Strategic Planning and Vehicle Routing Algorithm for Newspaper Delivery Problem: Case study of Morning Newspaper, Bangkok, Thailand

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Abstract—**In this paper, the vehicle routing problem and one of its variants, the vehicle routing problem with Time window (VRPTW) is studied. In the vehicle routing problem, a set of vehicles with limited capacity, are to be routed from a central depot to a set of geographically dispersed customers with known demands and predefined time windows. The VRPTW is NP-hard and best solved to optimum or near optimum is heuristic, so to solve this NP-hard vehicle problem Sweep Algorithm is developed. Our research aims to examine distribution problem of a morning newspaper and to minimize the total cost without violating the capacity and time window constraints. The problems consist of vehicle departure times, the routing of vehicles, the location of distribution centers and drop-off points and allocating drop-off points to distribution centers. Results provide evidence of the dramatic impact on costs achieved by developing routing and dispatching schedule simultaneously.**

Index Terms—**Sweep Algorithm, Vehicle Routing problem, Heuristic, Newspaper Distribution Problem (NDP).**

I. INTRODUCTION

On account of declining circulation with increasing distribution cost per copy, morning newspaper need to improve the production and distribution process as well as other processes within the company in order to compete with other off-line service and with other media such as TV, radio and other online services. On time, neither early nor late, delivery is vital in the newspaper industry provided that it is directly tied to customer service level. As a result, delayed delivery could hurt sales because newspaper readers especially subscribing ones expect to have paper outside their doors before leaving for works. Guaranteed on time delivery and service quality are the main key success factors of newspaper industry, therefore it gives the company competitive advantage.

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Achieving the on time paper delivery is quite challenging because newspaper wants to delay their printing as much as possible in order to get the latest news into the prints. This gives delivery department time window as little as three hours or less to get the papers to readers. Consequently, the logistics department has to work quickly and make available more trucks than needed which cost the company more than it should. Traditionally, the idea of low cost and fast delivery could not be attained, simultaneously. It is belief that some kind of trade-off is necessary; the more of one advantage means less of another. However, it was suggested that "seeking time reduction, both time reduction and cost reduction are often the rewards" [1].

In this paper, the study of a newspaper distribution in Bangkok, the Capital of Thailand, is presented. The newspaper distribution is a major expense for the total newspaper, making up approximately 23 % (Labor cost is 40% while transport and petrol costs are account for 60% of distribution cost) of the total cost, which it was important to improve upon this research area in order for the newspaper company to remain competitive. Table 1 shows the strategic planning that company target for future distribution.

Table1: Strategic planning for a newspaper distribution company.

Strategic planning	Current	Target
Provide service at lower cost	23.0%	16.0-20.0%
Improve service quality by reducing delivery complain	0.050%	0.045%

This research has been divided into two objectives. The first objective was to find out how morning newspaper distribution could be improved. The second objective was to develop a vehicle routing algorithm for solving the newspaper delivery problem.

II. CHARACTERISTICS OF NEWSPAPER DISTRIBUTION PROBLEM

Based on demand, newspaper can be categorized into two parts, subscribing newspaper and non subscribing newspaper. Demand of subscribing newspaper is deterministic; it does not need to be estimated for distribution while demand of non subscribing newspaper is probabilistic so it needs an estimation to determine the amount of newspaper to be printed and distributed. Loss of unsold newspaper would happen if the amount of distributing newspaper was bigger than sold newspaper that may cause the problem of reverse logistic.

The Newspaper Distribution Problem (NDP) involves the downstream movement of newspaper from the printing process to the hand of readers. The NDP can be viewed as a hierarchical distribution problem. That means the newspaper delivery involves at least two distinct stages. The first stage is from the production facility to the transfer points and the second stage is from the transfer points to customers [2].

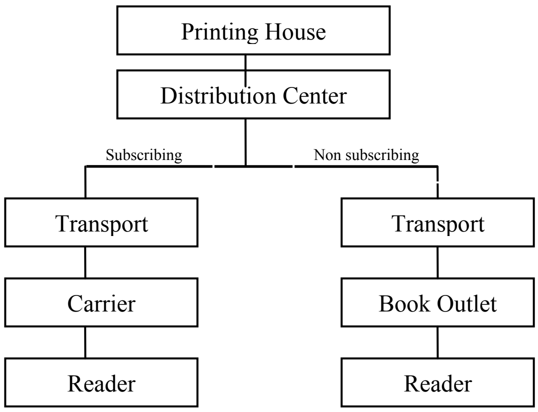

Figure1: A rough model of newspaper distribution system in Thailand.

Model of the physical newspaper distribution is presented in Figure 1. The physical newspaper distribution process involves carrier, truck routes and loading. How early the distribution process could start depending on when the printing starts and how efficient the mail room activities are. The printing and mail room processes (or production process) will not be deliberate in this paper. However, all process has to be planned to meet the delivery deadline. As seen in Figure 1, for both subscribing newspaper and non subscribing newspaper are distributed at starting point of Printing House or Distribution Center nearby. The delivery operation generally involved two legs: from the presses to transfer points (which can be drop points, the location of news agents, or newspaper racks), and from the transfer points to the ultimate customer [2].

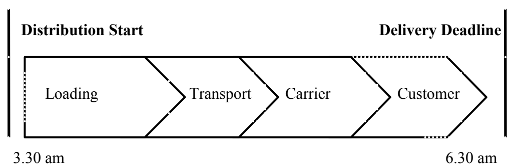

Figure2: Processes and lead time to be considered for physical newspaper distribution

Figure 2 shows current processes and lead time of physical newspaper distribution. When the delivery deadline is set, 6.30 am, an analysis of the process time for each process will generate the required starting times for each process. The carriers have to be finished by the delivery deadline. The transports have to depart from the loading dock at planed departure times in order to arrive at the drop-offs before the carriers start to delivery their first customer or reader. Definitely, when the transports depart from the loading dock, the correct load such as edition, edition version, quantity of each route have to be loaded consequently.

III. LITERATURE REVIEW

The company seeking for an effective strategy to improve morning newspaper by pertaining its internal resource with external resource (the market), the competitive advantage can be achieved by concentrating all the available resource on one basic strategy which is short delivery time. The shot delivery time if administered efficiently and effectively could also result in less distribution cost. This may be the ultimate choice since a declining and enterprise has difficulty to increase sales [1], [2].

A. Vehicle Routing Problem in General

The most general version of the VRP is the Capacitated Vehicle Routing Problem (CVRP) which is a problem in which all customers must be satisfied, all demands are known, and all vehicles have identical, limited capacity and are based at a central depot. The objective is to minimize the vehicle fleet and the sum of travel time and the total demand of commodities for each route may not exceed the capacity of the vehicle which serves that route [3].

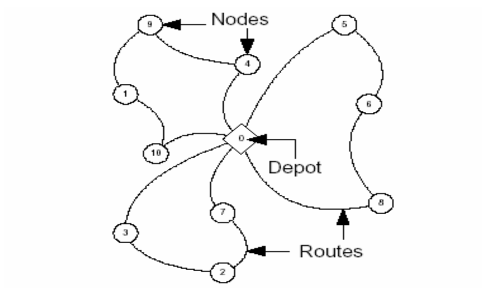

Figure3: Vehicle Routing Problem [4]

One of the most important extensions of the CVRP is the Vehicle Routing Problem with Time Window (VRPTW) which is each customer must be served within a specific time window. The objective is to minimize the vehicle fleet and the sum of travel time and waiting time needed to supply all customers in their required hour [3].

Multiple Depot Vehicle Routing Problem (MDVRP) is a problem that customer can be served from several depots. If the customers are clustered around depots, then the distribution problem should be modeled as a set of independent VRP. The Objective is to minimize the vehicle fleet and the sum of travel time and the total demand of commodities must be served from several depots.

Vehicle Routing Problem with Pick-Up and Delivery (VRPPD) is a VRP in which the possibility that customers return some commodities is contemplated. The objective is to minimize the vehicle fleet and the sum of travel time, with the restriction that the vehicle must have enough capacity for transporting the commodities to be delivered and those ones picked-up at customers for returning them to the depot.

Vehicle Routing Problem with Backhauls (VRPB) is a VRP in which customers can demand or return some commodities. The objective is to find such a set of routes that minimized the total distance traveled.

The VRP was first studied in [5]. Since then there have been many VRP studies reported in the literature. References [6], [7] apply VRP to school bus routing. Other applications include inventory and vehicle routing in the dairy food [8], transportation service at university [9], public library system [10], post service [11], and grocery delivery [12].

B. Vehicle Routing Problem in Newspaper Industries

Many researches on this area indicated that VRP was and is still a great tool for minimizing the total cost of delivery in the newspaper industry. Some example include the works [13] work on the open VRP, their solution to the open vehicle routing problem and zoning constraints (OVRPTWZC) showed significant improvement in both the number of vehicles employed and the total distance traveled over the existing operations of a U.S. metropolitan newspaper. A genetic algorithm (GA) was used to approach to the pre-print advertising scheduling problem and computational results using data from a mid-size newspaper show that the GA approach to developing schedules reduces the processing time associated with creating the preprint packages [14]. Regret Distance Calculation algorithm was selected for agent allocation, a Modified Urgent Route First algorithm for vehicle scheduling, and a Weighted Savings algorithm for routing in addressing the optimal agent allocation, vehicle scheduling and routing for a major newspaper in Korea, the experiment showed that the formulation could significantly reduce delivery costs and delays [15]. A newspaper distribution problem for a metropolitan daily Korean newspaper was also studies and developed a delivery plan using a branch-and-bound heuristic with simulated annealing (SA) [16]. Before that [17] develop a deterministic approach to a medium sized newspaper production/distribution problem in which they employ a greedy heuristic followed by an Or-Opt route improvement heuristic. The problem is smaller and involved only one printing press and more importantly considered only a single product delivery to each zone. Thus, each zone contained its own routing problem. A Dutch regional newspaper's distribution process was also studied [18] and the process was modeled by constructing the travel time matrix using [19] algorithm and use [20] savings technique as the vehicle routing heuristic. In [21], a newspaper delivery problem for the city of San Francisco is considered as an application of a formulation developed for predicting the distance traveled by fleets of vehicles in distribution problems. The formulation is a variant of the "cluster-first, route-second" approach to solving vehicle routing problems. In a follow up to In [21] work, [22] extend the solution method to include metaheuristics including simulated annealing and tabu search. Their approach is deterministic and one of the main findings is that recycling trucks to create more routes while using fewer vehicles can lead to significant cost reductions.

IV. STRATEGIC PLANING IN NEWSPAPER INDUSTRY

Followings are the main strategies for the company so employee and management have to pay much attention to the strategies to receive customer satisfaction.

Product: Experienced auditors will review and develop the content of newspaper every year in order to response the need of customers.

Price: For subscription sales, discount and premium are always offered in order to increase their sale volumes. For non subscription sales, discount will be offered to agents or bookshops, not direct to the reader. The price movement in the domestic market is also monitored closely and a competitive price is always set to compete with their competitors.

Distribution Channel: The Company sells their newspaper directly to their customers by attending Bangkok International Book Fair and Book Expo Thailand which are held on March and October yearly in Thailand. Bookshop is the main distribution channel for newspaper. Internet is another mean for the company to present their products via the company web site. Customer can purchase the newspaper in bookshops or place their order by using mail order or they can order directly at company Home Center.

Delivery Time: For subscribers, they would like to have their copy before leaving home to work. For Bookshops, the newspapers must be arrived before shops opening.

Handle Process of Customer Complaints: Responding to customer complaints is the major concern of the company. Customers will receive the answer back within 1 hour after the placed complains.

V. AN ASSUMPTION TO NEWSPAPER DELIVERY PROBLEM

Below are the assumption lists that shaped our formulation of the VRP model for the company.

1. Each route will start from and end at the Depot.
2. The cost of a route is proportional to the time traveled.
3. Travel times between each stop are known and accurate.
4. Demands (i.e., number of copies) at each of the stops are known.
5. Unloading time per stop is constant for every stop.
6. The demand at each stop cannot split.

Constraints in this problem are

1. Total of 7 vehicles are available.
2. Hour of operations: there are time window of t =180 minutes for delivering newspapers to the last stops/customer and t=60 minutes for returning to depot.

However, there are other constraints that did not define in this paper due to intangible factor which cannot be part of the model i.e. Vehicle capacity which all copies shall be stored behind the truck with door closing at all time of running. The paper shall not be stored in the front seat or the roof of the truck.

VI. A VRP MODEL FOR OPTIMIZEING NEWSPAPER DELIVERY PROBLEM

A mathematical explanation of VRP for newspaper delivery problem in this case may be defined as follows. Let $G = (V, A)$ be a network where $V = \{0, 1, \ldots, n\}$ is the vertex set and $A \subseteq V \times V$ is the arc set. Vertex 0 is the depot and $V\backslash\{0\}$ is the set of locations on the road network. Associated with vertex $i \in V\backslash\{0\}$ is a non-negative demand d_i. The parameter c_{ij} represents a non-negative cost (traveling time in this case) between vertices i and j. The parameters K and U_k are the number of vehicles and the capacity of vehicle k, respectively. A three-index integer programming formulation will be presented here where binary variables x_{ijk} count the number of times arc $(i,j) \in A$ is traversed by vehicle k ($k = 1,\ldots,K$) in the optimal solution. In addition, there are binary variables y_{ik} ($i \in V$; $k = 1,\ldots,K$) that take a value of 1 if vertex i is visited by vehicle k in the optimal solution and take a value of 0, otherwise. The formulation is as follows:

$$\min \sum_{(i,j)\in A} c_{ij} \sum_{k=1}^{K} x_{ijk} + 0.1 \sum_{i\in V} Y_{ik} \quad (1)$$

subject to

$$\sum_{k=1}^{K} y_{ik} = 1 \qquad \forall i \in V \setminus \{0\} \quad (2)$$

$$\sum_{k=1}^{K} y_{0k} = K \quad (3)$$

$$\sum_{j\in V\setminus\{i\}} x_{ijk} = y_{ik} \qquad \forall i \in V, k = 1,\ldots,K \quad (4)$$

$$\sum_{j\in V\setminus\{i\}} x_{jik} = y_{ik} \qquad \forall i \in V, k = 1,\ldots,K \quad (5)$$

$$\sum_{i\in V\setminus\{0\}} d_i y_{ik} \le U_k \qquad \forall k = 1,\ldots,K \quad (6)$$

$$\sum_{(i,j)\in A} c_{ij} \sum_{k=1}^{K} x_{ijk} + 0.1 \sum_{i\in V} Y_{ik} \le t \quad k = 1,\ldots,K \quad (7)$$

$$\sum_{i\in S} \sum_{j\in S\setminus\{i\}} x_{ijk} \le |S| - 1 \quad \forall S \subseteq V \setminus \{0\}, |S| \ge 2, k = 1,\ldots,K \quad (8)$$

$$y_{ik} \in \{0,1\} \qquad \forall i \in V, k = 1,\ldots,K \quad (9)$$

$$x_{ijk} \in \{0,1\} \qquad \forall (i,j) \in A, k = 1,\ldots,K \quad (10)$$

Equation (1) represents the objective function of this problem to minimize total travel time of the operations. Constraints (2) - (5) ensure that each customer is visited exactly once, that K vehicles leave the depot, and that the same vehicle enters and leaves a given customer vertex, respectively. Constraints (6) are the capacity restrictions for each vehicle k, whereas constraint (7) is a time window constraint. The unloading time also presented here in (7). The sub-tour elimination constraint for each vehicle is shown in constraint (8).

VII. A MODIFIED SWEEP ALGORITHM APPROACH

The sweep algorithm is 2-phase algorithm [1]. The problem is decomposed into its two natural components: Clustering of vertices into feasible routes, then actual route construction, in other word cluster first and route second algorithm. The sweep algorithm applies to planar instances of the VRP. It consists of two parts:

1. Split: Feasible clusters are initialed formed rotating a ray centered at the depot.
2. TSP: A vehicle routing is then obtained for each cluster by solving a TSP.

The generic sweep algorithm uses the following steps [8].

1. Locate the depot as the center of the two – dimensional plane.
2. Determine all the polar coordinate of each stop with respect to the depot.
3. Start sweeping all customers by increasing polar angle.
4. Assign each customer encompassed by the sweep to the current cluster.
5. Stop the sweep when adding the next stop would violate the maximum vehicle capacity.
6. Create a new cluster by resuming the sweep where the last one left off.
7. Repeat steps 4-6, until all customers have been included in a cluster.

The original sweep method, as mentioned above, has the vehicle capacity and the travel time to next stop as the route termination rules. In this research, the vehicle capacity constraint is still hold. However, it allows the sweep to skip a stop when the travel time to that stop would exceed the time limit. The next stop after the skipped stop will be tested by the same termination rules. If it exceeds the capacity then the sweep terminates, and the stop which has the least angle which is not include in any cluster yet will be used as the starting stop in the next cluster. The sweep considers the stops in increasing angle until one is found that does not violate the time limit. If no such stop is found, the cluster is terminated and the next cluster is started at the stop with lowest degree angle which has not been included in previous cluster yet.

VIII. HEURISTIC RESULTS

In this section we will present the results achieved after the skipped sweep method has been applied and compare them with the previously one.

Table 2 summarize the results achieved by applying the Modified Sweep Method, every route took longer delivery time than the initial. That means apart of the customers has time delayed. The question is which drops points are there. We found that there were 49 drop points (representing 41.5%) received newspaper later than initial route. Nevertheless, in applying the new route, every customer remains to get the newspaper within the company's time window of 180 minutes. In addition, when analyzed the result in other aspects, we found that the 7th route has to be delivered only 4 drops and consumed total time at 341 minutes. As the results, conceptually, if drop points are adjusted again, it might take only 6 vehicles to deliver the entire customers.

Table2: Comparison result of newspaper delivery between initial routes and new routes.

	Stop Points		Total Travel Time (min)		Number of Copies	
Vehicle	Initial Route	New Route	Initial Route	New Route	Initial Route	New Route
1	20	22	176	179	1,265	1,800
2	15	20	145	166	1,311	1,742
3	17	19	165	172	1,153	1,140
4	17	15	156	177	1,372	1,115
5	19	20	168	176	1,451	1,597
6	19	18	153	173	1,593	1,621
7	11	4	142	162	1,211	341
Total	118	118	1,105	1,205	9,356	9,356

IX. CONCLUTION

In this paper, the two aspects of research area were studied, strategic planning and algorithm, for a morning newspaper in Bangkok which aim to improve delivery with time allowed. For the first aspect, it's time consuming to process and evaluate while continued developing of strategic planning is required. For the second aspect, develop a vehicle routing Algorithm for solving of variant VRPTW remain unsolved as modified sweep algorithm resulted the delay of delivery time for 41.5% of all drop points, however, to assure readers satisfaction on every drop point, a good distribution and precise amount distribution remain meet on time delivery.

Major question to be answered in this research –How will morning newspaper be delivered within delivery time efficiently and effectively in line with the corporate defined strategic. This may be required route adjustment which will help us get a better result. This will be the direction of future research.

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