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# Optimization of Block Ice Distribution Route using Insertion and Swap-based Local Search Improvement method: A Case Study

*Muhammad* Refaldi [a], *Arif* Imran [a,1], *Fadillah* Ramadhan [a], and *Arie* Desrianty [a]

[a] Department of Industrial Engineering, Institut Teknologi Nasional Bandung, 40124, Indonesia

**Abstract.** PT X is a company engaged in the production of block ice and tube (crystal) ice, which currently faces the problem of unplanned and non-systematic distribution routes. This problem falls within the category of the Vehicle Routing Problem (VRP), specifically the Multi-Trip Vehicle Routing Problem (MTVRP). This study aims to determine new distribution routes for 25 kg block ice at PT X that minimize total travel distance by applying the Saving Matrix and Nearest Neighbour methods, followed by route improvement using Local Search techniques, namely 1–Insertion Intra-Route and (1–1) Swap Intra-Route. The results indicate that the Local Search-based Insertion and Swap Intra-Route method yields the greatest improvement, achieving a distance reduction of 44.59% compared to the company's existing route.

## 1 Introduction

Logistics is one of the most important aspects in enhancing a company's competitive advantage [1]. A supply chain is a series of interrelated activities and procedures that effectively connect agents, producers, warehouses, transportation operations, and distributors [2]. Decision-making in supply chain management is critical because it involves long-term strategic planning and requires substantial costs to maintain efficiency in the distribution process. Distribution itself refers to the series of activities involved in delivering products from suppliers to agents or end customers.

This study identifies a case study called PT X as a company that operates in the ice production industry, producing block ice and crystal ice for the food and beverage sector. Established in 1888, PT X has continued to grow steadily to the present day. Ice production is carried out based on total customer demand, which must be continuously distributed to multiple delivery points using truck vehicles. Currently, delivery decisions are made without systematic route calculations and rely largely on driver intuition, which can result in longer travel times. Non-optimal distribution routes negatively affect the company in terms of both time and transportation costs. The transportation problem encountered in this case is commonly referred to as the Vehicle Routing Problem (VRP), specifically the Multi-Trip Vehicle Routing Problem (MTVRP).

[1] Corresponding author: imran@itenas.ac.id

The Vehicle Routing Problem (VRP) is a transportation optimization problem with many variants that model distribution activities on paths, graphs, or network structures, aiming to determine routes with minimum cost for delivering goods to customers at multiple locations [3]. Due to the complexity of VRP, heuristic algorithms are commonly applied to obtain near-optimal solutions within reasonable computational time. A heuristic algorithm is a solution-search approach that explores a large solution space efficiently; while it does not guarantee an optimal solution, it is able to produce high-quality and practical solutions. For this reason, heuristic algorithms are often referred to as approximation methods.

This study addresses the Vehicle Routing Problem (VRP) with a multi-trip aspect, aiming to determine the best distribution routes using multiple vehicles to deliver ice to customers under constraints on total travel distance and total vehicle operating time. The resulting routes are expected to minimize total travel distance, thereby reducing transportation time and distribution costs. Well-planned distribution routes can lower operational expenses incurred by the company in ice distribution while simultaneously improving service quality and delivery performance.

## 2 Related Literature

The Vehicle Routing Problem (VRP) has been extensively studied in the fields of logistics and transportation optimization due to its high practical relevance to distribution systems. The VRP focuses on determining optimal routes for a fleet of vehicles that deliver goods to customers with known demands, subject to various constraints such as vehicle capacity, travel distance, and service time. Over time, the classical VRP has evolved into numerous variants to more accurately represent the complexity of real-world problems [4, 5].

One important variant of the VRP is the multi-trip routing type, commonly referred to as the Multi-Trip Vehicle Routing Problem (MTVRP), in which each vehicle is allowed to perform multiple trips within a given planning horizon. This VRP variant is particularly suitable for distribution systems involving frequent deliveries, limited vehicle availability, and short service cycles. Previous studies have shown that MTVRP is widely applied in the distribution of food, beverages, and other perishable goods, where vehicles are required to return to the depot multiple times for reloading [6, 3].

Due to the NP-hard nature of the VRP and its variants, exact optimization methods often become computationally infeasible for large-scale problem instances. Consequently, heuristic methods are commonly employed to obtain near-optimal solutions within reasonable computational times. Construction heuristics, such as the Savings Matrix method and the Nearest Neighbor algorithm, are frequently used to generate initial solutions due to their simplicity and computational efficiency [7, 8].

On the other hand, local search methods are typically implemented to improve initial routing solutions by modifying customer sequences within existing routes. Intra-route improvement techniques, such as the 1–Insertion and (1–1) Swap methods, have been proven to be effective local search strategies for reducing total travel distance and operational costs. Several studies have confirmed that combining construction heuristics with local search approaches produces higher-quality solutions for practical routing problems compared to single-method strategies [9, 10, 11].

Although extensive research has been conducted on the VRP and MTVRP, studies that focus specifically on ice distribution logistics remain limited, particularly in the context of long-established manufacturing companies. Therefore, this study contributes to the existing literature by applying local search methods to an MTVRP case study in the ice production industry, with the objective of minimizing total travel distance and improving distribution efficiency as well as service quality.

# 3 Problem Identification and Solution Method

## 3.1 Case Study Problem

PT. X is an ice manufacturing company located in Bandung, Indonesia, serving 49 customers with demand for 25 kg block ice (ice balok 25 kg). The company operates six delivery vehicles, each with a capacity of 200 units of 25 kg ice blocks. In the distribution process, vehicles often need to return to the factory to replenish inventory in order to fulfill customer demand. Inefficient route planning and the absence of proper calculations can increase distribution costs, waste time, and prolong the overall distribution process. To address these issues, this study applies the Savings Matrix method, Nearest Neighbor, Local Search 1-Insertion Intra-Route, and Local Search (1–1) Swap Intra-Route to analyze and improve the distribution routes in order to obtain the best possible solution, with detailed procedures explained in the subsequent sections.

## 3.2 Solution Method

The data processing in this study is conducted sequentially using several routing and route improvement methods. The process begins with the construction of initial distribution routes using the Savings Matrix method, followed by route sequencing using the Nearest Neighbor method. The obtained routes are then further improved using Local Search 1–Insertion Intra-Route and Local Search (1–1) Swap Intra-Route methods to obtain more optimal distribution routes. The detailed procedures of each method are explained as follows.

### *3.2.1 Savings Matrix Method*

The Savings Matrix approach is employed to generate initial distribution routes by combining delivery points in a manner that minimizes total travel distance and transportation costs while considering vehicle capacity constraints [12]. To apply this method, a distance matrix, customer demand data, and vehicle capacity information are required. Savings values are calculated as the difference between the sum of distances from the depot to two delivery points and the direct distance between those points. Delivery points are then allocated according to the largest savings values, subject to vehicle capacity limitations. If the combined demand of selected delivery points exceeds vehicle capacity, the next highest savings combination is chosen. This process continues until all delivery points are assigned and the initial routes are formed.

#### *3.2.2 Nearest Neighbor Method*

Another important method is the Nearest Neighbor approach, which is used to determine the sequence of delivery points within each route generated by the Savings Matrix method by iteratively selecting the closest destination from the depot or from the previously visited point. The routing process starts at the depot and proceeds to the nearest unvisited delivery point until all points in the route have been served, after which the vehicle returns to the depot [13]. If the route produced by this method results in a shorter total travel distance than the previous solution, the solution is updated and adopted as the new route.

#### *3.2.3 Local Search 1-Insertion and (1-1) Swap Intra-Route Method*

Local search methods, namely the 1-Insertion Intra-Route and (1–1) Swap Intra-Route techniques, are applied to improve the routing solution obtained from the Nearest Neighbor method. The 1–Insertion Intra-Route method operates by relocating a single delivery point to different positions within the same route, where each modified configuration is evaluated based on its total travel distance and accepted only if it yields an improvement. This iterative process continues until no further improvement can be achieved [14]. Subsequently, the (1–1) Swap Intra-Route method is employed by exchanging the positions of two delivery points within the same route to further refine the solution. Each swap is evaluated by comparing the total travel distance of the new route with that of the existing one, and the swap is accepted only if it results in a shorter distance. This procedure is repeated until no additional improvements are possible, as described in [15, 16].

## 4 Result and Discussion

### 4.1 Existing Route

The distribution of 25 kg ice blocks by PT. X is conducted to 49 delivery locations. The existing distribution route refers to the route currently implemented by the company for delivering products to all customers. Details of the existing route and the corresponding total demand are presented in Table 1.

**Table 1.** Existing distribution route and total demand.

| No. | Route | Total demand |
|---|---|---|
| 1 | PB – P1 – P6 – P10 – P15 – P48 – PB | 167 |
| 2 | PB- P9 – P39 - PB | 105 |
| 3 | PB – P8 – P35 – P43 – P27 – P2 – P32 – P36 – P47 – P11 – PB | 196 |
| 4 | PB - P16 – P23 – PB | 27 |
| 5 | PB – P14 – P42 – P26 – P44 – P21 – P34 – P12 - PB | 166 |

| | | |
|---|---|---|
| 6 | PB – P38 – P4 – P24 – P5 – P40 – P41 – P37 – P45 – P17 – P28 – P49 – P7 – PB | 183 |
| 7 | PB – P29 – P25 – P22 – P20 – P31 – P30 – PB | 195 |
| 8 | PB – P46 – P13 – P18 – P19 – P33 -P3 – PB | 139 |
| Total | | 1178 |

The visualization of the existing distribution route for ice block products implemented by PT. X is shown in Figure 1.

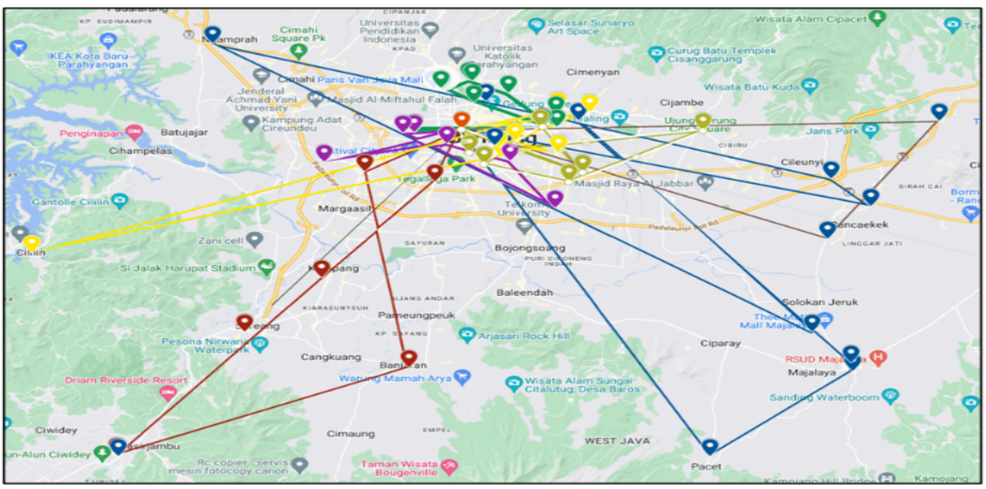

**Fig. 1.** Existing Distribution Route

## 4.2 Implementation of Solution Method

The Saving Matrix method is calculated using distance data from the factory to each customer and the distances among customers. The results of the Saving Matrix are then used to determine route destinations based on the largest saving values. The allocation process continues until all customers are assigned, resulting in a new distribution route. The resulting routes are presented in Table 2.

**Table 2.** Route solution based on Saving Matrix.

| No. | Route | Total distance |
|---|---|---|
| 1 | P11-P36-P43-P2-P8-P35-P16-P23-P17-P19 | 125,3 |
| 2 | P9-P39-P10-P6-P41 | 74,1 |
| 3 | P33-P47-P46-P12-P22-P24-P21-P27-P34-P37 | 74 |

| | | |
|---|---|---|
| 4 | P30-P42-P32-P13-P14 | 102,2 |
| 5 | P4-P49-P1-P31-P5-P44-P38-P20-P48-P15-P18-P25 | 57 |
| 6 | P7-P29-P28-P40-P3-P26-P45 | 32,4 |
| Total | | 465 |

After applying the Saving Matrix method, the nearest neighbor procedure is performed to obtain a shorter distribution route. The results of this procedure are presented in Table 3.

**Table 3.** Improvement solution based on Nearest Neighbor.

| No. | Route | Total distance |
|---|---|---|
| 1 | P-P11-P36-P43-P2-P8-P35-P16-P23-P17-P19-P | 125,3 |
| 2 | P-P41-P6-P39-P9-P10-P | 73,9 |
| 3 | P-P34-P37-P22-P46-P21-P27-P12-P24-P33-P47-P | 63 |
| 4 | P-P13-P14-P30-P32-P42-P | 94,8 |
| 5 | P-P15-P18-P20-P44-P4-P38-P49-P31-P5-P25-P48-P1-P | 42,7 |
| 6 | P-P28-P45-P40-P26-P3-P29-P7-P | 28 |
| Total | | 427.7 |

To improve the solution, the 1–Insertion intra-route procedure is applied by inserting each arrival node within the same route to obtain the minimum travel distance. This method uses the route obtained from the Nearest Neighbor procedure as the initial solution for the insertion and sorting process. The results of this improvement method are presented in Table 4.

**Table 4.** Improvement solution based on 1-Insertion Intra Route.

| No. | Route | Total distance |
|---|---|---|
| 1 | P-P19-P11-P36-P35-P8-P43-P2-P16-P23-P17-P | 116,6 |
| 2 | P-P41-P6-P9-P39-P10-P | 73,6 |
| 3 | P-P34-P37-P22-P46-P47-P21-P27-P12-P33-P24-P | 51,2 |
| 4 | P-P13-P14-P42-P32-P30-P | 89,9 |
| 5 | P-P15-P18-P20-P44-P38-P49-P4-P5-P31-P48-P1-P25-P | 33,1 |

| | | |
|---|---|---|
| 6 | P-P45-P28-P40-P26-P3-P7-P29-P | 25,9 |
| Total | | 390.3 |

The Local Search (1–1) Swap Intra-Route method determines distribution routes by exchanging delivery points within the same route to minimize the total travel distance. This method uses the solution obtained from the Local Search 1–Insertion Intra-Route method as the initial solution for the sequencing process. However, in this study, the Local Search (1–1) Swap Intra-Route method did not yield any routes with a shorter total distance. Therefore, the final solution remains the same as that obtained from the Local Search 1–Insertion Intra-Route method.

### 4.3 Total Completion Time of the Final Route

The calculation of the total designed travel time is conducted using the selected optimal route, namely the route obtained from the Local Search 1–Insertion Intra-Route method. The results of the total designed travel time calculation are presented in Table 5, while the corresponding visualization is shown in Figure 2.

**Table 5.** Total completion time in the final route

| No. | Route | Total Demand | Completion Time (hours) |
|---|---|---|---|
| 1 | P11-P36-P43-P2-P8-P35-P16-P23-P17-P1 9 | 190 | 5,68 |
| 2 | P-P41-P6-P39-P9-P10-P | 200 | 4,45 |
| 3 | P-P34-P37-P22-P46-P21-P27-P12-P24-P3 3-P47-P | 196 | 4,22 |
| 4 | P-P13-P14-P30-P32-P42-P | 200 | 4,59 |
| 5 | P-P15-P18-P20-P44-P4-P38-P49-P31-P5-P25-P48-P1-P | 198 | 2,98 |
| 6 | P-P28-P45-P40-P26-P3-P29-P7-P | 194 | 2,80 |
| Total | | 1178 | 24.73 |

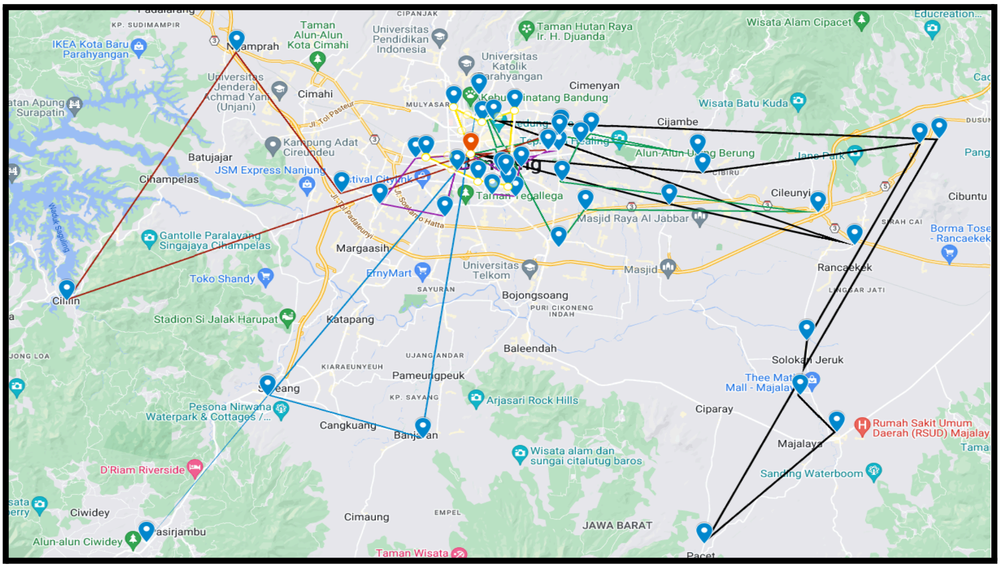


**Fig. 2.** Visualization of the final route

## 5 Conclusions

The total distance savings achieved using the Local Search 1–Insertion Intra-Route method reach 44.59% compared to the actual distribution route currently implemented by the company. This substantial reduction indicates that the proposed method is able to significantly optimize the sequence of customer visits within each route. In addition to the considerable decrease in total travel distance, the application of this method also results in a 27% reduction in total completion time. The reduction in travel time reflects more efficient vehicle movement and better route structuring, which in turn can improve service punctuality and operational performance. Overall, these findings demonstrate that the proposed routing approach is effective in enhancing distribution efficiency by simultaneously minimizing travel distance and delivery duration, thereby providing a more optimal and practical solution for ice block distribution operations.

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