Strategic Planning for Newspaper Delivery Problem Using Vehicle Routing Algorithm with Time Window (VRPTW)

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Abstract— **We present a case study on the application of techniques for solving the Vehicle Routing Problem with Time Window (VRPTW) to improve the newspaper distribution service in Bangkok, Thailand. The improvement of the distribution activity is part of the strategic planning of the company which aims to reduce number of staffs and to reduce cost occurred in the distribution process. Empirical results indicate that the heuristic method with some modification of steps and constraints can find relatively good relations. It trends to save cost of distribution up to 5.3% which bring service cost from 23 % to 17.70%.**

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

I. INTRODUCTION

The Vehicle Routing Problem was first introduced in 1959 by Dantzig and Ramser [1]. Their paper appeared in the journal of Management Science concerning a fleet of gasoline delivery trucks between terminal and a truck number of service stations supplied by the terminal [2]. The problem formulated in the Dantzig and Ramser's paper given the name "Dispatching Problem" and many years later was coined the name "Dantzig and Ramser's Problem" and "Vehicle Routing Problem" respectively.

Ever since, the Vehicle Routing Problem (VRP) and its variants have been intensively studied and received considerable attention for many decades because of the importance of mobility and its interest in different application in logistics and supply chain management.

VRP is an optimization problem basically consists of finding the set of routes with overall minimum total cost or total travel times. The followings are some of its variant constraint: every customer must be visited at once by vehicle, all demands must be served, overalls demands must not exceed the vehicle's capacity, customer demands are known, travel time is accurate.

VRP is an integer programming and is one of the representative combinatorial optimizing problem and known to be NP-hard and therefore difficult to solve [3]. The traveling salesman problem (TSP) can be viewed as a special case of VRP in which number of vehicle is one. TSP has been intensively studied as well.

In this paper, the study of a newspaper distribution was presented. The performance of initial routes was based on data from a morning newspaper company located in Bangkok, Thailand. We considered only the problem concerning the distribution of newspaper between a Distribution Center (DC) to drop points, not to final customers.

Because getting the best results by applying the exact algorithm from instance computer program is very costly, therefore approximate solutions with sufficient accuracy are often desired by the small and medium-sized enterprises. The vehicle routing problem with time window (VRPTW) was considered in this paper since customers often set windows in which the vehicle has to arrive before they left their home for work. For that, guaranteed on time delivery and service quality are the main key success factors of newspaper industry, which give the company competitive advantage.

This research was to develop VRP to serve morning newspaper company's strategic planning of minimizing total traveling time and cost while increasing customer satisfaction. The improvement is achieved by adjusting new routs, reducing number of vehicles with result in lower total cost.

In the last section, the routes performances achieved by vehicle routing algorithm were then compared to that of initial routes. Sensitivity analysis was also presented for alternative solutions. Delivery time allowed and vehicle capacity were the main criterion.

II. LITERATURE REVIEW

In this section, we briefly review the literature in general of VRP with some of its variants - Capacitated Vehicle Routing Problem (CVRP), Vehicle Routing Problem with Time Window (VRPTW), Multiple Depot Vehicle Routing Problem (MDVRP), Vehicle Routing Problem with Pick-Up and Delivery (VRPPD), Vehicle Routing Problem with

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Backhauls (VRPB) - and an application of VRP in newspaper industries.

A. *Vehicle Routing Problem*

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 objectives are to minimize the vehicle fleet and the sum of travel time while the total demand of commodities for each route may not exceed the capacity of the vehicle which serves that route [4],[5].

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 with the sum of travel time and waiting time needed to supply all customers in their required hour [4][6]. A variety of algorithms including exact methods and efficient heuristics have already been proposed for VRPTW.

Many researches have been studied intensively on heuristic and meta-heuristic methods from 1995-2009 as summarized in Table 1.

Table 1: Representative algorithms for Vehicle Routing Problem with Time Window

Authors	Year	Methodologies
Dumas et all	1995	Time constraint routing and scheduling [7]
Liu and Shen	1999	Route-neighborhood-based metaheuristic [8]
Bent et al.	2003	Two-stage hybrid algorithm [9]
Kima, et al.	2005	Capacitated clustering [10]
Lysgaard	2006	Precedence constraints [11]
Russell and Chiang	2006	Robust solution methods [12]
Chena, Hsueh and Chang	2009	An elaborated solution Algorithms [13]
Li, et al.	2009	Lagrangian heuristic [14]

Multiple Depot Vehicle Routing Problem (MDVRP) is a problem that customers 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 objectives are to minimize the vehicle fleet and the sum of travel time while the total demand of commodities must be served from several depots.

Vehicle Routing Problem with Pick-Up and Delivery (VRPPD) is a VRP with the possibility that customers' returning of some commodities is contemplated. The objectives are 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 for picking up at customers to return 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 distances traveled.

In addition, Table 2 represents the various methods applying in Exact Algorithm, Classical Heuristic Algorithms and Metaheuristic Algorithms.

Table 2: Representative Exact algorithms, Classical Heuristic Algorithms and Metaheuristic Algorithms for VRP

a) Exact Algorithms

Authors	Year	Methodologies
Christofides and Eilon	1969	Branch and Bound [15]
Miller	1995	Branch and Bound [16]
Hadjiconstantinou et al	1995	Set-partitioning [17]
Baldacci et al.	2004	Branch and Cut [18]

b) Classical Heuristic Algorithms

Authors	Year	Methodologies
Dantzig and Ramser	1959	Constructive algorithm. First approach [1]
Clarke and Wright	1964	Saving. Concurrent & sequential [19]
Wren and Holliday	1972	Sweep Algorithm. Multiple depots [20]
Lin and Kernighan	1973	Single-route improvement Sequential k-exchange [21]
Gillett and Miller	1974	Sweep Algorithm. Single depot [22]
Foster and Ryan	1976	Petal algorithm. Optimal petal solution [23]
Mole and Jameson	1976	Sequential Route-Building Insertion position check [24]
Christofides et al.	1979	Sequential Route-Building Sequential & Parallel construction [25]
Fisher and Jaikumar	1981	Cluster-First Route-Second Generalized Assignment + TSP [26]
Beasley	1983	Route-First Cluster-Second [27]
Altinkemer and Gavish	1991	Matching Algorithm. Matching clusters [28]
Ryan et al.	1993	Petal algorithm [29]
Thompson and Psaraftis	1993	Multiple-Route Improvement b-cyclic k-transfer [30]
Potvin and Rousseau	1995	Single-route improvement. Based on 2-opt [31]
Bramel and Simchi-Levi	1995	Cluster-First Route-Second [32]
Renaud et al.	1996	Single-route improvement [33]
Kindervater and Savelsbergh	1997	Multiple-Route Improvement [34]

c) Metaheuristic Algorithms

Authors	Year	Methodologies
Osman	1993	SA [35]
Taillard	1993	TS [36]
Gendreau et al.	1994	TS [37]
Van Breedam	1995	SA[38]
Rochat and Taillard	1995	TS [39]
Xu and Kelly	1996	TS [40]
Kawamura et al.	1998	ACO [41]
Bullnheimer et al.	1999	ACO [42]
Toth and Vigo	2003	TS [43]
Baker and Ayechew	2003	GA [44]
Mazzeo and Loiseau	2004	ACO [45]

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 or total travel time in the newspaper industry. Table 3 presents some of heuristic VRP specifically to newspaper industries during 1964-2008.

Table 3: Representative Algorithms for the Vehicle Routing Problem (VRP) in Newspaper industry from 1964-2008

Authors	Years	Methodologies
Clarke, J.W. Wright	1964	Savings technique [19]
Floyd	1967	Algorithm 97 shortest path[46]
Daganzo	1981	The Distance Traveled to Visit N-point with C-stop[47]
Ree and Yun	1996	Branch and Bound [48]
Hurter, M. Van Buer	1996	Greedy and Or-Opt route improvement heuristic[49]
Van Buer, Woodruff, and Olson	1999	Metaheuristics-simulated annealing /tabu search [50]
Carter and Ragsdale	2002	GA [51]
Song, Lee &. Kim	2002	Regret Distance Calculation algorithm [52]
Russell, et al.	2008	Open vehicle routing problem and zoning constraints [53]

There were many researches studied about production and distribution process, but not many about preprint process. Several literatures are summarized as below:

- Preprint Process

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. The result showed that the GA approach to developing schedules reduces the processing time associated with creating the preprint packages [51].

- Production and Distribution Process

A newspaper distribution problem for a metropolitan daily Korean newspaper was also studied and then developed a delivery plan using a branch-and-bound heuristic with simulated annealing (SA) [48].

Before that [49] 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 was 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.

Also, 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 [52].

Other examples included [53] 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 Dutch regional newspaper's distribution process was also studied [54] and the process was modeled by constructing the travel time matrix using [46] algorithm and [19] savings technique as the vehicle routing heuristic. In [47], a newspaper delivery problem for the city of San Francisco was considered as an application of a formulation developed for predicting the distance traveled by fleets of vehicles in distribution problems.

The formulation was a variant of the "cluster-first, route-second" approach to solve vehicle routing problems. In a follow up to [47] work, [50] extended the solution method to include metaheuristics, simulated annealing and tabu search. Its approach was deterministic and one of the main findings was that recycling trucks to create more routes while using fewer vehicles can lead to significant cost reductions.

Moreover, references [55], [56] applied VRP to school bus routing. Other applications included inventory and vehicle routing in the dairy food [57], transportation service at university [58], public library system [59], post service [60], and grocery delivery [61], waste collection [62], magazine [63].

III. CHARACTERISTICS OF NEWSPAPER DISTRIBUTION PROBLEM

In real world, fleet of transportation is very complicated. Number of trips, links/path and cost are to be considered. Transportation often involves routing vehicles according to customer given time allows that determines the customer's satisfaction level. Therefore, all publishers intensively improve and adjust company' strategies by pertaining their internal resources with external resource (the market). The competitive advantage can be achieved by concentrating all the available resources on one basic strategy which is shorten delivery time. The short delivery time if administered efficiently and effectively could also result in less distribution cost. This may be the ultimate choice since a declining enterprise had difficulty to increase sales [64], [65].

a) Newspaper Industry Situation

Newspapers in Thailand and others countries are confronting the most serious situation of their history. They are facing an unprecedented famine in news print. Because of declining circulation, many publishers are now carrying printing and distribution cost per copy more than they formerly did.

In order to keep all expenses and costs as budgeted, many owners and investors have decided a general increase in advertising rate and subscription rates. The reasons are to keeps the smaller newspaper from being forced to suspend and be able to compete with other off-line services and with other media such as TV, radio and other on line services. Moreover, publisher needs to improve the production and distribution process as well as other processes in the company.

Currently, end consumer or reader prefers to consume news from websites like Google or Yahoo and other search engines. Those sources are sharing revenue and customers in the market. They are also mimicking the job of editors by using sophisticated computer programs to automatically compile links to content from newspapers, wire services, blogs, and other sources from around the world.

The newspaper companies cannot print the news sections

of the newspaper in advance because of the requirement that news be timely. Achieving on time delivery therefore is quite challenging because publisher 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 the readers. Consequently, the logistics staffs have to work as fast as possible. They also have to provide more available trucks than needed and that cost the company more than it should. Traditionally, the idea of low cost and fast delivery could not be attained, simultaneously. It is a belief that some kind of trade-off is necessary; the more of one advantage means less of another. However, it was suggested that "seeking reduction, either time or cost reduction is often the rewards" [64].

b) Newspaper Category

Based on customer demand, newspaper can be categorized into two parts, subscribing newspaper and non- subscribing newspaper.

For non-subscribing newspaper delivery, demand is probabilistic, so it needs an estimation to determine the amount of newspaper to be printed and distributed. Waste of unsold newspapers would happen if the amount of distributing newspapers were bigger than sold newspapers and that also cause the problem of reverse logistics. Therefore, the distribution problem is not only about a delivery problem but also about collecting back unsold copies on a daily or weekly basis. In effect, about 50% of the distributed copies were returned to the warehouse. Because of internal audit policy, warehouse must provide enough space to keep unsold copies until all are checked by internal auditor. Also, delivery document must be promptly signed by outlet staffs authorized by shop owners. Without signed document, cost from complaining may occur if there is loss of whole pack of paper. Consequently, cost of making a delivery of replacement to those outlets would occur.

For Subscribing Newspapers Delivery, Demand of subscribing newspaper is deterministic; it does not need to be estimated for distribution. However, time allowed is a very crucial issue in this type of delivery.

c) Newspaper Distribution Models and Lead Time

There are 4 models for newspaper distribution system in Thailand as shown in Figure 1 and described below.

Model 1: In case that loading dock and DC are not located in the same place, Newspapers will be transferred to DC for packing, then delivered to drop points and then carrier will distribute to final customers.

Model 2: In case that loading dock and DC are located in the same place with packing required, newspaper will be packed immediately, then delivered to drop points and then carrier will distribute to final customers.

Model 3: In case that loading dock and DC are located in the same place without packing required, newspaper will be directly loaded into vehicle and delivered to drop points, and then carrier will distribute to final customers.

Mode 4: In case that the final customers' residents are close to the printing house, carrier will pick newspaper at loading dock and deliver to designated customers.

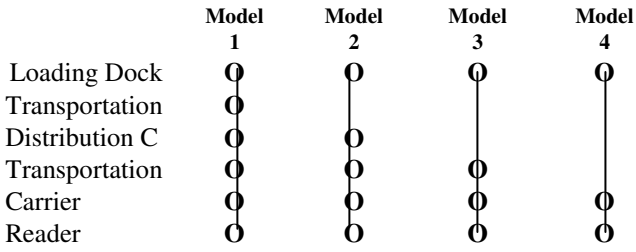

Figure 1: Models of newspaper distribution system in Thailand

Figure 2 shows current processes and lead time of physical newspaper distribution. The processes involve loading, transport, and carrier. 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 processes have to be planned to meet the delivery deadline. When the delivery deadline is set, say at 6.30 am, an analysis of the process time for each process will generate the required starting times. The key timing parameters are the start of the press run, say at 1.00 am. The carriers have to finish 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 deliver to their first customer or reader.

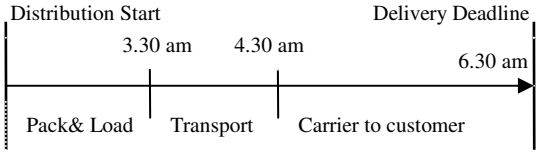

Figure 2: Processes and lead time to be considered for physical newspaper distribution

d) Newspaper Delivery Problem

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 [39].

NDP is an example of a perishable-good production and distribution problem. People who are working in publishing companies classify physical newspaper as perishable goods because they could be lost in significant value if delivered late or over printed [32].

NDP is also vital in the newspaper industry provided that it is directly tied to customer service level. Late delivery of a newspaper may result in the loss of customers or may result in the shutting down of a production line if numbers of customers are rapidly reduced [5].

IV. STRATEGIC PLANING

During the global financial crisis in 2009, newspaper and magazine businesses, particularly medium-sized companies are in need of a revision of the current business strategy, which will not only allow businesses to maintain their long-term potentiality, but also facilitate future growth and also need to Improve the efficiency of the business process to make the company more attractive to potential customers or subscribers.

For a newspaper studied in this paper, local advertisement accounted for 80% of newspaper revenues. Subscriptions and newsstand sales make up most of the rest. The traditional advertising model for years generated healthy profits, subsidized all expensive expenses and help keep subscription and newsstand prices low as the results of gaining number of readers. But the model is breaking down. Newspapers have a dramatic drop in advertising during the recession. Newspaper ads revenue fell by 20% in the first and second quarter of 2009 compared to a year earlier.

As mentioned earlier, traditional printed newspapers take a financial beating, new media sources are rising on the Internet, helped by low entry costs. Alternative sources of news and information are becoming available to a potentially vast audience via an increasing number of wired and wireless devices. So far, in the company, no one has come up with a workable strategy for garnering sufficient advertising or subscription revenues on the Internet. For short term plan, however they intend to increase subscription prices for their traditional print editions. The profit per order will definitely be increased and the main reason is to keep the bottom line in black ink.

a) General Strategies for newspaper's company

The followings are the main strategies for a newspaper company so employee and management have to pay much attention to the strategies to get 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.

Table 4: Newspaper price model in 2009
(Unit: Baht*)

Condition	Newsstand	Subscription	Save
Per issue	25	13.4	46%
1-year rate	9,125	4,900	46%
2-year rate	18,250	9,500	48%

* Exchange rate was 34 Baht / USD as of 1 Feb 2010

Table 4 shows the comparison between newsstand and subscription prices of a morning newspaper in Bangkok. One-year subscription rate is offered about 46 % less than newsstand price whereas two-year subscription rate is offered with more discount at 48 %. Premium, free gift and free reading copy are also additionally offered in certain of period. Free home delivery is offered as a complimentary to all readers.

Distribution Channel: Table 5 shows the proportion of sales with allowed conditions. The Company sells newspapers directly to their customers by attending Bangkok International Book Fair and Book Expo Thailand which are held in March and October yearly in Thailand. Meanwhile, Bookshop is the main distribution channel for newspapers. Internet is another mean for the company to present their products via the company web site. Customers can purchase the newspaper in bookshops, place their orders by using mail order or they can order directly at company call center. For delivery time, subscribers would like to have their copy before leaving home to work while for bookshops, the newspapers must be arrived before shops opening.

Table 5: Proportion of sales with allowed sales condition in each channel.

Channel	% Sales	Sales Condition
Direct Sales	50%	Subscription rate
Telesales	40 %	Subscription rate
Bookshop	5%	Subscription rate
Internet	4%	Subscription rate
Book Fair	1%	Newsstand rate

Process of Customer Complaints handling: Responding to customer complaints is the major concern of the company. Customers will receive the answer back within 1 hour after the placed complaints and customer will receive replaced paper within 3 hours if paper cannot be found. Figure 3 show the detail of customer complaint's process.

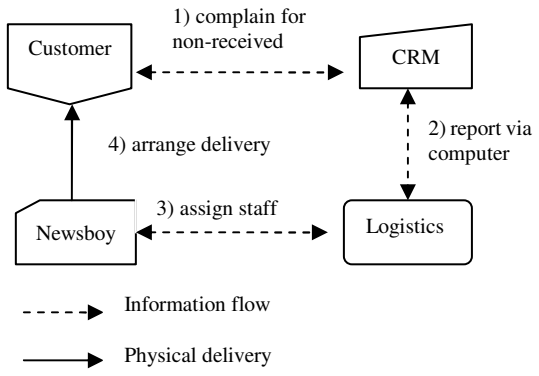

Figure 3: Process of Customer complaint handling

1. Customer call CRM to complain non-received paper
2. CRM report logistics department via computer system
3. Logistic assign staff and report back to CRM the estimated arrival time.
4. CRM call to inform customer.
5. Newsboy delivers special newspaper to customer and report back to Logistics Department when task is done.

Two main objectives that a newspaper company sets for their annual strategic business plan are to achieve total annual sales and profit, and to meet customer satisfactions. To gain more profit, all cost has to be monitored and controlled under consideration of customer satisfaction fulfillment. The following section, distribution cost which consists mainly of labor cost and also transportation cost will be discussed in detail.

b) Newspaper Distribution Cost

The distribution of newspaper has a number of features distinguishing it from other distribution operations because newspaper is not to be produced in advance for inventory keeping. As a result, distribution centers play an important role, while print production and distribution are necessarily intimately related. In addition, the total time devoted to both production and to distribution may be severely limited, thereby further tying together the design and operation of the production and distribution functions. These distinguishing features increase the complexity of the production and distribution problem for newspaper [32].

Table 6 shows the strategic planning that company target for future distribution. The newspaper company aims to reduce distribution cost from 23% down to 20% and complain rate from 0.05% to 0.45 % in following year.

Table 6: Strategic planning for a newspaper distribution company.

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

Newspaper distribution cost can be divided into two major categories: first, costs associated with the actual production and distribution activities and second, costs directly attributable to the perish ability of either an input or an output. In the newspaper problem, an infeasible solution would be one in which not all newspapers are delivered by the deadline. The costs associated with this infeasibility may include the cost of the newspaper, a lost subscription, the cost of processing the complaint, the cost of making a special delivery, etc.

Table 7: Component of newspaper distribution cost.
(Unit: Baht*/ day)

Activity	Pack & Load	Transport	Total
No. Staff	4	7	11
No. of Vehicle		7	7
1.Staff exp.	800	2,100	2,900
2.Distribution exp.		4,330	4,330
2.1 Petrol		*3,500*	*3,500*
2.2 Toll way		*630*	*630*
2.3 Maintenance & other		*200*	*200*

* Exchange rate was 34 Baht / USD as of 1 Feb 2010

Distribution cost in newspaper industry is a major expense for the newspaper, making up to approximately 23 % of the total cost. As shown in Table 6 and 7, distribution cost consists of labor cost at 40% while transport and petrol costs are account for 60% of distribution cost.

Labor Cost: In distribution department, labor cost is mainly from packing staffs, loading staff, and drivers. In studied company, there is no material handling equipment to support in packing or loading process, therefore company requires a number of labors to produce its goods and service. Labor costs are considered variable which gives labor-intensive industries as newspaper's company an advantage in cutting expenses during market downturns by controlling the size of the employee base.

Beside distribution department, people from the finance, marketing, operations, and human resources departments are often self-directed. That is, they are given broad objectives, but not specific directives. Decision making within a team is usually based on consensus. Each department does not well understand the common objectives of the company. Up until recently, decision making flowed in one direction so each of department does not see the big picture of the company. Therefore, Cross function team can be of help the company improve employee performance and increase their multi skills that is an initial way to save labor cost. Consensus should be created within the team through an interactive process. Ideally, when all department and management level are working as a team, direction of increasing revenue is well cleared and understood, all actions will be performed by following company direction and definitely percentage of expenses will be automatically decreased.

Transportation Cost: Transportation cost in studied company includes petrol cost, toll way fee and maintenance cost. Further, transportation costs have recently spiked due to increases in gasoline and diesel fuel prices. To rise and therefore delivery costs will trend higher. A method for reducing newspaper distribution costs is by delivering more products to the destinations during each delivery trip without affecting constraints. In addition, multiple uses of vehicles can also reduce transportation cost, yet implemented in studied newspaper company. Currently, single use of vehicles only for newspaper delivery is still a common strategy.

In addition, newspaper distribution cost analysis should be done from time to time. Newspaper distribution cost analysis is a technique which examines in detail all the costs incurred in process of printing, loading, packing and carrying of newspaper to the customer, it involves a study of cost control which is directly applicable to the whole delivery operations. In particular, by showing the degree of expense that each part of the printing and delivery activity attracts, it helps to improve the delivery policy of the company.

Newspaper's company must provide just-in-time delivery services to their customers. Typically those customers or subscribers require daily. It is a significant management challenge to design and develop an efficient delivery schedule to meet demand. In other word, newspaper's company can take advantage of the just-in-time (JIT) approach to achieve goals such as cost reduction, lead-time reduction, quality assurance, and respect for humanity. Since the performance of the publisher can be evaluated by various criteria including lead times, on-time delivery, delivery reliability, quality, and cost , deploying the JIT system is crucial in improving customer satisfaction.

There are many strategies planning studied report in literature. Reference [27] addressed route planning for magazine and newspaper wholesalers. Other report include cooperate strategy for express delivery services [40], and JIT and TQM studied for improving delivery performance [41].

V. AN ASSUMPTION TO NEWSPAPER DELIVERY PROBLEM

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

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:

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

subject to

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

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

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

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

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

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

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

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

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

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 [38]. 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[5],[57],[58]:

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

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. Figure 4 illustrates a clustering process.

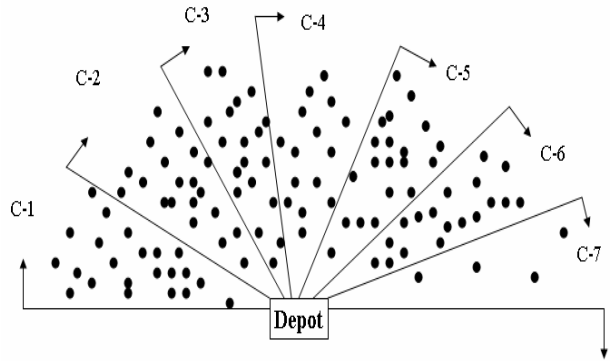

Figure 4: Clustering process: clockwise manner

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 AND SENSITIVITY ANALYSIS

In this section we will present the initial results achieved after the skipped sweep method has been applied and compare with the previous one. This research comprises 118 nodes, with different demand values ranging from 22 to 235. The vehicle capacity is 2,000. The solution reveals that seven vehicles will be used with total delivery time of 1,205 minutes or 10.21 minute per node in average.

Table 8 summarizes the results achieved by applying the Modified Sweep Method. Every customer remains received newspaper as time promised even apart of the customers, 49 drop points or representing 41.5%, received newspaper later initial routes.

After we monitored the initial results, we found that there were many opportunities and possibilities to improve the results for example, reallocating drop points, adjusting lead time without violating capacity constraints.

Table 8: Comparison initial results of newspaper delivery between initial routes and new routes.

No. Vehicle	Stop points		Total Travel Time (minute)		No. of copies	
	Initial	New	Initial	New	Initial	New
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

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 162 minutes with total capacity of 341 copies only. Therefore, we strongly believe that there were still rooms for improving the results. Sensitivity analysis will be proposed for reducing number of vehicle which is part of minimizing total cost of using vehicle as targeted in company's strategic planning.

Considering company's current operations, we determined that the *t* value could be larger than the stated time window. The heuristics results when we assigned the wider time window revealed that at *t* equal to 200 minutes gave a preferable result. Only 6 vehicles will be needed in the delivery process. However, total travel time of every route exceed the previous stated time window. Therefore, we adopted traveling salesman problem method to order the drop points in each route.

Table 9 shows the comparable result of total travel time obtained by skipped sweep algorithm only and improving results after using TSP method. It shows that only 2 routes used time to operate in distribution activity more than previous stated time window of 180 minutes.

Table 9: The results of total travel time (minute) obtained by skipped sweep algorithm

No. Vehicle	No. of Stop Points	Skipped Sweep Algorithm with Time Window 200 minutes	After Ordering Using Traveling Salesman Problem Methods
1	25	198	179
2	20	192	173
3	16	188	180
4	19	196	177
5	12	199	189
6	26	196	188
Total	118	1,169	1,086

IX. CONCLUTION AND DISCUSSION

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 service within time allowed.

For the first aspect, strategic planning for newspaper's company was studied and discussed specifically to price model, labor cost and distribution cost. Subscription and newsstand prices should be set as low as possible when advertising sales generated healthy revenue and profits.

However, in the crisis situation when newspaper ads dropped and affect the bottom line of the company, increasing subscription prices should be taken into consideration. Transportation cost can be improved by reducing traveling lead time and by multiple uses of vehicle. Transportation cost should be monitored continuously.

For the second aspect, the experiment has been developed twice for vehicle routing algorithm. The first result showed that developing a vehicle routing algorithm to solve variant VRPTW remains unsolved as modified sweep algorithm resulted in 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 remains meet on time delivery.

Moreover, sensitivity analysis was conducted as to improve results by increasing time allowed from 180 minutes to 200 minutes in sweep algorithm steps. The results indicate that the heuristic method with some modification of steps and constraints can find relatively good relations. It trends to save cost of distribution up to 5.3% which bring service cost from 23 % to 17.70%.

The following study areas will be the direction of future research.

1. Scheduling of production process.
2. Relocating drop points
3. In this paper, only DC to drop points was solved, therefore to complete all process of distribution network, drop points to end customers should be considered as multi-time window, multi- customer points.

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