USING HEURISTICS TO IMPROVE A TRANSPORT ROUTING SYSTEM

Teerayut Charoenkittirak*
School of Management, Assumption University of Thailand

ABSTRACT

Routing and scheduling of delivery vehicles is an important factor affecting the cost of a product. This article presents a case study of a company in Bangkok which is a distributor of dairy products, using delivery vans. The study focuses on finding a method of reducing the fuel cost, total distance and driving time, while keeping the same service level, to achieve the maximum capability of the vans.

The company provided data of transportation costs and delivery distances and times. This data is anlysed, using Microsoft Excel, Visual Basic Application software, and six heuristic devices. Two scenarios are developed, which provide for different situations. The first scenario improves the existing routing and scheduling, and the second provides for possible future expansion of the business, to identify how many vans would be needed. Both scenarios have the same objective, which is saving fuel cost and distance for each delivery van. The actual implementation of a new system needs to consider the constraints which apply in the real situation.

INTRODUCTION

Transportation problems exist in many companies and are difficult to solve. Yet solutions must be sought as the transportation process represents about 10% - 20% of the final cost of the goods. The distribution of goods is an important part of a supply chain. It involves a set of customers, a set of vehicles and drivers, one or more distribution centers, and a road network. Optimum vehicle routing needs the determination of a set of routes, each for a single vehicle that starts and ends at its distribution center, such that customer requirements are fulfilled, operational constraints are satisfied, and overall transportation is minimized. Operational constraints depend on the nature of the transported goods, on the quality of the service level, and on the characteristics of customers and vehicles.

---

*Mr. Charoenkittirak is now a Master of Science in Supply Chain Management, awarded by Assumption University. This article is a reduced version of his MSc project report.

'DistCo' (a pseudonym) is the company chosen for this case study. It is a distributor for a dairy-products firm. The customers consist of some major supermarket chains and other retailers. Four delivery vans (and drivers) are used, and the distribution area is Bangkok.

Before this research, DistCo had inadequate planning to properly manage their vehicle routing. Each day, the distribution supervisor, based on experience, assigns to each driver a group of customer destinationst which are located in the same area, as this would seem to save time and fuel. He ignores the total distance for each van, or transportation cost, or any other factor, but focuses on the time of delivery and the retail customers who are in the same geographical area. Sometimes a van takes a whole day to deliver the products to the assigned retailers, and there are many complaints from customers about delays. Specifically, the problems are:

* Sometimes too many vans are used without good scheduling, resulting in overtime payments to the drivers.
* Sometimes the routing and scheduling for each driver is not fair, and leads to driver dissatisfaction.
* Some problems affect delivery times and are difficult to control, such as traffic jams, rain, or even accidents.
* There is no plan for transportation to new customers in the future, and orders will exceed the vans' carrying capacities.
* In the assigned routing and scheduling for each driver, bias occurs

The routing and scheduling assigned to drivers sometimes cause them a whole day involved in traffic jams in the city area. Also, when a driver reaches the retailer, he has to load the products into the freezer room or storage room, and if there is no space in the room, he has to re-arrange the space first. This process may take more than 20 minutes, is a non value-added process but the retailer does not provide staff to help. Moreover, the process of product checking before loading the products into the room and taking back the expired products of the retailers, also takes time. Uncontrollable events such as accidents or engine breakdown are also obstacles.

Because of al these problems, the company needs:

* To have a better routing and scheduling of product delivery for all their customers.
* To have a good scheduling plan, which is easy to use and needs only a short learning time.
* To reduce the company's transportation cost.

Ballou (2004), in describing routing, said that the logistician frequently encounters routing problems in which the origin point is the same as the destination point. This class of routing problem commonly occurs when transport vehicles are privately owned. A familiar example is school bus routing. The requirement that the journey is not complete until the vehicle returns to its starting points is the complicating dimension. The objective is to find the sequence in which the points should be visited that will minimize total travel time or distance.

METHODOLOGY

The routing problem due to coincident origin and destination is generally known as the "traveling salesman" problem. Numerous methods have been proposed to solve it. Finding the optimal route for a particular problem has not been practical for such problems when they contain many points or require a solution to be found quickly. Computation time on the fastest computers takes too long for many practical problems. However, heuristic, optimization solution procedures are good alternatives.

The problem of finding good solutions to the vehicle routing and scheduling problem becomes more difficult as additional constraints are placed on the problem. Time windows, trucks with different capacities, maximum total driving time allowed on the route, different speed in different zones, barriers to travel, and break times for the driver, are a few of the practical considerations that need to be given to route design. One method, the Clark-Wright savings approach has been used over the years as being flexible enough to handle a wide range of practical constraints, being relatively fast computationally for problems with a moderate number of stops, and capable of generating solutions that are nearly optimum. The objective of this method is to minimize the total distance traveled by all vehicles and to indirectly minimize the number of vehicles needed to serve all stops. The logic of the method is to begin with a dummy vehicle serving each stop and returning to the depot.

Martin (1991) said that routing and scheduling does not follow a single "one size fits all" formula. Routing and scheduling must be customized to reflect the operating environment and the customer needs and characteristics. His objectives are to:

- * Minimize Kilometers, vehicles, and labour;
- * Maximize orders and volume delivered per Kilometer;
- * Satisfy service requirements.

Bodin (1996) described situations when routing and scheduling problems arise, presented mathematical formulations for them, and surveyed representative solution algorithms. He also discussed issues relating to real-world computer implementation of these algorithms. Routing and scheduling has become an important research area, and computer application area. Computer assisted vehicle routing and scheduling systems are common, and visualization is a key aspect in these systems.

A popular tool used is the heuristic device. With trial and error, heuristic is a tool for every possible method. One example is packing odd-shaped items into a box. What most people do, heuristically, is to put the largest items in first, then fit the smaller items into the spaces left around them. This may not be perfect packing, but it will usually produce good packing.

Marius (1985) considered the design and analysis of algorithms for vehicle routing and scheduling problems with time window constraints. Given the intrinsic difficulty of this problem, approximation methods seem to offer the most promise for practical size problems. After describing a variety of heuristics, he conducted an extensive computational study of their performance. The problems included routing and scheduling environments that differ in their details. He found that several heuristics performed well in different problem environments; in particular an insertion-type heuristic consistently gave very good results.

Gaudioso and Paletta (1992) used a heuristic for the periodic vehicle routing problem. They wanted an integrated unified model of relevant components of the decision making process in managing the distribution activities of a firm (such as fleet size determination, scheduling of deliveries, and routing of vehicles). They concluded that heuristic algorithms have proved effective.

Amico et al. (1993) used a heuristic algorithm for the multiple depot vehicle scheduling problem, in which a given set of time-tabled trips have to be assigned to vehicles stationed at different depots, so as to minimize the number of vehicles used and the overall operational cost. Some structural properties of the problem were studied and used to design a new polynomial-time heuristic algorithm which always guarantees the use of the minimum number of vehicles.

Therefore, the use of heuristics is very common in real world implementations. For many practical problems, a heuristic algorithm may be the only way to get good solutions in a reasonable amount of time. The computer spreadsheet is an ideal medium for implementing such interactive methodologies. Richard (1998) described a successful application of a spreadsheet based model for assigning buses to routes. One approach for developing the model was to implement a simple and straightforward heuristic.

Although all modern spreadsheets hold powerful programming capabilities, Excel is commonly used because of the simplicity and availability of its Visual Basic for Applications (VBA) language. Enns (2002) described how the Excel spreadsheet is useful to understand the effects of average utilization of system performance as well as the effect bottlenecks have when loads are not balanced. It is also useful to determine and compare the effects of routing variability.

Chantaravarapan et al. (2004) show that an Excel spreadsheet is an alternative powerful tool in solving complex scheduling problems. As most users are already familiar with this spreadsheet tool, training becomes easier and requires less time to understand how to use the model. They developed several effective algorithms by using Visual Basic for Applications (VBA) which provides consistently good results, although not necessarily optimal, within an acceptable running time. The heuristic algorithm is a suitable tool for this research. Due to limitations of time and budget, a simple tool seemed best suited to this project, and therefore the researcher built a simple tool to integrate with the existing spreadsheet approach.

The reason for using a spreadsheet in this research is simply because the actual users of data visualization systems are not usually computer programmers. Spreadsheet is a tool easy to use, with little implementation effort, and low training requirements. As most users are already familiar with this spreadsheet tool, training becomes easier and requires less time to understand how to use the model. Spreadsheet also gives users the ability to move or schedule orders manually.

This project designed a solution to automate the process of creating an initial schedule. Because of the use of the heuristic algorithm and Excel spreadssheet, new routes and schedules for each van were created to use in the real situation. A model was created in Microsoft Excel and spreadsheet, and VBA (Visual Basic for Application) was used to calculate the new routing and scheduling. In VBA, the data of oil price, speed of car per hour, and the number of vans was put into the model in order to find the best result by using the heuristic method.

Data of transportation costs was provided by the company. Also collected was data of the driving time between retailers, or the speed of the van while driving in different times. Data was also obtained of the distance between DistCo and each retailer. Unfortunately the company did not keep records of distances from the distribution center to each retailer, and distances between retailers, so the Google map website was used.

The following two scenarios were created in order to find a better method than the old daily assignment method.

The first scenario "*Finding new routing and scheduling for four vans*"

This scenario uses the present routing and scheduling as data in order to apply the new daily routing and scheduling for each of the four vans. In this scenario any constraints of distance, work hours, and capacity of each van are ignored. The objective is to have new routing and scheduling which is better than that existing.

The second scenario "*Concentrating on the capacity of the van*"

For this scenario, the distance limit, the delivery time and the capacity of each van are examined to find the appropriate number of vans for each day. The limitation of these three constraints was determined as a result of using VBA to calculate the new routing and scheduling that could be used in real life. Why put these constraints in this scenario? From the first scenario, the result of the new routing and scheduling could decrease the fuel cost, but it uses the same number of vans, and does not show the maximum destinations that one van can reach. For example, if one van has to deliver to seven retailers and those retailers always order high volumes, the orders might exceed the carrying capacity of the van. Or the driver might have to work overtime to complete the seven deliveries. Therefore, this scenario accounts for the driver's limited work time per day, the limited capacity of the van and the maximum distances for each van, in order to find the maximum capability of each van when these constraints are present.

The first heuristic to be used is Logic Z. It simply selects the nearest customer from the distribution centre as the first destination for a van, and then the second nearest, and so on. Then the process is continued for the second van, and so on. The existing scheduling is followed, for the number of destinations on each day and the number of vans. Four vans are not used every day; sometimes it is two or three depending on the number of customers for that day. After using Logic Z and finding it unsatisfactory, three further heuristics are used for scenario 1 (Logics A, B, C), and two for scenario 2 (Logics D and E).

Logic A

1. Follow the existing scheduling on each day and numbers of vans, then divide the destinations equally for each van.
2. Random the first destination for the first van and then find the next nearest unvisited destination as a second destination and go on until the last destination of the first van.
3. The first destination of the second van will be random also but it will not be the destination which first van has visited. Then find the next nearest unvisited destination as a second destination. Go on till the last destination of the second van. The third and fourth van will follow the same process as the first and second van.
4. Each van will go back to the distribution center once they have visited the entire assigned destinations.
5. The destinations of each van will not be repeated.

Logic B

1. Find out how many destinations each van has to visit.
2. Random the first destination for each van at the same time. Then find the second destination which is the nearest destination from the first destination for four vans. Continue this process until the last destination of each van.
3. The first destination to the last destination of each van will be selected by the number of each van. For example, the second destination of the first van will not be selected until the fourth van has it first destination. Or the fourth destination of the first van will not be selected until the fourth van has its third destination.
4. Each van will go back to the distribution center once they visited the entire assigned destinations.
5. The destinations of each van will not be repeated.

Logic C

1. Find out the number of destinations for each van.

2. Starting with the van number 1, then random one destination (which is not always the first destination) and find out whether the van can come to this destination with the shortest distance and which other destination is nearest from this destination. For example, random one destination, named as Destination A, then find out the destination that could come next to destination A with the shortest distance. It was found to be destination B. And then find the destination that is located nearest to Destination A. It was found as destination C. So it could be said that destination A is not the first destination for this route. Moreover, when destination B was found, this logic will continue to find which destination could come next to destination B with the shortest distance; and if the nearest destination is the distribution center, then destination B is the first destination of the first van. Also, this logic will find out which destination is nearest to destination C, and if the nearest destination is the distribution center, so that destination C is the last destination of the first van. Continue this process until completion of the number of destinations of van number 1.

3. Vans numbers 2, 3 and 4: do the same as for van number1.

4. The destinations of each van will not be repeated.

Logic D

1. Determine the constraints of the maximum distance for each van, maximum capacity, and maximum work time of the drivers.

2. Start with van number one, random the first destination and then find out the second destination which is located nearest to the destination 1. Continue finding the next destination until the last destination of van number one (the same concept as with Logic A.)

3. The last destination of each van will be found when one of the three constraints was met. For example, the maximum distance was set at 100 kilometers including the return to the distribution center: van number one has been to five destinations, and, if including the distance of the next destination and distribution center, it would be more than 100 kilometers, thus van number one will stop at destination 5 and then return to the distribution center.

4. Van number two will start finding its destinations by the same logic as the first van when van number one has reach its last destination.

5. The destinations of each van will not be repeated.

Logic E

1. Determine constraints of maximum distance for each van, maximum capacity, and maximum work time of the drivers.

2. Start with van number 1, then random one destination (which is not always the first destination) and find out which destination can come next with the shortest distance and which destination is nearest from this destination. For example, random one destination is given the name of Destination A, then find out the destination that could come next with the shortest distance. It was found as destination B. And then find the destination that is located nearest

from the destination A. It was found as destination C. So it could be said that destination A is not the first destination for this route. Moreover, when destination B is found, this Logic will continue to find which destination could come next to destination B with the shortest distance and if the nearest destination is the distribution center. Thus, destination B is the first destination of the first van. Also, this logic will find out which destination is nearest to the destination C and if the nearest destination is the distribution center: so destination C is the last destination of the first van. Do this until the complete number of destinations of van number 1 (the same concept as with Logic C.)

3. The last destination of each van will be found when one of the three constraints was met. For example, the maximum of distance was set at 100 kilometers including the return to the distribution center. Van number one has been to five destinations, and if including the distance to the next destination and distribution center, the distance would be more than 100 kilometers, therefore van number one will stop at destination 5 and then return to the distribution center.

4. Other vans will do the same as the first van until no destinations are left.
5. The destinations of each van will not be repeated.

The objective of each heurustic Logic is to reduce fuel cost and total distance of each van. Therefore the data needed to be used in VBA consists of

1. The distance between DistCo and each retailer.
2. The distance between retailers and retailers.
3. The existing schedule of each sales van.
4. The fuel price.
5. The approximate speed of the car for each hour (from 7 am - 5 pm).

The results from each heuristic Logic are assessed against the others, to find the most appropriate, for recommendation to DistCo.

FINDINGS

The results from applying Logic Z, clearly show that this Logic does not work, because its fuel cost and total distance are worse than the existing method. Moreover, it perpetuates the problem of unfair routing, which obviously makes drivers unhappy.

Therefore, for scenario 1, the Logics A, B, C are applied, and the results about fuel cost and total distance compared in order to consider which logic could be the best and would therefore be used in real life by the staff of DistCo.

Logic A

Logic A uses the Logic A button in the Excel spreadsheet to calculate the new routing and scheduling for each van. The lowest distance and fuel cost of each day will be compared with the existing amounts. As the distance and the fuel cost are related, this means that the less the distance, the less the fuel cost. This Logic could save a total distance at 65.7 km or 7.11% per week. Not only does it decrease the distance, but this Logic also decreases the fuel for each van. The new reduced fuel cost will decrease the company's expense by 7.33%. In addition to fuel cost, the total transportation cost includes drivers' daily wages, and this total cost reduces the company's expense by 1.89% from the existing amount.

Next, is a time consumed comparison As the number of vans each day can be either 2, 3, or 4, and as the total time consumed consists of driving time and loading time, this research compares only the existing and new driving times. The loading time per destination will always be one hour and the total driving time is derived from total time consumed minus total loading time. This Logic could save driving time for the whole week, meaning a decrease of 0.89% from the existing time consumed.

Logic B

Logic B uses the Logic B button in the Excel spreadsheet to calculate the new routing and scheduling for each van. The calculation steps in logic B are the same as with logic A. The results of fuel cost, total distance and time consumed are stated and compared.

As the distance and the fuel cost are directly related, it means that the less the distance, the less the fuel cost. This Logic could save a total distance of 8.04% per week. The new fuel cost will decrease the fuel expense for the company by 8.26%. Total transportation cost also includes the drivers' wages, and that total would decrease by 2.13% from the existing cost. Loading time per destination will always be one hour and the total driving time for the whole week would decrease by 4.05% from the existing.

Logic C

Logic C uses the Logic C button in the Excel spreadsheet to calculate the new routing and scheduling for each sales van. The calculation steps in logic C are the same as with logic A and Logic B. This Logic could save a total distance 9.08% per week. The new fuel cost will redcue the fuel expense 9.3%. Total transportation costs will reduce by 2.4%. Loading time per destination will always be one hour, and the total driving time could be reduced by 5.92% from the existing time.

With these three heuristic results, the question is: Which logic is the best for this scenario? All three give a new routing and scheduling which shows less fuel cost and less distance. But, which logic is the best for this scenario? After comparing the result of fuel cost, total distance and time consumed, Logic C seems to be the best for this scenario because it can save greater total distance and fuel costs. Although Logic C cannot save as much total time consumed as can logic A and logic B, as this paper considers only the lower fuel cost and distance, therefore logic C seems to be the best.

Logic C could save 9.30% of the fuel cost, 9.08% of the total distance, and 5.92% of time consumed.

<u>Scenario 2 *"Concentrating on the capacity of the sales van"*</u>
This scenario finds a new routing scheduling which could make greater savings than Logics A, B, C, by controlling the amount of carrying capacity, distances and delivery time per van, which will also affect the number of vans.

Logic D
First, a reminder that there are three constraints: work time per day, maximum distance for one van per day; maximum carrying capacity per van. This Logic could save a total distance of 15.47% per week. The number of vans per week would also reduce, from a weekly total of 18 to 12, and so would the number of drivers. So, this Logic could save the drivers' wages for each day. The new fuel cost, plus drivers' wages, would result in a 28.66% reduction of total transportation costs. Since this Logic results in less vans, so will then the time consumed, by 17.42%

Logic E
Now, let us turn to the last heuristic, Logic E. It could save a total distance of 16.40% per week. There would be a lower number of vans and drivers.

So, this Logic could save on drivers' daily wages. And the total transportation cost of this Logic would mean a weekly saving of 28.78%. Since this Logic produces less vans, the driving time would be reduced by 17.36% from the existing.

Since these two Logics were used in VBA to find out the lower costs and distances, the results from those two Logics give the new routing and scheduling which have less fuel cost and less distance. Again, the question is: Which Logic is the best for this scenario?

From the figures, it could be said that Logic E seems to be the best one for this scenario because it can make greater savings in fuel cost and total distance. Even though it may use more driving time than Logic D, that is not as important as fuel cost and distance, and therefore Logic E is the one recommended for use.

The number of vans in Logic E will decrease by one van each day, which means that the company could reduce fuel cost by 16.60%, total distance by 16.40%, driving time by 17.36%, and drivers' wages by 33.33%.

SUMMARY AND CONCLUSIONS

As the objectives of this paper are to improve the routing and scheduling of each van for DistCo, and identify a new application for the company as a tool to manage their future routing and scheduling, the results from using VBA can prove that the existing routing and scheduling is not the best. However, the results above are not the last answer but just one of the many possible ways to improve the distances, fuel cost and work time.

Moreover, the scenario was divided into two scenarios and five heuristic logics, because this study tried to find the solution by using different ways and different assumptions in order to cover all constraints that the company is facing in the real situation. So, each scenario can be summarized as follows:

1. Scenario 1 was created as the tool to find better routing and scheduling without considering any constraints. Of the three heuristics, the best is Logic C as it produces a better result than Logics A and B.
2. Scenario 2 was created as the tool to find the maximum capability of one van to serve in one day, and also to indicate the appropriate number of vans per day. From the result of the two heuristics, the best result is from Logic E.

Which situation should be used from which scenario,

1. When the company would like to find new routing and scheduling when there are more retailers to serve, or,
2. When the company would like to find an appropriate number of vans which could serve all the existing retailers?

In the future, if the company has to deliver to more retailers, and would like know how many vans they need to serve all destinations with the same or better service level, then it should use Logic E.

For aplication training, the user will be trained for one day as this application is easy to use. The application itself also provides the function which the user can adjust to match the situation at that time, such as the oil price, speed of the van, number of retailers, and even loading time. So, in the future, if there is any change, DistCo can input the latest data into the application to find the result.

BIBLIOGRAPHY

Amico M.D., Fischetti M., Toth P. (1993). Heuristic Algorithm for the Multiple Depot Vehicle Scheduling Problem. *Management Science* Vol.39, No.1, January 1993.

Ballou, R.H. (2004). Chapter 7 Transport Decisions. *Business Logistics/Supply Chain Man-*

agement. 5th edition, 232-244.

Bodily, S. (1986). Spreadsheet Modelling as a Stepping Stone *Interfaces*, 16: 5, 34-52.

Bodin L.(1996). Contemporary Transportation, 5th edition. *Upper Saddle River*, NJ: Prentice Hall, 1996

Chantaravarapan S., Gunal A. & William J. E. (2004) On Using Monte Carlo Methods for Scheduling, from: http://www.informs-sim.org/wsc04papers/248.pdf Proceedings of the 2004 Winter Simulation Conference R .G. Ingalls, M. D. Rossetti, J. S. Smith, and B. A. Peters, eds.

Enns S. T. (2002). A Simple Spreadsheet-Based Rapid Modeler. http://www.enme.ucalgary.ca/~enns/RMtrainingTool_files/RM_Jobshop_Manual.pdf

Gaudioso M., Paletta G.(1992). A Heuristic for the Periodic Vehicle Routing Problem. *Transportation Science* Vol.26, No.2, May 1992

Marius M. S. Algorithms for Vehicle Routing and Scheduling Problems with Time Window Constraints (1985). http://www.jstor.org/pss/170697?cookieSet=1

Martin S. (1991). The Logistics Institute, Georgia Institution of Technology. http://www2.isye.gatech.edu/~mwps/presentations/VRP_part1.pdf

Richard H. Using Spreadsheet Based MILP to Develop a Bus Management DSS for a Texas ISD. http://www.swdsi.org/swdsi05/Proceedings05/paper_pdf/FBD_2005_Tiger_proceedings-Hawk%20(T3B3).pdf