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OPTIMAL VEHICLE ROUTING SYSTEM FOR RELIEF GOODS DISTRIBUTION IN THE 4TH DISTRICT OF NUEVA ECIJA, PHILIPPINES

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ABSTRACT – Being a lowland province, Nueva Ecija experiences massive flooding during typhoons. This causes the residents to be stuck in their homes without enough food and personal care items. To relieve such problem, the local government delivers relief goods to every barangay. However, there is no existing system to follow in the implementation of the said activity. Hence, an efficient system in delivering the relief goods was developed in this study. In particular, this paper provides a set of routes for relief goods distribution such that the demands of all the barangays in the 4th district of Nueva are served and total travel time is minimized. This problem is classified as a Vehicle Routing Problem (VRP), an NP-hard problem. Primarily, Clarke and Wright's Savings Algorithm (CW) was used in determining the set of routes. The Improved Clarke and Wright's Algorithm (ICW) was then used to further improve the primary solutions derived from CW. ICW is a hybridized version of CW which makes use of tournament and roulette wheel selection. On the average, the ICW reduced the total travel time by 1.36%. Furthermore, a computer program called "iCW solver" was created for the implementation of the algorithms which can also be used to obtain vehicle routing system for other localities. With an efficient routing system, it can mitigate the loss of lives and devastating effects to humans during disasters brought about by natural calamities.

Key words: vehicle routing problem, relief distribution, improved Clarke and Wright's Savings algorithm

INTRODUCTION

Nueva Ecija is a province in the Philippines located in the Central Luzon region. It consists of 27 municipalities and five cites, and is divided into four congressional districts. Classified as lowland, the province experiences natural disasters such as flood and landslides caused by typhoons. Particularly, the 4th District is a flood-prone area. Due to this adverse event, the roads are blocked for quite some time.

Residents are trapped in their homes and do not have an easy access to the market, causing lack of basic needs such as food and personal care items. Natural disasters can really interrupt community functioning which may cause human, property, economic or environmental losses (Hsueh, Chen, & Chou2, 2008; Torre, Dolinskaya, & Smilowitz, 2011; Jitt-Aer, 2016; Wisetjindawata, Itob, Fujitaa, & Eizoa, 2014). In the Philippines, problems on the distribution always surfacing during typhoon (Pazzibugan, 2013; Laude, 2013; Branigan & Hodal, 2013).

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According to the Local Government Code of 1991, each local government has funds allocated for calamity relief operations. With a given set of vehicles, each municipality is tasked to provide and distribute relief goods for every household of all its barangays during natural disasters. However, there is no existing system to follow in the implementation of the said activity. For this reason, determining the optimal sets of routes the vehicles have to traverse in order to distribute the relief goods to the barangays of each municipality and city in the district in the shortest time possible is needed. With an efficient routing system, distribution of usually limited relief commodities can be easier and faster especially in the delivery of critical supplies reducing the adverse effects of post-disaster problems.

The problem can be regarded as a vehicle routing problem (VRP). The VRP, also known as “Truck Dispatching Problem”, was first introduced by Dantzig and Ramser in 1959. They used it to determine the optimal set of routes for a specific number of vehicles in delivering gasoline to the service stations from the terminal (Dantzig & Ramser, 1959). VRP can be described as set of vehicles with known capacity delivering goods from a source to customers with known demands and locations in the shortest possible time. Being an NP-hard problem, heuristics have been developed to provide solution to VRP. In 1964, Clarke and Wright introduced one of these heuristics named as the Clarke and Wright Saving Algorithm (CW). CW is one of the best and widely used method in solving VRP because of its speed, simplicity and accuracy (Cordeau, et al., 2007). In 2013, De Lara et al. conducted a study about determining the optimal route of vehicles delivering relief goods to the calamity-prone areas in region IV-A. They used Clarke and Wright’s Savings Algorithm in determining the routes of the vehicles from the warehouses to the affected areas (De Lara, et al., 2013).

Although Clarke and Wright Saving Algorithm (CW) is the mostly used method in obtaining solutions (Clarke & Wirght, 1964; Pichpibula & Kawtummachaib, 2012) of the VRP, the solutions can be enhanced by using Improved Clarke and Wright Savings Algorithm (ICW) (Pichpibula & Kawtummachaib, 2012). The result of ICW was compared against 14 other algorithms including CW. The result of the comparison showed that the proposed ICW algorithm exceed the results obtained using CW. The algorithm was shown to competitive or even outdone newly developed heuristics. On average, the deviation between the solution obtained and the optimal solution is 0.14% (Pichpibula & Kawtummachaib, 2012).

The general objective of this study is to provide the 4th district of Nueva Ecija a set of routes for the relief goods distribution that will minimize the total delivery time and satisfy the demand of each barangay. In particular, the goal of disaster relief vehicle routing problems (VRPs) is to mitigate the loss of lives and devastating effects to humans during disasters brought about by natural calamities. With the use of both CW and ICW, the optimal routing system can be determined. Results of this study can serve as a mathematical basis for improving the system of distribution of relief goods in the province of Nueva Ecija. To our knowledge, there are no other researches about application of ICW in disaster vehicle routing problem.

STUDY AREA AND METHODS

The study considered the city and municipalities in the 4th District of Nueva Ecija. However, due to unavailability of an updated political map, the municipality of General Tinio was not included in this study.

The assumptions of the study are as follows:

1. It is assumed that there is only one delivery vehicle assigned to each municipality and city;
2. all delivery vehicles are of equal carrying capacity;
3. the barangays to be served are of equal priority;
4. there is little to no traffic while delivering the relief goods; and
5. the maximum time allowed for each route is 120 minutes.

The methodology is composed of four sections; data collection, vehicle routing problem model, CW and ICW algorithms and program creation. These are discussed in details as follow:

A. Data Collection

The data used in this study were provided by the offices of the Governor's Provincial Disaster Risk Reduction and Management Office (PDRRMO), Provincial Social Welfare and Development Office (PSWDO) and Provincial Planning and Development Office (PPDO). The information collected were the following:

1. relief goods packaging size
2. number of household per municipality and barangay (NSO, 2010)
3. political map of each municipality and city

Networks were drawn as representations of each municipality and city within the district. The nodes denote the barangays while the edges denote the direct path between two adjacent nodes. A municipal or city hall was labeled as node 0. Each edge has corresponding weights computed by approximating the travel time (in minutes) between two nodes, considering that there is little to no traffic situation (See Appendix A). The computation of the approximate travel time between node *i* and node *j* is as follows:

$$travel\ time\left(i,\ j\right) = \frac{distance}{speed\ of\ delivery\ truck}$$

$$where\ i,\ j = 1, 2, \ldots, N\ or\ the\ number\ of\ barangays\ in\ municipal\ city$$

The distance between node *i* and node *j* was obtained using Google Maps while the speed of the delivery truck considered for this study is 30 km/hr. The number of households per barangay for the year 2015 was forecasted using the existing data and exponential smoothing algorithm. The carrying capacity of the delivery truck is 2500 packs of relief goods.

The following are the network representations of each municipality and city and their respective node labels.

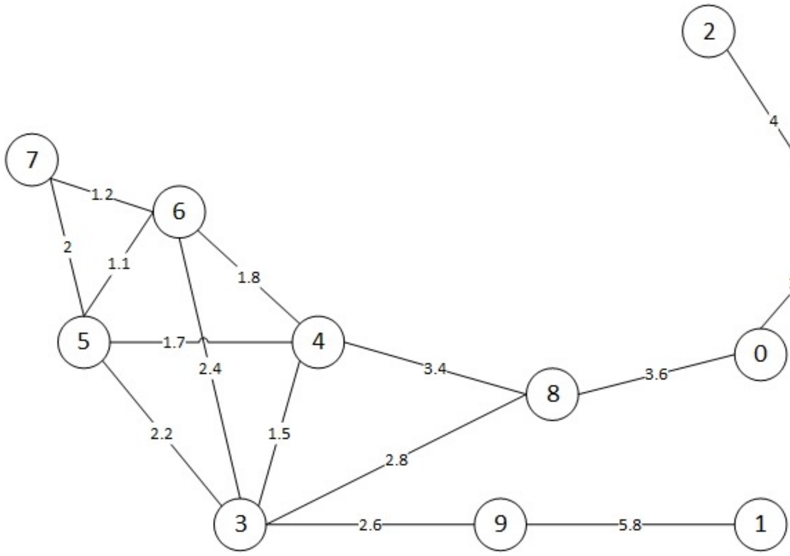

Figure 1. Network Representation for Municipality of Peñaranda

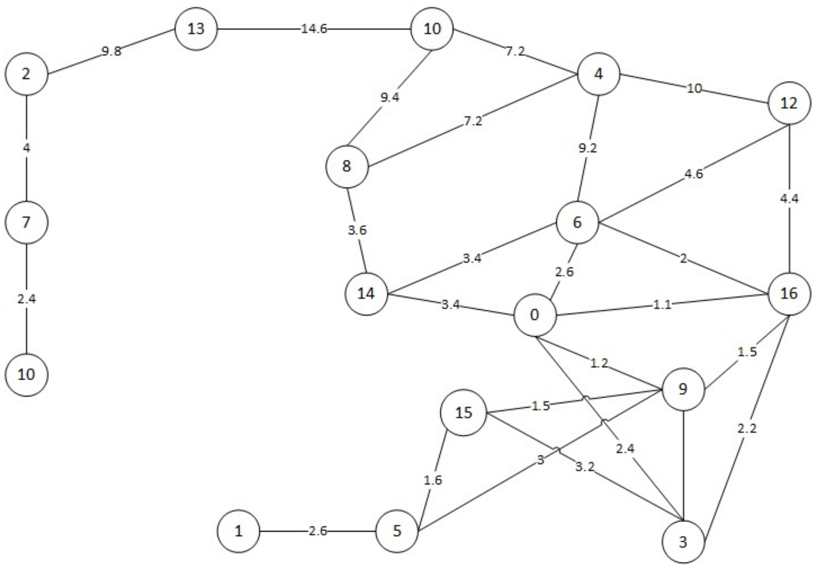

Figure 2. Network Representation for Municipality of San Antonio

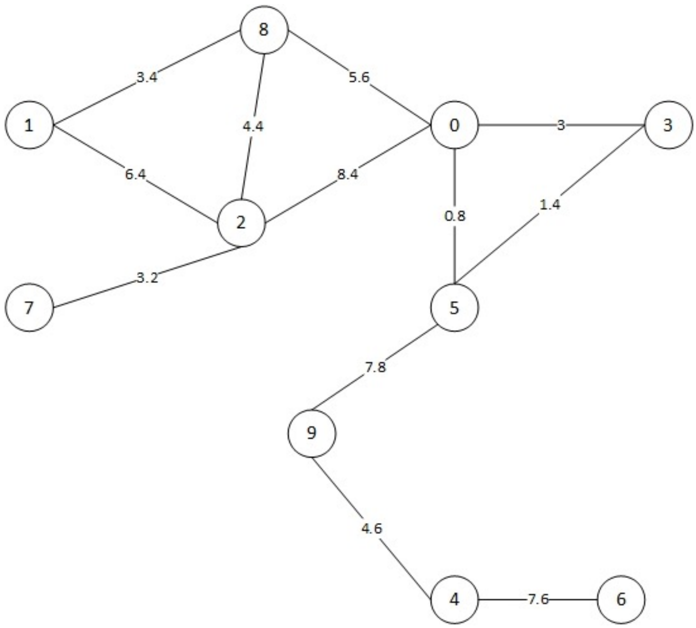

Figure 3. Network Representation for Municipality of San Isidro

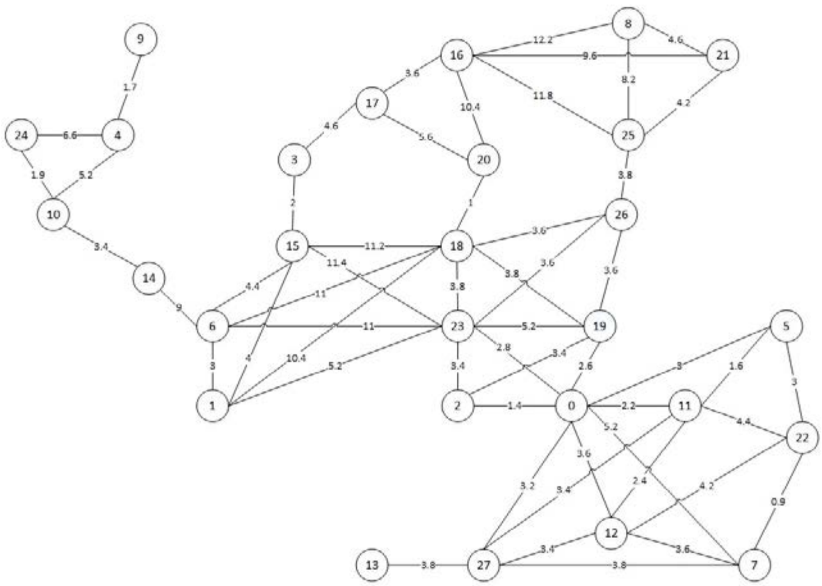

Figure 4. Network Representation for Municipality of Jaen

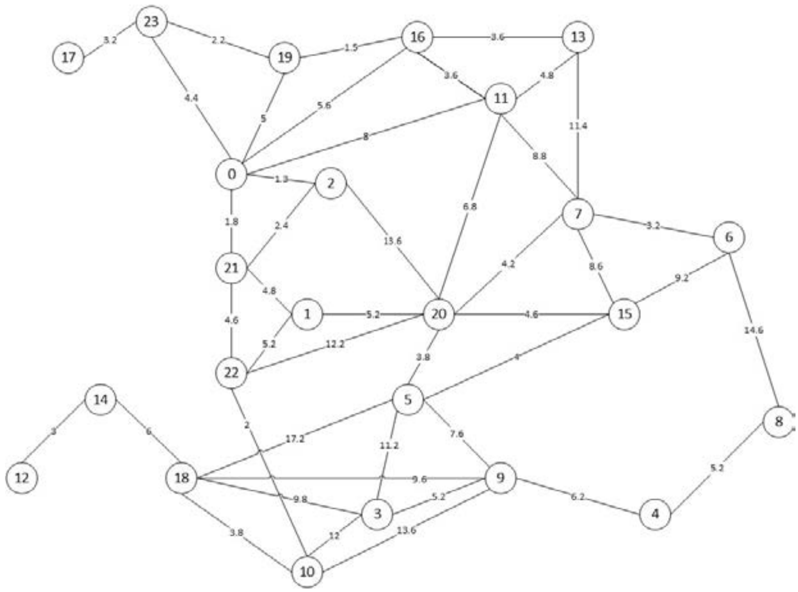

Figure 5. Network Representation for City of Gapan

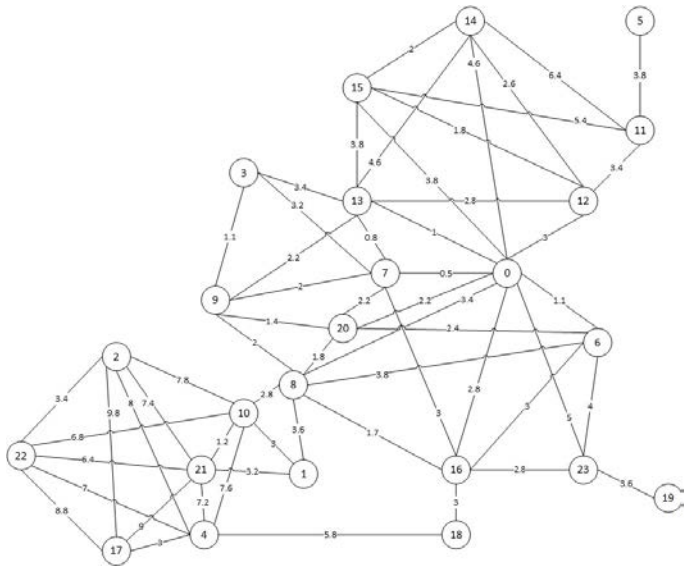

Figure 6. Network Representation for Municipality of Cabiao

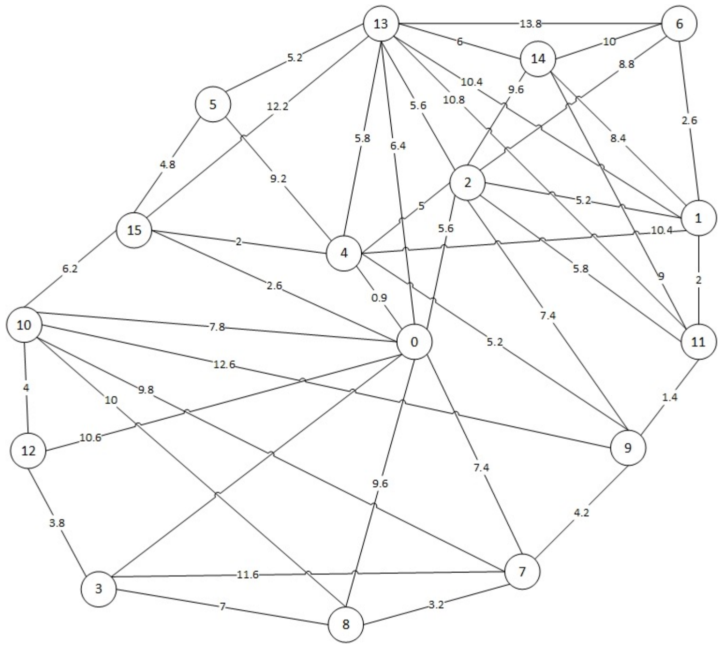

Figure 7. Network Representation for Municipality of San Leonardo

Table 1. Node Labels of Network Representation for Municipality of Peñaranda

Node	Area
0	Peñaranda Municipal Hall
1	Callos
2	Las Pinas
3	Poblacion I
4	Poblacion II
5	Poblacion III
6	Poblacion IV
7	Santo Tomas
8	Sinasahan
9	San Josef
10	San Mariano

Table 2. Node Labels of Network Representation for Municipality of San Antonio

Node	Area	Node	Area
0	San Antonio Municipal Hall	9	Poblacion
1	Buliran	10	San Francisco
2	Cama Juan	11	San Jose
3	Julo	12	San Mariano
4	Lawang Kupang	13	Sta Barbara
5	Luyos	14	Sta Cruz
6	Maugat	15	Sto Cristo
7	Panabingan	16	Tikiw
8	Papaya		

Table 3. Node Labels of Network Representation for Municipality of San Isidro

Node	Area
0	San Isidro Municipal Hall
1	Alua
2	Calaba
3	Malapit
4	Mangga
5	Poblacion
6	Pulo
7	San Roque
8	Sto Cristo
9	Tabon

Table 4. Node Labels of Network Representation for Municipality of Jaen

Node	Area	Node	Area
0	Jaen Municipal Hall	14	Pamacpacan
1	Calabasa	15	Pakul
2	Dampulan	16	Pinanggaan
3	Hilera	17	Ulanin-Pitak
4	Imbunia	18	Putlod
5	Apo Esquivel	19	Ocampo Rivera
6	Lambakin	20	San Jose
7	Langla	21	San Pablo
8	Magsalisi	22	San Roque
9	Malabon Kaingin	23	San Vicente
10	Marawa	24	Sta Rita
11	Antonino	25	Sto Tomas North
12	San Josef	26	Sto Tomas South
13	Niyugan	27	Sapang

Table 5. Node Labels of Network Representation for City of Gapan

Node	Area	Node	Area
0	Gapan City Hall	12	Marelo
1	Balante	13	Pambuan
2	Bayanihan	14	Parcutela
3	Bulak	15	Puting Tubig
4	Bungo	16	San Lorenzo
5	Kapalangan	17	San Nicolas
6	Mabunga	18	San Roque
7	Maburak	19	San Vicente
8	Macabaklay	20	Sta Cruz
9	Mahipon	21	Sto Cristo Norte
10	Malimba	22	Sto Cristo Sur
11	Mangino	23	Sto Nino

Table 6. Node Labels of Network Representation for Municipality of Cabio

Node	Area	Node	Area
0	Cabiao Municipal Hall	12	San Fernando S
1	Bagong Buhay	13	San Gregorio
2	Bagong Sikat	14	San Juan N
3	Bagong Silang	15	San Juan S
4	Concepcion	16	San Roque
5	Entablado	17	San Vicente
6	Maligaya	18	Santa Rita
7	Natividad N	19	Sinipit
8	Natividad S	20	Polilio
9	Palasinan	21	San Carlos
10	San Antonio	22	Santa Isabel
11	San Fernando N	23	Santa Ines

Table 7. Node Labels of Network Representation for Municipality of San Leonardo

Node	Area	Node	Area
0	San Leonardo Municipal Hall	8	Nieves
1	Bonifacio	9	Rizal
2	Burgos	10	San Anton
3	Castellano	11	San Bartolome
4	Diversion	12	San Roque
5	Magpapalayok	13	Tabuating
6	Mallorca	14	Tagumpay
7	Mambangnan	15	Tambo-Adorable

B. Vehicle Routing Problem (VRP) Model

The mathematical model for the relief goods distribution formulated as a VRP model was developed and was presented in the following sequence.

Parameters

$$N = \text{number of barangays}$$

$$v = \text{number of vehicles}$$

$$d_i = \text{demand of barangay } i,\ i = 0, 1, 2, \ldots, N$$

$$t_{i,j} = \text{travel time between barangay } i \text{ and barangay } j,\ i, j = 0, 1, 2, \ldots, N$$

$$p_k = \text{capacity of vehicle } k, \text{ where } k = 1, \ldots, V$$

Decision variables

$$w_i^k = \begin{cases} 1, & \text{if vehicle } k \text{ visits barangay } i, \\ 0, & \text{otherwise} \end{cases} \quad \text{where } i = 0, 1, 2, \ldots, N$$

$$x_{ij}^k = \begin{cases} 1, & \text{if vehicle } k \text{ travels from barangay } i \text{ to barangay } j, \\ 0, & \text{otherwise} \end{cases} \quad i, j = 0, 1, 2, .., N, k = 1, \ldots, V$$

Mathematical Model

$$Minimize \sum_{i=0}^{N} \sum_{j=0}^{N} \sum_{k=1}^{V} t_{ij} x_{ij}^{k}$$

The objective is to minimize the total travel time of all the vehicles.

$$\sum_{k=1}^{V} w_i^k = 1 \text{ for } i = 0,1,2,...,N \qquad (1)$$

Constraint (1) ensures that each barangay is assigned to only one vehicle.

$$\sum_{j=0}^{N} x_{ij}^k = w_j^k \text{ for } i = 0,1,2,...,N \text{ and } k = 1,...,V \qquad (2)$$

$$\sum_{i=0}^{N} x_{ij}^k = w_j^k \text{ for } i = 0,1,2,...,N \text{ and } k = 1,...,V \qquad (3)$$

Constraints (2) and (3) guarantee that each barangay is visited and left with a same vehicle.

$$\sum_{i=0}^{N} d_i w_i^k \le p_k \text{ for } k = 1,...,V \qquad (4)$$

Constraint (4) ensures that a vehicle does not exceed its carrying capacity.

$$\sum_{i=0}^{N} x_{i0}^k \le 1 \text{ for } k = 1,...,V \qquad (5)$$

$$\sum_{j=0}^{N} x_{0j}^k \le 1 \text{ for } k = 1,...,V \qquad (6)$$

Constraint (5) and (6) guarantee that vehicle availability is not exceeded.

C. Classical Clarke and Wright Savings Algorithm and Improved Clarke and Wright's Algorithm

Parallel version of CW was used because generally, it produces more efficient results than the sequential version. Both the classical and the improved were used in solving the VRP.

The step-by-step procedure of the parallel version of CW is as follows.

1. Given the distance between nodes, distance matrix is constructed.
2. The savings value matrix is formed. Each savings value between customer i and j is computed as $s_{i,j} = d_{0,i} + d_{j,0} - d_{i,j}$

Note: $d_{0,i}$ is the distance between the source node and node i

3. Savings list is sorted in decreasing order.

4. Starting from top of savings list, it should be decided whether a link *(i,j)* is included in a route or not.

   A route is constructed if either of the following constraints is satisfied.

   i. *i* and *j* are not included in an existing route;

   ii. either *i* or *j*, but not both, is included in a route but that node is not interior; or

   iii. both nodes *i* and *j* are already included in an existing route but neither is interior.

   Violating any of these constraints means that link *(i,j)* must not be included in the route. Also, sum of the demands of the nodes in the route must not exceed the vehicle capacity.

   This step is repeated until the savings list is exhausted or all the customers have already been served.

5. Lastly, total distance traveled is computed.

ICW was then used to further improve the solutions of CW. Its algorithm is an iterative improvement of the classical CW which incorporates tournament and roulette wheel selection. New savings lists were generated and the one with the most improvement was chosen as the solution. The step-by-step procedure is as follows:

1. Given the distance between nodes, the distance matrix is constructed.

2. The savings value matrix is formed. Each savings value between customer *i* and *j* is computed as $s_{i,j} = d_{0,i} + d_{j,0} - d_{i,j}$

Note: $d_{0,i}$ is the distance between the source node and node i

3. The savings list is sorted in decreasing order.

   A random number between 2 to 6 for the tournament size *T* is generated. If the savings list has less than 6 elements, adjust the range of the tournament size number. Get a set of savings values of size *T* from the savings list generated using CW.

4. The selection probability and the cumulative probability for savings number n are computed.

$$p_n = {}^{s_n}\Big/_{\sum i \in T^{s_i}} \ \ for\ n \in T \qquad\qquad q_n = \sum_{i \in n} p_i \ for\ n \in T$$

Table 8. Number of elements in the savings list and respective interval of tournament size

Number of elements in the savings list	Range of tournament size
≥ 6	2 – 6
5	2 – 5
4	2 – 4
3	2 – 3
2	2
1	1

5. A random number *r* between 0 and 1 is generated. If $0 \le r \le q_1$, choose S_1.

   a. For $2 \le n \le T$, S_n is chosen such that $q_{n-1} \le r \le q_n$.

6. The chosen S_n is in the new savings list and should be removed from the previous list.

7. Steps 4 – 7 are repeated until all S_n are in the new savings list.

8. Starting from top of the new savings list, a decision must be made whether a link *(i,j)* will be included in a route or not.

   A route is constructed if either of the following constraints is satisfied.

   i. *i* and *j* are not included in an existing route;

   ii. either *i* or *j*, but not both, is included in a route but that node is not interior; or

   iii. both nodes i and j are already included in an existing route but neither is interior.

   Violating any of these constraints means that link *(i,j)* must not be included in the route. Also, sum of the demands of the nodes in the route must not exceed the vehicle capacity.

   This step is repeated until the savings list is exhausted or all the customers have already been served.

9. The total distance traveled is computed.

10. Steps 1-9 are repeated *n* times (maximum iterations used for the study was 50; *n=50*).

11. All the results are compared and the solution with most improvement is chosen.

The two algorithms were computed by a program particularly created for this study. Floyd's Algorithm was also used to compute the total time traveled per route.

D. Creation of the Computer Program

Since there is no available software, a computer program was created for the implementation of both CW and ICW. The software is called “iCW” solver.

RESULSTS AND DISCUSSION

Each network indicated in the appendix section was analyzed using iCW solver. The results included outputs from both CW and ICW for each barangay in each municipality.

Below are the solutions obtained using CW and ICW. Tables 9-22 showed the routes that the assigned vehicle has to traverse to serve nodes. The corresponding travel time for each route was also indicated. Table 23 summarized the comparison of the results for each municipality. In analyzing the tables, consider Table 22. The delivery vehicle must traverse the route indicated in column 2 to serve the barangays/nodes in column 3 and go back to the depot. Hence, the route starts and ends in node 0. The travel time (in minutes) in doing this is indicated in column 3. For instance, the delivery vehicle must traverse the route 0-10-8-0 (San Leonardo Municipal Hall-San Anton-Nieves-San Leonardo Municipal Hall) to serve the demands of barangays 8 and 10 and go back to the depot. The time to accomplish the said task is 27.4 minutes. The total time to serve the demands of all the barangays is 146.7 minutes. The routes in column 2 are traversed in no particular order. Moreover, it can be inferred from Table 23 that using the routes obtained from Improved Clarke and Wright’s Savings Algorithm to serve all the barangays of San Leonardo decreased the delivery time by 6.4 minutes or 4.18% of the original time. Similar interpretations can be inferred from Tables 9-21.

Applying ICW yielded either equal or better solutions compared to the solutions generated through the use of CW. On the average, ICW reduced the total travel time by 1.36%.

Table 9. Routes obtained with corresponding travel time and nodes served for the Municipality of Peñaranda using CW

Route	Nodes Served	Travel Time (in minutes)
0-8-5-6-7-5-8-0	5, 6, 7	**18.7**
0-8-3-4-3-9-1-9-3-8-0	3, 4, 9, 1	**32.6**
0-10-2-10-0-8-0	8, 2, 10	**18.4**
	TOTAL	**69.7**

Table 10. Routes obtained with corresponding travel time and nodes served for the Municipality of Peñaranda using ICW

Route	Nodes Served	Travel Time (in minutes)
0-8-5-6-7-5-8-0	5, 6, 7	18.7
0-8-3-4-3-9-1-9-3-8-0	3, 4, 9, 1	32.6
0-10-2-10-0-8-0	8, 2, 10	18.4
	TOTAL	69.7

Table 11. Routes obtained with corresponding travel time and nodes served for the Municipality of San Antonio using CW

Route	Nodes Served	Travel Time (in minutes)
0-9-15-9-0-14-8-10-13-10-8-14-0	8, 14	14
0-16-6-0	6, 16	5.7
0-16-12-4-6-0	4, 12	27.3
0-3-0	3	4.8
0-9-15-9-0	15	5.4
0-14-8-10-13-2-7-11-7-2-13-10-8-14-0	13, 2, 7, 11	94.4
0-9-5-1-5-9-0	1, 5, 9	13.6
0-14-8-10-8-14-0	10	32.8
	TOTAL	198

Table 12. Routes obtained with corresponding travel time and nodes served for the Municipality of San Antonio using ICW

Route	Nodes Served	Travel Time (in minutes)
0-9-15-9-0-14-8-10-13-10-8-14-0	8, 14	14
0-16-6-0	6, 16	5.7
0-16-12-4-6-0	4, 12	27.3
0-3-0	3	4.8
0-9-15-9-0	15	5.4
0-14-8-10-13-2-7-11-7-2-13-10-8-14-0	13, 2, 7, 11	94.4
0-9-5-1-5-9-0	1, 5, 9	13.6
0-14-8-10-8-14-0	10	32.8
	TOTAL	198

Table 13. Routes obtained with corresponding travel time and nodes served for the Municipality of San Isidro using CW

Route	Nodes Served	Travel Time (in minutes)
0-5-9-4-9-5-0	9,4	26.4
0-2-1-8-0	2,1	23.8
0-5-3-5-0	3	4.4
0-5-0	5	1.6
0-5-9-4-6-4-9-5-0	6	28
0-8-7-8-0	7	15.2
0-8-0	8	11.2
	TOTAL	110.6

Table 14. Routes obtained with corresponding travel time and nodes served for the Municipality of San Isidro using ICW

Route	Nodes Served	Travel Time (in minutes)
0-5-9-4-6-4-9-5-0	4, 6	34.8
0-8-7-8-0-5-9-5-0	7, 9	32.4
0-2-1-8-0	2,1	23.8
0-5-3-5-0	3	4.4
0-5-0	5	1.6
0-8-0	8	11.2
	TOTAL	108.2

Table 15. Routes obtained with corresponding travel time and nodes served for the Municipality of Jaen using CW

Route	Nodes Served	Travel Time (in minutes)
0-23-1-6-15-3-15-6-1-23-0	1, 6, 15, 3	33.4
0-19-18-20-17-16-8-25-26-19-0	17, 16, 8	47
0-7-22-5-0-23-1-6-14-10-4-9-4-10-14-6-1-23-0	7, 22, 4, 9	72.7
0-27-13-27-0	13, 27	14
0-19-26-25-21-25-26-19-0	19, 26, 25, 21	28.4
0-12-0-23-1-6-14-10-24-10-14-6-1-23-0	12, 14, 10, 24	57.8
0-11-5-0-23-18-20-18-19-0	11, 5, 23, 18, 20	21.8
0-2-0	2	2.8
	TOTAL	277.9

Table 16. Routes obtained with corresponding travel time and nodes served for the Municipality of Jaen using ICW

Route	Nodes Served	Travel Time (in minutes)
0-23-1-6-15-3-15-6-1-23-0	1, 6, 15, 3	33.4
0-19-18-20-17-16-21-8-25-26-19-0	17, 16, 8, 21	49
0-7-22-5-0-23-1-6-14-10-4-9-4-10-14-6-1-23-0	7, 22, 4, 9	72.7
0-27-13-27-0	13, 27	14
0-19-26-25-26-19-0	25, 26, 19	20
0-12-0-23-1-6-14-10-24-10-14-6-1-23-0	12, 14, 10, 24	57.8
0-11-5-0-23-18-20-18-19-0	11, 5, 23, 18, 20	21.8
0-2-0	2	2.8
	TOTAL	271.5

Table 17. Routes obtained with corresponding travel time and nodes served for the Gapan City using CW

Route	Nodes Served	Travel Time (in minutes)
0-21-1-20-7-6-7-20-1-21-0	6, 7	38.4
0-21-1-20-5-15	5, 15	36
0-21-22-10-18-9-4-8-4-9-18-10-22-21-0	4, 8, 10	66.4
0-21-22-10-3-9-18-10-22-21-0	3, 9	47.4
0-21-1-20-1-22-10-18-14-12-14-18-10-22-21-0	12, 14, 20	58.2
0-21-22-1-21-0	1, 22	18.2
0-23-0	23	8.8
0-2-0	2	2.6
0-21-0	21	3.6
0-19-0	19	10
0-23-17-23-0	17	15.2
0-16-0	16	11.2
0-11-0	11	16
0-21-22-10-18-10-22-21-0	18	24.4
0-16-13-16-0	13	18.4
	TOTAL	374.8

Table 18. Routes obtained with corresponding travel time and nodes served for the Gapan City using ICW

Route	Nodes Served	Travel Time (in minutes)
0-21-1-20-7-6-7-20-1-21-0	6, 7	38.4
0-21-1-20-5-15	5, 15	36
0-21-22-10-18-9-4-8-4-9-18-10-22-21-0	4, 8, 10	66.4
0-21-22-10-3-9-18-10-22-21-0	3, 9	47.4
0-21-1-20-1-22-10-18-14-12-14-18-10-22-21-0	12, 14, 20	58.2
0-21-22-1-21-0	1, 22	18.2
0-23-0	23	8.8
0-2-0	2	2.6
0-21-0	21	3.6
0-19-0	19	10
0-23-17-23-0	17	15.2
0-16-0	16	11.2
0-11-0	11	16
0-21-22-10-18-10-22-21-0	18	24.4
0-16-13-16-0	13	18.4
	TOTAL	374.8

Table 19. Routes obtained with corresponding travel time and nodes served for the Municipality of Cabiao using CW

Route	Nodes Served	Travel Time (in minutes)
0-16-18-4-17-4-18-16-0	4, 17	29.2
0-8-10-1-21-22-2-10-8-0	1, 10, 21, 22, 2	37.6
0-15-14-12-11-5-11-12-0	5, 11, 15, 14	25.8
0-16-23-19-23-16-0	19, 23, 16	17.8
0-13-9-3-9-20-8-0	13, 3, 9, 8, 20	12
0-7-0-6-16-18-16-0	6, 18, 7	13.9
0-12-0	12	6
	TOTAL	142.3

Table 20. Routes obtained with corresponding travel time and nodes served for the Municipality of Cabiao using ICW

Route	Nodes Served	Travel Time (in minutes)
0-16-18-4-17-4-18-16-0	4, 17	29.2
0-8-10-1-21-22-2-10-8-0	1, 10, 21, 22, 2	37.6
0-15-14-12-11-5-11-12-0	5, 11, 15, 14	25.8
0-16-23-19-23-16-0	19, 23, 16	17.8
0-7-13-9-3-9-20-0	7, 13, 9, 3, 20	9.3
0-6-8-16-18-16-0	8, 6, 18	15.4
	TOTAL	141.1

Table 21. Routes obtained with corresponding travel time and nodes served for the Municipality of San Leonardo using CW

Route	Nodes Served	Travel Time (in minutes)
0-10-8-0	8, 10	27.4
0-13-5-15-0	5, 13	19
0-2-1-11-9-11-14-13-0	9, 11, 1, 2, 14	36.6
0-10-12-3-0	12, 3	25.6
0-4-15-0	4, 15	5.5
0-4-9-11-1-6-1-11-9-4-0	6	24.2
0-7-0	7	14.8
	TOTAL	153.1

Table 22. Routes obtained with corresponding travel time and nodes served for the Municipality of San Leonardo using ICW

Route	Nodes Served	Travel Time (in minutes)
0-10-8-0	8, 10	27.4
0-13-5-15-0	5, 13	19
0-2-1-11-9-4-0	9, 11, 1, 2	19.9
0-10-12-3-0	12, 3	25.6
0-4-15-0	4, 15	5.5
0-9-11-1-6-14-13-0	14, 6	34.5
0-7-0	7	14.8
	TOTAL	146.7

Table 23. Comparison of Results from using CW and ICW

Municipality/City	Total travel time using Clarke and Wright's Savings Algorithm (in minutes)	Total travel time using Improved Clarke and Wright's Savings Algorithm (in minutes)	Solution Improvement Percentage (%)
Peñaranda	69.7	69.7	0.00
San Antonio	198.0	198.0	0.00
San Isidro	110.6	108.2	2.17
Jaen	277.9	271.5	2.30
Gapan	374.8	374.8	0.00
Cabiao	142.3	141.1	0.84
San Leonardo	153.1	146.7	4.18

SUMMARY AND CONCLUSION

The 4th District of Nueva Ecija is a flood-prone area but has no existing system for the relief goods operation. It is necessary for the locality to develop an efficient routing system. In order to achieve this, optimal sets of routes are needed to be determined in order to make the relief goods distribution more efficient. With this system, it can alleviate the adverse effects during and after natural disasters. There are so many problems emerging during natural calamities and creating a system can provide a good starting point for the government to come up with a strategic plan as preparation for typhoons coming in the country.

In this study, a general integer linear programming model for the said problem was formulated. The model was then solved using CW and ICW through the use of a software specifically developed for this study. The sets of routes that the vehicle has to traverse to serve the demands of all the barangays in each municipality and city were determined using CW which is an already established algorithm. Through the use of ICW, some of the solutions obtained can be enhanced and the total travel time can be reduced. Therefore, the relief goods operation will be more efficient when the sets of routes obtained using ICW was used.

RECOMMENDATION

The study can be used as a basis to determine optimal sets of routes for the relief goods distribution in other municipalities and cities in the country. The computer program developed is readily available to be used in the implementation of the method.

The study assumes that there is only one vehicle available in each city/municipality. For future studies, having the number of vehicles variable for a faster relief good distribution in the city/municipality can be considered. Other assumptions that can be considered are priorities among the barangays and presence of traffic jams and restricted roads which can be incorporated in the computer program. The computer program can serve as a good initial efforts for developing a software for solving VRP.

STATEMENT OF AUTHORSHIP

The first author conceptualized the research study and reviewed the final paper. The second and the third author gathered the data, employed all the computations. All the authors were involved in the writing process.

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