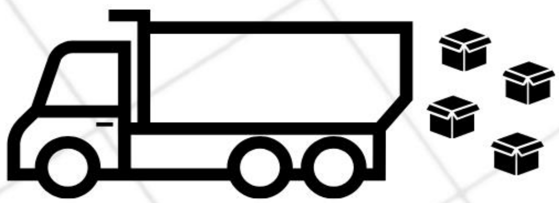
NORTHERN UNIVERSITY
OF BUSINESS & TECHNOLOGY KHULNA

2024

OPTIMIZING DELIVERY ROUTES TO REDUCE COSTS



COURSE TITLE: LINEAR PROGRAMMING AND COMBINATORIAL OPTIMIZATION LABS
COURSE CODE: CSE 2202
SECTION: 4B

"You may delay, but time will not."
- Benjamin Franklin

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Project Overview

Aim and Scope:

I aim to develop an algorithm to optimize vehicle routing for goods delivery, reducing costs and improving efficiency by doing this project. And the scopes of this can be various. In this project, the Vehicle Routing Problem (VRP) will be formulated with several constraints, including delivery time windows and vehicle capacity. Information on delivery locations, distances, and vehicle capacity will be gathered.

The problem I intend to solve and its significance:

I have worked with some organizations that need to deliver goods daily. There I have seen many scenarios where sometimes the goods were not delivered on time, sometimes the delivery route was so long that the delivery boy had to suffer a long, and sometimes the online map was not accurate. So, I came up with the idea of developing something that would help find the shortest route and maximize the profit for anyone who will be using this. Other than that, optimizing routes can lead to better utilization of the vehicle fleet, reducing the number of vehicles needed and maximizing their usage. Future enhancements could include real-time traffic data integration, allowing for dynamic route adjustments based on current road conditions. So, to solve these problems I find my project very significant.

Objectives:

I aim to develop this project to develop an algorithm to optimize vehicle routing for goods delivery. This optimization will aim to minimize total delivery costs and travel distances while ensuring timely and efficient delivery services. I seek to enhance logistical operations by providing a practical, data-driven solution that can be integrated into existing delivery systems, thereby improving overall operational efficiency and customer satisfaction by developing this project. Additionally, the project will measure performance metrics, validate the algorithm with real or simulated data, and explore potential future enhancements for dynamic routing and additional constraints.

Literature Review:

The optimization of vehicle routing for goods delivery has been extensively studied in the field of operations research and logistics management. Vehicle Routing Problems (VRP) and their variations have been solved using a variety of optimization techniques. The effectiveness of heuristic algorithms in locating nearly-optimal solutions has been extensively studied. Examples of these algorithms include Genetic Algorithms (GA), Simulated Annealing (SA), Ant Colony Optimization (ACO), and Tabu Search (Dantzig & Ramser, 1959; Osman & Laporte, 1996)[1]. These strategies are appropriate for large-scale VRP cases because they frequently strike a compromise between computational viability and solution quality.

Exact algorithms like "Branch and Bound" and "Branch and Cut" have also been employed to find optimal solutions by systematically exploring the solution space (Desrochers et al., 1992)[3]. Smaller-scale VRP cases can be solved with fewer constraints when we use dynamic programming techniques (Bellman, 1957)[2].

Real-world implementations of VRP optimization have shown significant benefits across various sectors. For instance, in transportation and distribution, optimized routing has led to reduced fuel consumption, vehicle maintenance costs, and delivery times (Toth & Vigo, 2014)[4].

References:

- [1] Dantzig, G. B., & Ramser, J. H. (1959). The Truck Dispatching Problem. Management Science, 6(1), 80-91.
- [2] Bellman, R. (1957). Dynamic Programming. Princeton University Press.
- [3] Desrochers, M., Lenstra, J. K., Savelsbergh, M. W. P., & Soumis, F. (1992). Vehicle Routing with Time Windows: Optimization and Approximation. Vehicle Routing: Methods and Studies, 65-84.
- [4] Toth, P., & Vigo, D. (2014). Vehicle Routing: Problems, Methods, and Applications (2nd ed.). SIAM.

Methodology:

To achieve the project objectives of optimizing vehicle routing for goods delivery, the following methods and techniques will be implemented:

Problem Definition

The project will begin with specific constraints such as vehicle capacities, delivery time windows, and depot locations. This involves identifying the key parameters and requirements for the optimization model.

Data Collection

Data will be gathered on delivery locations, distances between locations, vehicle capacities, and delivery time windows. This data will be structured into a format suitable for input into optimization algorithms.

Algorithm Selection and Development

Heuristic Methods [Genetic Algorithms (GA), Simulated Annealing (SA), Ant Colony Optimization (ACO), Tabu Search]

Exact Algorithms [Branch and Bound, Branch and Cut, Dynamic Programming]

Metaheuristic Methods [Adaptive Large Neighborhood Search (ALNS), Hybrid Approaches]

Specialized VRP Solvers [Google OR-Tools,]

Distance Matrix Creation:

A distance matrix will be created to represent the distances between all pairs of delivery locations. This matrix will serve as the foundation for route optimization.

Routing Model:

A routing model will be developed using OR-Tools, incorporating constraints such as vehicle capacities and delivery time windows. The model will define the number of vehicles, the depot location, and the distance matrix.

Cost Function and Constraints:

The cost function will minimize the total distance traveled. Constraints will include vehicle capacity limits and adherence to delivery time windows.

Optimization Techniques

Various optimization techniques provided by OR-Tools will be employed to solve the VRP.

<u>Heuristic Methods:</u>

Path Cheapest Arc: This heuristic selects the next node to visit based on the cheapest arc cost, providing a quick and efficient initial solution.

<u>Exact Methods:</u>

Branch and Bound: This method will be used to find the optimal solution by systematically exploring the solution space.

Experimental Design

The algorithm will be tested and validated using both real and simulated data:

Simulation:

A set of simulated delivery scenarios will be created to test the algorithm under controlled conditions. This will help evaluate the performance of the algorithm in different contexts.

Real-World Data:

The algorithm will be applied to real-world delivery data to validate its practical applicability and effectiveness. This will involve collaboration with a logistics company to obtain relevant data.

Performance Metrics

The performance of the optimization algorithm will be measured using the following metrics:

Total Distance Traveled:

The primary metric will be the total distance traveled by all vehicles, which should be minimized.

Number of Vehicles Used:

The number of vehicles required to complete the deliveries will be monitored to ensure efficient fleet utilization.

Delivery Time:

The total delivery time and adherence to specified delivery time windows will be evaluated.

Documentation and Reporting

The development process, including problem definition, data collection, algorithm implementation, testing, and results, will be thoroughly documented. Detailed reports on the algorithm's performance and the benefits of optimized delivery routing will be provided.

By following this methodology, the project aims to develop a robust and efficient algorithm for optimizing vehicle routing, ultimately reducing delivery costs and improving operational efficiency.

Expected Outcomes

The primary outcome of this project will be the development of a fully functional algorithm using Google OR-Tools to optimize vehicle routing for goods delivery. This algorithm aims to minimize the total travel distance and delivery costs while adhering to constraints such as vehicle capacity and delivery time windows. By implementing this optimized routing algorithm, we expect to achieve significant improvements in delivery efficiency and cost savings compared to existing methods.

Additionally, the project will deliver detailed performance metrics and analysis. These metrics will include the total distance traveled, the number of vehicles used, and the overall delivery time. This quantitative evidence will provide a clear measure of the improvements brought about by the optimized routing solution. To demonstrate the practical applicability of the algorithm, it will be applied to real or simulated delivery data. This case study implementation will showcase the algorithm's effectiveness in optimizing delivery routes in real-world or controlled scenarios.

Comprehensive documentation detailing the development process, algorithm implementation, data collection, testing, and results will also be provided. This documentation will ensure a complete understanding of the project, enabling future enhancements and maintenance.

Finally, the project will include recommendations for future enhancements, such as integrating real-time traffic data, considering additional constraints, and improving scalability. These suggestions will provide a roadmap for further development, addressing additional challenges and enhancing the algorithm's performance. By achieving these outcomes, the project aims to deliver a robust solution for optimizing vehicle routing, leading to significant cost savings and operational efficiency improvements in goods delivery logistics.

Project Timeline:

Week 01: Project Proposal Submission

I will be submitting a proposal to my supervisor/course conductor to have his authorization to check the validation of the project and if he accepts, I will conduct the project in the next following weeks.

Week 02: Problem Definition and Data Collection

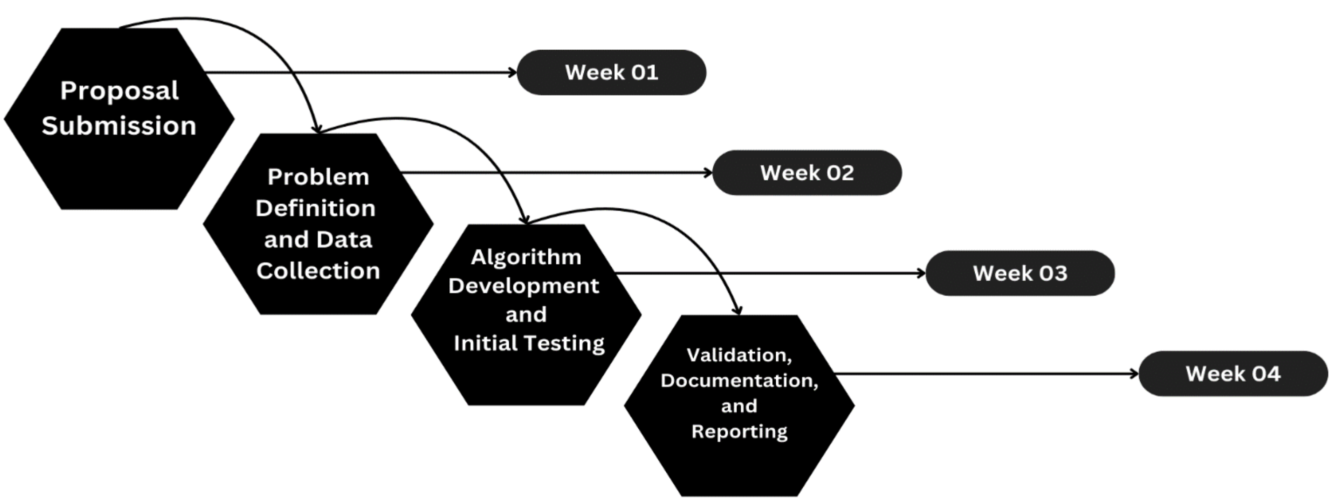
During the first week, the focus will be on defining the Vehicle Routing Problem (VRP) and collecting the necessary data. This includes identifying and specifying the key parameters and constraints of the problem, such as vehicle capacities, delivery time windows, and depot locations.

Week 03: Algorithm Development and Initial Testing

In the second week, the development of the optimization algorithm will take place. Using Google OR-Tools, a routing model will be created, incorporating the constraints and parameters defined in the first week. The algorithm will be implemented with a focus on heuristic methods such as Genetic Algorithms (GA), Simulated Annealing (SA), Ant Colony Optimization (ACO), and Tabu Search. Initial testing of the algorithm will be conducted using simulated data to validate its functionality and effectiveness.

Week 04: Validation, Documentation, and Reporting

The third week will be dedicated to the validation and final testing of the algorithm using both real-world and simulated data. The performance of the algorithm will be thoroughly evaluated, and detailed performance metrics such as total distance traveled, number of vehicles used, and overall delivery time will be recorded. Based on these results, a comprehensive analysis will be conducted to assess the improvements in delivery efficiency and cost savings. In this week the project will also be submitted to the advisor/supervisor/course conductor to check the validation of the project.



Resources Required:

01. Software

Google OR-Tools: A versatile suite of optimization tools that will be used to develop and implement the vehicle routing algorithm.

Python: The programming language in which the algorithm will be developed and tested, along with various libraries such as NumPy and pandas for data manipulation and analysis.

Integrated Development Environment (IDE): An IDE like PyCharm or Visual Studio Code for coding, testing, and debugging the algorithm.

GIS Software: Geographic Information System (GIS) software like QGIS or Google Maps API for mapping and calculating distances between delivery locations.

02. Hardware

Computer/Laptop: A computer with sufficient processing power and memory to handle data processing and run optimization algorithms. Recommended specifications include at least 16 GB of RAM and a multi-core processor.

Internet Access: Reliable internet access for downloading software, accessing online resources, and potentially using cloud-based services for additional computational power if necessary.

03. Data

Delivery Location Data: Data on the geographic coordinates (latitude and longitude) of delivery locations, including customer addresses and depot locations.

Distance Matrix Data: Pre-calculated distances or travel times between all pairs of delivery locations, which can be obtained through GIS software or APIs like Google Maps.

Vehicle Data: Information on the fleet of delivery vehicles, including their capacities, fuel consumption rates, and operational costs.

Delivery Schedule Data: Details on delivery time windows, service time at each location, and any specific constraints or requirements for certain deliveries.

04. Human Resources

Project Supervisor: An experienced professional or academic advisor to provide guidance and support throughout the project.

Logistics Expert: Access to a logistics expert or consultant who can provide insights into real-world delivery operations and validate the practical applicability of the algorithm.