Designing Optimal Distribution Routes using a Vehicle Routing Problem (VRP) Model in a Logistics Service Provider

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Abstract. In a running business, it is common for companies to face some challenges. One of them is related to supply chain performances, especially product distribution. Companies often have a problem determining the distribution route from the origin (warehouse) to the destination (consumer). This research will discuss the distribution route in a case study at a logistics service provider in Yogyakarta. The problem is that each courier does not have a fixed distribution route, causing couriers to overload and less effective when distributing goods to consumers. To solve this problem, we created a delivery zone for each courier done in previous studies using courier assignment optimization to minimize mileage. Furthermore, based on the zones that have been created, we determined the route using the classical vehicle routing problem (VRP) mathematical model to minimize travel time in this study. Based on the results obtained, couriers not only reduce mileage but also travel time, which makes this distribution route more optimal. Later, a vehicle routing problem with a time window can be carried out and compared with the current VRP for further research.

1. Introduction
Supply Chain Management (SCM) is a crucial element when a company runs its business system. Why? When the company has managed its supply chain well, consumer demand can be ensured to be met, or the service level at the company is close to 100%. However, indeed, this is very problematic. Many things can be a challenge to supply chain performance.

According to Li [1], one of the supply chain challenges is the configuration process in the supply chain network and the arrangement of the goods transportation process to minimize production, inventory, and transportation costs. Even a process of distributing products from place of origin to a destination can be a significant problem affecting supply chain performance [2]. Therefore, it is a manager’s job to design a distribution route [3].

Much of the current literature on some journals pay particular attention to a distribution problem, especially determining a case study distribution route. There are some cases in waste recycling industries about waste management. Here, vehicles will collect and/or drop-off the waste at specific points, taking into account vehicles’ capacity and minimization of total travel distances [4]–[6]. Nowakowski [4] took a case study in Poland to collect WEEE (waste electrical and electronic equipment) and put them into a recycling company. The route is gained using a combination of CVRP (capacitated vehicle routing problem) and VRLP (vehicle routing problem). Kuo [5] solved a problem
in Indonesia to pick-up garbage from temporary dumps and drop-off them to the main dump applying a combination of CVRP, Genetic Algorithm, Ant Colony Optimization, and two-local search algorithm. Puspita [6] has a similar problem as Kuo [5], but the study case took place in Palembang, Indonesia, using a mathematical model of RC-OCVRP (robust counterpart open capacitated vehicle routing).

Other case studies have also examined the route distribution problem to minimize travel distances in some other industries. It is because distribution is the main problem that can affect business performance. Mingprasert [7] found a distribution problem in the plastic packaging industry. The industry had received many complaints from its customers due to delivery delays. Thus, it urged the industry to solve this problem by optimizing the distribution routes using a combination of multiple capacitated vehicle routing problems and Artificial Bee Colony and the objective of minimizing total traveling distance [7]. Another case occurred in a natural gas company. It applied the CVRP and Saving Algorithm to determine the natural gas distribution regarding time windows [8]. Also, a study case in a supermarket chain in which an effective and efficient distribution route is crucial. Comert [9] tried for optimizing a route distribution using the Clustering Algorithm and Branch-and-Bound Algorithm. Here, the customers were grouped applying the Clustering Algorithm, and every group is determined the route using the Branch-and-Bound Algorithm.

Two other studies are in service industries, hospitals, and a post-office. Clarke [10] optimized some distribution routes for supplying medications to rural and remote hospitals. Here, it worked with the concept of pick-ups and drop-offs. The vehicles collected the medications from some pick-up areas and would drop-off them in the hospitals [10]. Clarke [10] used CVRP with synchronous pickups-dropoffs to minimize the total distances and costs. Sbai [11] solved distribution routes in Tunisian Post Office. They determined the delivery routes for mail and parcel pick-up to minimize total distances using CVRP with HGA-VNS (genetic variable neighborhood search algorithm).

Overall, these case studies highlight the need to minimize total travel distances, whereas we can also minimize transportation costs or travel time. This paper will determine several distribution routes in particular regions that minimize the total travel distances and travel time in a logistic service provider in Yogyakarta. Given all that has been mentioned so far, most of them focus on minimizing total travel distances. One paper mentioned that it grouped customers first then made the distribution route. This research also re-groups the customers or regions using a modified assignment problem to minimize total travel distances, which it had been carried out [12]. This paper will then determine the optimal routes using VRP classic with Branch-and-Bound Algorithm to minimize total travel time.

2. Method

The main objective is to find an optimum route for each courier in the city of Yogyakarta. The first method is to group the regions for each courier using a modified assignment problem model [12]. This model aims to minimize the total mileage of each courier and travel time in a logistic service provider in Yogyakarta. Given all that has been mentioned so far, most of them focus on minimizing total travel distances. One paper mentioned that it grouped customers first then made the distribution route. This research also re-groups the customers or regions using a modified assignment problem to minimize total travel distances, which it had been carried out [12]. This paper will then determine the optimal routes using VRP classic with Branch-and-Bound Algorithm to minimize total travel time.

Minimize $Z = \sum_{i \in N} \sum_{j \in N} c_{ij} x_{ij}$

(1)
\[ \begin{align*}
\text{s.t.} & \\
\sum_{i \in N} x_{pj} = \sum_{j \in N} x_{pj} & , \ \forall p \in N_c \\
\sum_{i \in N} x_{ij} = 1 & , \ \forall j \in N_c \\
\sum_{j \in N} y_{ij} - \sum_{j \in N} y_{ji} = D_i & , \ \forall j \in N_c \\
D_i \times x_{ij} \leq y_{ij} & , \ \forall i, j \in N \\
x_{ij} \in \{0,1\} & 
\end{align*} \]

\[ (2) \]

\[ (3) \]

\[ (4) \]

\[ (5) \]

\[ (6) \]

To minimize the total travel time in each zone, equation (1) is calculated by multiplying travel time from the warehouse to regions with the number of quantities delivered. Equation (2) shows a vehicle visiting a region \( i \) must leave it immediately. Equation (3) indicates a region \( i \) should only be visited once. Equations (4) and (5) indicate that quantities distributed must be according to the demands. The last equation (6) points out a decision variable that must be a binary variable, which 1 shows a route from region \( i \) to \( j \), 0 otherwise.

3. Results and Discussions

A logistics service provider serves good deliveries to areas in the city of Yogyakarta. It owns one big warehouse as an origin point storing many goods. Once packages arrive in the warehouse, it will be delivered to the ultimate customers in a region. It provides the deliveries which are not only in Daerah Istimewa Yogyakarta but also in Klaten and Magelang. However, this case study is only limited to areas in the city of Yogyakarta, having 45 regions served and divided into four zones. We focus on these regions because they are thickly crowded based on a data history of delivery volume and frequency. Also, there is an overload problem here. Existing distribution routes do not exist. In other words, a courier defines the route randomly, which may cause ineffectively and inefficient routes. At the same time, it has another problem that the courier has a limited capacity.

To solve this problem, we re-group the existing zones to minimize the total distances, taking into account each courier's limited capacity, 55 kgs, and demands that must be met. Zone 1 was overcapacity that led to Zone 2, 3, and 4 having uneven capacity distribution from the previous zones. Using the modified assignment optimization model, we can overcome the overcapacity problem, and the capacity distribution for each zone becomes more evenly [12]. Despite being still four zones, each new zone consists of different regions [12]. It is shown in Table 1.

**Table 1.** The new zones with the optimal condition [12]

| Region       | Avg daily vol (kg) | Region       | Avg daily vol (kg) | Region       | Avg daily vol (kg) | Region       | Avg daily vol (kg) |
|--------------|-------------------|--------------|-------------------|--------------|-------------------|--------------|-------------------|
| Zone 1       |                   | Zone 2       |                   | Zone 3       |                   | Zone 4       |                   |
| SRMJ(DR)     | 3.81              | PGKM(GT)     | 2.26              | TGPG(DR)     | 1.59              | BCRO(GK)     | 6.19              |
| DMGN(GK)     | 7.37              | SSRM(GT)     | 3.56              | BSRN(DR)     | 4.96              | MNTR(MR)     | 4.93              |
| GOWN(JT)     | 11.15             | KTBR(GK)     | 3.93              | TRBN(GK)     | 7.70              | KPRN(MG)     | 3.33              |
| TGRJ(TR)     | 23.00             | KTRN(GK)     | 6.59              | PRGN(KG)     | 1.52              | NMPN(NP)     | 1.93              |
| SRST(UB)     | 8.52              | PWDJ(GM)     | 2.70              | PRBY(KG)     | 0.30              | GNKT(PL)     | 0.70              |
|              |                   | NPSN(GM)     | 7.11              | KDPT(KR)     | 1.15              | KRCK(TR)     | 2.44              |
|              |                   | BMJO(JT)     | 2.11              | BTKM(MG)     | 4.74              | KRWR(TR)     | 4.37              |
|              |                   | CKRD(JT)     | 4.37              | NPRJ(NP)     | 3.22              | SMKI(UB)     | 1.56              |
|              |                   | RJWN(KG)     | 4.67              | PWKT(PL)     | 4.30              | WRBT(UB)     | 6.19              |
|              |                   | PTHN(KR)     | 1.63              | BNER(TR)     | 15.44             | PNDY(UB)     | 4.96              |
Having defined the optimal zones, we will now move on to determine a distribution route in Zone 1, 2, 3, and 4. Firstly, time travel matrices in each zone are obtained with the origin started from the warehouse. The matrices assumed symmetric are the costs, $c_{ij}$, which will be minimized in the objective function. Also, we consider demand in every region that must be fulfilled. Zone 1 has five regions that must be visited with a total demand of 53.85 kgs out of 55 kgs. Zone 2 has 14 regions that must be visited with a total demand of 54.93 kgs out of 55 kgs. Zone 3 has 11 regions that must be visited with a total demand of 54.5 kgs out of 55 kgs. Zone 4 has 15 regions that must be visited with a total demand of 54.3 kgs out of 55 kgs. Each region must be traveled once, as revealed in the mathematical model earlier. Working with the data and using LINGO 18.0, we calculate and obtain four zones’ distribution routes, as can be seen from Figure 1 – 4.

![Figure 1](image1.png)  
**Figure 1.** A distribution route of Zone 1  

![Figure 2](image2.png)  
**Figure 2.** A distribution route of Zone 2  

![Figure 3](image3.png)  
**Figure 3.** A distribution route of Zone 3  

![Figure 4](image4.png)  
**Figure 4.** A distribution route of Zone 4
From the figures above, we can see that the distribution route of each zone. Zone 1 is started from the warehouse, then goes to DMG, GOWN, TGRJ, SRMJ, SRST, and comes back to the warehouse, which needs 58 minutes to travel. Zone 2 is started from the warehouse then heads to RJWN, WRGN, SRYD, GDKW, PTHN, PWDJ, PNMB, NPSN, PGKM, BMJO, SSRM, KTBR, CKRD, KTRN, and returns to the warehouse, which needs 97 minutes to travel. Zone 3 is started from the warehouse then goes to MJMJ, PWKT, BSRN, TGPG, TRBN, BNER, NPRJ, KDP, BTKM, PRGN, PRBY, then comes back to the warehouse, which needs 86 minutes to travel. Zone 4 is begun from the warehouse then heads to BCRO, KRWR, KRCK, NMPN, PKCN, WRBJ, PTPL, MNTR, KPRN, GWNG, PNDY, WRBT, THNN, GNKT, SMKI, and heads back to the warehouse, which required 97 minutes.

4. Conclusions
In this investigation, the aim was to determine the optimal routes of four zones by minimizing total travel time. After defining the new four zones taking into account the mileage minimization in the previous research, a distribution route is made for every zone. Zone 1 consists of 5 regions and has a total travel time of 58 minutes. Zone 2 consists of 14 regions and has a total travel time of 97 minutes. Zone 3 consists of 11 regions and has a total travel time of 86 minutes. Zone 4 consists of 15 regions and has a total travel time of 97 minutes. Further research in this field would be of great help in using time windows or considering road congestion.

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