OPTIMIZING LOGISTICS OPERATIONS FOR INDUSTRIAL EXPANSION

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INTRODUCTION

In the dynamic landscape of modern logistics, optimizing operational efficiency is paramount for the success of any company. By leveraging advanced techniques such as assignment and vehicle routing problems, we aim to streamline the logistical operations of our company. Through careful allocation of tasks and routes, we seek to minimize costs, improve resource utilization, and enhance overall customer satisfaction.

Industrial Relevance

- **Logistics and Supply Chain Management:** Both problems are crucial in optimizing the allocation of resources and minimizing costs in logistics operations.
- **Transportation Industry:** Efficient assignment of tasks and routes to vehicles enhances fleet management, reducing fuel consumption and delivery times.

Challenges

- **Complexity:** Large-scale assignment and routing problems involve numerous variables and constraints, making optimization challenging.
- **Dynamic Environments:** Real-world scenarios often feature dynamic factors such as traffic conditions, demand fluctuations, and resource availability, complicating the optimization process.
- **Cost Considerations:** Balancing operational costs, including fuel, labor, and vehicle maintenance, while meeting delivery deadlines poses a significant challenge.
- **Resource Constraints:** Limited resources such as vehicles, drivers, and time necessitate efficient allocation to meet demand without overburdening the system.

RELATED PROBLEMS

Warehouse Efficiency Enhancement

Problem: Streamlining inventory management to minimize storage costs and expedite order fulfillment.
Solution: Implement assignment algorithms for optimal stock placement and vehicle routing algorithms for efficient picking routes.

Last-Mile Delivery Optimization

Problem: Enhancing final delivery stages to reduce delivery times and costs while boosting customer satisfaction.
Solution: Utilize vehicle routing algorithms to optimize delivery routes based on real-time factors like traffic and delivery priorities.

Service Technician Scheduling

Problem: Efficiently dispatching technicians for maintenance tasks to minimize downtime and maximize service coverage.
Solution: Apply assignment algorithms for task prioritization and vehicle routing algorithms for optimized travel routes.

Supply Chain Network Streamlining

Problem: Designing a cost-effective supply chain network to minimize transportation costs and enhance responsiveness.
Solution: Employ assignment algorithms for task allocation and vehicle routing algorithms for optimal transportation routes.

Fleet Management for Ride-Sharing

Problem: Managing ride-sharing fleets to match driver availability with passenger demand and reduce wait times.
Solution: Use assignment algorithms for real-time driver allocation and vehicle routing algorithms for efficient ride routes.

PROBLEM STATEMENT

Since its inception in 2015 by Rahul Garg, Moglix has been at the forefront of B2B commerce, redefining procurement through innovative technology. With a focus on streamlining processes globally, Moglix is committed to delivering efficient procurement experiences powered by advanced algorithms.
Expanding its reach beyond B2B, Moglix ventures into direct-to-consumer markets, with Russia as a key focus for expansion. Moglix aims to solidify its position as an industry leader by establishing warehouses nationwide.
This report delves into Moglix's journey of optimizing logistical operations through assignment and vehicle routing problems, showcasing its commitment to innovation and efficiency.

Expansion Strategy in Russia:

- **Strategic Warehouse Placement:** Moglix plans to establish warehouses strategically in key Russian cities to enhance operational efficiency and cut costs.
- **City Selection Criteria:** Cities are chosen based on population dynamics to ensure a substantial customer base and market potential.
- **Central Hub in Moscow:** Given Moscow's significance, establishing a warehouse there is paramount to upholding Moglix's reputation and streamlining operations.
- **Weekly Replenishment:** Utilizing truck drivers starting routes from Moscow, Moglix plans weekly warehouse replenishment to maintain inventory levels and operational continuity.

DATASET

CITY DATA

Includes data like City name, latitude, longitude , population size of the city

COSTS RELATED DATA

- Warehouse Rental costs
- Variable transport cost per unit distance.
- Fixed cost of Transportation

DISTANCE DATA

It encovers the distance between the two cities.

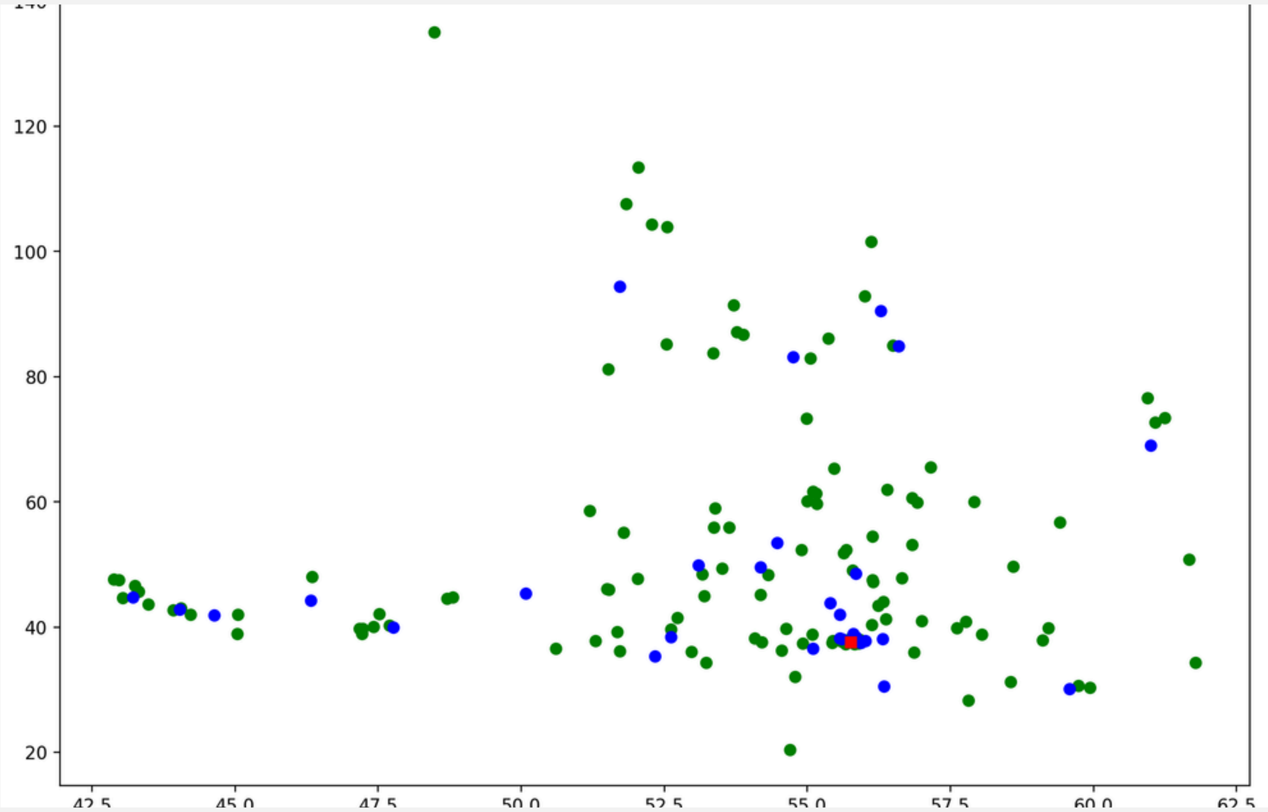
USABLE DATA

There are cities where the Warehouses cannot be installed.

city	lat	lng	country	iso2	admin_name	capital	populatior	population_proper	cost
Moscow	55.7558	37.6172	Russia	RU	Moskva	primary	1.7E+07	1733200000	6000
Khabarovs	48.4833	135.083	Russia	RU	Khabarovskiy Kray	admin	616242	616242	3140
Volgograd	48.7086	44.5147	Russia	RU	Volgogradskaya O	admin	1004763	1004763	2160
Saratov	51.5333	46.0167	Russia	RU	Saratovskaya Obla	admin	845300	845300	2070
Ulyanovsk	54.3167	48.3667	Russia	RU	Ulâ€™yanovskaya	admin	624518	624518	2080
Chelyabins	55.1547	61.3758	Russia	RU	Chelyabinskaya Ol	admin	1196680	1196680	1970

Sample Data

DATA VISUALIZATION



This is a graph where each point represents a city. This graph shows usable cities for warehouse installation as dots in vibrant green, indicating their suitability.

On the other hand, non-usable cities for warehouse installation are depicted as dots in striking blue, clearly highlighting their exclusion from consideration for this purpose.

The red dot represents Moscow, the central depot of Moglix in Russia.

DATA COLLECTION

OVERVIEW

- Distance between the cities has been calculated using the predefined library geopy in python, which in turn makes the use of latitudes and longitudes which have been carved through the geological data set.
- Usable cities has been interpreted using the population of the cities which was made available through the census data logs.
- Warehouse cost have been certified through the real estate cost.

PROPONENTS

- Warehouse costs mainly include costs like buying, estate, construction and labor attainment cost.
- Transportation cost include truck drivers' salaries, lodging cost, maintenance cost and exorbitant cost.
- Average of the transportation costs have been considered through the individual cities' transportation cost.

ASSUMPTIONS IN DATASET

- **Direct Distance Measurement:** Utilizing direct distance measurements ensures accuracy in assessing transportation logistics, providing a clear understanding of the distances involved between the depot, cities, and destinations.

- **Single Depot Strategy:** By employing a single depot, logistical operations are simplified, reducing complexity and facilitating efficient coordination of transportation activities.

- **Focus on Top 150 Populated Cities**: Limiting the analysis to the top 150 populated cities allows for a concentrated study area, focusing efforts on areas with higher demand and potential for significant transportation activity.

- **Fixed Transportation Cost**: A fixed cost of $75 per transportation operation provides predictability in budgeting and cost analysis, aiding in financial planning and decision-making processes.

- **Variable Transportation Cost:** The variable cost of $12 per transportation operation accounts for fluctuations in expenses based on factors such as distance, fuel prices, and other operational variables.

- **Consideration of Truck Capacity:** Incorporating truck capacity considerations ensures efficient utilization of resources, optimizing load sizes for both refurbishing and warehousing operations.

METHODOLOGY

To solve the problem effectively, we've devised a two-part approach. The first part involves determining optimal locations for installing the warehouse, while the second part focuses on establishing efficient truck routes to periodically restock these stores, all aimed at minimizing total costs defined as follows:

Total Costs = Building Costs + Driving Costs

Let's break down these components further:

Building Costs:
This refers to the costs associated with establishing the store locations. The objective is strategically deciding where to install the stores to minimize these initial building costs.
Driving Costs:
This encompasses the costs related to truck routes used for periodic refilling of the stores. The goal is to plan efficient driving routes that minimize fuel expenses, vehicle wear and tear, and overall operational costs.

Part 1: Warehouse Installation Locations

We've modeled this sub-problem as a binary linear programming problem as follows

$$\text{INSTALLATION COST} = \sum_{I \in N} C[I]*X[I]$$

$$\text{SUBJECT TO,} \quad \sum_{\text{distance}[i][j] <= \text{range}} X[J] >= 1 \quad \forall\ I \in N,$$

$$X[I] = 0 \quad \forall\ I \in N, \text{USABLE}[I]=0$$

$$X[0] = 1 \text{ (Moscow)}$$

$$X[J] \in 0,1 \quad \forall\ J \in N$$

- N is the set of the Russian Cities
- C[I] is the cost of building warehouse at city I
- Distance[I,J] is the Euclidian distance between the city I and J and range is the maximum feasible distance between a warehouse and city.
- The binary X[I] variable will tell us whether to to build warehouse city or not
- and Usable[I] tells us whether it is possible to build warehouse in that city

Part 2: Route Finding Problem

Determining the optimal solution to a VRP problem is known being NP-hard, which will take lot of time as well as lot of computational resource. So we need to use a heuristic approach to bring the problem to have a polynomial computation time.

Clark-Wright Savings Algorithm:

To solve our problem we will use a heuristic algorithm known as Clark-Wright algorithm. The Clark-Wright Savings Algorithm is a widely used heuristic for solving the Vehicle Routing Problem (VRP) efficiently. It efficiently constructs delivery routes for the VRP by leveraging potential savings from combining demand points into single vehicle routes. By iteratively considering the largest potential savings first and following specific rules for route construction, this heuristic provides a near-optimal solution for the problem, especially useful when dealing with a large number of delivery points.

Steps of the Clark-Wright Savings Algorithm:

Step 1: Calculate Savings

- For each pair of demand points (i, j), calculate the potential savings **s(i,j)** by the formula: **s(i,j)=d(D,i)+d(D,j)−d(i,j)** where:
- **d(D,i)** is the distance from the depot **D** to point i.
- **d(D,j)** is the distance from the depot **D** to point **j**.
- **d(i,j)** is the direct distance between points **i** and **j**.

Step 2: Rank Savings

- Sort the calculated savings **s(i,j)** in descending order. This creates a savings list where the most significant potential savings appear first.

Step 3: Construct Routes

- Starting from the top of the savings list (largest s(i,j)), consider combining points i and j into a route if the following conditions are met:
- Combining i and j does not violate any route constraints.
- Determine how to include i and j based on the following:
- If neither i nor j are assigned to any route, start a new route including both.
- If one of i or j is already in an existing route but not inside the route (not adjacent to the depot in the route's order), add the other point to the same route.
- If both i and j are in different routes and neither is inside a route, merge the two routes.

Step 4: Finalize Routes

- Continue processing the savings list until all potential combinations have been considered.
- The resulting routes after processing all savings will provide the solution to the VRP.

Pseudocode of the Algorithm

routes ⟵ (1,i,1) ∀ i in warehouses

S ⟵ saving(i,j) ∀ (i,j) in warehouses

Repeat :

currSaving ⟵ Best (S)

S ⟵ S / { currSaving}

if Ind(routes, currSaving) then :

newRoute = mergeRoutesUsing (currSaving)

routesroutes / {r1,r2} ∪ {newRoute}

until S ⟵ ∅

where
saving (i,j) = 2 * d_cost(1,i) + 2*d_cost(1,j) - (d_cost(1,i) + d_cost(i,j) + d_cost(j,1))
= d_cost(1,i) + d_cost(1,j) - d_cost(i,j)

- saving (i,j) = 2 * d_cost(1,i) + 2*d_cost(1,j) - (d_cost(1,i) + d_cost(i,j) + d_cost(j,1))
  = d_cost(1,i) + d_cost(1,j) - d_cost(i,j)
- Best(S) at the first iteration sorts S in decreasing order, and simply return the first element (the greatest one) removing it from S
- Ind(routes, currSaving) is true if and only if there are two routes in routes that can be merged exploiting the currSaving, checking also if the truck capacity isn't exceeded.
- mergeRoutesUsing(currSaving): merges the two routes r1 and r2 that pass through s1 and s2 (the points of currSaving). These two routes are found by another function which ensures that they are such that r1=(1, ... , s1 ,1) and r2=(1, s2 , ... , 1). It also checks the reversed order of r1 and r2 given that the routes can be considered as undirected. The newRoute=(1,... , s1, s2, ..., 1).

Requirements

Solver - Cplex

Code Language - Python

Module - GAMSPY

Package Requirements -

- Gamspy
- Geopy
- Matplotlib
- Pandas

RESULT

Utilizing the Clark Wright algorithm, we efficiently determine the routing of assigned warehouses, optimizing truck routes to minimize costs and maximize operational efficiency. By leveraging this algorithm, we ensure that our logistical operations are streamlined and cost-effective, driving Moglix towards greater success in the competitive market landscape.

No. of Warehouse - 19

No. of Path - 4

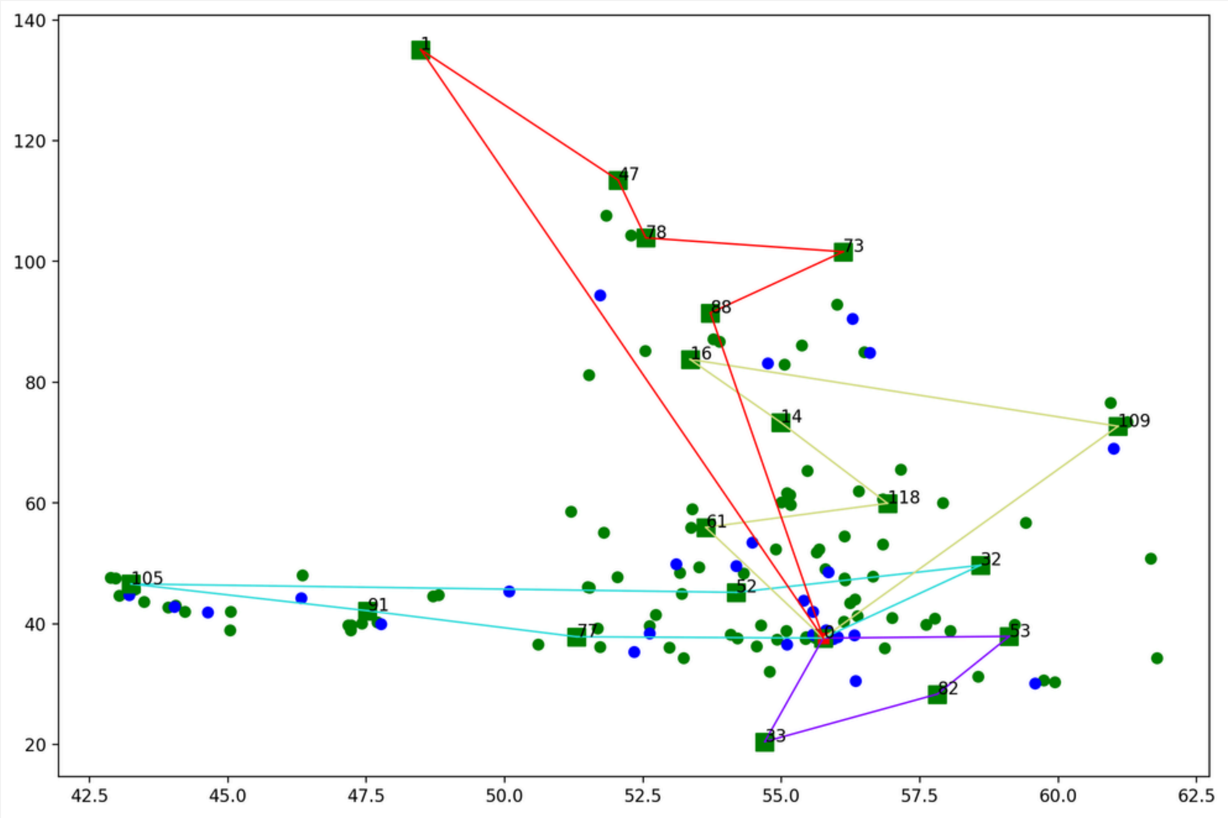
Intital Warehouse Opening Cost

Building Cost	= $ 43.17M
Driving Cost	= $ 314.12K
Total Cost	= $ 43.48M

Optimization Results:

- **City Selection:** From 250 populous cities, 19 strategic locations are identified for warehouse placement, ensuring comprehensive coverage across all regions.
- **Truck Routes:** Our algorithm determines 4 optimal paths for truck refurbishment of all warehouses on a weekly basis, minimizing travel time and maximizing efficiency.
- **Warehouse Construction Cost:** The total expenditure for building warehouses amounts to $43.17 million, reflecting our commitment to establishing a robust logistical network.
- **Driving Cost:** Calculated at $314.12 thousand dollars, our driving costs demonstrate the efficiency of our optimization algorithm in minimizing operational expenses.

Optimized Routes



The warehouses are installed in the regions highlighted by green square blocks.

Each route is depicted by a pattern connecting the starting point (depot) to the warehouses, thereby minimizing the cost of traveling.

There are five different optimal routes that we have found for the trucks to go through the warehouses (each in different colours).

These warehouses(Square blocks) can be used to commute to other cities as well, but the city must be within a range of calibration for warehouses.

CONCLUSION

Moglix's strategic expansion into Russia marks a significant step in its evolution from a B2B leader to a formidable player in the D2C market. By utilizing advanced data analytics and operational research techniques, Moglix aims to optimize its warehouse distribution across strategically selected Russian cities. This approach not only ensures maximum coverage and accessibility but also significantly enhances operational efficiency and cost-effectiveness.

The establishment of a main branch in Moscow serves as the central hub for logistics operations, facilitating the weekly replenishment of regional warehouses. Through the application of the Clark-Wright Savings Algorithm and installation optimization techniques, our analysis indicates that the proposed network of warehouses will not only cater effectively to the vast geographic and demographic diversity of Russia but also align with Moglix’s commitment to technology-driven solutions.

The project's financial assessment, detailing a building cost of $43.17 million and driving costs of $314.12 thousand, results in a total estimated expenditure of $43.48 million. This investment is justified by the considerable benefits in terms of increased market penetration, improved customer service, and enhanced operational efficiencies.

The use of Python, GAMS, and other analytical tools has provided a robust framework for decision-making, demonstrating the potential for scalability and replication in other markets.

Overall, Moglix's expansion strategy, supported by sophisticated operations research methodologies, sets a new industry standard in integrating technological innovation with logistics and supply chain management. As Moglix continues to explore new markets, the insights gained from this project will undoubtedly serve as a valuable blueprint for future expansions.

This conclusion ties together the project's goals, methodologies, and potential impact, while also setting a forward-looking tone for Moglix’s expansion efforts.

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