



## A MATHEMATICAL MODEL FOR DELIVERY ZONE GROUPS BASED ON COURIER ASSIGNMENT OPTIMIZATION: A CASE STUDY IN A LOGISTICS SERVICE PROVIDER

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### ABSTRACT

*Logistics service providers are the key stakeholder in Indonesian logistics activities that are growing significantly and face many challenges. In this research, a case study on a logistics service provider located in the city of Yogyakarta Indonesia is evaluated. The provider is currently experiencing rapid growth indicated by increasing delivery volume and scopes. However, optimal resource management has not been able to be adequately calculated, such as inefficient courier assignment and overloaded couriers' volume. Thus, this study aims to minimize total distances through optimal zone groups under several restrictions. An optimization approach is selected in this research by initially building a mathematical model using a standard form of linear programming. Then, the mathematical model is solved to generate minimum distances. The result indicated that the total minimum distances had been reached with considerable changes in delivery zone grouping, and the couriers' capacity was optimally utilized without overloaded capacity. These zone groups can be used as a reference for further research by taking into account some restrictions such as packages fluctuations as well as adding objective to minimize couriers' traveling time.*

### INTRODUCTION

The logistics sector particularly referred to logistics service providers is one of the business sectors that has a significant Indonesia growth. The sector's potential is mainly caused by three factors, which are: (1) Indonesia's geographic condition, (2) a national e-commerce market growth, and (3) improved infrastructure and technology resources ("Menilik Peluang Bisnis," 2017; Christian, 2019). Geographically, Indonesia is an archipelago country with 16.056 islands

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in 34 provinces based on data from the Central Bureau of Statistics of Indonesia in 2019 (Statistik, 2019). This geographical advantage has encouraged the logistics sector's role as able to connect the distribution chain of goods from one to another ("Menilik Peluang Bisnis", 2017). Secondly, the rapid growth of the national e-commerce market due to today's people's lifestyle tends to shop online has a domino effect indirectly on the logistics service business. In 2019, the gross merchandise value (GMV) or the total value of e-commerce transactions in Indonesia reached US\$ 21 billion and was estimated to reach US\$ 82 billion by 2025 (Christian, 2019). Thirdly, the improved infrastructure and technological development in Indonesia have enabled connections between regions. This situation has stimulated the logistics business's innovation in combining its functions, such as improving express delivery services at a more affordable price. Apart from this, the ubiquitous technology has added more values to logistics service providers.

Despite the increase in national logistics activities, there are more problems and challenges that various stakeholders should address to ensure their sustainability. Płaczek (2010) generally stated that logistics service providers need to develop flexible transport systems to achieve the time of service expected by customers. Besides, internal aspects such as lack of human resources, operational processes in a supply chain network which are also affected by the threat of new competitors, and information technology including data sources, regulation, and development for businesses have not been mature (Ali, Jaafar, & Mohamad, 2008; Samapaty, 2015). In Indonesia, the challenges in logistics industries can be classified into internal and external aspects, which include logistics infrastructure that has not been connected completely, limited access to particular technology due to preferred paper-based processes, lack of competencies, and partial-institutions oriented policy (Peraturan Presiden (PERPRES), 2012; Samapaty, 2015).

Logistics service providers can independently prioritize internal improvements. The improvements executed will increase the business scale due to the broad market, even though they have restricted resources. In that situation, the providers may select the optimization techniques to produce the best solution under limited situations. An optimization approach is a scientific approach represented by a mathematical model that describes the existing system to find optimal solutions considering scarce resources (Winston & Goldberg, 2004). Optimization techniques are applicable in diverse areas, including the logistics and supply chain areas.

Pertinent studies have taken optimization techniques to solve logistics and supply chain problems in various scopes, including processes, distribution networks, and scheduling problems. The optimization studies' objectives in previous studies were mainly to minimize costs such as operational cost, distance, or delivery time, or to maximize profit shown in Table 1. As can be seen from Table 1 that several researchers have conducted studies on network distribution for the vehicle routing problem or traveling salesman problem using robust optimization techniques, either a heuristic-based algorithm or modified exact methods. The heuristic-based optimization that was most widely developed is a genetic algorithm; further, Wang et al. (2020) developed a hybrid-heuristic algorithm-based on improved multi-objective particle swarm optimization. Besides, the scheduling problem was also evaluated by Zhou, Zhang, & Fang (2020). The study considered a logistics service scheduling method based on the total time from the initial location to customers using the total time-based logistics scheduling algorithm (TTLS) approach. In Indonesia, it is essential to carry out optimization studies on logistics service providers; moreover, the country has many regions and thousands of islands with complex connectivity that provide opportunities for research and development at various scopes. For this reason, improvement studies on providers must be initiated on a small scale, determining providers which operate in a limited area so that logistics parameters and network can be calculated specifically. Hence, an optimization approach will be used in this study to improve delivery service in an Indonesian-based logistics service provider that has its branch in the city of Yogyakarta.

The provider taken in this research has two main processes: the outgoing process, delivery from senders, and the incoming process, delivery to recipients. Optimization will be needed, especially in the incoming process, since the company is required to deliver goods to recipients

with a short waiting time. In contrast, the number of couriers assigned to the entire delivery areas is limited. The company has currently divided four delivery zones and assigned four couriers to serve each zone. However, some couriers experienced exceed capacity, particularly in an area with the highest volume load, while the others are less-utilized. Hence, this research's primary purpose is to group delivery zones to minimize total couriers' distances given a limited number of resources.

Table 1. The objectives, methods, and problems of selected studies about optimization techniques in logistics service providers

Author & Year	Objectives	Method	Problem
Zhou, Zhang, & Fang (2020)	Selecting the best logistics service through average delivery time reduction	Simulation, Logistics Scheduling	Logistics service scheduling
Wang et al. (2020)	Optimizing logistics network based on minimum total cost, waiting time, and the number of vehicles	Hybrid Heuristic Algorithm	Vehicle routing problem (multi depot and multiperiod)
Wang, Yuan, et al. (2020)	Optimizing routes by minimizing the number of vehicles and the total cost	Bi-objective Linear Programming, Clustering, Genetic Algorithm	Vehicle routing problem
Wang, Hu, et al. (2020)	Maximizing profit, customer satisfaction based on delivery time, and the company's satisfaction based on order allocation	Nonlinear Mixed-Int. Multi-objective Optimization	Selection and allocation problem
Sedláček (2017)	Optimizing logistics processes with truck's downtime elimination	Simulation, Dynamic Discrete Simulation	Processes optimization
Başligil et al. (2011)	Optimizing vehicles' routes by minimizing the routing distance and the number of fleets	Mixed Integer Programming, Genetic Algorithm	Vehicle routing problem, distribution network
Ferdinand & Ferdinand (2018)	Designing a profitable tour by minimizing price of pickup and delivery in different areas	Genetic Algorithm	The shortest path problem, traveling salesman problem

Previous studies have been conducted on either delivery zone or clustering in order to achieve efficient logistics. Ducret, Lemarié, & Roset (2016) proposed a decision-making framework for efficient urban logistics based on cities' characteristics. The study successfully grouped nine urban zones using spatial modeling and clustering. In addition, zone clustering has also been carried out using a fuzzy clustering approach (Sheu, 2006; Wang, Ma, et al., 2014). These studies classified areas based on customers' characteristics and delivery service priorities so that total operational costs and average lead time can be reduced. These three studies aimed to achieve efficient logistics with a clustering approach. Meanwhile, in this study, a case study of delivery zones undertaken at a private logistics service provider will be regrouped using the exact optimization method, namely linear programming. The optimization approach in this study aims to obtain optimal delivery zone groups by minimizing total distances and allocating

limited resources in terms of the number and volume capacity of couriers to increase customer satisfaction.

## RESEARCH METHOD

The optimization method in this research is initially done by building a mathematical model. The mathematical model is formulated using a standard linear programming form which comprises the objective function, constraints, and decision variables (Hillier & Lieberman, 2010; Sivarethinamohan, 2005). A mathematical model comprises two main functions: objective functions that maximize or minimize performance, and constraint functions classified into functional constraints containing restrictions from decision variables and non-negativity constraints.

In this study, the mathematical model is built from a case study at a logistics service provider that assists its logistics service in the city of Yogyakarta, Indonesia, and the optimal solution will be generated from the Excel Solver simulation. There are only two indices used in this model,  $i$ , courier, and  $j$ , region. These indices indicate the assignment problem in which the courier is assigned to a particular region.

Indices:

$i$  = courier

$j$  = region

The model also has two parameters,  $D_j$  and  $K_i$ . Every region has a different demand for packages,  $D_j$ . Each courier must fulfill the demand. However, each courier also has a capacity limitation symbolized as  $K_i$ .

Parameters:

$D_j$  = an average number of packages (kgs) sent at region  $j$ .

$K_i$  = a maximum capacity of courier  $i$  (kgs).

After determining the indices and parameters, a mathematical formulation is built. As stated in paragraph one, the mathematical formulation consists of an objective function, a decision variable, and some constraints.

Decision variables:

$X_{ij}$  = if a courier  $i$  assigned to deliver packages to region  $j$ .

$X_{ij} \begin{cases} 1, & \text{if a courier } i \text{ assigned to deliver packages to region } j \\ 0, & \text{otherwise} \end{cases}$

An objective function:

$$\text{Minimize, } Z = \sum_{i=1}^n \sum_{j=1}^m d_{ij} \times X_{ij} \quad (1)$$

Where  $d_{ij}$  is a distance that must be traveled by a courier  $i$  to region  $j$ .

Subject to:

$$\sum_{j=1}^m X_{ij} \times D_j \leq K_i \quad \forall i = 1, \dots, n \quad (2)$$

$$\sum_{i=1}^n X_{ij} = 1 \quad \forall j = 1, \dots, m \quad (3)$$

$$X_{ij} \geq 0, X_{ij} \text{ binary} \quad (4)$$

The objective function is to minimize total distances traveled by the four couriers (1). Every total distance traveled by a courier will indicate his zone group. In this case study, a courier will send several packages (kgs),  $D_j$ , to some particular regions. These packages shipped are only for small items since the courier rides a motorcycle with limited capacity (kgs),  $K_i$ . Each courier

who delivers the packages must consider the maximum capacity of his motorcycle (2). However, every region can only be visited by one courier (3). The model determines whether a courier will assign to deliver the packages to some regions (4) by taking into account the total distances traveled.

## RESULTS AND DISCUSSION

### A. Problem Description

The paper solves a case study at a logistics service provider in the city of Yogyakarta. There are two business processes had in this logistics service provider. One is outgoing, and the other is incoming. Outgoing is a set of activities in the delivery process from senders to recipients, whereas incoming is a set of activities in fair distribution from its warehouse to ultimate recipients in some areas, such as sub-districts and regions. The provider only has one central warehouse in the city. In incoming activities, it is required to deliver packages that once arrive in the warehouse to the recipients efficiently, taking into account the limited couriers' resources and customer satisfaction that is indicated through short waiting time.

In this research, the logistics service provider's incoming activities are only limited to small items consisting of 12 shipping zones that span five districts. In one district, the delivery rate is thickly crowded, presented in a 1-month data history of delivery volume and the destination's delivery frequency. As a consequence, the company has classified the destination points at the regional level into four zones served by one courier per zone. However, the classification carried out by the company currently is not optimal, caused by the uneven distribution of courier load. It is due to the difference in the shipping volume of each zone. To a greater extent, there is overcapacity in its courier in a zone, as shown in the following table, Table 2. On the other hand, efficient urban logistics is an essential issue for the company to minimize its costs under restricted conditions, such as the capacity and number of couriers in this case.

Table 2 shows the destination point and the region in every zone. The table indicates that the number of points served by each zone differs significantly, especially in Zone 1. Here, courier 1 serves 16 regions having the highest volume load with an average daily volume of 85.70 kg or 155.82% of the maximum capacity per courier (given 55 kgs). Meanwhile, the couriers serving Zone 2, Zone 3, and Zone 4 are under maximum capacity even though Zone 4 only deal with seven regions, which also occupies the second-highest volume load. The orientation of zone classification done by the logistics service provider refers to the sub-district and has not considered the efficiency of urban logistics both in terms of cost and distance. In fact, one sub-district with an area reaching 2.3 km<sup>2</sup> has an average of 3 regions. As a result, the zone classification of 14 sub-districts in the city cannot represent the customer point with more detailed coordinates. Thus, in this study, the objective function is to minimize the total distances taken from coordinates of the regions that reach the end-consumers with a more specific and representative point.

Table 2. The number of average volume per day (kgs) in four zones for a current condition

Region	Avg daily vol (kg)						
Zone 1		Zone 2		Zone 3		Zone 4	
GWNG <sub>(UB)</sub>	2.67	GDKW <sub>(MR)</sub>	3.22	BSRN <sub>(DR)</sub>	4.96	RJWN <sub>(KG)</sub>	4.67
MJMJ <sub>(UB)</sub>	9.56	MNTR <sub>(MR)</sub>	4.93	SRMJ <sub>(DR)</sub>	3.81	PRGN <sub>(KG)</sub>	1.52
PNDY <sub>(UB)</sub>	4.96	SRYD <sub>(MR)</sub>	5.19	TGPG <sub>(DR)</sub>	1.59	PRBY <sub>(KG)</sub>	0.30
SMKI <sub>(UB)</sub>	1.56	BTKM <sub>(MG)</sub>	4.74	GNKT <sub>(PL)</sub>	0.70	KRCK <sub>(TR)</sub>	2.44
SRST <sub>(UB)</sub>	8.52	KPRN <sub>(MG)</sub>	3.33	PWKT <sub>(PL)</sub>	4.30	KRWR <sub>(TR)</sub>	4.37
THNN <sub>(UB)</sub>	4.85	WRGN <sub>(MG)</sub>	4.33	KDPT <sub>(KR)</sub>	1.15	TGRJ <sub>(TR)</sub>	23.00
WRBT <sub>(UB)</sub>	6.19	PKCN <sub>(WB)</sub>	4.81	PNMB <sub>(KR)</sub>	3.26	BNER <sub>(TR)</sub>	15.44

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	
BCRO <sub>(GK)</sub>	6.19	PTPL <sub>(WB)</sub>	2.48	PTHN <sub>(KR)</sub>	1.63		
DMGN <sub>(GK)</sub>	7.37	WRBJ <sub>(WB)</sub>	2.89	BMJO <sub>(JT)</sub>	2.11		
KTRN <sub>(GK)</sub>	6.59	NMPN <sub>(NP)</sub>	1.93	CKRD <sub>(JT)</sub>	4.37		
KTBR <sub>(GK)</sub>	3.93	NPRJ <sub>(NP)</sub>	3.22	GOWN <sub>(JT)</sub>	11.15		
TRBN <sub>(GK)</sub>	7.70						
NPSN <sub>(GM)</sub>	7.11						
PWDJ <sub>(GM)</sub>	2.70						
PGKM <sub>(GT)</sub>	2.26						
SSRM <sub>(GT)</sub>	3.56						
$\Sigma$	<b>85.70</b>		<b>41.07</b>		<b>39.04</b>		<b>51.74</b>

Note: GWNG<sub>(UB)</sub>, GWNG: Region, UB: Sub-district

## B. Linear Programming Model

As shown in the problem description, the case study will be modeled into a mathematical formulation already mentioned in Research Method by adding the data. The logistic service provider has four couriers ( $i$ ): courier 1, 2, 3, and 4. These four couriers will be assigned to some certain regions  $j$  to deliver the packages. The total number of regions is 45 regions that must be served. In addition, there are two parameters in this model:  $D_j$ , also known as an average demand in each region  $j$ , and  $K_i$  or a maximum capacity of every courier  $i$ . Since the couriers serve 45 regions, the model has 45 various demands in every region that must be met. Also, there are four maximum capacities of the couriers. The maximum capacity of a courier is 55 kgs.

Indices:

$i$  = courier = 1, 2, 3, 4.

$j$  = region = 1, 2, 3, ..., 45.

Parameters:

$D_j$  = an average number of packages (kgs) sent at region  $j = D_1, D_2, D_3, \dots, D_{45}$ .

$K_i$  = a maximum capacity of a courier  $i$  (kgs) =  $K_1, K_2, K_3, K_4$ .

In this model, there is only one decision variable,  $X_{ij}$ . The model should be solved to obtain the values of  $X_{ij}$ , which is if a courier might deliver packages to a certain region. The values are binary. Because there are four couriers and 45 regions, the value of  $X_{ij}$  is started from  $X_{11}, X_{12}, X_{13}, \dots, X_{444}, X_{445}$ .

Decision variables:

$X_{ij}$  = if a courier  $i$  assigned to deliver packages to region  $j = X_{11}, X_{12}, X_{13}, \dots, X_{445}$ .

$$X_{ij} \begin{cases} 1, & \text{if a courier } i \text{ assigned to deliver packages to region } j \\ 0, & \text{otherwise} \end{cases}$$

The objective function is to minimize the total distances traveled by all couriers. A distance traveled by a courier  $i$  to region  $j$  is known as  $d_{ij}$ , which is  $d_{11}, d_{12}, d_{13}, \dots, d_{345}, d_{445}$ . For example,  $d_{11}$  is a distance traveled by courier 1 to region 1,  $d_{12}$  is a distance traveled by courier 1 to region 2, and so forth. These distances are summed up and should be minimized. The objective function is presented into minimization of  $d_{11} \times X_{11}, d_{12} \times X_{12}, d_{13} \times X_{13}, \dots, d_{445} \times X_{445}$ .

The objective function:

$$\text{Minimize } Z = \sum_{i=1}^4 \sum_{j=1}^{45} d_{ij} \times X_{ij} = d_{11} \times X_{11} + d_{12} \times X_{12} + d_{13} \times X_{13} + \dots + d_{445} \times X_{445} \quad (5)$$

There are three constraints here. The first constraint considers the maximum capacity of a courier  $i$ . The courier  $i$  delivers packages to some regions  $j$  with various demands,  $D_j$ , and cannot exceed its maximum capacity,  $K_i$ . It is written as:

$$\sum_{j=1}^{45} X_{ij} \times D_j \leq K_i \quad \forall i = 1, \dots, 4 \quad (6)$$

$$i = 1: X_{11} \times D_1 + X_{12} \times D_2 + X_{13} \times D_3 + \dots + X_{145} \times D_{45} \leq K_1 \quad (7)$$

$$i = 2: X_{21} \times D_1 + X_{22} \times D_2 + X_{23} \times D_3 + \dots + X_{245} \times D_{45} \leq K_2 \quad (8)$$

$$i = 3: X_{31} \times D_1 + X_{32} \times D_2 + X_{33} \times D_3 + \dots + X_{345} \times D_{45} \leq K_3 \quad (9)$$

$$i = 4: X_{41} \times D_1 + X_{42} \times D_2 + X_{43} \times D_3 + \dots + X_{445} \times D_{45} \leq K_4 \quad (10)$$

The second constraint restricts that each region  $j$  is visited more than once or toured once. It is shown as follows:

$$\sum_{i=1}^4 X_{ij} = 1 \quad \forall j = 1, \dots, 45 \quad (11)$$

$$j = 1: X_{11} + X_{21} + X_{31} + X_{41} = 1 \quad (12)$$

$$j = 2: X_{12} + X_{22} + X_{32} + X_{42} = 1 \quad (13)$$

$$j = 3: X_{13} + X_{23} + X_{33} + X_{43} = 1 \quad (14)$$

⋮  
⋮  
⋮

$$j = 45: X_{145} + X_{245} + X_{345} + X_{445} = 1 \quad (15)$$

The last constraint is the binary variables of  $X_{ij}$ . They are shown as follows:

$$X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17}, X_{18}, X_{19}, X_{110}, X_{111}, X_{112}, X_{113}, X_{114}, X_{115}, \dots, X_{444}, X_{445} \text{ binary}$$

### C. The Problem Solution

The mathematical model is simulated using Excel Solver. The total minimum distances are 113.8 kms with a more efficient geographical zoning. Figure 1 illustrates the regions' coordinates in each zone for delivery zone groups arranged by the company and optimized groups obtained from this study. As shown in Figure 1, the company's delivery zone groups based on sub-districts zoning system tend to be segmented regardless of whether they should deliver the volume in each region. Furthermore, the company's current zones cannot represent the end-customer delivery points because each sub-district grouped in every zone has broad coverage points to reach regions in which each region also has various delivery rates, the number of packages (kgs) per frequency. Meanwhile, the optimal groups on the right side of Figure 1 show evenly delivery spread as the best solution is obtained, taking into account capacity, the number of packages, and the number of couriers. The optimal result has succeeded in minimizing the total distances for four couriers to each delivery point. The overcapacity experienced by courier 1 in Table 2 may not occur in the optimal result, as shown in Table 3.

The optimal result is still classifying delivery zone into four zones, with four couriers assumed to serve their zones. Table 3 reports that there has been a significant change in zone grouping since the 45 regions within the sub-districts are not in the same group. For example, region GWNG, MJMJ, PNDY, SMKI, SRST, and THNN located under the same sub-district, UB, and were previously grouped in Zone 1 are spread over to different zones for optimal condition. As a result, for sub-district UB, there are one region includes in Zone 1 and Zone 3, served by courier one and courier 3, and there are four regions grouped in Zone 4. It shows that the sub-district based zoning system that is currently carried out by the company tends to be inefficient because it has not considered several variables, including limited resources.

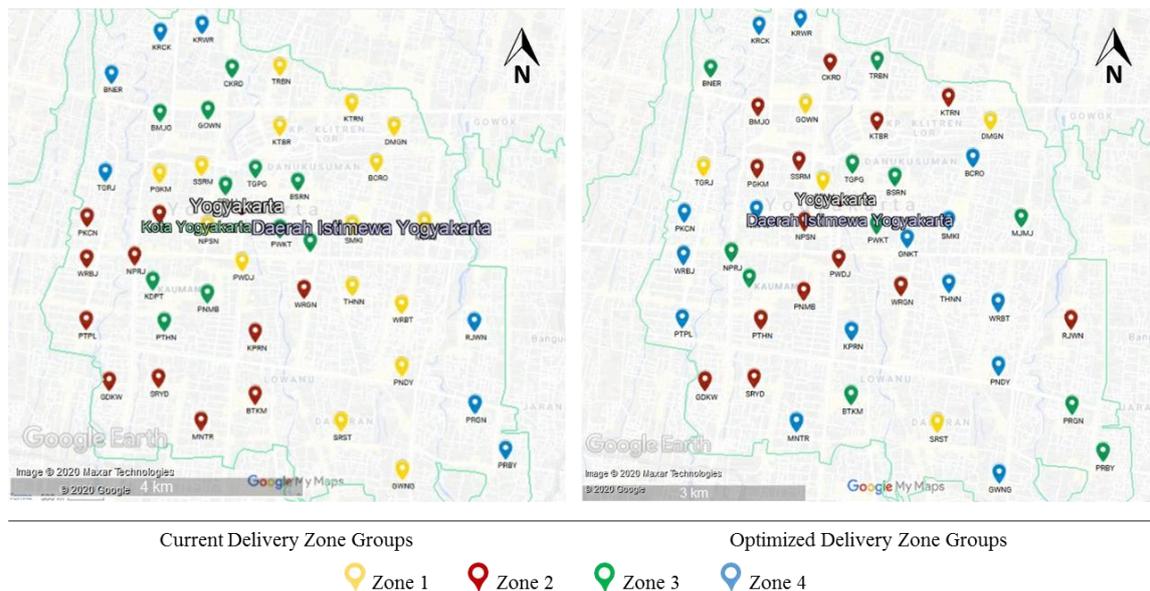


Figure 1. A geographic coordinate of delivery zones between current groups and optimized result

Table 3. The number of average volume per day (kgs) in four zones for optimal condition

Region	Avg daily vol (kg)						
Zone 1		Zone 2		Zone 3		Zone 4	
SRMJ <sub>(DR)</sub>	3.81	PGKM <sub>(GT)</sub>	2.26	TGPG <sub>(DR)</sub>	1.59	BCRO <sub>(GK)</sub>	6.19
DMGN <sub>(GK)</sub>	7.37	SSRM <sub>(GT)</sub>	3.56	BSRN <sub>(DR)</sub>	4.96	MNTR <sub>(MR)</sub>	4.93
GOWN <sub>(JT)</sub>	11.15	KTBR <sub>(GK)</sub>	3.93	TRBN <sub>(GK)</sub>	7.70	KPRN <sub>(MG)</sub>	3.33
TGRJ <sub>(TR)</sub>	23.00	KTRN <sub>(GK)</sub>	6.59	PRGN <sub>(KG)</sub>	1.52	NMPN <sub>(NP)</sub>	1.93
SRST <sub>(UB)</sub>	8.52	PWDJ <sub>(GM)</sub>	2.70	PRBY <sub>(KG)</sub>	0.30	GNKT <sub>(PL)</sub>	0.70
		NPSN <sub>(GM)</sub>	7.11	KDPT <sub>(KR)</sub>	1.15	KRCK <sub>(TR)</sub>	2.44
		BMJO <sub>(JT)</sub>	2.11	BTKM <sub>(MG)</sub>	4.74	KRWR <sub>(TR)</sub>	4.37
		CKRD <sub>(JT)</sub>	4.37	NPRJ <sub>(NP)</sub>	3.22	SMKI <sub>(UB)</sub>	1.56
		RJWN <sub>(KG)</sub>	4.67	PWKT <sub>(PL)</sub>	4.30	WRBT <sub>(UB)</sub>	6.19
		PTHN <sub>(KR)</sub>	1.63	BNER <sub>(TR)</sub>	15.44	PNDY <sub>(UB)</sub>	4.96
		PNMB <sub>(KR)</sub>	3.26	MJMJ <sub>(UB)</sub>	9.56	GWNG <sub>(UB)</sub>	2.67
		SRYD <sub>(MR)</sub>	5.19			THNN <sub>(UB)</sub>	4.85
		GDKW <sub>(MR)</sub>	3.22			WRBJ <sub>(WB)</sub>	2.89
		WRGN <sub>(MG)</sub>	4.33			PTPL <sub>(WB)</sub>	2.48
						PKCN <sub>(WB)</sub>	4.81
<b>Σ</b>	<b>53.85</b>		<b>54.93</b>		<b>54.5</b>		<b>54.3</b>

Note: GWNG<sub>(UB)</sub>, GWNG: Region, UB: Sub-district

The number of regions grouped based on the optimal result for Zone 1, Zone 2, Zone 3, and Zone 4 is five regions, 14 regions, 11 regions, and 15 regions, respectively. The company's current zone, the exceed capacity experienced by courier one, and the largest number of regions served in Zone 1 have changed significantly in optimal condition. As compared between Table 2 and Table 3, there are ten regions out of 45 regions that are still in the same zone, including two regions in Zone 1, Zone 2, and Zone 4, and four regions in Zone 3. This reports that 77.78% of the regions experience a marked change due to the optimization process. Therefore, it can be

concluded that the delivery zone groups that are currently carried out by the provider are not optimal.

A considerable change also occurs in the number of packages (kgs) served by each courier for each zone, as shown in Figure 2. It can be seen that the current zoning by the company has not evaluated the total volume delivered in each zone so that Zone 1 has not only has the largest number of regions served, but it also has the largest number of packages delivered, hit a high of 87.50 kgs on a daily average. According to the current group, the courier one's capacity even reaches 155.8% of the maximum capacity that is 55 kgs. In contrast, the capacities of the other couriers vary between 39.04 kgs and 51.74 kgs. This situation is not seen in the optimal condition in which the entire four zones have been efficiently grouped by considering the couriers' maximum capacity. Consequently, the average daily packages carried by each courier to each zone range from 53.85 kgs to 54.93 kgs, with a minimum utility percentage of 97.91% for courier one and a maximum of 99.86% for courier 2. This presents that all couriers are utilized optimally.

Finally, the delivery zone grouping carried out in this research is solved by an optimization approach in which the mathematical model is formulated from a modified vehicle assignment model and location cases. The optimization approach undertaken in this study has a different impact from the clustering study that has been conducted by Wang, Ma, et al. (2014). Wang, Ma, et al. (2014) proposed six areas for business planning purposes using a fuzzy clustering approach based on customer criteria. Those six areas can guide logistics operators in assigning vehicles, reducing operational costs, and improving customer satisfaction. Besides, the clustering studies mostly consider the similarity of specific characteristics to generate new clusters or groups. The resulting groups are usually proposed for structuring a geographic area, although their objectives are to achieve efficient logistics.

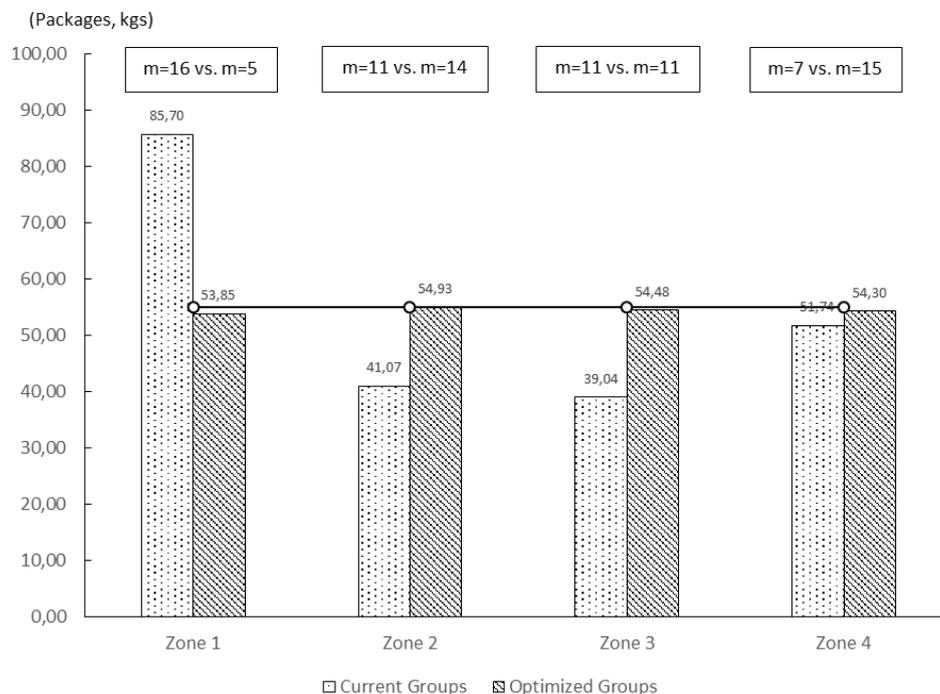


Figure 2. The comparison of average total volume (kgs) between the current condition and optimal condition based on zones

Meanwhile, with the optimization approach, this study succeeds in grouping the optimal delivery zones by minimizing the total distances of assigned couriers. This result provides a milestone for further opportunities. The follow-up research can be carried out by utilizing these

optimal zones to calculate another objective function, minimizing travel time. Furthermore, more specific routing cases can be addressed by applying either a dynamic approach or evolutionary algorithms.

## CONCLUSIONS

In conclusion, the formulated mathematical model can provide the best solution. The total minimum distances are 113.8 kms in which the four couriers serve four optimal zones with an efficient utility level of minimum utility is 97.91%. There are also no couriers that exceed maximum couriers' capacity. The solution presents that the logistic service provider's current delivery zone groups should be optimized, indicated by 77.78% of regions moving to the different zones to achieve optimal conditions. Some limitations of this study should be followed up. The wider distribution area can be applied since this study has only taken one city of five cities located in Yogyakarta. Besides, the mathematical model formulated in this study still assumes linearity and static decision-making. For further research, the model can be developed with a dynamic approach by considering packages fluctuations in a more extended period of time so that the standard form, as well as the algorithm, can be generalized to more cases. Lastly, in-depth vehicle routing can be easily carried out to calculate minimum delivery cost per courier within the zones and minimum couriers' traveling time.

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