An Empirical Study of Vehicle Routing Problem for Medical Consumable Materials by Using Clustering Approach: Taking Zueling Pharma Corporate as an Example

W-H Ouyang¹, T-Y Lin¹ and C-C Chiou¹

¹Department of Industrial Engineering and Enterprise Information, No. 1727, Sec. 4, Taiwan Blvd., Xitun Dist., Taichung City 407, Taiwan (R.O.C.)
cjchiou@thu.edu.tw.

Abstract. The purpose of the paper is aiming to improve the medical supply distribution routing. From the empirical data, we examine four major issues which are multiple replenishments, unidentifiable distribution spot, implementation of wrong information in the system, and matching issues. Repetition, delay, and cross-district sequence of delivery cause extra transportation cost. We proposed a clustering approach to improve the efficiency. We group all the points into several clusters, then routing the path. A distribution centre inside the hive-shaped formation can significantly shorten the distance and reduce the time by allocating to the surrounding individual point separately. Lastly, the objective of logistics is to satisfy the requirements of the end consumers with high quality service, as a special and integrated activity, logistics plays a focal position in modern society, routing optimization is the main focus of VRP. The most significant improvement is the distribution distance reduced from 52 km to 29.4 km, 43.46%. The cost improvement in terms of time decreased from 130 minutes to 61 minutes, 53.08%.

1. Introduction
This study focuses on the distribution and logistics system of hospital drugs and health materials, and takes Yuli Co., Ltd as the object, which is the largest foreign company in Taiwan's medical logistics and agency (Switzerland), distributing all medical products in Taiwan and is also the original drug agency. The orders that are usually distributed are divided into hospitals, clinics, and chain stores. The distribution goods are pharmaceuticals, sanitary materials, consumables, and instruments. The pipelines accepted by the orders are multi-format and inconsistent. The warehouse complains that the order department is processing too slowly, which delays the subsequent picking and delivery operations. In the process of analyzing the distribution vehicle path of Yuli, it is found that there are often abnormal situations in the distribution path, including the abnormal opening and closing time of the truck, the discrepancy between the record displayed by the sensor and the manual input of the personnel, the fluctuation of the cold chain temperature, and the error-delivery or even mis-delivery caused by the failure of the delivery person to follow the order, and so on. Whether the above conditions can be reduced or even eliminated by scientific analysis methods determines whether the overall delivery efficiency and consumer service level can be optimized.
2. Literature Review
There are mainly three levels in logistic systems, i.e., plant, distribution center, and retailer, respectively. Distribution Requirements/Resource Planning (DRP I/II), adopting the basic concept from MRP, integrates each and every function of the entire logistic systems. Its primary concern focuses on the minimization of the total logistic cost including ordering, inventory, in-transit inventory, and transportation cost. For retailers, DRP can help maintain the inventory control. The distribution center collects the demand information from its retailer and car fleet would be sent out to satisfy retailers’ demand. The routing plan can be obtained by VRP (Vehicle Routing Problem) algorithm. In the past, most of the research did not consider transportation cost in the distribution management [1].

Recently, more attention is being focused on the business of home delivery service. How to minimizing transportation costs is an important issue in this business. The research makes an attempt to study how the sale drivers find optimal routes to pick up and deliver packets each day. Essentially, this problem for each sale driver is a Traveling Salesman Problem, consisting of four aspects: single-vehicle, ordered cluster, dynamic and pickup-delivery. We define it as a Pickup-Delivery Dynamic Traveling Salesman Problem with Backhauls (PDDTSPB). In order to deal with the dynamic aspect in the PDDTSPB we formulate a pre-event routing model and a real-time routing model for it [2].

One of the most important functions of e-map navigation is path planning. People use it in dynamic path planning for cargo delivery. It can not only efficiently apply customer’s need in time, but also dispatch the right car according to the attributes of the goods. So that drivers can improve their deliver efficiency. In this study, we use the function–Gdirection provided by Google Maps, vehicle computer system and GPS to transmit the coordinates of the cars to a remote database server [3].

The development of electronic commerce has driven its strong impact to the global logistics. This evolvement also motivates Taiwan’s domestic home-delivery industry to face greater challenges in competing on the areas of increasing management efficiency and effectiveness as well as reducing distribution costs. Furthermore, the distribution routing planning in home-delivery industry plays significant effects to the customer satisfaction and the total logistics costs. Therefore, it is important to have a well-designed distribution system for the home-delivery company to cope with its industry features and practical needs and to satisfy the marketing demand requirements [4].

3. Status and Problem Analysis

3.1 Description of Status
On the basis of the delivery order provided by Yuli from 5 cases and the GPS positioning of the truck, this paper conducts an analysis. The delivery routes are generally used in the Wuqi, Shalu, and Xitun District, priority is given to starting delivery from the farthest and most demanding locations; The Guangtian General Hospital, Ande Biotechnology, and Rongzong General Hospital are to the biggest demand point, respectively. The main distribution area is shown below (Figure 1).

Figure 1. Zuellig Pharma Corporate distribution area
3.1.1 Case 1 Analysis. Case 1 A total of 28 demand points need to be distributed on the same day. From the road analysis map before the improvement on Case 1, the arrow represents the distribution route followed by the truck. In accordance with the area of the pharmacy and clinic in the area where the demand point is located, the demand point can be divided into Wuqi, Shalu and Xitun District. Among these 28 demand points, there are a total of 4 major demand points in the Wuqi Dis., of which Dr. Li Lihua is the largest demand point in the area; There are 7 major demand points in Shalu Dis., of which Guangtian Hospital is the largest demand point in the area; It can be seen that the area where Xitun Dis. is located covers the most demand points. Finally, according to Google Map, the total distance travel before the improvement is 38.1 km, and the total driving time is one hour and forty-three minutes (Figure 2).

![Figure 2. Zuellig Pharma Corporate distribution routes for Case1](image)

Problem Analysis: sent to Dewei Chinese and Western Pharmacy, but the truck returns to the demand point, during which time the goods are picked up twice, then the truck leaves, it is suspected that the delivery staff misses the delivery or recovers the documents.

3.1.2 Case 2 Analysis. Case 2 a total of 30 demand points need to be distributed on the same day. The total distance travelled before the improvement is 46.6 km, and the total driving time is two hours (Figure 3).

![Figure 3. Zuellig Pharma Corporate distribution routes for the day of Case2](image)

Problem Analysis: The place of manual input is Changhua Christian Hospital, which is not actually delivered, it is a human error. The corresponding location of the time is the Yuli Headquarter, loading and unloading twice, and the deliveryman stops replenishing. In the evening, it is suddenly delivered to
the second section of the high-speed railway in Wuzhong Dis., that is, the Taichung High-speed Railway Station, loading and unloading once. This location is the newly built Kerry Darong Logistics Center, which can be assessed as a special pick-up point.

3.1.3 Case 3 Analysis. Case3 A total of 35 demand points need to be distributed on the same day. The total distance travelled before the improvement is 52 km, and the total driving time is two hours and ten minutes (Figure 4).

![Figure 4. Zuellig Pharma Corporate distribution routes for the day of Case3](image)

Problem Analysis: Xingyi Yiqi New Children's Store is the first conventional cluster point A, but it is manually entered into the 7th station. Delivered to No. 94-7, Section 3, Zhonggang Road, Fuyali, Xitun Dis., Taichung City, but the manual input is Zhuodaifu Clinic, the two addresses are far apart and the delivery location is not clear.

3.1.4 Case 4 Analysis. Case 4 a total of 29 demand points need to be distributed on the same day. The total distance travelled before the improvement is 51.4 km, and the total driving time is two hours (Figure 5).

![Figure 5. Zuellig Pharma Corporate distribution routes for the day of Case4](image)

Problem Analysis: Xingyi Yiqi New Children's Store is the first conventional cluster point A, but it is manually entered into the 7th station. At noon, arrival, but Dekang Pharmacy does not open the front and rear doors, suspected that the sensor fails; Then the truck returns to the Yuli Headquarter; During three times of truck checking, parking in Yuli in the afternoon, but there is a contradiction between the location and time of the artificial clustering point F and other small demand delivery, which may be the delivery with another truck. A special order appears, and that is Zeng Xiaozhong Paediatrics Clinic.
3.1.5 Case 5 Analysis. Case 5 a total of 28 demand points need to be distributed on the same day. The total distance travelled before the improvement is 38.3 km, and the total driving time is one hour and forty minutes (Figure 6).

![Figure 6. Zuellig Pharma Corporate improved distribution routes for the day of Case 5](image)

Problem Analysis: The route is smooth, before sending to Ande Technology in the morning, the truck returns to the Company to replenish the goods for once and the Youcheng Pharmacy is not delivered. The fifth day is the most ideal delivery situation. The route is smooth, and there is no re-entry in the middle, and the shortest path principle is realized.

3.2 Summary
According to the above analysis, we organize four major issues to be discussed and addressed later on;
1. Multiple replenishments
2. Unidentifiable destination
3. Implementation of incorrect information
4. Matching issues

3.2.1 Methodology (Cluster-First Route-Second). Similar to an Online to Offline community, providing much needed procurement services to the nearby residents.

Especially, for pharmaceuticals with extremely high volume, we are searching for a centralized distribution center, establish it inside the hive-shaped distribution zone which, in essence, can directly ship the cargos to the designated spot or even acquired personally by the pharmacy or local clinic itself.

Consequently, within the linear distance of five kilometres, we subtly categorize into six major demanding points by volume, which require the most amount.

This is a type of decentralized service style. In detail, we brainstorming a distribution center located in the crux of a hive-shaped formation, where all the pharmacies and clinics are being covered. Ideally, this can somehow fulfil the principle of shipping to the designated place within an hour, same as moving a warehouse to the residential areas, then shipping accordingly.

3.2.2 Proposed Routing Plan. Case 1 Solution—establishing a hexagon with a centralized distribution centre.

Narration:
Undoubtedly, after a deep and intensive discussion, we eventually realize the importance of Vehicle Routing Problem to be addressed is associated with how to create a path in order to ship the cargos on time. On Case 1, take a short glimpse on the picture expressed below, where the blue line indicates the “As is” situation, whereas black line represents the “To be” situation. Firstly, if you follow through the path of the blue line, you will come across six major demanding points, which are Dr. Li Lihua, Guangtian general hospital, Cheng Ching drug storeroom, branch Zhonggang of Cheng Ching hospital, Dewei pharmacy, Weikang pharmacy;
To be able to cover the adjacent demanding points altogether, we decided to establish a warehouse in the center of the hexagon. The benefit of this is that within the region, the warehouse can directly ship the individual requirement to a designated spot, in contrast to the blue line, the distance and the time had significantly shorten by applying to this approach. In addition, star sign shows the location of the warehouse, from a geographical standpoint, latitude and longitude (Figure 7).

Finally, setting off from Zuellig pharma corporate all the way to each warehouse and then head back, the overall distance can be as long as 29.4 km, which takes nearly 61 minutes to finish.

Figure 7. Zuellig Pharma Corporate distribution routes for the day of Case 1

Case 2 Solution—establishing a hexagon with a centralized distribution center.

Figure 8. Zuellig Pharma Corporate distribution routes for the day of Case 2

Case 3 Solution—establishing a hexagon with a centralized distribution center.

Figure 9. Zuellig Pharma Corporate distribution routes for the day of Case 3
Case 4 Solution—establishing a hexagon with a centralized distribution center.

Figure 10. Zuellig Pharma Corporate distribution routes for the day of Case 4

Case 5 Solution—establishing a hexagon with a centralized distribution center.

Figure 11. Zuellig Pharma Corporate distribution routes for the day of Case 5

3.3 Evaluation

|                  | As is  | To be  | Progression rate |
|------------------|--------|--------|------------------|
| Case1            |        |        |                  |
| Distance         | 38.1 km| 29.4 km| 22.83            |
| Time             | 103 min| 61 min | 40.78            |
| Case2            |        |        |                  |
| distance         | 46.6 km| 29.4 km| 36.91            |
| time             | 120 min| 61 min | 49.17            |
| Case3            |        |        |                  |
| Distance         | 52 km  | 29.4 km| 43.46            |
| time             | 130 min| 61 min | 53.08            |
| Case4            |        |        |                  |
| Distance         | 51.4 km| 29.4 km| 42.8             |
| time             | 120 min| 61 min | 49.17            |
| Case5            |        |        |                  |
| Distance         | 38.3 km| 29.4 km| 23.24            |
| time             | 100 min| 61 min | 39               |

Generally speaking, we summarize four primary issues from the detail, which in the sequence were multiple replenishment, unidentifiable destination, implementation of incorrect information and matching issues, respectively. From the outset we already knew that distance and time are two underlying reasons which causes delay delivery, therefore we try to come up with a feasible solution to address the issues, with further endeavour the solution finally show up in our mind, we decided to draw
a hexagon which could cover as many demanding points as possible and establish a centralized warehouse. However, another thorny problem emerges unexpectedly, there is no standard operation procedure to organize cargo, the principle of code classification might help us deal with the issue; Unidentifiable destination were highlighted by the system, where we couldn’t match the information, simply speaking, fuel cost is our major concern in this paper.

In conclusion, again take a closer on the table listed above, Case3, in comparison, the distance was shorten to from 52 to 29.4 kilometers whereas the time was cut down from 130 to 61 minutes.

4. Conclusion and Future Prospects
We proposed the approach of clustering approach to improve the efficiency. The cluster-first-route-second method from the seven methods of vehicle routing problem is adopted. We group all the points into several clusters, then routing the path base on clusters; the area is a hive-shaped formation which cover all the demanding points. A distribution centre inside the hive-shaped formation can significantly shorten the distance and reduce the time by allocating to the surrounding individual point separately. In general, the actual benefits of route improvement were examined on a daily basis.

4.1 The Limitation of the Research
This study focuses on the logistics distribution of medical consumable materials. The empirical data are collected from Zuellig Pharma Company. In the process of analysing the path of distribution vehicles. We examine four major issues and found that the truck opening and closing time are abnormal, the records displayed by the sensors are different from the manual entry of data by the personnel, the temperatures of the cold chain fluctuate, and the deliveryman fails to deliver the goods according to the order, resulting in the missed delivery or even wrong delivery. But we couldn’t have chance to prove them in the real world yet.

4.2 Suggestions for Future Research
This research mainly focuses on improving the delivery path and establishing distribution stations to reduce the delivery time. For problems such as errors in the manual entry of data and repeated replenishment, personnel education and training can be strengthened in the future, standard SOP can be implemented to reduce errors, and replenishment can also move towards better planning of supporting measures.

5. References
[1] You S-M 1998 A distribution management model integrating distribution requirements planning & vehicle routing. The Department of Industrial Engineering and Management, Da-Yeh University.
[2] Hus C-C 2003 The vehicle routing problem for home delivery. The Department of Transportation and Communication Management Science, National Cheng Kung University.
[3] Lien C-C 2010 The study of dynamic real-time path planning in logistics management. The Department of Information Technology, Hsing Wu University.
[4] Tsai C-C 2004 An ant colony system to establish the optimal routing planning for home-delivery distribution. The Department of Industrial Management, National Pingtung University of Science and Technology.