served customers should be visited by the same vehicle

subject to DepotOut {k in VECH}:sum{(0,j) in ARCS} X[0,j,k] <= 1;#out from depot is one or zero

subject to Continuity_pick {j in 1..n}:sum{ (j,i) in ARCS } Y[j,i] - sum{ (i,j) in ARCS } Y[i,j] = p_pickup[j];#flow equation for pickup demands of the customers

subject to Continuity_delivery {j in 1..n}:sum{ (i,j) in ARCS } Z[i,j] - sum{ (j,i) in ARCS } Z[j,i] = d_delivery[j];#flow equation for delivery demands of the customers

subject to Load_consistence {(i,j) in ARCS}: Y[i,j] + Z[i,j] <= C_capacity*sum{ k in VECH } X[i,j,k];# ensure the consistence of load

subject to Time_consistence {(i,j) in ARCS, k in VECH}:W[i,k] + s_service[i] + t_time[i,j] - W[j,k] <= M*(1 - X[i,j,k]);# ensure the consistence of time

subject to THStart {k in VECH}: W[0,k] = E; #start time

subject to TimeW_a {i in 1..n, k in VECH}: W[i,k] >= a[i]*sum{(i,j) in ARCS} X[i,j,k]; #arrival time should be within time window

subject to TimeW_b {i in 1..n, k in VECH}: W[i,k] <= b[i]*sum{(i,j) in ARCS} X[i,j,k]; #arrival time should be within time window

subject to TimeHor {i in {0,n+1}, k in VECH}:E <= W[i,k]<= L;#the duration of each vehicle should be within time horizon
```

****.dat file***

```
param n = 17;
```

```
param K = 8;

param t_time : 0      1      2      3      4      5      6      7      8      9
       10     11     12     13     14     15     16     17     18:=
    0  .      11.6   12.8   12.8   15.3   9.6    10.3   9.6    11.7   11.7   13.3
       9.9    11     5.2    12.4   12.6   12.8   1.7    0
    1  11.2   .      1.8    2.9    4.3    2.3    4.5    4.7    5.8    1.9    4.1
       10.7   8.7    9.4    2.4    2.6    2.7    12.3   11.2
    2  11.8   3.7    .      3.9    2.5    3.3    3.7    6.3    5      1.9    2.6    9
       7.3    10.2   0.55   0.75   0.9    13.4   11.8
    3  10.5   3.2    4.2    .      6.7    4.1    6.2    7.2    8.1    3.9    7.5
       11     9.3    8.7    4.3    4.8    5      11.4   10.5
    4  13.4   5.8    2.9    6      .      5.4    5.1    7      5.6    3.9    0.6
       9.1    7.5    11     2.7    2.6    2      13.6   13.4
    5  8.8    1.5    2.7    4.5    5.2    .      4.7    5.6    6.6    2.7    5.1
       11.5   7.1    6.4    3.4    3.6    3.8    9.1    8.8
    6  9.6    5.3    3.4    5.2    4.6    4.6    .      3.2    3.2    2.3    3.8
       6.1    4.5    7.9    4      4.2    4.4    10.6   9.6
    7  7.8    4.7    5.3    6.9    6.5    5.1    2.7    .      3      4.1    5.7
       3.7    2.4    6.1    5.9    6.6    6.8    8.7    7.8
    8  11.4   6      4.5    6.9    5.1    7      2.6    3      .      3.9    4.3
       4.1    2.4    9.8    5.1    4.7    4.9    12.8   11.4
    9  10.5   2.4    1.2    3      3.5    2.3    2.4    4.1    4      .      3.7
       7.5    5.4    8.8    1.8    2      2.1    11.5   10.5
    10        12.4   5.4    2.6    5.6    0.6    5      3.8    5.7    4.3    3.6    .
       8.9    7.2    10.7   2.6    2.5    2.7    13.3   12.4
    11        10.8   7      6.3    8.1    7.4    7.6    4      3.4    2      5.1
       6.5    .      1.1    7.9    6.8    7      7.7    11.8   10.8
    12        8.5    6.1    6.9    8.7    8.1    6.7    4.6    2.4    2.7    5.8
       7.3    3.4    .      6.9    7.5    8.2    7.8    9.9    8.5
    13        1.9    9.3    9.9    11.5   11.1   7.9    7.3    6.6    8.9    8.7
       10.3   7.8    7.9    .      10.5   11.2   12.1   2.8    1.9
    14        12.1   4      1.2    3.2    2.4    3.6    4.1    6.6    5.8    2.6
       2.5    9.8    7.2    11.4   .      0.45   0.8    14.4   12.1
```

```
 15      12    3.9   1.1   4.1   2.3   3.5   3.9   6.5   5.7   2
   2.4   9     7.8   11.2  0.45  .     0.65  14.3  12
 16      13.6  5.5   2.7   5.7   2.1   5.1   5.5   8.1   6.4   3.6
   2.7   11.3  9.4   12.8  2.4   2.3   .     15.9  13.6
 17      2.9   11.5  11.9  12.3  13.3  8.8   9.4   8.8   11    10.9
   14.5  10.3  10.1  4.7   12.8  13    13.1  .     2.9
 18      0     11.6  12.8  12.8  15.3  9.6   10.3  9.6   11.7  11.7
   13.3  9.9   11    5.2   12.4  12.6  12.8  1.7   .;

param c_distance:  0     1     2     3     4     5     6     7     8     9
   10    11    12    13    14    15    16    17    18:=
     0   .     30    29    33    35    27    28    26    33    35
   41    27    28    19    36    37    36    10    0
     1   24    .     6     8     11    8     9     11    13    7
   12    30    25    35    8     10    14    47    24
     2   26    9     .     8     5     6     10    13    10    5     6
   16    15    24    2     2     2     31    26
     3   23    8     9     .     14    12    14    16    15    8
   14    19    17    20    11    10    9     29    23
     4   27    12    6     11    .     9     12    15    10    9     2
   18    15    24    6     5     4     31    27
     5   21    6     5     9     11    .     11    13    13    11
   17    25    20    16    12    13    12    25    21
     6   21    12    8     11    11    10    .     9     7     8
   12    18    14    20    13    15    14    29    21
     7   17    11    13    15    16    12    8     .     9     14
   17    10    8     14    21    22    20    23    17
     8   19    14    9     13    11    13    6     8     .     13
   14    10    11    18    17    20    18    29    19
     9   24    6     3     5     9     6     9     11    17    .     9
   15    12    18    6     6     5     25    24
    10   28    13    7     11    2     12    11    16    17    9     .
   17    16    21    7     7     6     30    28
```

```
        11  20    16    11    14    14    20    13    11    8     10
      15    .     2     16    17    17    17    30    20
        12  21    14    14    16    16    18    14    8     11    12
      17    9     .     19    17    18    17    26    21
        13  7     19    21    22    22    26    24    20    23    18
      22    15    13    .     38    37    38    9     7
        14  44    12    4     8     7     15    14    19    22    7     7
      29    18    23    .     4     4     34    44
        15  42    10    3     8     6     13    12    18    22    6     6
      28    17    22    3     .     2     31    42
        16  45    10    4     10    4     15    14    19    26    7     6
      34    18    24    6     5     .     34    45
        17  11    27    25    26    29    33    34    28    33    25
      30    23    21    18    40    42    41    .     11
        18  0     30    29    33    35    27    28    26    33    35
      41    27    28    19    36    37    36    10    .;

param d_delivery:=0 0 1 200 2 300 3 100  4 85     5 112 6 90  7 80  8 50  9 120
      10 6  11 8  12 50 13 60 14 40 15 97 16 220 17 15 18 0;

param p_pickup := 0 0 1 180 2 280 3 80  4 70      5 100 6 90  7 64  8 50  9 100
      10 6  11 6  12 30 13 55 14 38 15 100  16 150 17 5 18 0;

param C_capacity :=500;

param s_service:= 0 0 1 150  2 60  3 60  4 60  5 30  6 30  7 25  8 30  9 10
      10 10 11 35 12 40 13 15 14 40 15 80 16 30 17 35 18 0;

param a:= 1 0  2 0   3 180 4 0   5 0   6 0   7 0   8 0   9 240 10 0  11 0
      12 0  13 0  14 0  15 60  16 0 17 0;

param b:= 1 420      2 420 3 300 4 420 5 420 6 420 7 420 8 420 9 300 10 420
      11 420 12 90  13 420 14 420 15 300 16 420 17 420;
```

```
param E:=0;
param L:=420;
param M:=9999;
```

****.run file***

```
option solver cplex;
model VRPPDTW(17key).mod;
data VRPPDTW(17key).dat;
solve;
option omit_zero_rows 1;
option omit_zero_cols ;
display X > VRPPDTW(17key).sol;
display W > VRPPDTW(17key).sol;
display Z,Y > VRPPDTW(17key).sol;
display Total_distance > VRPPDTW(17key).sol;
display _total_solve_elapsed_time > VRPPDTW(17key).sol;
exit;
```

*.sol file

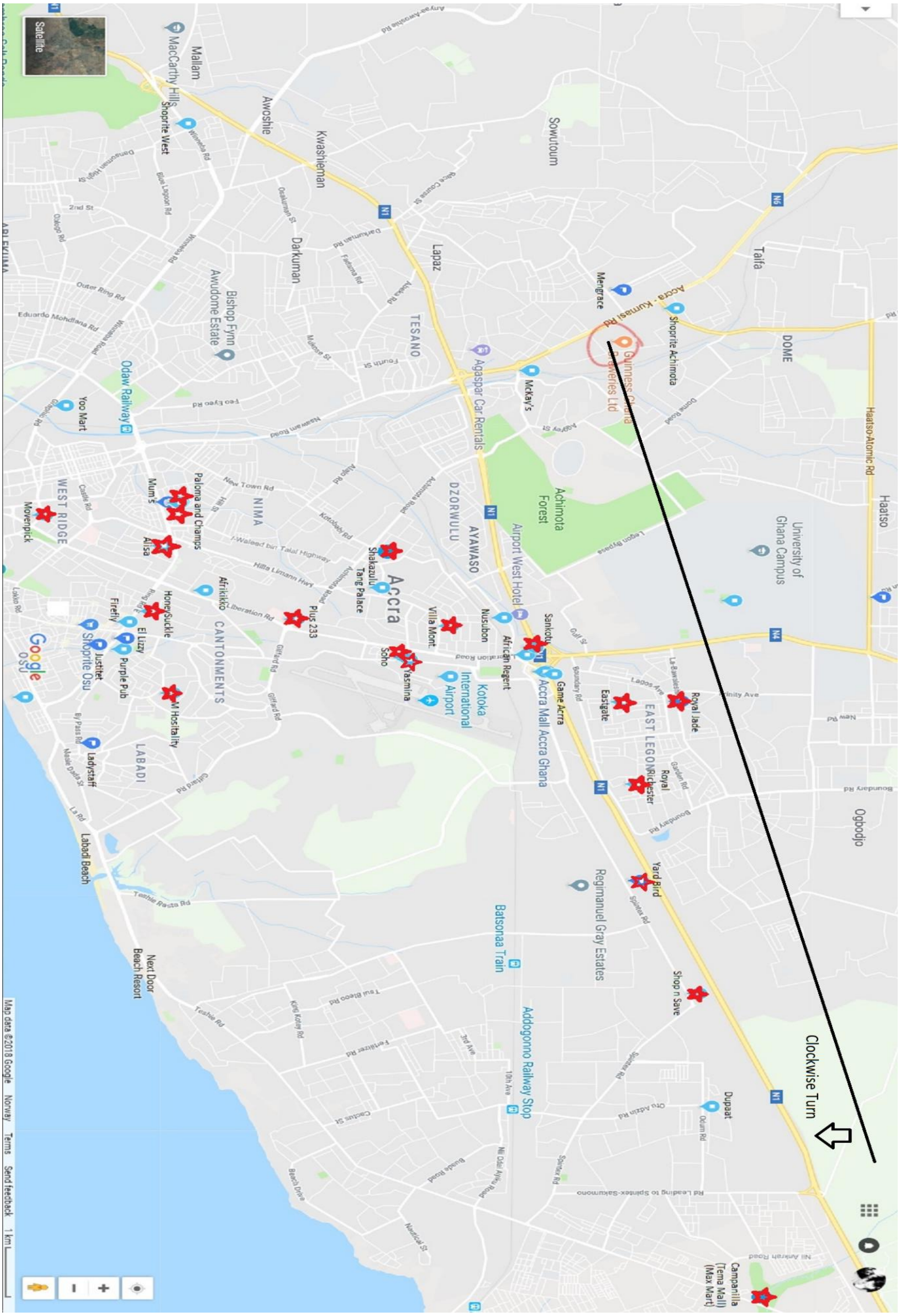
```
X [*,*,1]
:   0  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18 :=
0   .  0  0  0  0  1  0  0  0  0  0   0   0   0   0   0   0   0   0
1   0  .  0  0  0  0  0  0  0  1  0   0   0   0   0   0   0   0   0
5   0  1  0  0  0  .  0  0  0  0  0   0   0   0   0   0   0   0   0
9   0  0  0  0  0  0  0  0  0  .  0   0   0   1   0   0   0   0   0
13  0  0  0  0  0  0  0  0  0  0  0   0   0   .   0   0   0   0   1

 [*,*,2]
:   0  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18 :=
0   .  0  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   1

 [*,*,3]
:   0  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18 :=
0   .  0  0  0  0  0  0  0  0  0  0   0   0   0   1   0   0   0   0
```

```
4   0  0  0  0  .  0  0  0  1  0  0  0  0  0  0  0  0  0  0
8   0  0  0  0  0  0  0  0  .  0  0  0  0  0  0  0  0  0  1
10  0  0  0  0  1  0  0  0  0  0  .  0  0  0  0  0  0  0  0
14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  .  1  0  0  0
15  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  .  1  0  0
16  0  0  0  0  0  0  0  0  0  0  1  0  0  0  0  0  .  0  0

 [*,*,4]
:   0  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18 :=
0   .  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  1

 [*,*,5]
:   0  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18 :=
0   .  0  0  0  0  0  0  0  0  0  0  1  0  0  0  0  0  0  0
6   0  0  0  0  0  0  .  0  0  0  0  0  0  0  0  0  0  0  1
7   0  0  0  0  0  0  1  .  0  0  0  0  0  0  0  0  0  0  0
11  0  0  0  0  0  0  0  0  0  0  0  .  1  0  0  0  0  0  0
12  0  0  0  0  0  0  0  1  0  0  0  0  .  0  0  0  0  0  0

 [*,*,6]
:   0  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18 :=
0   .  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  1

 [*,*,7]
:   0  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18 :=
0   .  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  1  0
2   0  0  .  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
3   0  0  0  .  0  0  0  0  0  0  0  0  0  0  0  0  0  0  1
17  0  0  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  .  0

 [*,*,8]
:   0  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18 :=
0   .  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  1
;
```

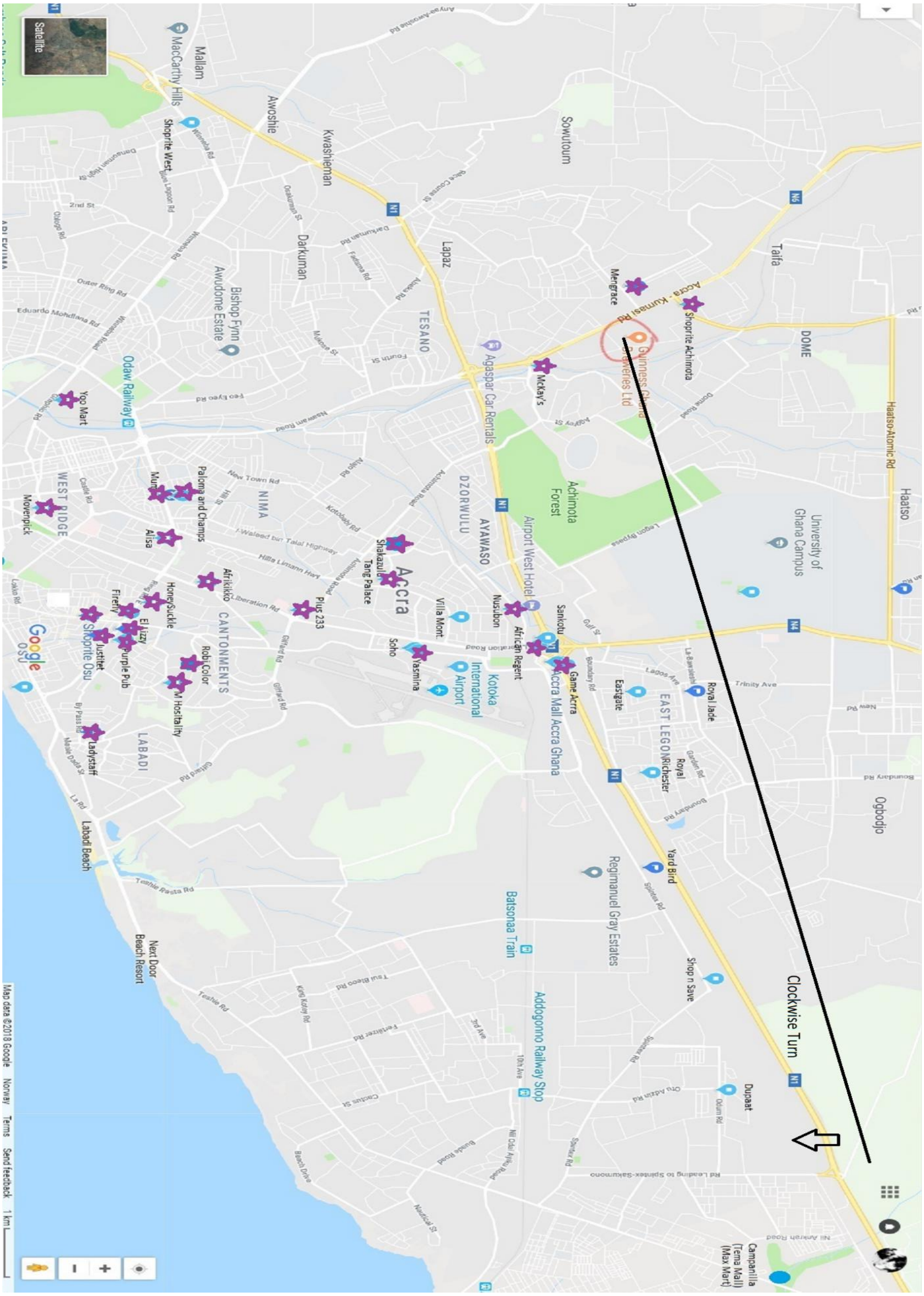
```
W [*,*]
:    1    2    3   4   5    6    7    8    :=
1    88    0    0  0    0    0    0    0
2     0    0    0  0    0    0   49    0
3     0    0    0  0    0    0  300    0
4     0    0  185  0    0    0    0    0
5    56    0    0  0    0    0    0    0
6     0    0    0  0  380    0    0    0
7     0    0    0  0   90    0    0    0
8     0    0  251  0    0    0    0    0
9   240    0    0  0    0    0    0    0
10    0    0  174  0    0    0    0    0
11    0    0    0  0   10    0    0    0
12    0    0    0  0   47    0    0    0
13  403    0    0  0    0    0    0    0
14    0    0   13  0    0    0    0    0
15    0    0   60  0    0    0    0    0
16    0    0  141  0    0    0    0    0
17    0    0    0  0    0    0    2    0
18  420  420  420  0  420  420  420  420
;

:       Z    Y    :=
0  5    492    0
0  11   228    0
0  14   498    0
0  17   415    0
1  9    180  280
2  3    100  285
3  18     0  365
4  8     50  364
5  1    380  100
6  18     0  190
```

```
7  6     90   100
8  18     0   414
9  13    60   380
10 4    135   294
11 12   220     6
12 7    170    36
13 18     0   435
14 15   458    38
15 16   361   138
16 10   141   288
17 2    400     5
;

Total_distance = 276

_total_solve_elapsed_time = 5501.19
```

Appendix F: Map for Sweep Algorithm (with 18 customers)



Appendix G: Map for Sweep Algorithm (with 25 customers)



Appendix H: Cost per day for GGBL ARTC current operations

	GGBL ARTC Operations Current Daily Cost		
	ACTIVITY	**BUDGET (GHC)**	**ACCRUAL (GHS)**
1	**WAREHOUSE**		
	Stocks Handling		194.27
	Forklift		286.75
	Electricity		-
	Water		-
	Gen set		-
			481.02
2	**PEOPLE**		
	L'aine		1,448.37
	Phone credit		7.08
			1,455.45
3	**TRANSPORT**		
	Fuel (own fleet)		503.97
	Stanbic		-
	Maintenance		-
	Insurance (VIT, AMA)		-
	Truck washing		-
	Intel Supply Chain(3rd party trucks)		3,290.00
			3,793.97
4	**MISCELLANEOUS**		
	Repair works / Maintenance		8.33
	Depot items		8.33
	IS Installation cost		-
			16.67
5	**SECURITY**		
			-
	Total Cost		**5,747.11**

Appendix I: Cost per day for Our Solution

	Our Solution's cost per day		
	ACTIVITY	**BUDGET (GHC)**	**ACCRUAL (GHS)**
1	**WAREHOUSE**		
	Stocks Handling		194.27
	Forklift		286.75
	Electricity		-
	Water		-
	Gen set		-
			481.02
2	**PEOPLE**		
	L'aine		1,648.37
	Phone credit		7.08
			1,655.45
3	**TRANSPORT**		
	Fuel (own fleet)		659.94
	Stanbic		-
	Maintenance		-
	Insurance (VIT, AMA)		-
	Truck washing		-
	Intel Supply Chain(3rd party trucks)		-
			659.94
4	**MISCELLANEOUS**		
	Repair works / Maintenance		16.66
	Depot items		16.66
	IS Installation cost		-
			33.32
5	**SECURITY**		
			-
	Total Cost		**2,829.73**

Appendix J: Current GGBL Route Plan

TRUCK 1

ROUTE 1	e	R	U	CUSTOMER'S NAME	LOCATION	CASES	UNIT	Estimated Delivery Time
1				PALOMA HOTEL LIMITED		112	**112**	**08:30 - 09:00**
2				Mum's Corner Enterprise		65	**65**	**09:15 - 09:50**
3				Mckays Bar & Restaurant		60	**60**	**10:20 - 10:35**
4				ROBI COLORS ENTERPRISE		6	**6**	**10:55 - 11:05**
5				Tang Palace Hotel		40	**40**	**11:35 - 11:45**
6				Airport west Hospitality (African R		8	**8**	**11:55 - 12:30**
7				NUSUBON VENTURES		50	**50**	**12:35 - 13:15**
8				Afrikiko Leisure Centre		120	**120**	**13:55 - 14:05**
9				SHAKAZULU LTD (SHAKAZULU WINE AND DRINKS)		80	**80**	**14:45 - 15:10**
10				Yasmina Restaurant		50	**50**	**15:35 - 16:05**
				TOTAL		**591**	**591**	

TRUCK 2

ROUTE 2	D	O	D	CUSTOMER'S NAME	LOCATION	CASES	UNIT	Estimated Delivery Time
1				Honeysuke Pub & Restaurant		300	**300**	**09:30 - 10:30**
2				M. HOSPITALITY LIMITED		85	**85**	**11:20 - 12:20**
3				KHI GH (Movenpick)		100	**100**	**13:10 - 14:10**
				TOTAL		**485**	**485**	

TRUCK 3

ROUTE 3	e	R	U	CUSTOMER'S NAME	LOCATION	CASES	UNIT	Estimated Delivery Time
1				Firefly Ltd		40	**40**	**09:30 - 10:10**
2				El-Lizzy Ent (Lizzy Spot)		97	**97**	**10:25 - 11:45**
3				Justitet Enterprise		175	**175**	**11:55 - 13:25**
4				PURPLE PUB		220	**220**	**13:45 - 14:15**
5				Ladystaff Ventures		50	**50**	**14:30 - 14:50**
				TOTAL		**582**	**582**	

TRUCK 4

ROUTE 4	D	O	D	CUSTOMER'S NAME	LOCATION	CASES	UNIT	Estimated Delivery Time
1				MENGRACE ENT (KEIVINS AKAD)		15	**15**	**09:30 - 10:05**
2				SHOPRITE ACHIMOTA		130	**130**	**10:20 - 11:20**
3				SHOPRITE GHANA (PTY) LIMITED		490	**490**	**12:05 - 15:05**
				TOTAL		**635**	**635**	

3RD PARTY TRUCK 1

ROUTE 5	e	R	U	CUSTOMER'S NAME	LOCATION	CASES	UNIT	Estimated Delivery Time
1				YOO MART LTD		480	**480**	**09:30 - 11:30**
2				ALISA HOTEL		200	**200**	**12:30 - 15:00**
				TOTAL		**680**	**680**	

3RD PARTY TRUCK 2

ROUTE 6	e	R	U	CUSTOMER'S NAME	LOCATION	CASES	UNIT	Estimated Delivery Time
1				GAME DISCOUNT WORLD (GHANA) LTD		345	**345**	**08:30 - 12:30**
2				Plus 233 JAZZ BAR AND GRILL (Travic Foods ltd)		90	**90**	**13:20 - 13:50**
				TOTAL		**435**	**435**	

Appendix K: Proposed Route Plan from Our Results

TRIP 1

TRUCK 1

TOUR 1	CUSTOMER'S NAME	LOCATION	CASES	UNIT	Estimated Delivery Time
5	PALOMA HOTEL LIMITED			0	10:00 - 10:30
1	ALISA HOTEL			0	10:36 - 13:06
9	Afrikiko Leisure Centre			0	13:13 - 13:23
13	Mckays Bar & Restaurant			0	13:41 - 13:56
	TOTAL		0	0	

TRUCK 2

TOUR 2	CUSTOMER'S NAME	LOCATION	CASES	UNIT	Estimated Delivery Time
11	Airport west Hospitality (African R			0	08:27 - 09:02
12	NUSUBON VENTURES			0	09:04 - 09:44
7	SHAKAZULU LTD (SHAKAZULU WINE AND DRINKS)			0	09:52 - 10:17
6	Plus 233 JAZZ BAR AND GRILL (Travic Foods ltd)			0	10:25 - 10:55
	TOTAL		0	0	

TRUCK 3

TOUR 3	CUSTOMER'S NAME	LOCATION	CASES	UNIT	Estimated Delivery Time
14	Firefly Ltd			0	08:36 - 09:16
15	El-Lizzy Ent (Lizzy Spot)			0	10:00 - 11:20
16	PURPLE PUB			0	11:22 - 11:52
10	ROBI COLORS ENTERPRISE			0	11:58 - 12:08
4	M. HOSPITALITY LIMITED			0	12:10 - 13:10
8	Yasmina Restaurant			0	13:20 - 13:50
	TOTAL		0	0	

TRUCK 4

TOUR 4	CUSTOMER'S NAME	LOCATION	CASES	UNIT	Estimated Delivery Time
17	MENGRACE ENT (KEIVINS AKAD)			0	08:10 - 08:45
2	Honeysuke Pub & Restaurant			0	09:10 - 10:10
3	KHI GH (Movenpick)			0	12:00 - 13:00
	TOTAL		0	0	

TRIP 2

TRUCK 1

ROUTE 8	CUSTOMER'S NAME	LOCATION	CASES	UNIT	Estimated Delivery Time
24	SHOPRITE GHANA (PTY) LIMITED			0	11:56 - 14:56
	TOTAL		0	0	

TRUCK 2

TOUR 6	CUSTOMER'S NAME	LOCATION	CASES	UNIT	Estimated Delivery Time
20	Yoo Mart Limited - Graphic Road Del			0	14:41 - 16:41
	TOTAL		0	0	

TRUCK 3

TOUR 7	CUSTOMER'S NAME	LOCATION	CASES	UNIT	Estimated Delivery Time
23	SHOPRITE ACHIMOTA			0	13:31 - 14:31
18	Mum's Corner Enterprise				14:44 - 15:19
22	Ladystaff Ventures				15:31 - 15:51
21	Justitet Enterprise			0	16:00 - 17:30
	TOTAL		0	0	

TRUCK 4

TOUR 5	CUSTOMER'S NAME	LOCATION	CASES	UNIT	Estimated Delivery Time
19	Tang Palace Hotel			0	14:34 - 14:44
25	GAME DISCOUNT WORLD (GHANA) LTD			0	14:59 - 18:59
	TOTAL		0	0	