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A Comparison Of Clarke-Wright Method And Branch & Bound Method For Vehicle Routing Problem In Pangasinan

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Abstract*-The Vehicle Routing Problem is an integer programming problem and combinatorial optimization that designs the optimal set of the route for a fleet of vehicles to travel in order to deliver to a given set of customers. This research study aimed to calculate and determine the best route for delivering the products in the different cities of Pangasinan using the Clarke-Wright Method and Branch & Bound Method with a starting point in Dagupan. The main objective of this study is to determine which of the two methods is more easy and effective to use for finding the optimal route for the vehicle routing problem that minimizes the cost of travel of deliveries. The two methods are used to solve the Vehicle Routing Problem for online shipment of the products in the entire Pangasinan using the data from JRS Express. After applying the two methods to the said problem, it was observed that the Clarke-Wright Method is more economical to use when it comes to Vehicle Routing Problem than Branch & Bound Method.*

Keywords: *Vehicle Routing Problem, Clarke-Wright Method, Branch & Bound Method*

INTRODUCTION

Modern life has become easier and the people of the world have to thank the immense contribution of Internet technology to communication and sharing information. There is no doubt that the Internet has made our life become easier and more convenient. It was UCLA (University of California, Los Angeles) who first introduced the Internet publicly through a press release in 1969. The Internet was first available in the Philippines on March 29, 1994. Many fun and interesting activities on the Internet were launched and one of these is online shopping. (Department of Information and Communication Technology, 2015).

Online Shopping is very popular nowadays. It plays a very important role in everybody's life most especially to those who have a very busy and hectic schedule for they do not have time to go and stroll in the mall to buy their stuff. But now, with the use of the internet, you can just click and shop what you want from home. The earliest online store started in business in 1992. It was Charles Stack who created the first online bookstore, Book Stack Unlimited (Book.com), and that is two years before Jeff Bezos started Amazon.com. Amazon is the world's largest online retailer and a prominent cloud service provider. (Miva, 2011).

As years passed by, the development of Online Shopping popularized all over the world and reached the Philippines. The most popular online store in the Philippines is Lazada. Lazada is now dubbed as the fast-growing online shopping website in the country since it offers a variety of products from home improvement, gadgets, fashion and lifestyle items, to appliances. Of course, the Province of Pangasinan will never be outdated in this kind of activity. The Pangasinenses definitely know how to go with the flow despite the rapidly growing modern civilization. Perhaps, not only local online retailers has been known and popularized in our province, but also from International. (Gelyka Ruth R. Dumaraos, 2016).

After the process of shopping online, delivery will come next. Purchased products will be delivered to their places in different

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areas in the Philippines, specifically in Pangasinan. The shipment will be done by some local delivery company. One of the largest express delivery providers in the country is JRS Express. JRS Express is a leading express delivery company in the Philippines. JRS provides express delivery service as well as other value-added logistics services consumers and businesses through its extensive and reliable nationwide network of 400 branches. The only disadvantage of this online shopping is that the delivery of the products will take days or weeks before it arrives in the buyer. That is why a Vehicle Routing Problem will be a big help in the shipment part.

The Vehicle Routing Problem (VRP) is a generalization of Traveling Salesman Problem (TSP). It is an integer programming problem seeking to service a number of customers with a fleet of vehicles and combinatorial optimization that designs the optimal set of the route for a fleet of vehicles to travel in order to calculate to a given set of customers. The goal in Vehicle Routing problem is to find the optimal set of routes for some vehicles delivering goods or services to various locations in order to serve the customer in less possible time or travel distance. The said problem was proposed by Dantzig and Ramser in 1959. And just like TSP, the Vehicle Routing Problem can be represented by a graph with distances assigned to the edges. (Tonci Caric and Hrvoje Gold, 2008).

A Vehicle Routing Problem has a set of assumptions. First, each route starts and ends at the depot. Second, each customer appears in exactly one route. Third, the total demand for a route does not exceed the vehicle capacity. And fourth, the length of a route or the total traveling distance does not exceed their maximum limit. And to execute this Vehicle Routing Problem, the researchers will be making use of these two most popular methods in VRP, the Clarke-Wright Method and the Branch & Bound Method. (Alvina Kek and Qiang Meng, 2007).

Clarke-Wright was also known as the saving method, which is based on the computation of savings for combining customers into the same route. The Clarke-Wright method is an algorithm with step by step process. The algorithm calculates all the savings S_{ij} between customers i and j. Meanwhile, just like the Clarke-Wight Method, the Branch and Bound Method is also an algorithm that is generally used for solving a combinatorial optimization problem. The Branch and Bound approach is based on the principle that we can partition the total set of feasible solutions into smaller subsets of solution. And these smaller subsets can then be evaluated systematically until the best feasible solution is found. When the best optimal solution was already found, the process will end and stop. (Tanktikom Pichpibul and Ruengsak Kawtummachai, nd).

OBJECTIVE OF THE STUDY

The primary objective of this study is to find an optimal set of routes for vehicles delivering goods of JRS Express to various locations in Pangasinan using the Clarke-Wright Method and Branch & Bound Method. This study also aimed to determine which of the two methods is more convenient and efficient to use.

MATERIAL AND METHODS

The researchers used the Clarke-Wright Method and Branch & Bound Method to solve the Vehicle Routing Problem for the delivery of the products in JRS Express. Wherein, Clarke-Wright Method and Branch & Bound Method are both an algorithm with a step by step process.

Clarke- Wright Method

Clarke-Wright, also known as the saving method, is based on the computation of savings for combining customers into the same route. Clarke-Wright Method has an algorithm that calculates all the savings S_{ij} between customers i and j. Assuming that c_{i0} is the cost of traveling from depot to customer i and c_{ij} is the cost of traveling from customer i to j. The following are the steps in doing the Clarke-Wright Methods.

Steps in doing Clarke- Wright Method

Step 1: Construct the shortest distance half matrix comprised of shortest distance or least time between each pair of nodes including starting node.

Step 2: Develop an initial allocation of one round-trip from the starting node to each destination.

Step 3: Calculate the net savings for each pair of nodes (excluding starting node) and construct a net savings half- matrix. Net savings are the savings achieved by pairing nodes relative to the cost of making a round trip to each paired node from depot or node 1.

Step 4: Introduce a special indicator, I, into appropriate cells of the net savings half-matrix. This indicator will tell if the two nodes in question are directly linked. The link can be from either node 1 to any other node j or it can be between any pair of nodes, i and j when (i≠1 and j≠1). This trip indicator, I may have one of three values.

Step 4.1: When a vehicle travels from point of origin (node 1) to node j (other than node 1) and then returns to point of origin then, I=2. That is, a round trip will have I=2. In the matrix, we can write the value of an indicator that is $I_{1j} = 2$ (where j≠1). This value will appear only in the first row of the net savings half- matrix.

Step 4.2: When a vehicle travels one way directly between two nodes, the $I_{ij} = 1$.

Step 4.3: The value of trip indicator $I_{ij} = 0$, if a vehicle does not travel directly between two particular nodes, then there is no trip between a pair of nodes.

Step 5: Select the (i, j) cell in the net savings half- matrix having maximum net savings and link i and j. But before linking the pair of nodes, the following condition should be fulfilled to link i and j.

Step 5.1: I_{1i} and I_{1j} must be greater than 0.

Step 5.2: Nodes i and j are not already on the same route or loop.

Step 5.3: There is no violation of constraint in linking i and j. (There can be some constraints like the one-way route which is only permissible between two streets.)

If the cell meets all the above conditions, then assign I_{ij} = 1otherwise assign zero and select the cell with the next highest net savings and check for the conditions stated in 5.1, 5.2 and 5.3.

Step 6: When all nodes are linked on a single route and no other cell meets the conditions in step 5, stop the algorithm. Otherwise, go to step 5.

Branch and Bound Method

The Branch and Bound Method is also an algorithm that is generally used for solving a combinatorial optimization problem. The Branch and Bound approach is based on the principle that we can partition the total set of feasible solutions into smaller subsets of solution. And these smaller subsets can then be evaluated systematically until the best feasible solution is found. The following are the steps in doing the Branch & Bound Method

Steps in doing Branch & Bound Method

Step 1: Draw and initiate the root node.

Step 2: Repeat the process until no unexplored non-terminal node has a smaller bound than the length of the best solution found.

Choose an unexplored non-terminal node with the smallest bound, and process it.

Step 3: And when a solution has been found and no unexplored non-terminal node has a smaller bound than the length of the best solution found, then the best solution found is optimal.

That is the last step in the Branch and Bound Algorithm. When the best optimal solution was already found, the process will end and stop.

RESULT AND DISCUSSION

Using the deliveries of JRS Express, this study wants to find the best minimal distance in kilometer by determining among the municipalities in Pangasinan. Consider the table of Vehicle Routing Problem with seven municipalities including the depot which is in Dagupan City. Let the following municipalities be denoted as

A – Dagupan City
B - Sual
C- Basista
D – Santa Barbara
E – Manaoag
F – Binalonan
G – Asingan

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Starting from the depot which is located in Dagupan City at Perez Boulevard, the delivery truck will find its best route among the seven municipalities given in kilometers. Table 4.1 shows data in kilometers and we will use to solve using the Clarke-Wright Method and the Branch & Bound Method.

The distances of each municipality will be our data in kilometers. Then the internet became the instrument to get the distance in each municipality. After finding the distances of each municipality we perform a table to shows data in kilometers.

Table 1. Seven Municipalities present in JRS Express deliveries

	Dagupan	Sual	Basista	Santa Barbara	Manaoag	Binalonan	Asingan
Dagupan	–	34.5	20.6	14.9	20.7	33.9	40.7
Sual	34.5	–	44.8	47.1	54.4	67.2	73.0
Basista	20.6	44.8	–	24.8	33.2	38.0	48.9
Santa Barbara	14.9	47.1	24.8	–	16.6	21.4	27.2
Manaoag	20.7	54.4	33.2	16.6	–	16.1	22.9
Binalonan	33.9	67.2	38.0	21.4	16.1	–	10.1
Asingan	40.7	73.0	48.9	27.2	22.9	10.1	–

Using the Clarke-Wright Method

Step 1: Construct a shortest distance half matrix.

	B	C	D	E	F	G
A	34.5	20.6	14.9	20.7	33.9	40.7
	B	44.8	47.1	54.4	67.2	73.0
		C	24.8	33.2	38.0	48.9
			D	16.6	21.4	27.2
				E	16.1	22.9
					F	10.1

The researchers only constructed a half matrix because the distance from node *i* to *j* will be the same as the distance from *j* to *i* such that our figure represents undirected arcs and it is said to be symmetrical.

Step 2: Develop an initial allocation of one round trip from the starting node to each destination.

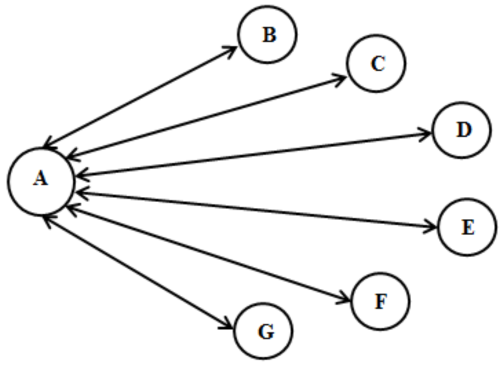

Figure 1. An Illustration for Initial Allocation

As shown in Figure 1, the vehicle starts at the depot, node A, and will go to node B and come back to the depot. Another vehicle will start from the depot, node A, and will go to node C and come back to the depot. Another vehicle will start from the depot, node A, and will go to node D and come back to the depot. Another vehicle will start from the depot, node A, and will go to node E and come back to the depot. Another vehicle will start from the depot, node A, and will go to node F and come back to the depot. And another vehicle again will start from the depot, node A, and will go to node G and come back to the depot.

Step 3: Calculate the net savings for each pair of nodes as given below. Use the formula $S_{ij} = C_{1i} + C_{1j} - c_{ij}$.

Paired nodes	Savings S_{ij}
B, C	S_{BC} = 34.5 + 20.6 – 44.8 = 10.3
B, D	S_{BD} = 34.5 +14.9 – 47.1 = 2.3
B, E	S_{BE} = 34.5 + 20.7 – 54.4 = 0.8
B, F	S_{BF} = 34.5 + 33.9 – 67.2 = 1.2
B, G	S_{BG} = 34.5 + 40.7 – 73.0 = 2.2
C, D	S_{CD} = 20.6 + 14.9 – 24.8 = 10.7
C, E	S_{CE} = 20.6 + 20.7 – 33.2 = 8.1
C, F	S_{CF} = 20.6 + 33.9 – 38.0 = 16.5
C, G	S_{CG} = 206 + 40.7 – 48.9 = 12.4
D, E	S_{DE} = 14.9 + 20.7 – 16.6 = 19

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D, F $S_{DF} = 14.9 + 33.9 - 21.4 = 27.4$

D, G $S_{DG} = 14.9 + 40.7 - 27.2 = 28.4$

E, F $S_{EF} = 20.7 + 33.9 - 16.1 = 38.5$

E, G $S_{EG} = 20.7 + 40.7 - 22.9 = 38.5$

F, G $S_{FG} = 33.9 + 40.7 - 10.1 = 64.5$

Then construct a half matrix with the net savings.

	B	C	D	E	F	G
A	-	-	-	-	-	-
	B	10.3	2.3	0.8	1.2	2.2
		C	10.7	8.1	16.5	12.4
			D	19	27.4	28.4
				E	38.5	38.5
					F	64.5

Step 4: Introduce the indicator I for the initial round trip allocation.

	B	C	D	E	F	G
A	$I_{AB} = 2$ -	$I_{AC} = 2$ -	$I_{AD} = 2$ -	$I_{AE} = 2$ -	$I_{AF} = 2$ -	$I_{AG} = 2$ -
	B	10.3	2.3	0.8	1.2	2.2
		C	10.7	8.1	16.5	12.4
			D	19	27.4	28.4
				E	38.5	38.5
					F	64.5

The indicator I tell if the two nodes are directly linked. The link can be from either node A (node 1) to any node *j* or it can be between any pair of nodes i and j (only if $i \neq 1$ and $i \neq j$) such that when a vehicle travels from node A to node j and then returns to node A then, I=2. That is, a round trip will have I=2. So, notice the half matrix above, the I_{AB}, I_{AC}, I_{AD}, I_{AE}, I_{AF}, and I_{AG} are all equal to 2 because AB, AC, AD, AE, AF, and AG are the initial round trip.

Step 5: Select the cell with maximum net savings.

	B	C	D	E	F	G
A	$I_{AB} = 2$ -	$I_{AC} = 2$ -	$I_{AD} = 2$ -	$I_{AE} = 2$ -	$I_{AF} = 2$ -	$I_{AG} = 2$ -
	B	10.3	2.3	0.8	1.2	2.2
		C	10.7	8.1	16.5	12.4
			D	19	27.4	28.4
				E	38.5	38.5
					F	64.5

From the half matrix with the indicator I, it shows that cell (F, G) or (G, F) has a maximum savings of 64.5 so the researchers link (F, G) after verifying the conditions 5.1, 5.2, and 5.3 given in Step 5.

- In condition 5.1, I_{AF} and I_{AG} are greater than 0 and both have a value equal to 2.
- In condition 5.2, nodes F and G are not on the same node.
- In condition 5.3, there is no constraint that is mentioned for this problem.

Hence, the cell (F, G) meets all the above conditions so the researchers assigned $I_{FG} = 1$ to the cell (F, G). And the indicator values of I_{AF} and I_{AG} will also change from 2, it becomes 1. Look at the half matrix below for the updated net savings matrix.

	B	C	D	E	F	G
A	$I_{AB} = 2$ -	$I_{AC} = 2$ -	$I_{AD} = 2$ -	$I_{AE} = 2$ -	$I_{AF} = 1$ -	$I_{AG} = 1$ -
	B	10.3	2.3	0.8	1.2	2.2
		C	10.7	8.1	16.5	12.4
			D	19	27.4	28.4
				E	38.5	38.5
					F	$I_{FG} = 1$ 64.5

The researchers repeated the process in step 5 until they found the feasible route. The table below represents the feasible route found in Vehicle Routing Problem using Clarke-Wright method.

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	B	C	D	E	F	G
A	$I_{AB} = 1$ -	$I_{AC} = 0$ -	$I_{AD} = 1$ -	$I_{AE} = 0$ -	$I_{AF} = 0$ -	$I_{AG} = 0$ -
	B	$I_{BC} = 1$ 10.3	2.3	0.8	1.2	2.2
		C	$I_{CD} = 1$ 10.7	8.1	16.5	12.4
			D	19	27.4	28.4
				E	$I_{EF} = 1$ 38.5	$I_{EG} = 1$ 38.5
					F	$I_{FG} = 1$ 64.5

Using the Branch & Bound Method

Using the data in table 1, the researchers performed the first step on getting the Lower Bound. First gets the minimum entry in a row then subtracts it from all the entries in a row which introduces a zero into a row. The minimum entry in row 1 (A) is 14.9, in row 2 (B) is 34.5, in row 3 (C) is 20.6, in row 4 (D) is 14.9, in row 5 (E) is 16.1, in row 6 (F) is 10.1, and in row 7 (G) is 10.1. Which the total amount of minimum entry row is 121.2. See the reduce matrix below.

	A	*B*	*C*	*D*	*E*	*F*	*G*
A	∞	19.6	5.7	0	5.8	19.0	25.8
B	0	∞	10.3	12.6	19.9	32.7	38.5
C	0	24.2	∞	4.2	12.6	17.4	28.3
D	0	32.2	9.9	∞	1.7	6.5	12.3
E	4.6	38.3	17.1	0.5	∞	0	6.8
F	23.8	57.1	27.9	11.9	6.0	∞	0
G	30.6	62.9	38.8	17.1	12.8	0	∞

From the matrix, they performed the next way to finally get the Lower Bound. First, they looked for a column that has no zero entry. Then after that, they get the minimum number in each column that has no zero entry and subtracted it from all the entries in the column. The minimum entry in column 2 (B) is 19.6, in column 3 (C) is 5.7, and in column 5 (E) is 1.7. Which the total amount of minimum entry column is 27. See the reduce matrix below.

	A	*B*	*C*	*D*	*E*	*F*	*G*
A	∞	0	0	0	4.1	19.0	25.8
B	0	∞	4.6	12.6	18.2	32.7	38.5
C	0	4.6	∞	4.2	10.9	17.4	28.3
D	0	12.6	4.2	∞	0	6.5	12.3
E	4.6	18.7	11.4	0.5	∞	0	6.8
F	23.8	37.5	22.2	11.9	4.3	∞	0
G	30.6	43.3	33.1	17.1	11.1	0	∞

Adding the total amount of minimum entry row and the total amount of minimum entry column will give us the value for Lower Bound. The Lower Bound is 148.2 by adding 121.2 and 27 the values of the total amount of minimum row and column.

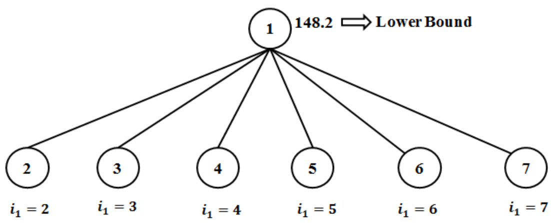

Figure 2. Illustration of lower Bond 148.2

The total amount subtracted from row and column is 148.2. Therefore, the minimum cost of the tour is at least 148.2 and the reduced matrix is:

	A	*B*	*C*	*D*	*E*	*F*	*G*
A	∞	0	0	0	4.1	19.0	25.8
B	0	∞	4.6	12.6	18.2	32.7	38.5
C	0	4.6	∞	4.2	10.9	17.4	28.3
D	0	12.6	4.2	∞	0	6.5	12.3
E	4.6	18.7	11.4	0.5	∞	0	6.8
F	23.8	37.5	22.2	11.9	4.3	∞	0
G	30.6	43.3	33.1	17.1	11.1	0	∞

The reduce cost matrix at node 2 of the search tree following path (A, B) is:

	A	*B*	*C*	*D*	*E*	*F*	*G*
A	∞	∞	∞	∞	∞	∞	∞
B	∞	∞	4.6	12.6	18.2	32.7	38.5
C	0	∞	∞	4.2	10.9	17.4	28.3
D	0	∞	4.2	∞	0	6.5	12.3
E	4.6	∞	11.4	0.5	∞	0	6.8
F	23.8	∞	22.2	11.9	4.3	∞	0
G	30.6	∞	33.1	17.1	11.1	0	∞

Reducing the cost matrix M by subtracting 4.6 from row 1(A) and subtracting

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0.5 from column 4 (D) where give a total amount of T as 5.1. Then the matrix after reducing is:

$$
\begin{array}{c|ccccccc}
 & A & B & C & D & E & F & G \\
\hline
A & \infty & \infty & \infty & \infty & \infty & \infty & \infty \\
B & \infty & \infty & 0 & 7.5 & 13.6 & 28.1 & 33.9 \\
C & 0 & \infty & \infty & 3.7 & 10.9 & 17.4 & 28.3 \\
D & 0 & \infty & 4.2 & \infty & 0 & 6.5 & 12.3 \\
E & 4.6 & \infty & 11.4 & 0 & \infty & 0 & 6.8 \\
F & 23.8 & \infty & 22.2 & 11.4 & 4.3 & \infty & 0 \\
G & 30.6 & \infty & 33.1 & 16.6 & 11.1 & 0 & \infty
\end{array}
$$

The minimum cost of $l(2) = l(1) + M(A,B) + T = 148.2 + 0 + 5.1 = 153.3.$ It indicates that route A to B has a minimum distance of 153.3. Then,

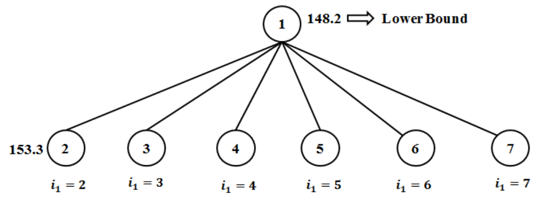

Figure 3. An Illustration for route A to B

Repeating this process, the cost matrix can be reduced. The tree below is a representation of a final reduced cost matrix and the feasible route we found is the distance A-C-D-E-F-G-B-A.

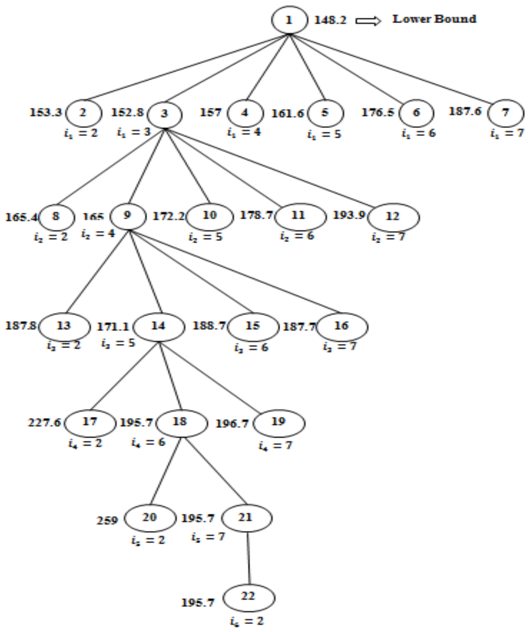

Figure 4. Illustration of route A-C-D-E-F-G-B

The researchers showed the process in finding the feasible route of the vehicle routing problem using the two methods, Clark-Wright Method and Branch & Bound Method. Clark-Wright Method has found a feasible route A-G-F-E-D-C-B-A, that is Dagupan- Asingan- Binalonan- Manaoag- Santa Barbara- Basista- Sual- Dagupan. Adding the distances of the feasible route found, which is 40.7, 10.1, 16.1, 16.6, 24.8, 44.8, and 34.5 will give a result of 187.6 kilometers. Meanwhile, Branch & Bound Method has found the feasible route is A-C-D-E-F-G-B-A, which is Dagupan- Basista- Santa Barbara- Manaoag- Binalonan- Asingan- Sual- Dagupan. And adding the distances of the feasible route found in Branch & Bound Method, which gives a result of 20.6 + 24.8 + 16.6 + 16.1 + 10.1 + 73.0 + 34.5 = 195.7 kilometers. Using the given data notice that between Clark-Wright Method and Branch & Bound Method, the Clark-Wright Method gives a shorter distance with a minimum distance of 187.6 kilometers. Therefore, comparing these two, we can conclude that Clark-Wright Method is more convenient to use in VRP than Branch & Bound Method. Using Clarke-Wright Method, the best route in delivering the products from different municipalities in Pangasinan will be Dagupan- Asingan- Binalonan- Manaoag- Santa Barbara- Basista- Sual- Dagupan with a total distance of 187.6 kilometers denoted as $\sum\sum X_{ij}C_{ij} = 187.6$. The illustration using a geographical map can be found in the Appendix.

CONCLUSION AND RECOMMENDATION

The deliveries of JRS Express in the different municipalities of Pangasinan were used as the data with the specific town as a node. Clarke- Wright Method and Branch & Bound Method have been used for solving the Vehicle Routing Problem. It shows that one of the methods gives the optimal route for the deliveries. It was observed that Clarke- Wright Method, with the minimum distance of 187.6 kilometers, is much better than Branch & Bound Method, with a distance of 195.7 kilometers, not just because Clarke- Wright Method has a short way in finding the feasible route but it has the best route that has a minimum distance.

Based on the application of the two methods in Vehicle Routing Problem which is the Clarke-Wright Method and Branch & Bound Method, we conclude that the Clarke-Wright Method is more convenient and effective to be used in Vehicle Routing Problem than Branch & Bound Method. Therefore, the best route in delivering the products from different municipalities of Pangasinan using Clarke-Wright Method and Branch & Bound Method from Dagupan-Asingan-Binalonan-Manaoag-Santa Barbara-Basista-Sual and back to Dagupan with a total distance of 187.6 kilometers.

The researchers highly recommend to the future researcher to use Constraint Programming Algorithm for Vehicle Routing Problem and compare it to the Clarke-Wright Method or to Branch & Bound Method to see the differences present in another method. The researchers also recommend to the future researcher to use an algorithm such as Ant Algorithm, 2-phase algorithm, Genetic Algorithm, Route-First and Tabu Search on VRP.

APPENDIX

The figure below is a geographical map illustration of the best route found in solving the Vehicle Routing Problem using the Clarke-Wright Method.

Figure 5. Directed Graph for the Deliveries per Municipalities

The figure below is an illustration of the best route found in solving vehicle routing problem using the Clarke-Wright Method with distances in each direction.

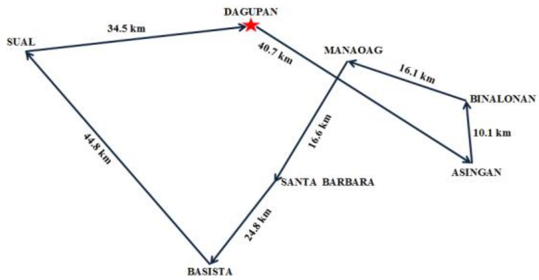

Figure 6. Weighted Graph for the Deliveries per Municipalities

REFERENCES

Kenneth H. Rosen 1999 "*Discrete Mathematics and its Applications*" Fourth Edition, New York, WCB/Mcgraw-Hill Companies, Inc. pp.439-440, pp.476

Kenneth H. Rosen 2008 "*Discrete Mathematics and its Applications*" Sixth Edition, New York, WCB/Mcgraw-Hill Companies, Inc. pp.490-491

Kenneth H. Rosen 2012 "*Discrete Mathematics and its Applications*" Seventh Edition, New York, WCB/Mcgraw-Hill Companies, Inc. pp.575-579

Susanna S. Epp 2011 "*Discrete Mathematics with Applications*" Fourth Edition

C. Barnhart and G. Laporte (Eds.) *Handbook in OR & MS*, Vol. 14 Copyright © 2007 Elsevier B.V. all rights reserved DOI: 10.1016/S0927-0507(06)14006-2

M. Gendreu and O. Braysy, 2008. *Vehicle Routing Problem with Time Windows, Part I: Route Construction and Local Search Algorithm*. Norway, INFORMS (Institute of Operation Research and Management)

An Improved Clarke and Wright Algorithm to Solve the Capacitated Vehicle Routing Problem by Louis Cacceta, Mamoon Alameen, Muhammed Abdul-Niby, 2013

New Enhancement for Clarke-Wright Savings Algorithm to Optimize the Capacitated Vehicle Routing Problem by Tanktikom Pichpibul and Ruengsak Kawtummachai

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Vehicle Routing Problem Mathematical and Tonci Caric and Hrvoje Gold, 2008

Computer Modelling by Alvina Kek and Qiang Meng, 2007

B. Kell, 2014. Retrieved from; http:// math.cmu.edu/-bkell/21257-2014f/tsp.pdf

Neo.lcc.umma.es/vrp/solution-methods/

Popular Online Website for shopping in the Philippines by Gelyka Ruth R. Dumaraos, 2016

The History of E-commerce: How did it all begin? By Miva, 2011

"*Directed Graph Definitions*" from Math Insights by Duane Q. Nykamp

"*Adjacency Matrix*" from Math World by Eric W. Weinstein, 2000

"*History of Internet in the Philippines*" from Department of Information and Communication Technology, 2015

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