出國報告（出國類別：出席國際會並發表論文）

出席 21st EurOMA Conference 及發表論文 心得報告

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報告日期：2014 年 07 月 17 日
出國時間：2014 年 06 月 21 日至 2014 年 06 月 29 日

摘要

本次出席的 21st EurOMA Conference 是由歐洲作業管理學會主辦的年度學術研討會，今年大會主題為「Operations Management in An Innovation Economy」，會議主體的研討議程持續三天(6/22-6/24, 2014)，今年主辦地點在義大利西西里島的巴勒摩市，於巴勒摩大學的校園內舉行。

參加本次國際會議的目的有二，其一在於了解歐洲作業管理領域最新的研究發展趨勢，同時得知作業管理專業領域應因全球經濟變遷下的因應措施。目的之二在於發表本人的學術研究論文，並藉此與「供應鏈與物流」相關研究領域之專家學者進行學術交流，藉以獲得研究方法的啓發與開發後續研究主題。

整體而言，研討會在實務與應用兩大主軸之下，參與討論的學者及專家均廣泛的交換意見，對於作業管理未來的發展及變化，與會學者及專家均有很高的共識。

目次

一、 目的

此次本人參加該國際會議的目的有二，目的之一在於了解歐洲作業管理領域最新的研究發展趨勢，同時得知作業管理專業領域在應因全球經濟變遷下，歐洲的專家學者所採取的因應措施。目的之二在於發表本人的學術研究論文，並藉此與「供應鏈與物流」相關研究領域之專家學者進行學術交流，藉以獲得研究方法的啓發與開發後續研究主題。

此外，亦藉此行深入了歐洲各國之作業管理研究領域，如何與產業結合、如何進行良好的產學合作計劃，使學術界與產業界能有良性互動、進而相互支援，造成雙贏局面。整體而言，藉由廣泛的心得交流，獲得甚多寶貴的經驗。

二、 過程

本次出席的 21st EurOMA Conference 是由歐洲作業管理學會主辦的年度學術研討會，今年大會主題為「Operations Management in An Innovation Economy」，會議共歷時六天(6/20-6/25, 2014)，主體的研討議程持續三天(6/22-6/24, 2014)，今年主辦地點在義大利西西里島的巴勒摩市，於巴勒摩大學的校園內舉行。本次研討會共計有 592 篇摘要提出，經嚴格篩選之後共有 513 篇摘要被大會接受，最後共有 402 篇全文論文獲得審查通過並在大會中口頭報告。在三天的主體研討議程中，共有 134 個平行場次(Parallel Sessions)進行論文發表及研討，共有 37 個子題(Tracks)分別進行。以此規模而言，已屬中大型之國際研討會。

出席會議的各國學者及專家橫跨七大洲、共計 41 個國家及地區代表與會：總計歐洲 21 國、北美洲 3 國、中南美洲 3 國、亞洲 7 國、中東 4 國、大洋洲 2 國、非洲 1 國。六

天的研討會期間，除專題演講、Workshops、博士生研討、及例行的學會年會之外，在學術論文發表部份：每天的上下午均共有四個時段並行發表，每時段約有 18 場地同時進行學術論文發表。討論及交流均十分熱列、交流與激盪的成果豐碩。

此次研討會本人發表的論文為「A Study of Periodic Vehicle Routing Problem Allowing Delivery in Advance」(論文全文詳見附錄)，大會分配屬於 Logistics Management and Physical Distribution 子題 (Paper ID: LOG-05)，安排於 6 月 24 日 09:00-10:30 於 Aula”11” 場地發表。本篇論文探討允許提前送貨下之週期性車輛途程規劃問題，該議題在現今運輸能源費用上漲的環境下更顯重要，與會學者及專家對於本研究的構想與解析均持肯定態度，並對後續的研究方向與研究方法亦提出中肯而建設性的意見。

三、 心得

大會在今年主題「創新經濟下的作業管理」之下，與會學者及專家討論極為踴躍，各項研究子題大致仍以實務導向研究為主、學術導向研究為輔。在實務導向方面，對作業管理於產業的實際應用及實務成效，具有相當可貴的經驗分享；在學術導向方面，著重於問題的模型與解析的方法為主，同時探討較佳的解題方法與概念。

此外，本次研討會的特色之一為安排六場 Special Sessions，分別由資深企業主管或資深學者主持，這六場主題依序為: Teaching OM, Crowdsourcing and open innovation, Workshop on social media in OM and EurOMA, OM research in fashion industry, Operations as practice, New supply chains 等。這些主題既討論作業管理未來趨勢、亦能兼顧義大利之地區特色，故能留下深刻印象亦值得未來效法。

四、 **建議事項**

本次與會學者及專家仍以歐洲 21 個國家為主，歐盟成員國之間的交流往來十分密切，在經濟上、文化上、學術上國界日益模糊，取而代之的是較無限制的交流與溝通，在區域整合及分工上較易落實，也容易獲得合作與分享的果實。因此，台灣若能再多一些開放與區域合作，方能截長補短、共同享受區域分工的成果。

五、 附錄：發表論文全文

「**A study of periodic vehicle routing problem allowing delivery in advance**」

A study of periodic vehicle routing problem allowing delivery in advance

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Abstract

This paper investigates a special periodic vehicle routing problem which accepts some goods can be delivered before the due date within a given cycle. The customer service includes either pickup goods or delivery goods. The objective of this study is to minimize total cost including the moving distance cost, the fixed cost per route, and the penalty for early delivery. The concept of early delivery provides one possible arrangement for management in the periodic vehicle routings. A numerical example illustrated at the end of this paper indicates benefit for cost reduction.

Keywords: Periodic vehicle routing problem, Delivery in advance, Tabu search

Background and motivation

In the recent years, the business environment of distribution system has changed dramatically. Demands of customer are quickly changing and the delivery time is continuously reducing by customers. On the other hand, distribution centres face the pressure of cost reduction as well as increasing service level by quick response for each customer. Therefore, the periodic vehicle routing plan (Christofides and Beasley, 1984) may be a better choice than a traditional vehicle routing plan. A typical vehicle routing plan serves the fixed-demand customers by several independent routes in one period. The periodic vehicle routing plan enlarges time horizon to several periods, i.e. a cycle, and the system integrates service resources in a cycle. In addition, the service level can be further improved by arranging pickup operations and delivery operations in one route.

It is believed that the performance of a periodic vehicle routing plan still can be further improved by different approaches and considerations, such as delivering goods in advance, separating pickup operations and delivery operations in different stages, choosing suitable size of vehicle, using dynamic routing plan to catch the real-time conditions, etc.

This research proposes one possible improvement approach for a periodic vehicle routing plan by allowing some delivery operations to be executed before the due date, if it is accept by the customers. The benefits of these arrangements are to increase utilization of each vehicle and to reduce number of routings required in a planning cycle. On the other hand, goods delivered in advance might cause additional inventory cost as well as storage cost. These addition costs are represented by a special defined penalty cost per unit per period in this study. Therefore, the objective function of this study is to minimize the overall cost which can be classified as the following three categories: the travelling distance cost, the fixed cost of each route, and the penalty cost. Two critical conditions should be evaluated before we introduce this routing arrangement. The first condition is all customers accept goods may be delivered before the due period and agree with the unit penalty cost. The second condition is the overall cost is less than the cost of traditional periodical vehicle routing arrangement. In this paper, the first condition is the basic assumption and the second condition is illustrated by a numerical example.

This paper is organized as the following sections: literatures review, model and solution algorithm, illustration example and findings, and conclusion.

Literatures review

Vehicle routing problem (VRP) have been developed in the past few decades starting from the travel sales man problem introduced by Dantzig and Ramser in 1959. The application area of VRP broadly covers the transportation systems and distribution systems (Daneshzand, 2011). The original objective function focuses on finding a minimal travel distance or transportation cost. However, several VRP models with different assumptions and limitations has been developed on the basis of real-world requirements, such as hard or soft time windows for delivery time, limitation for vehicle loading capacity or travel distance per route, delivery goods or pick-up goods in one route, different fleet size or mixed loading capacities in one fleet (Kang et al., 2008)

The periodic vehicle routing problem (Christofides and Beasley, 1984) extends planning horizon from single period to multiple periods which is useful for integrating service resources. This study is based on a periodic vehicle routing problem as the basic model. For cost reduction purpose, we assume the relaxed constraint which is that the customers accept some goods can be delivered before the due date. If this case is feasible, an additional penalty cost will be activated on the basis of time and quantity.

A traditional VRP deals with either pure delivery goods or pure pickup goods. Other possible routing arrangements include the VRP with backhaul, the VRP with mixed pickups and deliveries, and the VRP with simultaneous pickups and deliveries (Nagy and Salhi, 2005). The model discussed in this study is the VRP with backhaul, which assumes that each customer requires either pickup goods or delivery goods. In addition, only the customer with delivery requirement can possibly be arranged earlier than due date.

The periodic vehicle routing problem is also known as the NP-hard problem. The optimal solution of a periodical VRP is difficult to find when the problem size is large. Therefore, a meta-heuristic algorithm should be applied in developing the solution algorithm. Several meta-heuristic algorithms have been used to solve VRP, such as Tabu search (Glover, 1989), simulated annealing algorithm, ant colony optimization (Dorigo et al., 1991), etc. This research uses the logic of Tabu search to develop the solution algorithm. An Excel-VBA program is then developed for solving the illustration example. Several important parameters of Tabu search should be tested and evaluated before solving the illustration example. This research uses the Taguchi experiment to fine tune these parameters, such as number of iteration, length of Tabu list, probabilities of selection moves, i.e. improvement approaches.

Model and solution algorithm

Problem description and Assumptions

The periodical vehicle routing problem discussed in this paper investigates a special option on delivery goods in advance. If this option is profitable, it can further reduce the overall cost and provide a better vehicle arrangement within a planning cycle. Several assumptions and limitations are described as follows:

(1) One planning cycle includes a fixed number of period.

(2) One depot is considered and location of the depot is given and fixed.

(3) Customers and their locations are given and fixed. Each customer requires either delivery service or pickup service in each period. Service quantity is fixed and given. Each customer can only be served once by one vehicle in each period. The service quantity of each customer should be less than the loading capacity of a vehicle.

(4) All customers accept some goods can be delivered before the due period. A penalty cost is activated if the earlier delivery is executed. The penalty value is proportional to number of period and quantity to be delivered in advance.

(5) When the earlier delivery is considered, we assume that all delivery goods for one period which required by a customer should be arranged to another period.

(6) No earlier pickup service is considered i.e. hard-time window applies in all pickup operations.

(7) Each route is served by one vehicle and the depot is the starting and ending point of each route. If a vehicle arrives one customer, the same vehicle should leave this customer.

(8) Single type of vehicle, i.e. same loading capacity for all vehicles. Each route is served by one vehicle and there is a fixed cost for each route.

Notations and decision variables

The following notations, parameters, and decision variables should be defined before construction of the mathematical model. The notations are defined as follows.

N: a set of all nodes including depot and customers. $N = \{ b \mid 0, 1, 2, \ldots, n \}$, where 0 represents the depot, n is the customer number, b represents current location ID.

K: a set of vehicle activated in each period. $K = \{ k \mid 0, 1, 2, \ldots, K_m \}$, where k is the vehicle number, K_m is the size of the fleet.

H: a set of period in a cycle. $H = \{ t \mid 1, 2, \ldots, z\}$, where z is the period number.

The parameters are defined as follows.

d_{ij} : distance between node i and node j, which is given and fixed.

c_{ij} : transportation cost between node i and node j. $c_{ij}=d_{ij}\times c$, where c is the unit travelling cost for one distance unit.

V: the fixed cost of each route which is given and fixed.

q^{-}_{jkt} : delivery quantity for customer j using vehicle k in period t.

q^{+}_{jkt} : pickup quantity for customer j using vehicle k in period t.

q_{jkz} : earlier delivery quantity for customer j using vehicle k in advanced period t.

α_{jz} : the original period number z for customer j to be delivered.

β_{jz} : the actual period number z for customer j to be delivered.

Q: loading capacity of a vehicle, a given constant.

P: unit penalty cost for earlier delivery per unit per period.

W_{jz} : total penalty cost for customer j in period z.

L: the maximal travel distance for a vehicle in one route.

M: an arbitrarily positive number.

The decision variables are defined as follows.

$$x_{ijkt} = \begin{cases} 1, \text{vehicle } k \text{ travels between node } i \text{ and node } j \text{ in period } t \\ 0, \text{otherwise} \end{cases}$$

$$y_{jkt} = \begin{cases} 1, \text{vehicle } k \text{ serves node } j \text{ in period } t \\ 0, \text{otherwise} \end{cases}$$

$$F_{jkz} = \begin{cases} 1, \text{if earlier delivery is activated in period } z \text{ for customer } j \text{ by vehicle } k \\ 0, \text{otherwise} \end{cases}$$

$$S_{kt} = \begin{cases} 1, \text{vehicle } k \text{ is activated in period } t \\ 0, \text{otherwise} \end{cases}$$

Mathematical model

Based on the concept of this study, a mathematical model is developed as the following objective function and constraints.

$$Min.\ \ Z = \sum_{t\in H}\sum_{i\in N}\sum_{j\in N}\sum_{k\in K} c_{ij}\cdot x_{ijkt} + \sum_{t\in H}\sum_{k\in K} V\cdot S_{kt} + \sum_{j\in N}\sum_{z\in H} W_{jz} \tag{1}$$

Subject to:

$$\sum_{j\in N} x_{ijkt} - \sum_{j\in N} x_{jikt} = 0 \qquad \forall i \in N,\ \ \forall t \in H,\ \ \forall k \in K \quad i \tag{2}$$

$$\sum_{j\in N}\sum_{k\in K} x_{0jkt} \le K_m \qquad \forall t \in H \tag{3}$$

$$\sum_{i\in N}\sum_{k\in K} x_{ijkt} + \sum_{k\in K}\sum_{z\in H} F_{jkz} = 1 \qquad \forall j \in N,\ \forall t \in H,\ i \ne j \tag{4}$$

$$\sum_{j\in N}\sum_{k\in K} x_{ijkt} + \sum_{j\in N}\sum_{k\in K}\sum_{z\in H} F_{jkz} = 1 \qquad \forall i \in N,\ \forall t \in H,\ i \ne j \tag{5}$$

$$Q - \sum_{j\in N} q^{-}_{jkt} \ge \sum_{j\in N}\sum_{z\in H} q_{jkz} - M(1 - \sum_{j\in N}\sum_{z\in H} F_{jkz}) \qquad \forall t \in H,\ \ \forall k \in 1 \tag{6}$$

$$Q - \sum_{j \in N} q^{-}_{jkt} < \sum_{j \in N} \sum_{z \in H} q_{jkz} - M \cdot \sum_{j \in N} \sum_{z \in H} F_{jkz} \qquad \forall t \in H, \quad \forall k \in I \tag{7}$$

$$\sum_{j \in N} y_{jkt} \cdot q^{-}_{jkt} + \sum_{j \in N} \sum_{z \in H} y_{jkt} \cdot q_{jkz} \cdot F_{jkz} - \sum_{j=1}^{b} \sum_{z \in H} y_{jkt} (q^{-}_{jkt} + q_{jkz} \cdot F_{jkz}) + \sum_{j \in N} y_{jkt} \cdot q^{+}_{jkt} \leq Q$$

$$\forall b \in N, \ \forall t \in H, \ \forall k \in K \tag{8}$$

$$\sum_{i \in N} \sum_{j \in N} d_{ij} \cdot x_{ijkt} \leq L \qquad \forall t \in H, \forall k \in K \tag{9}$$

$$W_{jz} = F_{jkz} (\alpha_{jz} - \beta_{jt}) \cdot q_{jkz} \cdot P \qquad \forall j \in N, \ \forall t, z \in H, \ \forall k \in K \tag{10}$$

$$\sum_{i \in N} \sum_{j \in N} x_{ijkt} \leq M \cdot S_{kt} \qquad \forall t \in H, \ \forall k \in I \tag{11}$$

$$x_{ijkt} \in \{0, \ 1\} \qquad \forall i, \ j \in N, \ \forall t \in H, \ \forall k \in \tag{12}$$

$$y_{jkt} \in \{0, \ 1\} \qquad \forall j \in N, \ \forall t \in H, \ \forall k \in K \tag{13}$$

$$F_{jkz} \in \{0, \ 1\} \qquad \forall j \in N, \ \forall z \in H, \ \forall k \in K \tag{14}$$

$$S_{kt} \in \{0, \ 1\} \qquad \forall t \in H, \quad \forall k \in I \tag{15}$$

$$q^{-}_{jkt}, \ q^{+}_{jkt}, \ q_{jkz}, \ W_{jz}, \ S_{kt} \geq 0 \qquad \forall j \in N, \ \forall t, z \in H, \ \forall k \in K \tag{16}$$

The objective function is defined in equation (1) which minimizes the overall system cost. Three categories included in the system cost: the travelling cost, the fixed cost of each route if the vehicle is activated, and the penalty cost if the delivery service is executed before the due period. The constraints of this model are defined from equation (2) to (16).

The equation (2) ensures same vehicle will enter and leave a customer. In equation (3), the number of vehicle to be activated in each period should be less than or equal to the size of fleet. Equation (4) and (5) restrict each customer is served once in any planning period. Equation (6) and (7) make sure that no over loading situation is acceptable. In any service point within a route, loading limitation is strictly followed, which is described in equation (8). Equation (9) restricts the actual travel distance of each route less than the pre-defined, maximal travel distance. The penalty cost generated by a customer in one period is calculated in equation (10). The penalty cost considers the quantity and how many periods to be delivered in advance. Equation (11) makes sure that all customers should be served by an activated vehicle. Equation (12) to (15) restricts the decision variables to be an integer 0 or 1, respectively. The equation (16) makes sure some variables are not negative numbers. These variables are delivery quantities, pickup quantities, penalties, and number of vehicle activated.

Concept of the heuristic solution algorithm

Due to the NP-hard nature of the proposed model, a heuristic algorithm for solving the problem should be developed to find a near optimal solution. For evaluating the feasibility of the proposed system, even a near optimal solution still can be useful to decide whether the delivery in advance is profitable. It is believed that several other heuristics can further improve the solution quality. The logic of solution algorithm includes two stages, i.e. the initial routings and the routings improvement.

The first stage of solution algorithm is to construct an initial routings using the concept of neighbour search. The routing construction starts from the first period and ends on the last period in the planning cycle. The logic of neighbour search used in the first stage is quite simple and straight forwards. However, the logic for earlier delivery is an important feature which should be applied in each routing construction process.

The procedure of arranging goods in advance is activated when the following two conditions are satisfied in each route generation process: (a) The vehicle is currently not fully loaded. (b) After checking all customers in current period, no customer can be added in this route due to the limitation of travel distance. The procedure begins to consider other customers in later period. If it is feasible, then these selected goods will be delivered in current period, i.e. these goods are delivered before due period. The logic of selecting suitable customer to be delivered in advance can be summarized as follows: (a) Select a suitable customer one by one and period by period. (b) Check all the delivery customers in the next period first and repeat this process to the following periods, one period by one period. (c) Check the feasibility of each delivery customer in that period, i.e. fit the loading limitation and fit the limitation of travel distance. (d) Select a customer with the minimal penalty cost from all feasible customers in that period and add this customer to the current route. (e) Repeat (c) and (d) in all other periods until no more customer can be added in this route.

On the basis of the initial routings found in the first stage, the second stage deals with the routing improvement using the logic of Tabu search. The improvement process is independently executed in each period starting at the first period in the planning cycle. This improvement process repeats from one period to the next period until all routings have been modified. In each improvement iteration, one neighbourhood move will be executed and verified. There are three neighbourhood moves can be selected depending on a pre-defined probability. These neighbourhood moves are (a) external 1-0 node insertion, (2) internal 1-1 nodes exchange, and (c) external 1-1 2-Opt nodes exchange.

A set of probabilities for choosing the move is set as one parameter of Tabu search. The other two parameters used in Tabu search include the length of Tabu list and the number of iterations. These parameters will be confirmed by a Taguchi experiment. In the following illustration example, a Taguchi experiment should be executed first to fine tune parameters. Each parameter is evaluated by four different levels.

Illustration example and findings

Basic data of the illustration example

For illustration purpose, an example problem with 36 customers is designed. 50% of the customers require pickup services and the other 50% of the customers require delivery services which can possibly be delivered in advance. It is also assumes that the total delivery quantity is equal to the total pickup quantity in one planning cycle. This periodic vehicle routing system has 5 independent periods in a cycle. One depot with a fixed location will serve 36 independent customers in 5 independent periods through several independent vehicle routings with backhauls. The loading capacity of each vehicle is 200 units and the distance per route is limited to 480. The cost information is summarized as follows: The travel cost is set to be $7 per unit distance and the fixed cost of each route is $3000. The unit penalty cost is $1.5 per unit per period.

Based on the basic data of the illustration example, the parameters of Tabu search are confirmed by a Taguchi experiment. The Taguchi experiment is programmed in the Minitab software. Results of this experiment are summarized as follows: (1) Length of Tabu list is 8. (2) Number of iterations is 800. (3) Probabilities for choosing three different moves are 0.25, 0.50, and 0.25 for the following moves in sequence: external 1-0 node insertion, internal 1-1 nodes exchange, and external 1-1 2-Opt nodes exchange.

Solution

An Excel-VBA program is then developed for solving this illustration example. This illustration example is solved twice based on two types of arrangement. The first arrangement is the traditional periodic vehicle routing with no goods delivered in advance, i.e. the traditional approach. The second arrangement is the periodic vehicle routing accepting some deliveries in advance, i.e. the approach proposed in this study. All solution data are summarized in the following Tables.

Table 1 and Table 2 present the routings in details for the traditional approach and the approach proposed in this study, respectively. Table 3 and Table 4 summarize all cost information for both arrangements. The cost information includes travelling cost, penalty cost, and fixed cost of vehicle. For comparison purpose, Table 5 summarizes the distance travelled, number of vehicle used, and the overall cost for both arrangements. In addition, data for the initial solutions and the final solutions are also listed in Table 5 for comparison purpose.

Findings

From the data indicated in Table 1 and Table 2, the concept of delivery in advance can effectively reduce the travel distance up to 10.6%. In addition, the total number of routings can be reduced 14.2 %, i.e. from 14 to 12. It is believed that the utilization of vehicle can be increased by shifting the due period for some delivery goods. In the solution algorithm proposed in this research, the logic of selecting customer is effective, however, there are several other approaches could be developed and evaluated.

The cost data can be compared by examining both Table 3 and Table 4. There is 11.8% saving from the traditional routings and the fixed cost of route contributes the major saving. However, the routing arrangement suggested in this study still suffer from the penalty cost if the unit penalty cost goes higher than this case, i.e. higher than $1.5 per unit of goods per period. A trade-off study should be conducted to find the threshold value for the unit penalty cost. This threshold value will help the management level to make an accurate decision for whether to apply the concept of earlier delivery. It is believed that the value of unit penalty cost is a critical point in this study.

The overall results including the initial solutions and the final solutions for both arrangements are compared in Table 5. The effectiveness of the solution algorithm can be observed by comparing the deviation between the initial solution and the final solution. The improvement algorithm proposed in this study can reach 7% of cost reduction from the initial solution.

Table 1 – Routing details for the traditional approach

Period	Route	Path of Route (Nodes Visited in Sequence)	Delivery Quantity	Pickup Quantity	Distance Travelled
1	1	0-3-10-5-17-18-1-15-13-14-4-20-32-28-0	295	120	432.23
	2	0-2-6-9-8-29-31-23-30-36-34-26-21-0	147	250	449.69
	3	0-19-0	-	39	141.22
2	1	0-3-11-15-5-18-13-14-4-2-29-31-33-23-30-36-22-0	288	209	473.77
	2	0-9-8-12-25-32-28-35-19-27-0	126	144	427.03
	3	0-24-0	-	25	194.84
3	1	0-16-18-1-5-7-13-15-11-2-6-9-31-29-32-0	256	90	424.99
	2	0-8-12-25-33-30-36-34-28-0	61	149	323.33
	3	0-35-19-27-24-20-21-0	-	208	354.84
4	1	0-3-11-14-13-7-17-18-16-2-6-4-22-0	243	27	459.30
	2	0-12-8-31-29-30-34-26-19-0	92	173	451.81
	3	0-20-0	-	28	151.32
5	1	0-3-10-17-1-18-7-13-14-27-21-28-22-32-36-34-26-0	292	250	456.60
	2	0-16-4-2-6-8-12-25-23-33-31-29-24-20-0	137	225	462.94
Total	14	-	1,937	1,937	5,203.91

Table 2 – Routing details for the approach proposed in this study

Period	Route	Path of Route (Nodes Visited in Sequence)	Delivery Quantity	Pickup Quantity	Distance Travelled	Delivery in Advance		
						Node	Period	Q't y
1	1	0-3-10-5-17-1-18-13-15-14-4-20-32-28-0	295	120	430.53	-	-	-
	2	0-2-6-9-8-29-31-23-30-36-34-26-21-0	291	250	449.69	2	2	33
							3	26
						9	2	50
						8	2	35
	3	0-19-0	-	39	141.22	-	-	-
2	1	0-3-11-15-5-18-13-14-4-12-25-23-33-32-22-0	296	186	477.46	-	-	-
	2	0-28-36-30-31-29-24-27-19-35-0	-	192	453.97	-	-	-
3	1	0-16-18-1-5-7-13-15-11-9-31-29-32-0	300	90	403.33	16	4	15
						18	4	38
						7	4	15
						13	4	18
						11	4	26
	2	0-6-8-12-25-33-30-36-34-28-0	210	149	361.29	6	4	15
						8	4	45
						12	4	47
	3	0-35-19-27-24-20-21-0	-	208	354.84	-	-	-
4	1	0-3-17-14-4-2-29-31-30-34-26-22-0	116	165	443.03	-	-	-
	2	0-19-20-0	-	63	215.90	-	-	-
5	1	0-3-10-17-1-18-7-13-14-27-21-28-22-32-36-34-26-0	292	250	456.60	-	-	-
	2	0-16-4-2-6-8-12-25-23-33-31-29-24-20-0	137	225	462.94	-	-	-
Total	12	-	1,937	1,937	4,650.80	-	-	363

Table 3 – Cost information for the traditional approach

Item \ Period	1	2	3	4	5	Total
Travel Distance	1,023.14	1,095.64	1,103.16	1,062.43	919.54	5,203.91
Vehicle Used	3	3	3	3	2	14
Penalty Cost	-	-	-	-	-	-
Travelling Cost	7,161.98	7,669.48	7,722.12	7,437.01	6,436.78	36,427.37
Fixed Cost	9,000.00	9,000.00	9,000.00	9,000.00	6,000.00	42,000.00
Total Cost	16,161.98	16,669.48	16,722.12	16,437.01	12,436.78	78,427.37

Table 4 – Cost information for the approach proposed in this study

Item \ Period	1	2	3	4	5	Total
Travel Distance	1,021.44	931.43	1,119.46	658.93	919.54	4,650.80
Vehicle Used	3	2	3	2	2	12
Penalty Cost	255.00	0	328.50	0	0	583.50
Travelling Cost	7,150.08	6,520.01	7,836.22	4,612.51	6,436.78	32,555.60
Fixed Cost	9,000.00	6,000.00	9,000.00	6,000.00	6,000.00	36,000.00
Total Cost	16,405.08	12,520.01	17,164.72	10,612.51	12,436.78	69,139.10

Table 5 – Comparison of the traditional routings and the routings with delivery in advance

Comparison Item		(A) Traditional Approach	(B)* Delivery in Advance	(C)** Difference	(D)*** Difference %
Total Distance	Initial Solution	5,619.26	5,045.12	574.14	10.22%
	Final Solution	5,203.91	4,650.80	553.11	10.63%
Number of Vehicle Used	Initial Solution	15	13	2	13.33%
	Final Solution	14	12	2	14.29%
Total Cost (OFV)	Initial Solution	84,334.82	74,899.34	9,435.48	11.19%
	Final Solution	78,427.37	69,139.10	9,288.27	11.84%

Remarks: *The arrangement proposed in this study, **(C)=(A)-(B), ***(D)=(C)/(A).

Conclusion

This study proposes an effective option for arranging the periodical vehicle routings. This option is feasible if the customers accept goods can be delivered in advance. A mathematical model and the associated solution algorithm are suggested for solving the problem. The illustration example shows that the concept of delivery in advance can reduce the overall cost effectively and it is worth to implement in the real world cases.

For future researches, it is necessary to provide more evidences for confirmation the benefit of delivery in advance. Therefore, other types of periodical vehicle problem, such as simultaneous pickup and delivery or pure delivery operations, can be further evaluated using the concept proposed in this study to arrange routings. In addition, the algorithm for arranging the goods to be delivered in advance is worth for further investigation.

Acknowledgments

This research is supported by (1) the National Science Counsel, Taiwan ROC under the grant number: NSC102-2221-E-224-030 and (2) the National Yunlin University of Science and Technology, Taiwan ROC under the grant number: 103H502108.

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