Abstract: An efficient heuristic to balance two vehicle delivery completion times is developed in this research. Vehicle moving speeds are assumed to be unsymmetrical between two points and time various. Delivery area divisions for each vehicle are made by modified sweep algorithm by adding two-stage reassignment procedure to resolve a possible unbalance of two vehicle delivery completion times. Three different size of common area are examined to determine the optimum size of common area. Vehicle delivery route is constructed by the 4-time-zone heuristic to avoid time various vehicle moving speeds situations efficiently.

Key words: multi-vehicle, sweep algorithm, VRP, combinatorial optimization

1. INTRODUCTION

Vehicle routing problems are studied by many researchers in operations research and management science area due to the combinatorial optimization features. Many solution methods are suggested so far, but most of them are not good enough for real life applications such as door-to-door delivery system in metropolitan area. There are always traffic jams in certain area during rush hours. Also, vehicle moving speeds are changing time to time along moving directions. These limitations make VRPs (vehicle routing problems) really hard to solve.

In this research, such VRPs of traffic congestions during rush hours and various vehicle moving speeds are studied. It is extremely hard to design a good solution methodology for multi-vehicle delivery problems. A modified sweep algorithm is designed and applied to assign delivery area for each vehicle. The procedure consists of two stages such as initial solution search stage and an improvement stage. Improvements are made with common area to reassign them to balance delivery completion times. Many of related researches are found in the literature. Malandraki and Daski [4] developed a heuristic for time dependent VRPs. Cordeau et al. [5] studied on multi-vehicle delivery area assignment using Euclidean distance. Baker and Ayechew [6] used Genetic algorithm as well as sweep algorithm and assignment approach. Barreto et al [7] worked on five depots and fifty cities to visit with capacity limitation. They used 3-opt local search method to improve the routes found by an exact algorithm.

2. PROBLEM STATEMENTS

The model studied in this research is the same one as in Park and Moon [7]. The main objective of the research is to minimize the delivery completion time of both vehicles. It is assumed that the minimum completion time for all vehicles can be achieved by balancing delivery loads for all vehicles. If one vehicle loaded too much while less loads for the other, then the completion time will be very long due to the more loaded vehicle’s delayed completion time. There are no vehicle capacity limits, neither of delivery completion time limits. The delivery will be over after finishing all assigned parcels delivered for the day.
Problems descriptions and assumptions are summarized as follows:

1. There are one depot and two delivery vehicles.
2. Each delivery points are known in advance and visited by vehicle exactly once.
3. Each vehicle starts delivery from the depot and comes back to the depot after finishing delivery.
4. Final delivery completion time for each vehicle is the arrival time to depot after finishing all the parcels assigned.
5. Vehicle moving speeds between to points of i and j are known.
6. The vehicle speeds for from i to j and from j to i can be different.
7. Required time to move from i to j is calculated by dividing distance with vehicle moving speed.
8. The location of depot is assumed to be not located inside of delivery area. It is assumed to be located somewhere on the boundary of whole delivery area.

3. SUGGESTED HEURISTIC

3.1 Resolving Time Various Speeds

The vehicle moving speeds are changing every hour based on the surveys. The hourly moving speeds can be obtained from local government surveys. In this research a special heuristic is designed to make very complicated vehicle routing problems easy to solve. All vehicles moving speeds are analysed and then 4 stable moving speed hours are defined in Moon and Park [6]. Vehicle moving speeds in time zone “a” is stable for three hours from 10:00 am to 12:59, “b” for five hours from 1:00pm to 5:59, “c” for one hour from 6:00pm to 6:59, “d” from 7:00pm and rests as shown in Fig. 1. Therefore, it is possible to solve even a complicated VRP as a simple TSP (travelling salesman problem) with stable distance between two points within a time zone.
3.2 Multi-Vehicle and Sweep Algorithm

It is assumed that there are two delivery vehicles and one depot. In this case each vehicle is assigned to each delivery area. Delivery area assignment can be made by many different ways. Two algorithms among them would be good. One is K-means algorithm and the other is sweep algorithm. It might be true to get good area division using K-means. However, K-means could be good for N depot problem, but not for one depot problem. More experiments will be done for this issue. In this research, the sweep algorithm is applied for area assignment with some modifications of using common area and reassignment procedure.

3.3 Sweep Algorithm and Common Area

Common area is the narrow area positioned between two wide areas in Fig. 5. The delivery points in common area are to adjust completion times of other two area by assigning more delivery point to the area finished delivery earlier than the other.

The Fig. 4 is a sample result of simple sweep algorithm for two vehicle case. Bottom and upper area are separated to include equal number of delivery points. In this case the chance of having differences on completion times is bigger due to various vehicle moving speeds. Also there is no chance to adjust the difference one more time for improved results.

Fig. 3 Delivery route construction

Fig. 4 Half & Half division result

Fig. 5 Division with common zone

Fig. 6 Final route construction after reassignment of common area
Fig. 6 is a possible result of sharing the delivery points in common area by reassignment to other area between two for balancing delivery completion times. The vehicle took longer time on delivery with temporary assigned loads such as bottom-left one gets less additional numbers of 4 while top-right one gets 16 more from common area in reassignment stages as shown in Fig. 6.

3.4 Procedures for Route Construction
Two delivery vehicles and one depot are assumed in this study. Location of depot can be either inside or outside of delivery area, but only outside locations are studied. No significant difference is found with the position of depot while it is located on the boundary of the delivery area. The delivery area is assumed as a rectangle as shown in Fig. 7. The example cases in Fig. 4 – 6 are corner locations for easy of experimental design. Suggested route construction procedures are same as follows:

Step 1. Whole delivery points will be divided into 3 different groups using sweep algorithm. First group for vehicle 1 and second group for reassignment usage, and rest for vehicle 2. The size of second group will be 25 % and 37.5 % respectively.

Step 2. Initial delivery route for each area will be determined by the heuristic suggested by Moon and Park [7] excluding the common area located between the two area. And then delivery completion times for both vehicles are calculated.

Step 3. Find the differences between the completion times obtained in Step 2. Assign more delivery points to the area finished delivery earlier based on the time differences. Recalculate completion time for the area assigned more delivery points.

Step 4. Divide the rest delivery points in common area based on the completion times obtained in Step 3. More delivery points assignment to early finished vehicle to balance the completion time of two vehicles.

There’s no big difference in area division for one vehicle routing construction with irregular shaped area such as multi-vehicle case. Division example for triangle shape is given in Fig. 7.

4. EXPERIMENT FOR EVALUATION
Three different methods are studied to determine an efficient heuristic. One is the way assigning delivery points to each vehicle equally. Therefore, whole delivery area is divided into two by sweep algorithm as shown in Fig. 4. Results are summarized under “Half&Half” in Table 1. “Exp.” stands for “Experiments number” and “Ave” for “average” in Table 1. Other two methods are using common area, but with different sizes such as “20” out of 80 and “30” out of 80 to find better size. 20, 30, 80 are parcels. The results are presented under the name of “COM(20)” and “COM(30)” respectively.

For example, the numbers in case 1 for “COM(20)” is 237.6 for “max” and 10.62 for “diff”. This means completion times for one vehicle is 237.6 and the other is 226.98. Therefore, it is possible to say that the deliver completion time for both vehicles is 237.6 as of “max” and unbalance of two vehicle completion time is 10.62 as of “diff” in Table 1. It is clear that less “diff” value method obtained less “max”
value since the delivery assignments for both vehicles are well balanced. In comparison to “COM(20)” and “COM(30)”, “COM(20)” seems better than “COM(30)” in terms of max values. That is completion time of both vehicles for delivery. “COM(30)” is good only at two cases of 1 and 8.

5. CONCLUSION

Multi-vehicle routing problems with various vehicle speeds are studied in this research. A heuristic for efficient route construction is designed and experiments for evaluations are performed. The concept of common area for reassignment and sweep algorithm is applied to balance two vehicle delivery completion times. Three different sizes of common area are examined with 11 difference cases. First one is “no common area”, and the second one is the size of 20 out of 80 total delivery points. Last one is the size of 30 out of 80. The size of 20 common area leads to good results among them. 20 out of 80 are 25% of total delivery points. If the size of common is large, then it could be necessary to reassign many newly assigned delivery loads to each vehicle and reconstruct delivery route again. It will be a time consuming process. Another issue is about delivery area division methods as shown in Fig. 2. Grouping delivery points by splitting straight lines does not guarantee a good result. Therefore it is necessary to group area more reasonably. The K-means algorithm is one possible candidate to apply. Even sweep algorithm is adapted here, but the K-means algorithm might be valued enough to study on the design process for VRPs.

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6. REFERENCES

6. Moon, G. and Park, S. A Possible Heuristic for Variable Speed Vehicle

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Table 1. Comparisons of completion times


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