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Evaluation of Last-Mile Delivery Depot Locations for Third-Party Logistics Companies Using the K-Means Algorithm

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ABSTRACT

The study assesses the efficiency of last-mile delivery (LMD) depot locations for third-party logistics companies in Pontianak, West Kalimantan, using the K-means clustering algorithm. The goal is to optimize new depot placements to reduce delivery distances and operational costs. Data were gathered via field observations and Google Maps to map depots, customers, and geographic features. K-means clustered customer locations, and depot efficiency was measured by Euclidean distance to cluster centroids—shorter distances indicating better alignment.The results show minor distance deviations among some companies, but no significant efficiency differences were found, suggesting that depot strategies remain suboptimal and could benefit from more data-driven optimization. This study offers practical insights on using K-means for depot placement and underscores the need to refine clustering methods for better LMD performance.

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INTRODUCTION

This study evaluates the locations of last-mile delivery (LMD) depots for several third-party logistics companies in Pontianak, West Kalimantan. This evaluation plays a crucial role in shortening delivery distances, thereby reducing delivery lead time and maintaining customer satisfaction.

In recent years, efficiency in long-distance delivery, particularly in the final stage or last-mile delivery, has become a significant research topic. LMD is the final stage in the supply chain that involves the delivery of goods from distribution centers to end customers. This stage is often considered the most complex and expensive part of the entire logistics process [1]. It is characterized by direct interaction with customers, requiring timeliness and adaptability to various delivery conditions.

The last-mile stage in the supply chain is considered very expensive and often inefficient, contributing between 13% to 75% of the total supply chain costs. This is due to various factors, including the demand for fast and reliable delivery, and high personalization, which have significantly increased operational costs [2]. The complexity of last-mile logistics, arising from urbanization and population growth, urban congestion, parking difficulties, and environmental issues, also makes it a critical focus for improving logistics processes [3]. Technological innovations, such as electric vehicles and advanced route optimization algorithms, are continuously explored to address these challenges and reduce costs and emissions.

Last Mile Delivery Challenges and Growth Potential in Pontianak

Pontianak is the capital city with the smallest administrative area proportion in West Kalimantan, accounting for only 0.08% of the province's total area. However, it had the largest population of 675,468 people in 2023 [4]. Pontianak, divided into three parts by the Kapuas River, serves as an excellent case study for last-mile delivery. Its unique geographical characteristics add challenges to determining efficient depot locations.

Third-party logistics (3PL) companies are outsourced logistics providers that handle multiple logistics activities [5] such as transportation, warehousing, and delivery. Currently, there are at least eight third-party logistics companies operating LMD depots in Pontianak, offering parcel delivery services. This number is expected to increase as the demand for parcel delivery grows in tandem with the rise of online shopping transactions. The potential growth of online shopping among the residents of Pontianak through e-commerce platforms can be seen from their high enthusiasm for internet access, which is the highest in West Kalimantan. According to data from the West Kalimantan Central Statistics Agency, the percentage of Pontianak residents aged 5 and above who accessed the internet (including applications like Facebook, Twitter, and WhatsApp) in 2023 was 83.53% [6]. This growth potential creates opportunities and challenges for logistics companies to further optimize their last-mile delivery operations. This optimization is crucial given the high demand for fast and efficient package delivery, which is key to maintaining customer satisfaction and competitive advantage in today's digital era.

The Role of K-Means Clustering in Logistics Optimization

Strategic positioning of logistics distribution centers can significantly lower logistics costs, accelerate circulation speed, boost enterprise profitability, and strengthen the core competitiveness of businesses. A widely used method for improving last-mile logistics performance is the K-means algorithm.

The origin of the K-means algorithm can be traced back to the 1950s, with Stuart Lloyd's work focusing on optimizing quantization in signal processing. However, it was MacQueen in 1967 who formally introduced the algorithm to the statistical and machine-learning community [7]. The algorithm works by minimizing the within-cluster variance, iteratively assigning data points to the nearest cluster center, and updating the cluster centers until convergence.

K-means has been extensively utilized across various disciplines, including image processing, market segmentation, anomaly detection, bioinformatics, market segmentation, logistics and transportation. The use of K-means in logistics and distribution has been the focus of numerous studies, demonstrating its effectiveness in optimizing operations. For example, Gao et al. proposed the use of K-means clustering to optimize logistics distribution centers by analyzing distribution points to identify local centers and customer points, enhancing efficiency and reducing costs in terminal delivery operations [8]. Similarly, Zuhanda et al. applied K-means clustering in combination with the 2-opt algorithm to optimize two-echelon logistics distribution for e-commerce, thereby improving routing efficiency and reducing costs [9]. In warehouse management, K-means is utilized to optimize storage by clustering similar products together, thereby reducing retrieval time and enhancing operational efficiency [10]. Additionally, K-means has been integrated into a two-stage algorithm to address logistics center location-allocation models, balancing economic objectives with timeliness constraints [11]. When combined with other route optimization methods, such as genetic algorithms and swarm optimization, K-means can further minimize travel distances and delivery times, leading to more optimal solutions [12].

Evaluating Last-Mile Delivery Depot Locations Using K-Means Clustering

Despite the growing interest in last mile delivery (LMD) optimization, existing studies predominantly focus on major metropolitan areas such as Jakarta and Surabaya (e.g., [13] [14]), leaving mid-sized cities like Pontianak underexplored. Additionally, while many studies emphasize operational strategies and business models, limited research quantitatively evaluates LMD depot efficiency using clustering methods like K-means. For instance, Leenawong and Chaikajonwat applied Modified K-means Clustering to determine convenience store location [15], while Wang and Wei used Two-Stage K-means algorithms for the logistic center location-allocation problem [11]. Most optimization approaches in logistics rely on Vehicle Routing Problem (VRP) models or p-median formulations, with relatively few studies leveraging K-means for depot location assessment. Furthermore, empirical, data-driven recommendations tailored to local third-party logistics providers remain scarce, as many studies either present theoretical models or focus on broader supply chain efficiency rather than location-specific LMD performance.

One factor contributing to extended delivery lead times is the suboptimal positioning of last-mile delivery (LMD) depot locations relative to the customers they serve. Third-party logistics companies in Pontianak, for instance, may have attempted to optimize their LMD depot locations to varying degrees, employing methods ranging from mathematical models and heuristic approaches to trial and error or managerial intuition. Therefore, evaluating and comparing the effectiveness of these logistics companies in positioning their LMD depots presents a valuable research opportunity.

In this study, the K-means algorithm is applied to cluster LMD depot locations and allocate surrounding customers. The process begins by selecting the LMD depot locations as initial centroids. Subsequently, customers are assigned to the nearest centroid based on distance, forming clusters. These clusters are iteratively updated until the centroids stabilize or until other convergence criteria are satisfied [16].

Based on the aforementioned problem, this study evaluates the LMD depot locations of several third-party logistics companies in Pontianak using the K-means algorithm. By comparing efficiency scores—represented by the average Euclidean distance between LMD depots and their respective centroids—this study provides a data-driven assessment of existing depot placements. The findings will inform recommendations for customer allocation and optimal LMD depot positioning to minimize delivery distances and enhance operational efficiency.

Beyond its methodological contributions, the results of this study have important implications for the logistics industry in Pontianak and other urban areas facing similar geographic and infrastructural challenges. More efficient depot placements can lead to shorter delivery lead times, lower transportation costs, and improved service reliability, directly benefiting third-party logistics (3PL) providers and their customers. Furthermore, as e-commerce continues to grow, optimizing last-mile delivery networks will be critical in sustaining customer satisfaction and maintaining a competitive edge. The insights from this study can also serve as a framework for urban policymakers and logistics planners to improve city logistics, particularly in regions with complex geographic constraints like river-divided cities or densely populated areas.

RESEARCH METHOD

Data collection

This study involves the collection of both primary and secondary data. Primary data includes the geographical conditions of Pontianak, specifically rivers, roads, and the positions of LMD depots, as well as actual traffic conditions obtained from direct observations to verify the accuracy of secondary data. Secondary data consists of the coordinates of LMD depot points belonging to several third-party logistics companies and the sampling coordinates of customers in Pontianak, which are manually collected from Google Maps. The observations of Pontianak geographical conditions indicate that the city is divided by the wide Kapuas and Landak Rivers into three regions, as shown in Table 1.

Table 1. Classification of Pontianak Regions

Regions	Administrative Districts
I	Pontianak Utara
II	Pontianak Timur
III	Pontianak Selatan, Pontianak Kota, Pontianak Barat, Pontianak Tenggara

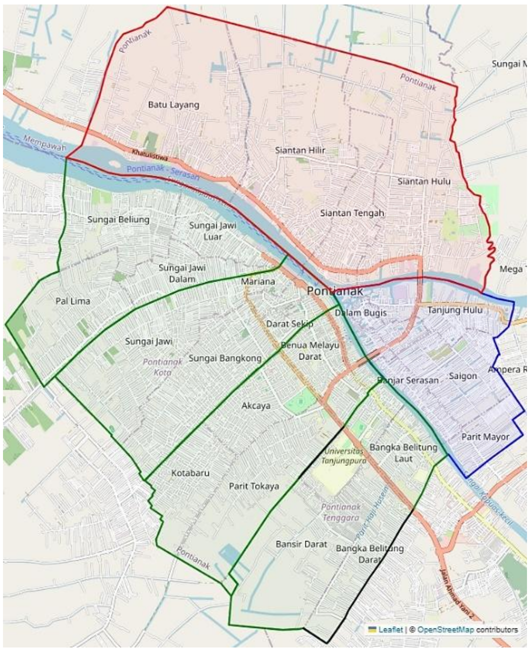

Figure 1. The division of Pontianak City into three regions based on geographical conditions: Region I (blue), Region II (green), and Region III (red). (Map source: ©OpenStreetMap)

This condition makes it impossible to form service clusters from LMD depots without considering these geographical characteristics (see Figure 1). Currently, the three regions of the city are connected by only two bridges, which link the regions with dense to very dense traffic flow, especially during peak hours. Therefore, to maintain the travel distance efficiency between LMD depots and customers, it is assumed that an LMD depot should exclusively serve only one city region, except when the logistics company under study has only one LMD depot for the entire Pontianak City. This assumption is also relevant considering the width of the Kapuas and Landak Rivers (250-550 meters). Without this assumption, the K-means algorithm might recommend centroids or ideal depot locations in the middle of the river, which would obviously be an infeasible solution.

The customer location coordinate points were collected manually using the proportionate stratified random sampling method through the Google Maps application. Stratified random sampling is a method that involves dividing a population into distinct subgroups, or strata, and then randomly selecting samples from each stratum. This approach ensures that the key characteristics of each subgroup are proportionately represented in the overall sample [17]. Initially, the population of customer locations throughout the city was grouped into six road strata according to their length, as shown in Tabel 2 Then, for each road strata, a number of random sampling points for customer locations were taken along these roads (see Figure 2).

The stratification of customer locations based on road length was guided by the assumption that longer roads generally accommodate a greater number of residences and businesses compared to shorter roads. In Pontianak, which is not yet a densely urbanized city, high-rise residential buildings such as apartment complexes are uncommon. Instead, the majority of residential areas consist of single-story housing clusters. Consequently, shorter roads typically serve fewer residents than longer roads. This stratification approach ensures a proportionate representation of customer locations across different urban settings, thereby enhancing the validity of the sample for last-mile delivery (LMD) analysis.

In this study, a total of 4,364 customer sample points were collected throughout Pontianak, with the following breakdown: 721 customer location points in Region I, 572 in Region II, and 3,065 in Region III. The distribution of sample points reflects the differences in urban density and road infrastructure across regions. Region III, which encompasses the central business and residential districts, has the highest concentration of commercial establishments and households, resulting in a greater number of sample points. Conversely, Regions I and II, which include more peripheral and less densely populated areas, have fewer sample points. This allocation ensures that the sample accurately represents the actual distribution of customer locations in the city, aligning with the characteristics of last-mile delivery (LMD) operations in Pontianak.

Table 2. Road Strata Based on Length and Number of Sampling Points

Strata	Road Length (m)	Number of Sampling Points
1	>6.000	10
2	>3.000 – 6.000	7
3	>2.000 – 3.000	5
4	>1.000 – 2.000	3
5	>500 – 1.000	2
6	0 – 500	1

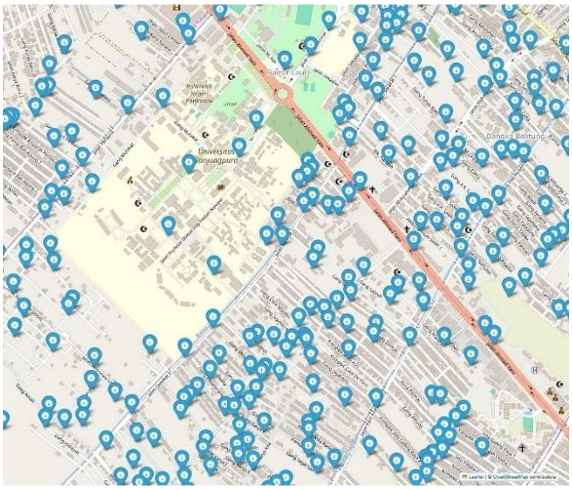

Figure 2. Example of customer location samples taken based on proportionate stratified random sampling in Bansir-Bangka Belitung Subdistrict. (Map source: ©OpenStreetMap)

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Evaluation of LMD depot locations

The evaluation of LMD depot locations for logistics companies is carried out through the following steps:

Generating service clusters

Service clusters for each logistics company are generated for each city region using the K-means algorithm. The number of clusters is determined by the number of existing LMD depots each company has in each part of the city. Clusters are visualized on a map as polygons formed from the perimeter of the outermost customers in each cluster. In this study, the K-means algorithm is implemented using Python. The plotting of the customer clustering results and LMD depots on an OpenStreetMap is done using the Folium library.

Matching centroids with the nearest LMD depot

With the number of generated centroids equal to the number of LMD depots, each centroid can be matched with its nearest LMD depot. This matching process is carried out using the Hungarian algorithm (optimal assignment algorithm).

Figure 3. The distance (d_i) is the length of the line segment connecting the centroid i (flag icon) and its paired LMD depot i (house icon). Each pair of centroids and LMD depot is marked with the same color. (Map source: ©OpenStreetMap)

Calculating the efficiency score of LMD depot locations

The centroid location generated by the K-means algorithm represents the optimal position that minimizes the sum of squared distances from all customers within that cluster to the centroid [18]. This position effectively reduces the average distance between the centroid and the customers it serves, making it an ideal location for an LMD depot within that cluster. Any deviation between the centroid location and the actual LMD depot location indicates inefficiency in the logistics company's depot placement strategy (see Figure 3). To quantify this inefficiency, a simple model was developed to calculate the efficiency score of LMD depot locations for each logistics company. This score can be calculated as the average nearest distance between the centroids obtained from the K-means algorithm cluster results and their corresponding LMD depots as defined in Equation (1).

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$$\bar{d}_p = \frac{\sum_{\forall C_p} d_i}{N_p} \quad (1)$$

where:

- $\bar{d}_p$: The average efficiency of the LMD depot location for Company p.
- C_p : Customer clusters belonging to Company p.
- d_i : Shortest distance between centroid i and its paired LMD depot i (in km).
- N_p : The number of LMD depots owned by Company p.

The company with the lowest score has the most efficient LMD depots, indicating that it is the best at determining the locations of its LMD depots.

The efficiency score metric was chosen as it quantifies the deviation between the existing depot locations and the optimal centroid locations derived from K-means clustering. This metric is particularly relevant to the study's objective of evaluating the effectiveness of LMD depot placement by logistics companies. A lower efficiency score indicates that a company's depots are well-positioned relative to customer demand, whereas a higher score suggests potential inefficiencies in location selection. By utilizing this metric, the study provides a data-driven assessment of depot placement strategies, highlighting areas for potential optimization.

The use of Euclidean distance in this study is justified by its computational efficiency, consistency in clustering, and neutrality in evaluating depot placement. Since the K-means algorithm inherently relies on Euclidean distance, incorporating actual road network distances would require modifications to the clustering process, adding complexity without necessarily improving the analysis. Moreover, Euclidean distance provides a simplified yet effective measure of spatial proximity, ensuring fair comparison across different logistics companies.

Using actual road distances from OpenStreetMap (OSM) presents challenges related to data accuracy, road accessibility variations, and computational burden. OSM data may not fully capture smaller roads or restricted access areas, leading to inconsistencies in distance calculations. Additionally, real-world factors such as traffic congestion, road conditions, and delivery restrictions could introduce biases, making it difficult to establish a standardized efficiency measure across different LMD depots.

Given the study's focus on depot placement rather than real-time route optimization, Euclidean distance serves as a practical and scalable approach. It allows for a clear assessment of how well-existing depot locations align with optimal customer clusters without unnecessary computational overhead. While road network distances might be useful for operational routing decisions, they are not essential for evaluating depot placement efficiency in this context.

Conducting Statistical Analysis to Identify Significant Differences in Companies' Efficiency Scores

In addition to using the K-means algorithm for customer clustering and the Hungarian algorithm for matching centroids with the nearest LMD depots, statistical analysis was conducted to evaluate the efficiency of depot locations across different companies.

Since the data did not follow a normal distribution and some companies had only a single data point, the Kruskal-Wallis rank sum test was employed as an initial test to determine whether there were significant differences in depot location efficiency among companies. If the results indicate no statistically significant differences, Dunn's test will be performed as a post-hoc analysis to further explore potential differences between specific pairs of companies. Dunn's test was chosen due to its ability to handle unequal sample sizes and its independence from normality assumptions. The Bonferroni correction was applied to control for Type I errors resulting from multiple comparisons. All statistical analyses were conducted using R software.

RESULT AND DISCUSSION

Customer cluster and LMD depot locations

The third-party logistics companies in Pontianak City evaluated in this study consist of eight companies with varying numbers of LMD depots. The number of depots ranges from a single depot owned by companies $P3$ and $P5$ to twenty-five depots owned by $P1$. Four companies have depots distributed across all city regions, while two companies have depots only in two city regions. The number and distribution of LMD depot locations in each city region can be seen in Figure 4.

Third-party logistics companies with a large number of LMD depots distributed throughout the city tend to handle a higher distribution workload and a distribution service coverage designed to reach all customers in Pontianak City. This extensive network facilitates route optimization, potentially reducing delivery times and operational costs in fulfilling orders. Conversely, logistics companies that do not have LMD depots spread across all city regions suggest that their distribution workload is still low, limiting them to opening a smaller number and range of LMD depots.

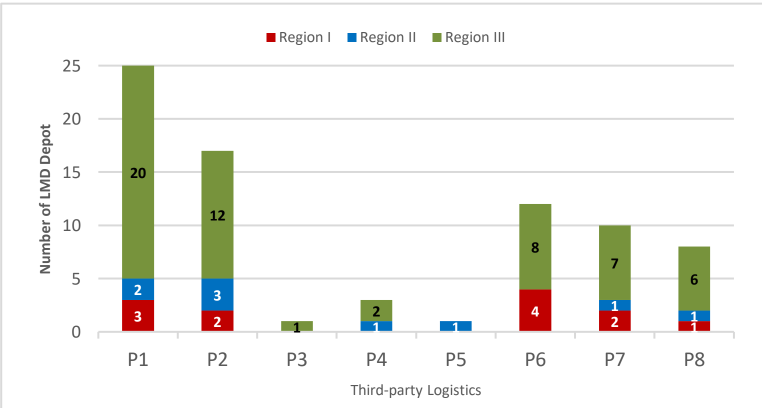

Figure 4. The distribution of locations and the number of LMD depots for each third-party logistics company in Pontianak.

The customer clusters, corresponding to the number of LMD depots for each company, generated using the K-means algorithm in the three regions of Pontianak City can be seen sequentially in Figure 5 and Figure 6.Figure 5(a) illustrates that the spatial distribution of LMD depots for $P1$ in Region I is suboptimal. This is evidenced by two out of the three operating depots being located at a considerable distance from their respective cluster centroids, with some even positioned in adjacent clusters. Additionally, all three depots are concentrated in the Siantan Tengah and Siantan Hulu sub-districts. Similarly, in Region III, 14 out of the 20 depots operated by $P1$ are significantly distant from the ideal locations, even situated outside their designated clusters.

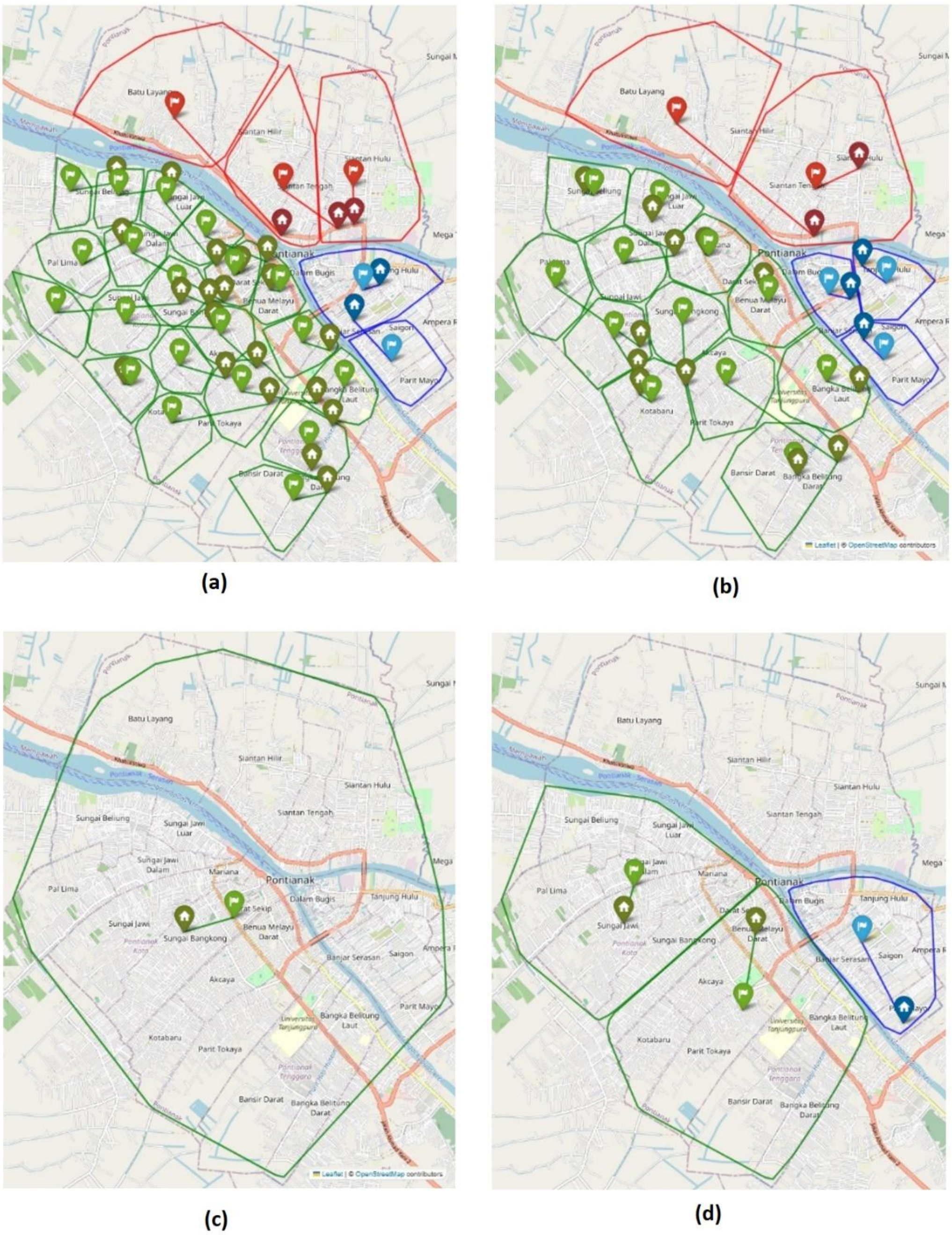

Figure 5. The customer clusters and LMD depots for the companies are as follows: (a) $P1$, (b) $P2$, (c) $P3$, dan (d) $P4$. LMD depots are represented by house icons, while cluster centroids are marked with flag icons, indicating the ideal central locations for each cluster (Map source: ©OpenStreetMap)

In Figure 5(b), it is evident that $P2$ has positioned 12 of their LMD depots well in Region III, although three depots are still located outside their respective clusters. In Region II, $P2$ has successfully placed all three of their depots within the appropriate customer clusters, minimizing the distance from the ideal centroid positions. However, in Region I, $P2$'s performance in positioning depots is poor, with both LMD depots concentrated solely in the Siantan sub-district.

Companies $P3$ and $P5$ (Figure 5(c) and Figure 6(a)) each operates a single depot to serve the entire area. With this setup, the depot will always be within a single cluster.

However, there is a significant deviation between the centroid location and the actual depot location, particularly for $P5$, where the centroid and depot are situated in different city regions. This indicates poor performance by $P5$ in determining an efficient location for their LMD depot.

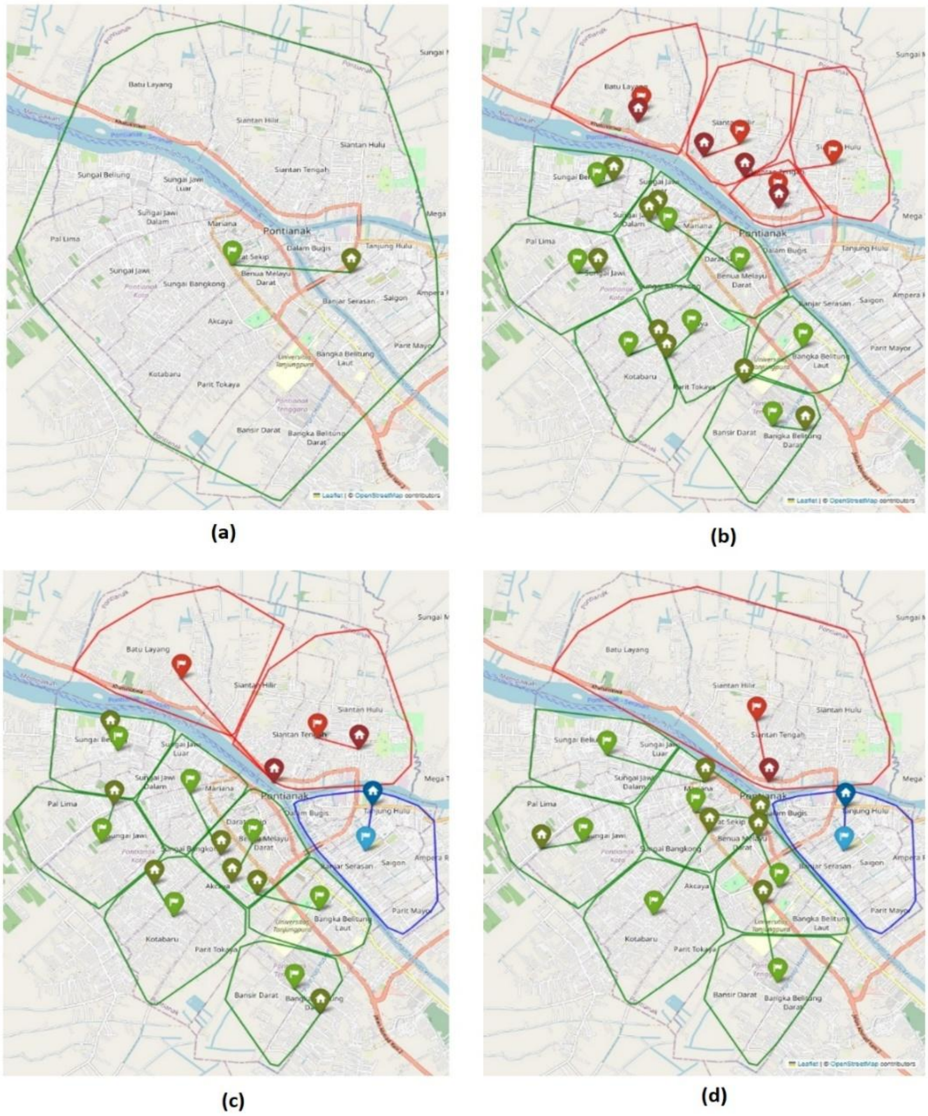

Figure 6. The customer clusters and LMD depots for the companies are as follows: (a) $P5$, (b) $P6$, (c) $P7$, dan (d) $P8$. LMD depots are represented by house icons, while cluster centroids are marked with flag icons, indicating the ideal central locations for each cluster. (Map source: ©OpenStreetMap)

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The regional division in this study was initially based on the natural separation of Pontianak by the Kapuas and Landak rivers, which influence logistics movement and accessibility. However, for Company $P5$ and $P3$, which operate with only one LMD depot, region-based separation was not applied because their delivery operations are centralized from a single location rather than distributed across multiple depots. Nevertheless, for companies with multiple depots, regional divisions were maintained to reflect logistical challenges posed by geographic barriers, and Euclidean distance was not applied across separate regions to preserve consistency with the initial assumptions.

Figure 5(d) illustrates $P4$'s performance in determining their LMD depot locations. $P4$ has placed two depots in Region III and one depot in Region II. While all three depots are within their respective clusters, this alignment does not necessarily result in small positional deviations between the depots and their cluster centroids. This issue arises due to the large size of the generated clusters, which is a consequence of the limited number of depots owned by $P4$. The limited number of depots, as seen with $P3$, $P4$, and $P5$, increases the average travel distance for parcel deliveries to and from the depots. This consequence should ideally motivate these companies to be more precise in selecting efficient depot locations.

In Figure 6(b), it is evident that $P6$ has excelled in determining the locations of their LMD depots in both of their operating regions. This is indicated by the small positional deviations between the LMD depots and their corresponding centroids in almost all clusters. Specifically, out of eight clusters in Region III, only two clusters have LMD depots deviating into another cluster. In Region I, only one out of four clusters have a depot located outside its respective cluster. $P6$ has effectively placed depots in Region I, ensuring a more even reach to their customers.

Table 3. Ranking of LMD depot location efficiency scores by region ($\bar{d}_{pw}$)

Wilayah	3PL Company	$\sum_{\forall C_{pw}} d_i$	N_{pw}	$\bar{d}_{pw}$*)	Rankings by Region
I	$P6$	4.28	4	1.07	1
	$P8$	1.88	1	1.88	2
	$P7$	5.28	2	2.64	3
	$P2$	6.18	2	3.09	4
	$P1$	7.24	2	3.62	5
II	$P1$	1.98	3	0.66	1
	$P2$	2.18	3	0.73	2
	$P8$	1.31	1	1.31	3
	$P7$	1.38	1	1.38	4
	$P4$	2.47	1	2.47	5
III	$P2$	13.62	12	1.13	1
	$P6$	9.37	8	1.17	2
	$P7$	9.01	7	1.29	3
	$P1$	29.28	20	1.46	4
	$P4$	3.15	2	1,57	5
	$P8$	12.88	6	2.15	6

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*) in km

Companies $P7$ and $P8$ (see Figure 6(c) and (d)) operating 10 and 8 LMD depots, respectively, throughout Pontianak, have not positioned these depots accurately. $P7$ placed two depots in Region I with a poor configuration similar to $P2$ and $P1$, concentrating on the Siantan Tengah and Hulu areas. Meanwhile, $P8$ poorly positioned its depots in Region III, with five out of six depots located far from their cluster centroids.

Efficiency Score of LMD Depot Locations for Logistics Companies

To strengthen the visual analysis conducted in the previous sub-chapter, efficiency scores for each company based on region are calculated and presented in Table 3. From Table 3, it can be seen that in Region I, $P6$ tends to have the most optimally placed LMD depots, scoring 1.07 km. Despite having the most LMD depots in Region I, the average distance between $P6$'s depots and their ideal positions are relatively lower compared to other companies with fewer depots. This indicates that $P6$ has carefully determined the location of each LMD depot. In Region II, companies $P1$ and $P2$ have positioned their three LMD depots relatively well, with location efficiency scores of 0.66 km and 0.73 km, respectively. These scores suggest better proximity to ideal locations compared to other companies in Region II. For instance, $P4$ has placed its only LMD depot 2.47 km away from its ideal position, which may indicate a less optimal placement strategy.

Table 4. Total location efficiency score rankings for 3PL companies ($\bar{d}_p$))

3PL Company	Region	$\sum_{\forall C_{pw}} d_i$	$\sum_{\forall C_p} d_i$	N_p	$\bar{d}_p$*)	Ranking
$P6$	I	4.28	13.65	12	1.14	1
	III	9.37				
$P2$	I	6.18	21.97	17	1.29	2
	II	2.18				
	III	13.62				
$P3$	**)	1.42	1,42	1	1.42	3
$P1$	I	7.24	38.51	25	1.54	4
	II	1.98				
	III	29.28				
$P7$	I	5.28	15.68	10	1.57	5
	II	1.38				
	III	9.01				
$P4$	II	2.47	5.62	3	1.87	6
	III	3.15				
$P8$	I	1.88	16.06	8	2.01	7
	II	1.31				
	III	12.88				
$P5$	**)	3.36	3.36	1	3.36	8

*) in km; **) a single depot for the entire region

In Region III, $P2$, operating 12 LMD depots, and $P6$, operating 8 depots, recorded the lowest average distance deviations from their ideal positions, with efficiency scores of 1.13 km and 1.17 km, respectively. In contrast, $P8$, which operates six LMD depots, had the highest distance deviation, with an efficiency score of 2.15 km, which is nearly twice as large as those of $P2$ and $P6$. In Table 3, the rankings do not include $P3$ and $P5$, as these companies have only one LMD depot for the entire city. Their performance rankings are presented in Table 4, which displays the aggregate location efficiency scores for all logistics companies across all regions in Pontianak.

Aggregately, $P6$ recorded the lowest average location efficiency score with a score of 1.14 km, involving a total of 12 depots across two regions. Conversely, $P5$ had the highest efficiency score at 3.36 km, operating only a single depot for the entire region. This pattern is also visually observable in Figure 6(a) and (b).

Statistical Analysis of Efficiency Score Differences Among Companies

While variations in efficiency scores were observed across companies, it is essential to determine whether these differences are statistically significant. To assess this, a Kruskal-Wallis rank sum test was conducted, followed by a Dunn post-hoc test for pairwise comparisons. The statistical analysis aimed to validate whether certain companies demonstrated significantly better depot efficiency than others.

The Kruskal-Wallis test results indicated no statistically significant differences in efficiency scores among the analyzed companies ($\chi^2 = 9.9186$, $p = 0.07757$). This suggests that, although efficiency scores varied, the observed differences were not strong enough to confirm that any one company consistently outperformed others in terms of depot placement efficiency. In other words, despite $P6$ having the lowest average distance deviation and $P5$ having the highest, these variations do not provide statistically conclusive evidence of superior or inferior depot positioning strategies.

To further investigate whether any specific pairwise differences existed, a Dunn post-hoc test was performed. Before Bonferroni's correction, some company pairs, such as $P2$ vs. $P8$ and $P6$ vs. $P8$, exhibited p-values below 0.05, indicating potential differences. However, after applying Bonferroni correction to adjust for multiple comparisons, no statistically significant differences remained among any company pairs (all adjusted p-values > 0.05). This confirms that no single company had a depot placement strategy that was statistically superior or inferior to others.

These findings suggest that last-mile delivery depot efficiency in Pontianak may be influenced by broader logistical challenges rather than company-specific strategies alone. The lack of significant differences implies that all third-party logistics providers in the study face similar constraints in optimizing depot locations, whether due to geographic limitations, infrastructure, or operational factors. Future studies could explore alternative clustering approaches or hybrid optimization methods to further refine depot positioning and improve efficiency.

CONCLUSION

This study assessed the efficiency of third-party logistics depot locations in Pontianak using K-means clustering, based on field observations and geospatial data. Depot efficiency was evaluated through Euclidean distances between depots and customer cluster centroids. Although variations in efficiency scores were found, statistical analysis showed no significant differences among companies. Companies with more depots generally achieved better alignment with demand centers, but exceptions indicate room for improvement. The findings suggest that depot placement strategies across the sector are not yet fully optimized. Companies could enhance last-mile delivery performance by integrating data-driven decision-making, incorporating real-time delivery patterns, and adopting hybrid clustering and optimization methods. However, limitations such as reliance on Euclidean distance and the exclusion of dynamic operational factors constrain the findings. Future research should integrate road network data, delivery variability, and explore alternative clustering approaches to refine depot location strategies over time.

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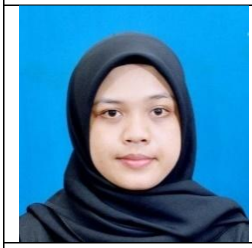	**Meissy Danjiah** earned her Bachelor of Industrial Engineering degree from Tanjungpura University, Pontianak, Indonesia in 2024. Currently she is a young researcher at Pusat Kajian Logistik & Rantai Pasok, Jurusan Teknik Industri, Universitas Tanjungpura. She can be contacted at email: d1061201001@student.untan.ac.id.
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