# OPTIMIZING THE FRESH-CUT FLOWER DISTRIBUTION USING THE VEHICLE ROUTING PROBLEM FOR PERISHABLE GOODS

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**ABSTRACT**- Real-world freight distribution problems are complex, primarily because they must adhere to several restrictions on multidimensional vehicle capacity, vehicle characteristics route duration/length restrictions, time windows, and compatibility. As a result, attention must be paid to the distinctive operating procedures and features of various distribution systems. In this context, cut flower distribution is recognized as one of the challenging operations as it requires maintaining a certain level of freshness. Through the entire supply chain (SC), it is vital to keep freshness because it decides the product price, quality as well as customer satisfaction level. We study the fresh flower distribution using data from a reputed floral company in Sri Lanka to find the optimal set of routes for the fresh-cut flower delivery. We employ Capacitated Heterogeneous Fleet Vehicle Routing Problem (VRP) for Perishable Goods with Time Windows and a Single Depot (CHFVRPPGTWSD). Therefore, the main objective of this paper is to minimize the total distribution time while keeping a maximum freshness rate as a KPI to maximize customer satisfaction. We use a hybrid algorithm to fulfill our research objectives. Floral companies would be benefitted from our model as it can assist to identify optimal routes to plan their distribution network with minimum distribution time.

**Keywords:** Fresh Flower Distribution; Perishable Vehicle Routing Problem; Metaheuristic Algorithms

## 1. INTRODUCTION

Perishability in the field of Supply Chain Management (SCM) addresses two sides; the capability of controlling the quality of the products or minimizing the wastage of perishable products. Reducing spoilage and wastage can have significant economic benefits for the flower industry as it reduces the costs associated with lost or damaged products. There are four types of perishability such as "(1) strictly fixed lifetime, (2) non-strict fixed lifetime, (3) random shelf life, and (4) gradual deterioration over time" [1]. We consider cut flowers that fall under the non-strict fixed lifetime category [1]. There is a 'finite maximum usable lifetime' for such products, and their due lifetime depend on some external factors like temperature, stock-keeping method, seasonality of the year, and moisture.

The quality of the cut flowers highly depends on external factors such as stock keeping method, environmental temperature, seasonality, moisture status of the air, water level, heat, and exposure level to sunlight [2]. Therefore, the floriculture trade meets extreme perishability due to the limited shelf life of the flowers [3]. Sirisaranlak [3] has introduced efficient cool SCM practices to reduce the risk of losing the flower value as it delivers to the customer. Customers are more concerned about the color, odor, appearance, size, and product presentation as those characteristics depend on the freshness of the flowers. By ensuring that the flowers are delivered to their destinations in the best possible condition, it is also possible to improve customer satisfaction and build a reputation for high-quality products. This, in turn, can lead to increased sales and profitability for the flower industry. Therefore, it is vital to keep the freshness at a required level because it decides the product price, and quality as well as the customer satisfaction level [3].

This study focus on single flower variety; chrysanthemum to develop the model. Considering the specified temperature range of 5°C - 10°C in the storage room and 10°C in the truck, we assume a direct transfer of products from the storage room to the truck. Throughout the entire journey, the truck maintains a consistent temperature of 10°C, as it has been determined that this temperature range has minimal impact on the flowers' perishability within the cut-flower SC. Applying VRP for cut flowers will ensure an efficient and effective method to deliver fresh products to the end customers. The VRP is a well-studied optimization problem in the

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field of logistics and transportation. Given the importance of studying the fresh flower SC due to its perishability [4], to the best of our knowledge, there is a notable absence of research endeavors addressing the optimization of the cut flower distribution network with a primary objective of minimizing the total distribution time, while simultaneously considering the perishability level of the cut flowers. Therefore, we seek to optimize the fresh flower distribution by minimizing the total distribution time (combination of the traveling time and service time) while considering the perishability level and also keeping freshness rate as a KPI. This CHFVRPPGTWSD model will help to on time delivery, with the best service level, to maximize customer satisfaction.

## 2. MODEL DEVELOPMENT

There are four methods to solve the VRP problem: exact, heuristic, metaheuristic, and hybrid methods. We selected hybrid as our methodology by considering several factors such as complexity, solution type, and execution time [5]. The utilized hybrid algorithm combines heuristics and metaheuristics. The routing model was configured with the chosen initial construction heuristic strategy of Path Cheapest Arc (PCA), which guided the initial solution generation. Additionally, a time limit was set to control the search process, and the option to enable the Guided Local Search (GLS) metaheuristic was provided to enhance the solution further.

We developed the algorithm using OR-Tools v9. 6. and Python version 3.10 in PyCharm Community Edition 2021.3. (Study [5] used OR tools to generate the solution through a hybrid algorithm.) There are 20,000 data points. Additionally, we collected data on the fleet, such as the number of refrigerated trucks available, their capacity, temperature settings, and average speed. Moreover, we obtained specific data related to Chrysanthemum flowers, including their perishability time at different temperatures and the average number of flowers per crate (1 SKU = 100 flowers). After analyzing customer data, we could make 150 clusters across the region, and we took a central point of these clusters separately and make 150 customer demand points. It performs a random sampling process to divide these data points into 10 distinct groups considering the demand values as the total affordable capacity of the 3 refrigerated trucks is 350 SKUs (150 SKUs for Vehicle 1, 150 SKUs for Vehicle 2, and 100 SKUs for Vehicle 3).

### 2.1. Model Formulation

Model Formulation is completed based on the previous work done by Noguera et al. [4] and Fernando et al. [5]. Fernando et al. [5] suggest a model to optimize a retail chain distribution network using a real-world road network. The goal of the model is to find a distribution strategy that minimizes the overall cost of distribution. Noguera et al. [4] proposes a mathematical model that attempts to reduce the perishable goods' freshness loss while taking into account the time they spend in the trucks. This paper attempts to propose an extension of VRP, integrating Capacitated VRP, Heterogenous Fleet VRP, VRP with time windows and Single Depot VRP while minimizing the total distribution time. Other than the common constraints in CVRP, we used maximum allowable perishability time constraint (based on the temperature that flowers are transported, we limit this time to 360 minutes), time window constraints and demand fulfillment constraints for customer locations.

## 3. RESULTS AND DISCUSSION

The following chart shows the obtained values for the total distribution time for the existing case and proposed case. We can see a significant reduction in average distribution time that a vehicle has taken to complete the assigned route. The distance also reduces to cover the same number of nodes per route.

**Table 2**. Results

| | **Existing Case** | **Proposed case** |
|---|---|---|
| Average distribution time per route (min) | 360 | 241 |
| Average distance per route (km) | 240 | 150 |
| Average no. of nodes met per route | 15 | 15 |

Galarcio Noguera et al. [4] give valuable insight into the freshness loss of perishable products. They present a mathematical model aimed at minimizing the degradation of the freshness of perishable products during transportation. The model convers factors including the duration of the product kept inside the vehicles and

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the frequency of opening the vehicle storage doors along the route, starting from the departure from the depot until reaching the ultimate customer. After considering the mathematical formulations in their study, we built a freshness factor for our research.

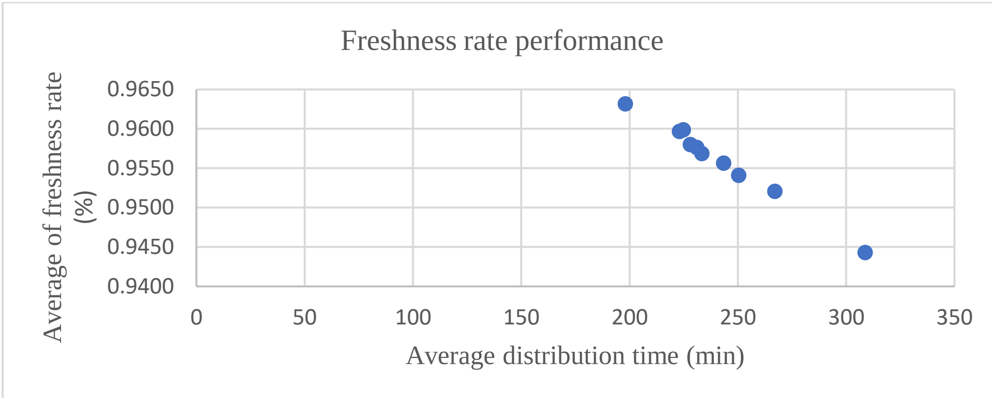


**Figure 1**. Freshness rate performance

The figure shows the freshness rate performance against the time for the 10 instances. This study enables to plan the optimal set of routes based on the minimum time to keep maximum freshness rate which generate a better service level to the customers.

## 4. CONCLUSION

This CHFVRPPGTWSD model enables planning a a route network with minimum time with a significant time difference from the existing scenario considering the flowers' freshness state as well. This research will be more important to academia to do future research projects by developing the proposed model. By applying this model to real-world scenarios, the floral industries can identify the optimal routes to plan their distribution network with minimum distribution time. For future research, we propose to integrate inventory decisions to enhance the applicability in the industry context.

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