Optimization of Forklift Leasing and Dock Management for Cost and Time Efficiency in Retail Distribution Centers

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Venugopal Bhamidi
24250106@iitgn.ac.in

Shivrajsinh Bhosale
shivrajsinh.bhosale@iitgn.ac.in

1 Introduction

This project aims to minimize the cost of leasing forklifts and the time required for unloading shipments at a retail distribution center. Specifically, this optimization problem seeks to:

- Minimize the total leasing cost of three types of forklifts (Type 1, Type 2, and Type 3) under different leasing conditions.
- Optimize assigning 23 incoming shipments to 6 docks, ensuring no overlap in unloading times.
- Ensure that all shipments are unloaded within their time windows while meeting the payload capacity requirements of the forklifts.

The problem is formulated and solved as a Mixed-Integer Linear Programming (MILP) model to provide an efficient unloading schedule and cost-effective leasing strategy for forklifts.

2 Methodology

2.1 Problem Formulation

The problem is formulated as a Mixed-Integer Linear Programming (MILP) model with the following key components:

2.1.1 Decision Variables

- x_1: Number of Type 1 forklifts leased (6 hours at 25 euros/hour; double the payload capacity of Type 2 forklifts).
- x_2: Number of Type 2 forklifts leased (4 hours at 30 euros/hour).
- x_3: Number of Type 3 forklifts leased (shared usage, available only during the 1st, 4th, and 6th hours at 25 euros/hour, with full payment required).
- $t_{i,j}$: Time window assignment of shipment i to dock j.
- T_i: Unloading time for shipment i, based on the assigned forklift type.

2.2 Objective Function

Minimize the total cost of forklift leasing and the time spent unloading shipments:

$$\text{minimize} = 150x_1 + 120x_2 + 75x_3 + \sum_{i=1}^{25}\sum_{j=1}^{6} t_{i,j}T_i$$

3 Constraints

3.1 Forklift Efficiency

- Type 1 and Type 3 forklifts unload at 0.25 hours per payload unit.
- Type 2 forklifts unload at 0.5 hours per payload unit.

3.2 Dock Assignment and Non-overlapping Shipments

Each shipment must be:

1. Assigned to exactly one dock.
2. Scheduled within its assigned time window, ensuring no two shipments overlap at the same dock during unloading.

3.3 Forklift Availability and Capacity

- The number of forklifts leased must satisfy the total payload requirements within a 4-hour window.
- Type 3 forklifts are unavailable during the 2nd hour and must only operate during the 1st, 4th, and 6th hours.

4 Solution Approach

The MILP model is solved using optimization algorithms such as branch-and-bound or branch-and-cut, leveraging optimization tools like Python's PuLP library.

5 Performance Metrics

1. **Cost of leasing forklifts**: Achieve the minimum total leasing cost.
2. **Total unloading time**: Ensure all shipments are unloaded within their allocated windows without delays.
3. **Efficiency of forklift utilization**: Demonstrate optimal usage, especially of the Type 3 forklifts, which have limited availability.

6 Dock Management and Shipment Data

6.1 Updated Shipment Assignments and Unloading Windows

The time windows and unloading times for each shipment, including dock assignments, are structured as follows:

- **12:00 - 14:00:** Shipments [1, 17, 21, 20]; Unloading times: [1 Hr, 0.5 Hr, 1.5 Hr, 1 Hr]
- **11:00 - 15:00:** Shipments [2, 5, 9, 14]; Unloading times: [2 Hr, 1 Hr, 1 Hr, 3 Hr]
- **11:00 - 13:00:** Shipments [3, 8, 12, 16, 19]; Unloading times: [2.5 Hr, 1 Hr, 2 Hr, 1.5 Hr, 2 Hr]
- **13:00 - 14:00:** Shipments [4, 6, 7, 18]; Unloading times: [2 Hr, 1.5 Hr, 2 Hr, 3 Hr]
- **11:00 - 15:00:** Shipments [10, 11, 22, 23]; Unloading times: [3 Hr, 1 Hr, 1 Hr, 1 Hr, 1.5 Hr]
- **14:00 - 15:00:** Shipments [12, 13, 15]; Unloading times: [2 Hr, 2 Hr, 1 Hr, 1.5 Hr]

7 Work Plan

Week 1: Problem Definition, Data Collection, Model Formulation and Development - Define the model's parameters and collect data on forklift costs and availability. - Formulate the MILP model with decision variables, objective function, and constraints.

Week 2: Testing, Refinement, Optimization, and Analysis - Test the model to verify feasibility, refine constraints to enable utilization of all forklift types. - Compare leasing strategies and assess the impact on cost and time.

Week 3: Final Report and Presentation - Compile a report on the methodology, results, and conclusions. - Prepare a presentation for stakeholders.

8 Expected Outcomes

- **Cost Reduction**: Achieve a cost-effective mix of forklifts.
- **Efficient Unloading Schedule**: Timely unloading without delays.
- **Improved Forklift Utilization**: Enhanced efficiency of all forklift types, particularly the constrained Type 3 forklifts.

This expanded formulation reflects all constraints and includes the necessary data and strategies to ensure the model balances leasing costs across all forklift types. This approach should guide the final optimization solution, aligning with the project's objectives for cost minimization and efficient scheduling.

9 References

https://towardsdatascience.com/supply-chain-process-optimization-using-linear-programming-b1511800630f

https://www.youtube.com/watch?v=XXzOCbbXM7s