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Optimazion of Manufacturing Product Distribution Systems Using the Heuristic Methods Nearest Neighbour and Nearest Insert

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***ABSTRACT**: Product distribution is a critical component of supply chain performance in manufacturing industries, as inefficient routing decisions can significantly increase logistics costs and reduce delivery reliability, especially for small and medium-sized enterprises (SMEs) with limited resources. Despite its importance, many companies continue to rely on manual or experience-based route planning, which often results in suboptimal travel distances and unnecessary transportation expenses. This issue is not limited to a single firm but is commonly encountered in manufacturing distribution systems characterized by multiple delivery points and constrained operational capacity. This study develops and evaluates a distribution route optimization model using two heuristic algorithms, namely Nearest Neighbour and Nearest Insert, both of which are widely applied to solve the Travelling Salesman Problem (TSP) in practical logistics contexts. A quantitative research approach was employed by collecting data on delivery locations, inter-point distances, and transportation costs, which were subsequently analyzed through mathematical modeling and algorithmic simulations. The results show that the initial distribution routes required a total weekly travel distance of 362.43 km with an estimated transportation cost of Rp 578.792,31. After optimization, the Nearest Neighbor method reduced the distance to 329.89 km with a cost of Rp 553.761,54, while the Nearest Insert method resulted in a distance of 336.08 km and a cost of Rp 558.526,15. Overall, the Nearest Neighbour algorithm achieved the best performance, yielding a distance reduction of 32.54 km (8.98%) and a transportation cost saving of Rp 25.030,77 (4.32%) compared to the initial routes. These findings demonstrate that simple heuristic-based optimization models can significantly improve distribution efficiency and cost performance in manufacturing supply chains. The study contributes empirical evidence that such methods can be effectively adopted by SMEs as a scalable and resource-efficient decision-support tool for route planning, enabling cost reductions without increasing fleet size or reducing service coverage.*

***Keywords:** Distribution; Logistic; Nearest Neighbour Method; Nearest Insert Method; Optimization*

1. INTRODUCTION

A supply chain is an integrated system of coordinated activities that explicitly includes raw material sourcing, production operations, inventory management, warehousing, transportation, and the systematic distribution of finished products to end users (Sani & Fahmi, 2023; Suudi & Sanusi, 2021). Within this framework, distribution represents a critical stage that directly determines supply chain performance; however, efficiency improvements at the distribution level are often pursued without systematic route optimization or quantitative evaluation of distance and cost impacts. As a result, opportunities to reduce operational costs and improve delivery reliability remain underexploited, despite their strategic importance for maintaining competitiveness in dynamic market environments. (Stephanus & Sumayyah, 2025)

In manufacturing industries, distribution extends beyond the mere delivery of goods. It involves comprehensive planning, fleet management, scheduling, and strategic decision-making to identify the most cost-effective delivery routes (Hidayat, 2022; Rohmah et al., 2022). An inadequately designed distribution system may generate multiple inefficiencies, including longer travel distances, delayed deliveries, fuel overconsumption, and escalating labor costs. Collectively, these inefficiencies increase logistics expenses and diminish corporate profitability (Casmadi & Hutagalung, 2022; Royhan & Dwiridotjahjono, 2025).

Although distribution efficiency is widely acknowledged as a critical factor in supply chain performance, many small and medium-sized enterprises (SMEs) have yet to implement structured and systematic approaches in managing their distribution routes. In many cases, distribution planning is still carried out without quantitative evaluation of distance efficiency or transportation cost implications, particularly in operational environments characterized by multiple delivery points and limited resources.These limitations are primarily driven by constraints in human resources, financial capacity, and access to analytical planning tools. As a result, companies tend to rely on conventional practices such as drivers' personal experience, habitual routes, or ad-hoc decisions made in the field. While such practices may appear practical in the short term, they do not provide a reliable basis for maintaining efficiency as distribution volumes increase or delivery networks become more complex (Suryawan et al., 2024).

One common type of business entity within the small-scale industrial sector is the Commanditaire Vennootschap (CV), which typically operates at the lower to middle scale but plays a significant role in distributing products directly to consumers or business partners. In many cases, CVs manage their distribution activities internally rather than outsourcing them to third parties. Consequently, distribution becomes highly resource-intensive, requiring substantial inputs in terms of vehicles, time, and labor. Without an efficient system, operational costs rise sharply, thereby reducing profit margins.

This issue is particularly evident in the CV under study, which operates in the manufacturing sector and conducts regular deliveries to customers both within and outside the city. Initial observations reveal that its distribution practices remain largely manual and unstructured. Delivery scheduling is carried out on a day-to-day basis, guided by customer requests and driver experience, without the support of systematic route planning based on distance, travel time, or vehicle capacity. As a result, redundant routes, unnecessary travel distances, and fluctuating often excessive operational costs are frequently observed.

Such inefficiencies not only increase the operational burden of the company but also weaken its overall supply chain performance. When distribution is poorly managed, finished products fail to reach customers on time, which can trigger delays in payment, reduced customer trust, and disruptions in subsequent production schedules. This highlights how ineffective distribution can serve as a critical bottleneck in the supply chain, particularly for businesses with simple structures that have not yet adopted digital systems (Goni et al., 2022)

If these distribution challenges remain unaddressed, the company will face difficulties in adapting to rising demand, expanding market coverage, or responding to shifts in customer behavior. Over time, these limitations may hinder growth and restrict competitiveness against more adaptive and efficient competitors. Hence, it is essential to systematically identify the current distribution problems and develop realistic solutions that align with the company's capacity and resources.

Research on distribution route optimization has advanced considerably, employing various approaches such as the Clarke and Wright Savings method, Saving Matrix, Genetic Algorithms, Tabu Search, Dijkstra's Algorithm, Greedy Algorithm, Excel Solver, or combinations of these techniques (Lakutu et al., 2023; Lizami et al., 2024; Marpaung et al., 2022; Ramadhani et al., 2021; Saputra & Sukmono, 2024; Sumantry et al., 2024). Among heuristic methods frequently applied to the Travelling Salesman Problem (TSP), the Nearest Neighbour and Nearest Insert algorithms are particularly prominent due to their computational simplicity and efficiency. However, most prior studies have concentrated on applications within large enterprises or computer-based simulation models, with a strong emphasis on algorithmic performance rather than the practical realities of field operations. Furthermore, the majority of existing work remains theoretical, with limited exploration of implementation in small and medium-sized enterprises (SMEs) that often rely on manual distribution systems and face resource constraints.

This study offers a novel contribution by applying heuristic routing methods in a small-scale manufacturing company operating under severe resource constraints and a fully manual distribution system. The novelty lies in demonstrating that effective route optimization can be achieved using simple heuristics and field-based data, without reliance on digital planning systems or advanced decision-support tools. Rather than merely modeling distribution routes, the research integrates practical validation through on-site assessments and discussions with company stakeholders. A further innovation lies in the combined use of real-world data and field conditions, bridging the gap between theoretical developments in academic contexts and the practical demands of industry. This approach offers a foundation for designing more effective distribution systems in the future.

2. MATERIALS AND METHODS

This study adopted a quantitative descriptive approach aimed at optimizing product distribution routes in a small-scale manufacturing enterprise to improve efficiency in terms of travel distance and transportation cost. The distribution system was modeled under several simplifying assumptions: each delivery vehicle starts and ends its route at a single depot, all customer demands were fully served within one planning period, vehicle capacity constraints are not binding, and traffic conditions as well as travel times are assumed to be constant. These assumptions allow the routing problem to be formulated as a Travelling Salesman Problem (TSP) and addressed using heuristic algorithms.

The research began with a preliminary study to understand the operational characteristics of the company's distribution activities. This stage involved direct observation and informal discussions with management and distribution personnel to identify the general distribution pattern, delivery frequency, and operational constraints. The insights obtained are used to determine the scope of the study and to focus the analysis on routing inefficiencies that have a measurable impact on distance and cost performance.

Problem identification was then conducted to explicitly define the key distribution issues faced by the company, including inefficient route sequences, excessive travel distances, high fuel consumption, extended delivery times, and scheduling inconsistencies. These issues form the basis for the development of the optimization model.

Primary data was collected directly from field operations through structured observations, interviews with relevant stakeholders, and documentation of daily distribution activities. The collected data include customer locations, inter-location distances, delivery sequences, shipment volumes, and associated transportation costs. Distance data are obtained using actual travel measurements and digital mapping tools, while cost data are derived from fuel consumption records and operational expense reports.

Based on the collected data, the existing distribution system was modeled both graphically and mathematically to represent the current product flow and routing structure. This model serves as the baseline for evaluating inefficiencies in the current routes. Subsequently, route optimization is performed using the Nearest Neighbour and Nearest Insert heuristic methods to generate alternative routing scenarios with improved distance and cost efficiency. The first approach, the Nearest Neighbour method, is a straightforward algorithm that selects the next destination based on the shortest distance from the most recently visited point (Juniwati et al., 2025). This method was particularly suitable for distribution scenarios that require rapid routing decisions with low to moderate complexity. Second, the Nearest Insert method is a stepwise approach that constructs the delivery route by adding new shipment points at positions that result in the smallest possible increase in distance or cost (Arsyadanie et al., 2023; Faiz et al., 2025). This method is considered more flexible and often produces routes that are more efficient than the Nearest Neighbour approach, as it evaluates the overall impact of each insertion on the existing route structure.

The results obtained from both heuristic methods were subsequently subjected to a quantitative validation process. Validation was conducted by comparing the optimized routes against the initial routes using measurable performance indicators, namely total travel distance and total transportation cost. To examine solution stability and robustness, a sensitivity analysis was performed by varying key input parameters, including inter-location distances and fuel cost rates within a predefined range. The resulting changes in route structure and performance metrics were analyzed to assess whether the solutions remained consistent under moderate data fluctuations.

The optimization model was developed under explicit assumptions to ensure clarity and reproducibility: all delivery points were fixed during the planning horizon, demand levels were assumed constant, each route originated and ended at a single depot, and no changes in fleet size occurred during the analysis period. Under these assumptions, the persistence of route sequences across multiple sensitivity scenarios indicates that the solutions were not coincidental but structurally robust to reasonable variations in distance and cost parameters.

Only solutions that satisfied predefined efficiency improvement thresholds and demonstrated stability across sensitivity scenarios were considered implementable. Once these criteria were met, the study proceeded to the discussion of results and the formulation of conclusions.

3. RESULTS AND DISCUSSION

3.1. Interpretation of Result

The optimization of distribution routes was carried out using two constructive heuristic methods: Nearest Neighbour and Nearest Insert. Table 1 presents the comparison between the initial routes and the proposed optimization results.

Table 1. Comparison of Total Distance (km) Between Initial and Optimized Routes

Day	Initial Route	Nearest Neighbour	Nearest Insert
Monday	53.33	43.13	43.13
Tuesday	37.59	30.16	31.79
Wednesday	49.67	41.06	45.63
Thursday	45.95	39.65	39.65
Friday	175.89	175.89	175.89
Total	362.43	329.89	336.08

The results show that the Nearest Neighbour method reduced the total weekly travel distance to 329.89 km, while the Nearest Insert method produced a total distance of 336.08 km, compared to the initial route of 362.43 km. In terms of distribution costs, both methods also indicated efficiency improvements.

Table 2. Comparison of Distribution Costs

Day	Initial Route	Nearest Neighbour	Nearest Insert
Monday	101,025.38	93,176.92	93,179.23
Tuesday	88,915.38	83,200.00	84,450.00
Wednesday	98,205.38	91,584.62	95,096.92
Thursday	95,346.15	90,500.00	90,500.00
Friday	195,300.00	195,300.00	195,300.00
Total	578,792.31	553,761.54	558,526.15

Based on the results shown in Table 2, The Nearest Neighbour method resulted in the lowest distribution cost at Rp 553,761.54, followed by the Nearest Insert method at Rp 558,526.15, compared to the initial cost of Rp 578,792.31. The stronger performance of the Nearest Neighbour approach is explained by the spatial structure of the delivery network, where customer nodes are relatively clustered and the distances between neighboring nodes are fairly uniform. Under these conditions, selecting the nearest unvisited node at each step effectively minimizes route detours and redundant travel. As a result, the Nearest Neighbour method reduced total travel distance by 32.54 km (8.98%) and distribution costs by Rp 25,030.77 (4.32%) compared to the initial routes.

The findings demonstrate that the application of route optimization algorithms can significantly improve the efficiency of distribution activities in small and medium enterprises (Aziz & Nugroho, 2026; Azzahra et al., 2025) . Both Nearest Neighbour and Nearest Insert methods successfully reduced total travel distance and costs relative to the existing routes. However, the Nearest Neighbour method yielded superior results, with shorter travel distances and lower overall costs. This outcome is consistent with previous studies on the Travelling Salesman Problem and Vehicle Routing Problem, where algorithms such as Nearest Neighbour are effective in relatively compact distribution networks. In the context of XYZ SME, the distribution area is linear and concentrated, making the approach more advantageous compared to insertion-based heuristics (Putri et al., 2025; Safitri et al., 2025; Wayan et al., 2025).

From a managerial perspective, the optimized routes not only lower transportation expenses but also reduce non-value-added activities such as unnecessary travel and fuel consumption. These improvements contribute to better time management, timely delivery performance, and higher customer satisfaction (Azahra & Habiburrohman, 2025; Aziz & Nugroho, 2026; Azzahra et al., 2025; Ghofur & Fuad, 2019).

Connecting to the introduction, this study contributes to the body of knowledge by empirically validating the practical benefits of heuristic-based optimization for small-scale distribution systems. Furthermore, the research provides actionable insights for

SMEs in similar settings, showing that relatively simple algorithms can generate measurable efficiency gains without requiring complex computational resources.

In summary, the study confirms that adopting algorithm based route optimization supports both operational efficiency and sustainability goals by minimizing costs, conserving energy, and enhancing service reliability in the supply chain.

4. CONCLUSIONS AND RECOMMENDATIONS

This study showed that both the Nearest Neighbour and Nearest Insert methods can optimize distribution routes by reducing travel distance and costs. Among the two, the Nearest Neighbour method gave the best results, lowering the weekly distance by 32.54 km (8.98%) and reducing costs by Rp 25,030.77 (4.32%). This proves that simple heuristic methods are effective and practical for small manufacturing companies that still rely on manual planning.

For future research, other factors such as vehicle capacity, delivery schedules, and fluctuating demand can be added to make the model more complete. Combining heuristics with more advanced algorithms and using digital tools or GIS is also recommended to improve accuracy and support wider supply chain systems.

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