LPG Delivery Sequencing for Real-Time Continuous Incoming Purchasing Orders

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Abstract

The research study presents a developed calculation algorithm for delivery sequencing for real-time purchasing orders in LPG (Liquefied Petroleum Gas) delivery business in Thailand. In practice, customers call the LPG call center requesting services and each customer's order mostly requires an immediate service. Then routing and scheduling is done in real time. That the delivery provider needs to make a decision all the time due to the incoming orders are increasing making things more complicated in routes and schedules. As a result, the delivery cannot determined well enough in an appropriate time period. Hence, the objective of this study is to develop a sequential delivery calculation algorithm for LPG Delivery in real-time continuous incoming purchasing orders for calculating an appropriate total distance and reducing lead time before dispatching. This algorithm has been developed for sequencing and routing a fleet of vehicles from a distribution center (DC) to multiple delivery points. The vehicle routing method applies heuristics techniques on vehicle capacities and distances to minimize the travel distance and do the sequencing by on a real time basis. The system is divided into 3 phases. The first phase is to collect the gradually incoming data for calculation. As soon as a customer orders LPG, the system uses the Google MAP API for generating a distance data matrix to calculate the distance between customer's location and the depot. The second phase is order assignment under the restriction; vehicle capacity and distances between routes and mapping out an appropriate route by using Nearest Neighbor Heuristics and 2-opt improvement. Finally, the third phase is to schedule the dispatches. The significance of the sequencing system is that it is all executed in real time. The findings in the research can be used by integrating the system to help the involved users in reducing the decision-making time for efficient routing, leading to less lead time before dispatching goods, having an efficient fleet control, and a right in time delivery with an appropriate total distance. To summarize, the system provides significantly better routes than those determined manually.

Keywords
Nearest Neighbor Heuristics, Vehicle Routing Problem, Delivery Sequencing, Real-Time Purchasing Order.

1. Introduction
In these days, LPG distribution business becomes more competitive. LPG delivery is a home-delivery service which requires effective and efficient management of goods and services distribution to customers. In Thailand, LPG business is the one of the major energy-related businesses. The overview by the Department of Thailand Energy in 2019 stated that the average consumption of LPG products was about 17.8million kg. per day, with the household consumption at 5.8 million kg. per day. At present, Thailand has 6,000-7,000 retail gas distributors who provide services in every province of the country. In the face of competition, each company has to compete with each other

by responding quickly to customers' demand, giving customers satisfaction and maintaining the service level. The key factor of LPG delivery business is a real-time operation, which mainly refers to the delivery service. The delivery providers have encountered the difficulty of having to make decisions all the time. With such a problem, whenever the orders come in abundantly, the delivery cannot be managed effectively in an appropriate time period. As a result, the total distance cannot be minimized, causing a longer lead time before dispatching goods and increasing customers' wait times. Examples of the effects of the time on past delivery procedure in one day is illustrated in table 1. Average lead time before dispatching, average customers' wait times, and a total distance are displayed.

Table 1. Example of Average time's result of past delivery procedure.

Procedure	Nodes	Average Lead time before Dispatching	Average Customer Waiting Time	Total Distance (Km.)
Past procedure	86	1:18 Hr.	1:39 Hr.	497.42 Km.

This research is studied in medium business size of LPG delivery in Chiang Mai, Thailand. The business delivers in average for 80 to 150 nodes per day or LPG tank average is 180 tanks per day. The business receives customer order by telephone at the distribution center (call center). Then, the deliver will deliver to the customer location. In a practical situation, when a customer calls to call center requesting service and each demand must be immediately serviced, then routing and sequencing must be done in real-time (the problem is referred as the dynamic or real-time problem). Since the demands are known at the time, schedules are constructed. Therefore, when a new demand is arrived, at least one schedule must be changes in order to serve this new demand. This real-time problem is Vehicle Routing Problem (VRP) so, heuristics techniques is applied. The VRP refers to a set of minimum cost routes that begins and ends at a depot, for a fleet of vehicles providing services to a group of customers with accepted orders. A customer needs to be assigned to vehicles with remaining capacity. However, there may be minor condition regarding possible routes such as the distances and delivery-time affirmation. In case there are so many vehicles available, the problem are both placing customers to vehicles and sequencing schedules for each vehicle. The real-time management has an effect on an optimal route and a schedule, and to solve the problem, re-optimizing is required. The system divided into 3 processes. The first process is collecting the gradually incoming data for prepare the essential information. When the newly customer arrived, the system use the Google MAP API for generate a distance data matrix to calculate the distance between both customers and depot. The second process is order assignment under the restriction; vehicle capacity and distances between routes and mapping out an appropriate route by using Nearest Neighbor Heuristics and 2-opt improvement. Finally, the dispatching time is determined. For this concept can developed a support system in the future to assist the deliver to make a decision in short time and deliver intime with appropriated total distance.

1.1 Objectives

To develop a sequential delivery calculation algorithm for LPG Delivery in real-time continuous incoming purchasing orders to calculate an appropriate total distance and reduce a lead time before dispatching goods.

2. Literature Review

Vehicle Routing Problem (VRP) has been studied for long time. It was developed from Traveling Salesman Problem (TSP) in the 1920s by the mathematician and economist Karl Menger. For further studying, Dantzig and Ramzer examined VRP in 1959. Dantzig et al. (1959) note that he VRP problem is similar to the TSP problem, with more than one traveling vehicle. It is divided into many types of problems depending on their characteristics. The primary problem is determined which all necessary information is known before starting the route and being arranged to travel through all points in the route with the lowest cost. Later, there were additional conditions such as vehicle capacity referred to as a Capacitated VRP Ibrahim et al. (2019), VRP with Time Windows:VRPTW El-Sherbeny (2010), VRP with Pick-up and Delivery (VRPPD) Gajpal and Abad (2010), or VRP with multiple time windows and multiple visits Favaretto et al. (2007) and split Deliveries Belfiore and Yoshizaki (2009). Then, as the real circumstance turns to be complicated, a new characteristic of VRP problem is studied. It is called "Real-Time" delivery routing. Ghiani et al. (2003) has provided examples of real-time routing problems such as repairing services, emergency vehicle, courier services, intermodal services, taxi-cab operations, pickup and delivery services, dial-a-ride service. This problem has happened in real-time with the instability of input data. However, the service must be performed within the specified time frame. Chang et al. (2003) studied the real-time routing problem under time frame and uncertain demand volumes. The problem also seems to be dynamic which necessary information is not known before routing, but it gradually comes during routing Larsen (2009). To solve the problem, two principles are introduced, the exact method and heuristics. The exact method is successful with less complicated problem, such as a classical TSP problem. However, as it takes much time to get the optimal answer to more complicated VRP problem, the exact method takes a longer time and sometimes is unable to solve the problem, so heuristics is used. Although the answer is not be the best, it may be the closest answer, and it takes shorter time than the exact method. A popular heuristics method is Nearest Neighborhood Algorithm (NNA). Mohammed et al. (2017) conducted a study to determine an optimal route for VRP by using K-Nearest Neighbor Algorithm (KNNA) with the accompanying targets (1) to reduce the distance and time for all routes leading to speedy transportation of customers to their locations and (2) to implement the capacitated vehicle routing problem model for optimizing the solutions. The result revealed that although the KNNA may not be able to find the optimal solution, it is capable of finding an approximate solution. Meesuptaweekoon and Chaovalitwongse (2014) used to solve the dynamic VRP solution for multiple distribution centers. The problem was improved through the use of Insertion Procedure (IP) and Sweeping and Recording Procedure (SRP) by comparing the accurate CPLEX. It was found that heuristics takes shorter computation times and gives better answer, especially in smaller problem size. Koweerawong (2019) improved the Nearest Neighborhood to solve the TSP and improve answer by 2-OPT moving. It was found that using NNA together with 2-OPT improvement gets a better answer than using only NNA. In the same manner, Waehayee (2014) examined the problem of VRP with time windows and split demand delivery, and so did Namphacharoen (2000) with the problem of ordering and delivery route. It was found that initial solution is generated by using segmentation method with First-come First-serve criterion under the weight limitation and re-route by using the Saving Algorithm method, which is one of the popular heuristics methods. Then 2-opt as a route improvement and Or-OPT were used to get the best answer.

3. Model Formulation

In real-time delivery sequencing for continuous incoming purchasing order, the routing and scheduling must be changed quickly. With a variety of information, this sequencing system needs to be handled to meet every incoming demand. The implementation of analytic routing and sequencing models will be elaborated in this chapter which will be of much help for decision-making. As far as the problem is concerned, the vehicle routing seems to have a dynamic characteristic. However, the system has taken into consideration both dynamic and static characteristics of vehicle routing. The classic Vehicle Routing Problem with Time Windows (VRPTW) has a static feature, but the added dynamics is the real-time factor that changes throughout the process. To clarify the scope of the research, necessary assumptions are stated as follows.

1. In real-time service for LPG delivery business, each customer's order is received by telephone at the distribution center (call-center). Then the call center will input the information into the system and put through to delivery provider to dispatch the goods as ordered as soon as possible.
2. Guarantee Time is the time from when a customer places an order of the goods until it is received. This research will set Guarantee Time by surveying customers' satisfaction to come up with an average time the customers receive the goods at a service level of 95%. By the way, this parameter can be changed depending on the providers' policy and the future situation.
3. Lead Time before dispatching is the time from when a customer places an order until the delivery starts.
4. Service time is the time of sending the goods to customers and it must be included in the total time. The service time is set by processing the past delivery information. The service time is the average service time between the difference total actual time and the total time in simulation on Google Map.
5. As far as a proper strategy is concerned, in case the capacity of a vehicle remains, the delivery provider can wait for more orders assigned to the vehicle. The latest assignment allows for a possible last minute change to the planned routing and schedule sequencing.
6. The vehicle will be ready for the dispatching all the time.
7. As the unpredictable orders may cause the overcapacity, in this study the overcapacity will be considered only when it occurs, whereas a regular coming order is not allowed to split the other orders.

3.1 Notation

1. Parameters and constants

dd_{ij} distances between node i and j
tt_{ij} time to depart from node i to j
tt_{ijk} time to depart from node i to j by vehicle k
q_i weight delivery demands at node i

n order sequential in particular node (For Split Order Procedure)
c set of product Types = {1 = 48 KG., 2 = 15 KG., 3 = 7 KG. ,4 = 4 KG.}
W_k weight capacity of vehicle k
NK vehicle Quantity
T_{now} current Time
t_{now} point of current time
GT guarantee time
S_i service time at node i

2. Superscripts and subscripts
i, j node designation
N set of all nodes
N_0 set of depot
$N_0 \cup N$ set of nodes in the problem
N_k set of assigned nodes in vehicle
V_k vehicle designation
K set of all vehicles

3.Variables
X_{ijk} set as integer 1 if vehicle k departs node i ; 0 otherwise
Y_{ik} set as integer 1 if vehicle k assigned to service node I ; 0 otherwise
q_{cn}^{i} weight of product c in sequence n of node i
Rem_{qi} remaining of unassigned delivery demands in node i
$RemW_k$ remaining capacity of vehicle k
$q_{i'}$ weight delivery demands which assigned by split procedure of node i
WT_i waiting time remaining of node i
DTV_k maximum dispatching time of vehicle k (set by $configDT$)
AT_i arrival time of node i
a_i difference of arrival time at node i with previous node
A_i point of arrival time of node i

3.2 Mathematical Model

At time t, the real-time routing and sequencing will be formulated as follows :

Minimize

$$Total\ distance\ = \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{NV} dd_{ij}X_{ijk} \tag{1}$$

The constraints :

$$\sum_{i=1}^{n}\sum_{k=1}^{NK} X_{ijk} = 1 \qquad \forall\, i \in N_k \tag{2}$$

$$\sum_{j=1}^{n}\sum_{k=1}^{NK} X_{ijk} = 1 \qquad \forall\, i \in N_k \tag{3}$$

$$\sum_{k=1}^{n} Y_{ik} = 1 \qquad \forall\, i \in N_k, k \in\ K \tag{4}$$

$$\sum_{j=2}^{n} X_{0jk} \leq 1 \qquad \forall\, i \in N_k \tag{5}$$

$$X_{ijk} \in 0,1 \qquad \forall\, i \in N_k, \mathrm{j} \in N_k, k \in K \qquad (6)$$

Vehicle Capacity Constraints :

$$\sum_{i=1}^{n} q_i\, Y_{ik} \leq RemW_k \qquad \forall\, i \in N_k, \mathrm{j} \in N_k, k \in K \qquad (7)$$

$$\sum_{n=1}^{n} q_{cn}^{i} \leq W_k \qquad \forall\, i \in N_k, \mathrm{j} \in N_k, k \in K \qquad (8)$$

$$Rem_{qi} = q_i - q_{i'} \qquad \forall\, i \in N_k, \mathrm{j} \in N_k, k \in K \qquad (9)$$

Definition Time Parameters :

$$a_i = AT_{i+1} - AT_i \qquad \forall\, i \in N_k, \mathrm{j} \in N_k, k \in K \qquad (10)$$

$$A_{i+1} = a_{i+1} + A_i \qquad \forall\, i \in N_k, \mathrm{j} \in N_k, k \in K \qquad (11)$$

$$t_{now} = T_{now} - AT_i \qquad \forall\, i \in N_k, \mathrm{j} \in N_k, k \in K \qquad (12)$$

$$WT_i = ((A_i + GT) - t_{now}) - tt_{ij} \qquad \forall\, i \in N_k, \mathrm{j} \in N_k, k \in K \qquad (13)$$

$$DT_k = T_{now} + WT_i \qquad \forall\, i \in N_k, \mathrm{j} \in N_k, k \in K \qquad (14)$$

The objective of the Real-Time VRP for delivery, as shown in Eqn (1), is constructed as a total of travel distances for all links in all vehicles dispatched. Eqn (2), which requires one vehicle leaving from a critical or unassigned node i once. Eqn (3), denotes only one vehicle can arrive at an unassigned node j once. Eqn (4) ensures that a customer is assigned to service by one vehicle. Eqn (5), designates that each vehicle can leave the depot once. Eqn (6), designates X_{ijk} as 0-1 integers; set X_{ijk} equals 1 if vehicle k departs node i toward node j, 0, otherwise. About the vehicle capacity Eqn (7) states that for each vehicle, the total delivery demands must not be greater than the vehicle capacity. Normally, this system is not allowed to split demand for delivery, but it says that real time demands always come with various quantities which sometimes cause overcapacity. In this case, this system will be allowed to handle only the case of overcapacity. Eqn (8), shows the procedure of assigned demand being switched over to be in part one. Eqn (9), part 2 of demand split, it must be split and find for remaining order's demand which not unassigned to vehicle yet. For time constraints definition for recalculating along the real-time Eqn (10), (11) indicates that the point of time is difference between the previous incoming order and the current order. Eqn (12), shows the point of time of current time Eqn (13) form of wait time for each order from its arrival into the system Eqn (14), dispatching time calculated for each vehicle and the latest time to dispatch.

4. Materials and Methods

4.1 Nearest Neighbor Algorithm (NNA)

Tavares et al. (2009) states that the Nearest Neighbor Algorithm denotes one of the most intuitive and best-known methods of heuristics in solving of the problem of a traveling salesman. The method comprises the construction of a route to a randomly selected location and an interactive extension of the route by inserting a vertex of target points unvisited, which is closest to the current vertex. Regarding the traveling salesman problem, where the lowest cost route is needed, the heuristics completes the construction in case that no more vertexes are to be included in the routes. In this case, the last vertex has a link to the initial vertex closing the path, known as the nearest neighbor tour. Obviously, It is noticeable that the quality of the solution achieved is based on the choice of the first vertex. After all, for instances of the TSPLIB, this heuristic generally presents solutions of around 20-35% worse than the most effective solution. In regard to the vehicle routing problem, a set of routes with the lowest cost is needed, the heuristics is employed multiple times to construct n paths. For a specific case, the construction of a route when a new vertex is interpolated in this path is greater than the capacity of the vehicle. The last vertex tested, and which was not inserted in the previous path due to the limited capacity of the vehicle, becomes the first vertex in the following path. In figure 1 shown some examples of solution generated through the NNA.

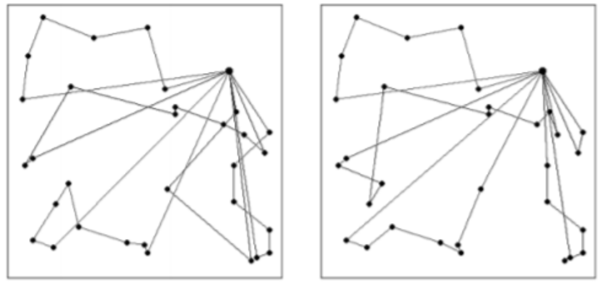

Figure 1. Examples of solutions generated through the NNA.

4.2 2-opt Intra-Route Heuristic

The 2-opt intra-route method for refinement was initially proposed for the traveling salesman problem by Lin and Kernighan. The heuristic consists initially in the random choice of two non-consecutive edges, which belong to the same route, as shown in Figure 2 the two edges selected are removed from the original path and their points are reconnected so that they create a new path. If the cost of the new path is less than the cost of the original, the new path is selected as the present solution. This concept is known as the first improvement in which the quality of the solution has improved As a result, a new route is introduced as a latest solution to the problem. The process terminates when a certain stopping criterion is achieved, e.g. a number of cycles with no improvement in the current solution.

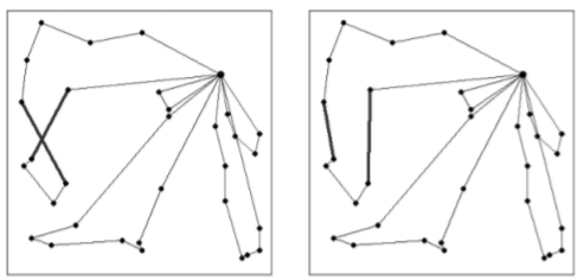

Figure 2. Movement of the 2-opt Intra-Route Heuristics.

5. Results and Discussion

The result of algorithm for the LPG delivery sequential problem is known as NP-hard problem, it becomes more difficult to be solved in a short time by exact methods due to the incoming purchasing order along working days. To handle this problem with both efficiency and real-time response requirement, a heuristics method is applied. For this research, the system is divided into 3 phases. First, data preparation. Second, order assignment under the restriction ,then routing and improvement is proposed. Last phase is to calculate dispatching time to delivery decision. In section 5.1, the operation of preparing phase and example transaction are described. In section 5.2, the operation flow of route construction by Nearest Neighbor Algorithm and 2-OPT improvement. In section 5.3, the last phase of sequencing to calculate dispatching time are shown.

5.1 Phase 1 : Data Preparation

The first phase is to collect the gradually incoming data calculation. As soon as a customer places his order, the system uses the Google MAP API for generating a distance data matrix (shown in Table 3) to calculate the distance between the customer and the depot. This phase requires the necessary incoming data as follows:

1.customer's information : customer id, location with latitude and longitude
2.customer's demand : product type, product quantity, product weight
3.route in system and vehicle capacity in system (already assigned but still waiting)
4.arrival time of customer

After that, the system will generate the distance matrix that will be used for next phase routing. The example of real-time incoming purchasing order is illustrated in Table 2

Table 2. The example of Real-time incoming purchasing order.

At Time = 7:00 am.			
Customer	Arrival Time	Weight (Kg.)	Location
i_1	7:00	32	18.788886,99.0312572

At Time = 7:10 am.			
Customer	Arrival Time	Weight (Kg.)	Location
i_1	7:00	32	18.788886,99.0312572
i_2	7:10	32	18.814871, 99.033698

At Time = 8:00 am.			
Customer	Arrival Time	Weight (Kg.)	Location
i_1	7:00	32	18.788886,99.0312572
i_2	7:10	32	18.814871, 99.033698
i_3	7:25	85	18.7904219,99.02699325
i_4	7:28	32	18.7908961,99.0031598
i_5	7:30	170	18.7904219,99.02699325
i_6	7:32	110	18.8304872,99.0523843
i_7	7:40	32	18.8259168,99.0368043
i_8	7:45	62	18.7520486,99.0087719
i_9	7:48	32	18.8373014,99.0292813

Table 3. The distance matrix.

	depot	i_1	i_2	i_3	i_4	i_5	i_6	i_7	i_8	i_9
depot	0	2.5	5.6	3.5	4.4	4.9	1.8	2.7	1.8	4.8
i_1		0	11.2	8.4	5.2	9.7	0.65	7.9	2.4	9.7
i_2			0	5.1	7	5.9	5	1.6	5	4.2
i_3				0	6.3	4	3.8	2.8	3.4	4
i_4					0	9.8	5.1	6.4	5.5	9.8
i_5						0	9.1	8.1	9.1	5.1
i_6							0	6.8	0.4	9.8
i_7								0	6.2	4.5
i_8									0	6.4
i_9										0

5.2 Phase 2 : Order assignment, Routing and Sequencing

This phase is divided into 2 stages: assigning each order to a vehicle to set an appropriate vehicle allocation by 2 constraints, and then routing and improving the sequence.

· **Phase 2.1 : Order assignment** (Shown in Figure 3) :

To ensure that the final answer will be under the constraints, the procedure of the first stage is consecutively considered by 2 steps, step1 : vehicle capacity and step 2 : distances.

Step 1 : Vehicle Capacity

Initially considered is examining the current new order's total weight to make sure it does not exceed the vehicle capacity. Sometimes, the demand cannot be determined and may cause the overcapacity. But, regarding the vehicle utilization, this system will allow for the split procedure only in case that the overcapacity demand occurs. By the way, if the current new order's total weight does not exceed the vehicle capacity, then on the remaining capacity of vehicles in the system is in normal weight consideration is based.

• First : Checking Weight Capacity

$$q_i > W_k$$

• Split Procedure (2steps)
(1) split into 2 parts. The first part is full capacity of new vehicle, and the other is the original vehicle capacity in the order assignment procedure with Rem_{qi}. Then change the status of part1 to $q_{i\prime}$ to be a new weight for next routing phase. Note that: because of the variety of product types, it will have the different weights accordingly. Thus, during the split procedure, the system has to do the splitting by considering both the product's weight and type. To identify the accurate weight, q_{cn}^{i} is included. Full vehicle calculation is the accumulated summation of weight by sequential in order, but not exceeding the capacity by this following formulation;

$$\sum_{n=1}^{n} q_{cn}^{i} \leq W_k$$

(2) Check Rem_{qi} for first checking weight constraint; if it still runs into overcapacity, then turn to (1) again and do it until assignment of all weights in order is completed.
• Second : Normal Weight Consideration
$Remq_i \leq RemW_k$

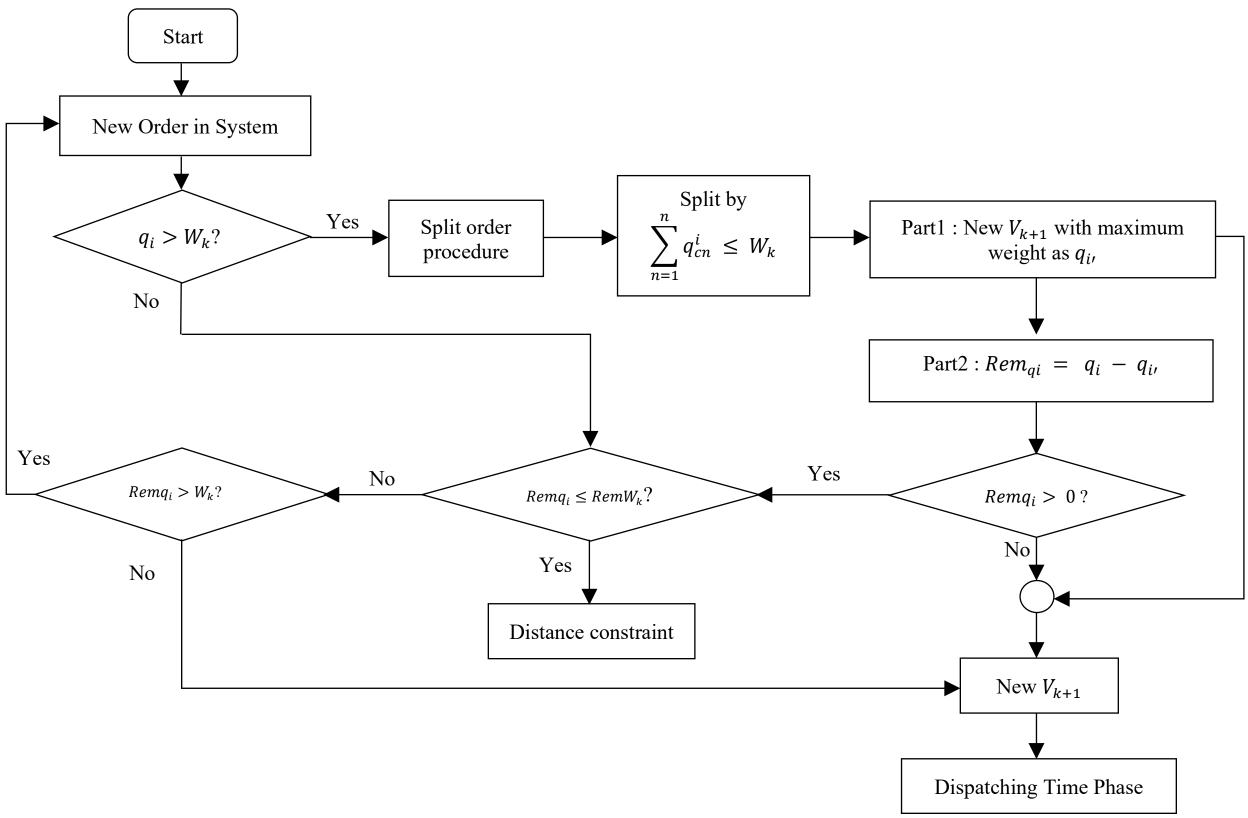

Figure 3. Order Assignment step1 Vehicle Capacity.

Step 2 : Distance constraint (Shown in Figure4) :
Set the distance configuration parameter to determine the routes that belong to the same group, and that have a reasonable distance. Without such configuration, the total distance may be large and off the routes that belong to the same group. It is similar to the customer's area clustering but the clustering sometimes has disadvantages such as that it causes an inefficiency in delivering when the customer locations are separated by area clustering, but in fact that it is close to each other and is able to be arranged together in the same route, or in some areas the orders are so few that the demand is not balancing. So, by dividing the areas, multiple trucks for delivery may be used instead of delivering products in the same old way. Therefore, the adjusted method was used to allow the delivery points in each area to be independent and support a wider variety of routing. In this research, the determination of distance between the

customer's location points ($config_{dd}$) was determined based on the average distance by sampling 86 customers, 6.1 kilometers. Then, set as a distance constraint parameter by the following constraint;

$$d_{ij} \leq config_{dd}$$

Figure 4. Order Assignment step2 Distance Constraint.

· **Phase 2.2 : Routing and sequencing**

After getting the result in phase 2.1, sets of orders in each vehicle are provided, then routing and sequencing is calculated. First, the initial solution by Nearest Neighbor Algorithm is used. NNA is the method for making a set of delivery points, and all points will be visited by the same vehicle. In this heuristics, the nearest customers are usually determined by a distance between nodes (customer or depot). For the first position, select the nearest from depot and then the next nearest customers to the first couple is added. This procedure continues until there is no nearest unvisited customer exists. To close the route, the vehicle returns to the starting depot. Second, Chang et al. (2003) proposed to improve the routes by adding the algorithm 2-opt. This is the extension of neighborhood for a problem with multiple routes. In this research, 2-opt intra-route was used in which the two edges selected are removed from the original path and their points are reconnected so as to create a new path. If this feasible exchange can result in a lower distance, the new path is selected as the current solution. It is noted that there is feasibility with respect to all the above constraints.

• Summarize for real-time route construction

Step 1 : Input data from the preparation phase by inputting customer's information, q_i, q^i_{cn}, AT_i

Step 2 : Assign orders to vehicles by considering orders assignment procedure by weight. If the order is completely accepted, go to step 4, if not, however, go to step 3 for split procedure.

Step 3 : The unaccepted order by overcapacity is split into 2 parts (described in the split procedure in phase 2.1). The new route (vehicle) will be opened. Check for remaining sub-order and then go to step 1 again until all orders are accepted.

Step 4 : Look into distance constraint by selecting the minimum distance between the current orders and points in the system. The current orders are assigned to the vehicles with minimum distance. Sometimes, many vehicles have minimum distance, so the system will choose vehicles with lower remaining weight capacity first.

Step 5 : Construct the route by Nearest Neighbor Algorithm and routes improved by 2-OPT. The result of this step is the order sequential in vehicles and all possible recorded accepted route.

Step 6 : Calculate the dispatching time for each vehicle after passing all steps above. The parameter which is used in this step is stated in the dispatching phase description in section 5.3.

Step 7 : If the dispatching time cannot be calculated by the route results from step 5, it will select the past result with possible greater total distance but still in an acceptable answer range. Do this step until the answer is completed which all accepted by every constraint. However, if all of the answers failed to find the dispatching time in all solutions, the system will allow for the new routes or for using the inferior routes that are also under the restriction (if there is any in step 4) this step is illustrated in Figure 5.

5.3 Phase 3 : Dispatching Time

In vehicle dispatching phase, the dispatching time of each vehicle is determined. It can be the longest wait time that a vehicle can wait (until reaching the critical time of each route) to provide the opportunity to add more future customers to the routes. To provide update good solutions, the solution of each state of time is reprocessed if there is a new customer entering the system. They are reprocessed until the dispatching time (DT_k) meets the Guarantee Time (GT) or the remaining weight capacity is less than 11 Kg., then it can also be dispatched.

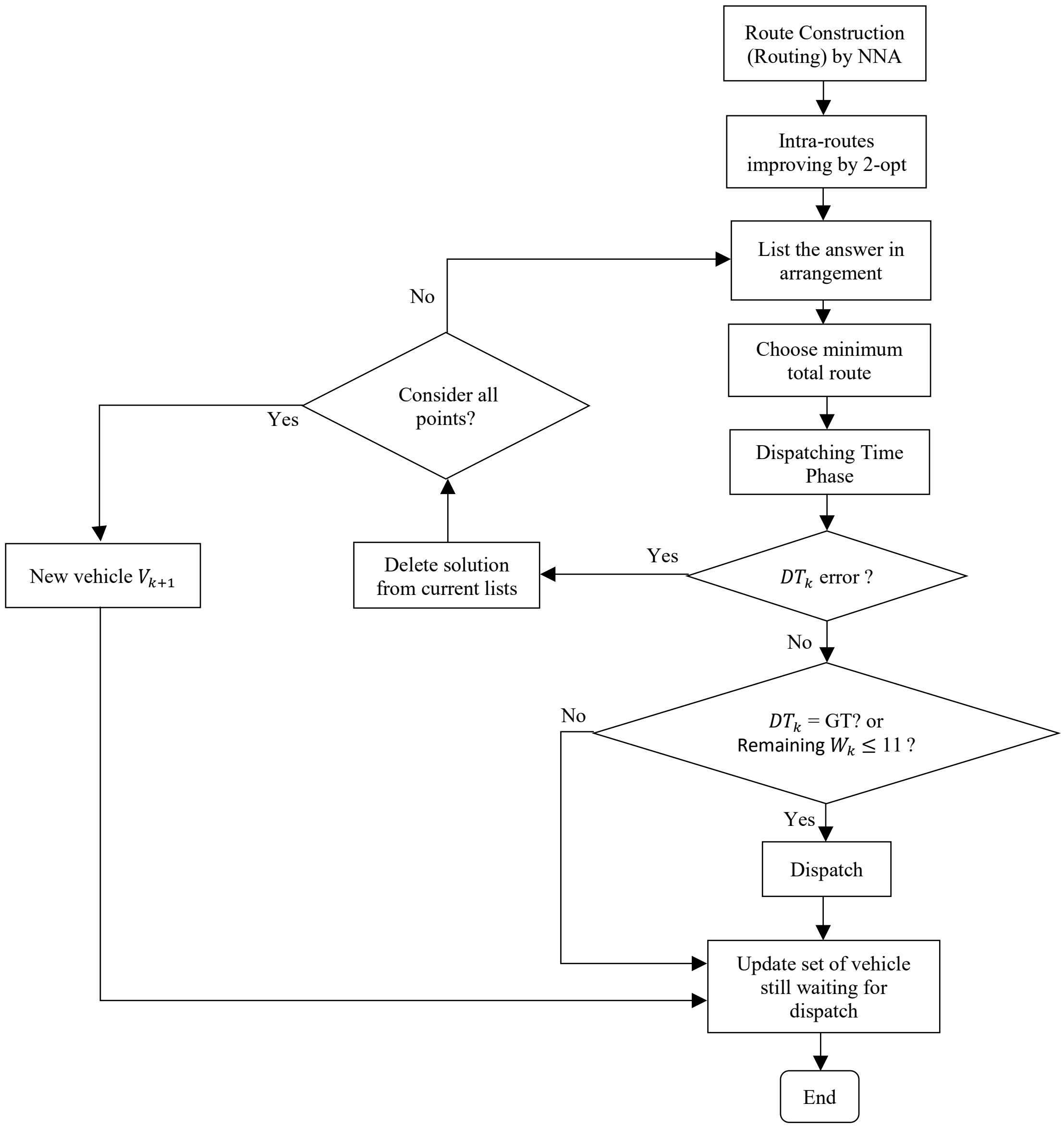

Figure 5. Phase2.2 Routing and sequencing and Phase 3 Dispatching Time.

5.4 Testing Results

The testing result of sample data in 1 day (with the same data set) by using the improved algorithm is shown in Table 4. This testing problem set Guarantee Time at 90 minutes, average vehicle speed of 60 Km. per hour, and service time at 10 minute for each node. The percentage of improvement shows that this improved algorithm can reduce average lead time before dispatching at about 46.15% and also reduce average customers' wait time at about 43.43%. Moreover, the total distance decreases 4.50%. With this improved calculation algorithm, the important parameter was set, i.e. Guarantee Time, which can monitor and control the delivery performance, and which was not included the past delivery procedure. As a result, the improved real-time procedure will provide significantly better routes than those determined manually.

Table 4. The testing result of sample data in 1 day comparing in both procedures.

Procedure	Nodes	Average Lead time before Dispatching	Average Customer Waiting Time	Total Distance (Km.)
Past procedure	86	1:18 Hr.	1:39 Hr.	497.42 Km.
Improved algorithm	86	0:42 Hr.	0:56 Hr.	475.05 Km.
Percentage of Improvement		46.15%	43.43%	4.50%

5.5 Graphical Results

The result analysis is shown in a graphical format in Figure 6. It shows the incoming orders' trend in each service hour and the average lead time before dispatching compared to the past procedure with improved algorithm. It can be analyzed that in the past procedure, when the order was placed in the peak time (referred to in the graph; the peak time was about 8-11am. and 1-2pm.), the average lead time before dispatching is quite short. But for the following slightly down time, the average lead time before dispatching increases greatly. For this reason, when the order comes abundantly, the delivery provider cannot determine well in an appropriate time period, causing the long lead time before dispatching and also affecting customers' waiting times and the total route. With the improved algorithm, the system can solve the problem. It not only reduces the average lead time before dispatching, but it also maintains the average for all day services.

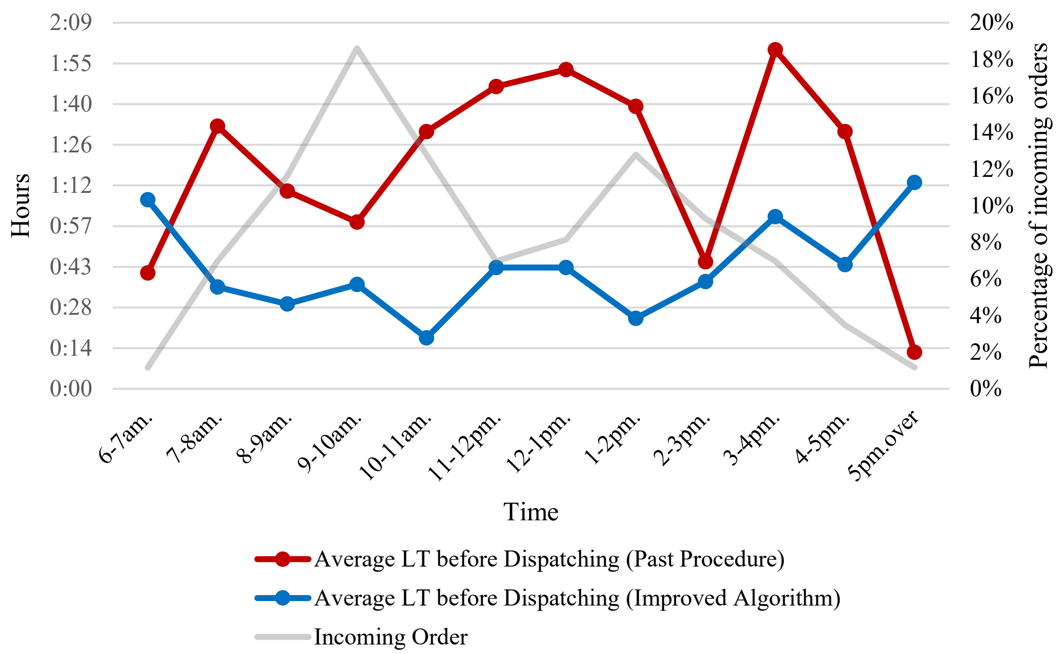

Figure 6. The result analysis of sampling data in 1 day in both procedure with incoming orders.

6. Conclusion

This research's problem is constantly changing throughout the process. The key factor contributing to the change is time and at any time point during the process to decide whether to delivery or wait for the next information. The system is divided to 3 phases. First, data preparation. Second, assign order to vehicle under restriction, routing and improvement is proposed. The last phase is to calculate dispatching time to delivery decision. For the routing process, both Nearest Neighbor Algorithm (NNA) and 2-opt improvement to find the best route were used. This developed calculation algorithm resulted in an appropriate total distance and a reduced lead time before dispatching. In the future, this calculation algorithm can be developed to real-time vehicle routing software to support the real situation and support the delivery for faster service response.

References

Belfiore, P., and Yoshizaki, H., Scatter search for a real-life heterogeneous fleet vehicle routing problem with time windows and split deliveries in Brazil, *European Journal of Operational Research*, vol. 199, pp. 750-758, 2009.

Chang, M. S., Chen, S. R., and Hsueh, C. F., Real-time vehicle routing problem with time windows and simultaneous delivery/pickup demands, *Journal of the Eastern Asia Society for Transportation Studies*, vol. 5, pp. 2273-2286, 2003.

Dantzig, G. B., and Ramser, J. H., The Truck Dispatching Problem, *Management Science*, vol. 6, pp. 80-91, 1959.

El-Sherbeny, N. A., Vehicle routing with time windows: An overview of exact, heuristic and metaheuristic methods, *Journal of King Saud University (Science)*, vol. 22, pp. 123-131, 2010.

Favaretto, D., Moretti, E., and Pellegrini, P., Ant colony system for a VRP with multiple time windows and multiple visits, *Journal of the Interdisciplinary Mathematics*, vol. 10, pp. 263-284, 2007.

Gajpal, Y., and Abad, P., Saving-based algorithms for vehicle routing problem with simultaneous pickup and delivery, *Journal of the Operational Research Society*, vol. 61, pp. 1498-1509, 2010.

Ghiani, G., Guerriero, F., Laporte, G., and Musmanno, R., Real-time vehicle routing: Solution concepts, algorithms and parallel computing strategies, *European Journal of Operational Research*, vol. 151, pp. 1-11, 2003.

Ibrahim A. A., Abdulaziz R. O., and Ishaya J. A., Capacitated Vehicle Routing Problem, *International Journal of Research Granthaalayah*, vol. 7, pp. 310-327, 2019.

Koweerawong, C., Improvement of Nearest Neighbor Travel Salesman Problem by using 2-opt technique, *The 6th Mational Conference Nakhonratchasima College*, Nakhonratchasima, Thailand, March 30, 2019, pp. 560-567.

Larsen, A., The Dynamic Vehicle Routing Problem, Denmark(Doctoral dissertation), 2009.

Meesuptaweekoon, K., and Chaovalitwongse, P., Dynamic Vehicle Routing Problem with Multiple Depots, *Engineering journal*, vol. 18, pp. 135-149, 2014.

Mohammed, M. A., Ghani, M. K. A., Hamed, R. I., Mostafa, S. A., Ibrahim, D. A., Jameei, H. K., and Alallah, A. H., Solving Behicle Routing Problem by Using Improved K-Nearest Neighbor Algorithm for Best Solution, *Journal of Computational Science*, vol. 21, pp. 232-240, 2017.

Namphacharoen, S., Delivery Routing and Scheduling using a GIS-Assisted Heuristic Approach, Thailand (Master's thesis), 2000.

Tavares, L., Lopes, H. S., and Lima, C. R. E., Construction and Improvement Heuristics Applies to the Capacitated Vehicle Routing Problem, *World Congress on Nature & Biologically Inspired Computing*, Coimbatore, India, December 9-11, 2009.

Waehayee, R., Algorithm for Vehicle Routing Problem with Time Windows and Split Demand Delivery Case Study: Fruit Juice Beverage Factory, Thailand (Master's thesis), 2014.

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