Optimization of the Logistics of a Courier Business

Khalid Moussaid
Universit Hasan II_Ain Chock, Faculte des Sciences de Casa
khmoussaid@fsac.ac.ma.

Mohamed Azouazi
Universit Hasan II_Mohammedia, Faculte des Sciences de Casa
azouazii@hotmail.com.

Amina EL Omri
Universit Hasan II_Ain Chock, Faculte des Sciences de Casa
a.elomri@fsac.ac.ma.

Abstract

The logistics is a horizontal function with a strategic impact at both the macro level of a country and the micro level of a company. In fact, well run logistics systems have a direct impact on the competitiveness of the economy of a country as a whole and increase the shareholder value of its constituent companies. To increase their margins, provide cost effective solutions while increasing the quality of service offered to their prospects and customers, transportation companies are continuously looking to decrease their cost while offering the service level customers expect.

In this paper we consider the case of an actual international courier business willing to reduce its cost and enhance the quality of the service delivered, and we address the question of optimizing its “Fleet Routing”. It is a known problem for which we suggest a solution based on the “Ant Colony System” algorithm. The different simulations we carried out allowed us to reach scenarios where we decreased both cost and shipping time. In fact, we were able to slash delivery time by 35.75% and trim down the total trip distance by 30.48%.

Keywords: Logistics, Transport, Optimization, Simulation, Ant-Colony system
1 Introduction

The courier business is essentially characterized by the pickup of the parcel and its delivery within a specified timing selected by the customer regarding the pickup, the delivery, or both. The rates the companies operating in this industry offer is based on the distance between pickup and delivery locations, the weight of the parcel and its volume, and the type of service required by the customer. To be competitive and profitable, these companies have to offer a good quality of service, mainly characterized by sticking to the timing schedules of the pick and delivery, while at the same time they need to control the underlying cost. To achieve this cost control imperative, an emphasis is put on the optimization of the pick & delivery process.

In this paper we selected an actual courier business and we looked at the optimization of the delivery process it implements. As presented by the company itself, the problem is static. However, some data might change during the distribution of the courier (such as failure of a vehicle, street unreachable ...); in such cases the problem can be qualified as a dynamic routing one and it will be addressed in a future article.

The case to be optimized can be summarized as follows:
For a given set of customers of a delivery trip, the delivery driver has to total the minimum distance possible while satisfying the criteria below:
1. stop at each customer once
2. pass by any street once
3. respect the timing schedule constraints

This optimization case looks like the “Vehicle routing” problem [1][2] which aims to:
1. respect the timing schedule to enhance the customer service
2. minimize the cost of the delivery trips
3. plan and determine the sequence of the stops of the delivery trip

2 Mathematical formulation of the problem

The problem is to minimize the criterion:

$$\sum_{i=1}^{m} \sum_{j=1}^{n} d_{ij} x_{ij}$$

under the constraints:

$$\sum_{j=1}^{n} x_{ij} = 1 \quad j = 1, \ldots, m \quad (1)$$

$$\sum_{j=1}^{n} x_{ij} = 1 \quad i = 1, \ldots, m \quad (2)$$
Optimization of the logistics of a courier business

where:

\( d_{ij} \): distance between street i and street j
\( x_{ij} \): binary variable which takes either value 1 if street i is visited immediately after street j or value 0 otherwise
\( m \): the number of the streets

The constraints (1) and (2) enable us to visit each street once only.

This is an Np-complete problem [3], furthermore the solution we should recommend to the courier business before hand must respect a compromise between the computing time and the cost effectiveness. Therefore, we abandon the exact methods (such as Branch &Bound, Integer programming…) [4] [5] and opt for an heuristic one based one the ACS (Ant Colony System) algorithm.

The basic idea of the ACS algorithm is to model the problem to solve as the search for a minimum cost path in a graph, and to use artificial ants to search for good paths. The behavior of these artificial ants is inspired from real ants who are renowned to find out the quickest path between two points in tough terrains. In fact, real ants communicate with each other thanks to a volatile hormone called “Pheromone”. On their way, ants lay pheromone leaving a trail behind. They select their path randomly according to the probability based on the quantity of pheromone left.

This algorithm proved to be efficient in solving the Travelling Salesman Problem [6]. It’s mainly used because of its simplicity, the ease of its implementation and its efficiency.

3 Optimization by the ACS algorithm

The problem is represented as a graph where the nodes are the streets and the segments are the trips between these streets. The valuation of each segment is a function of the delivery time at the node of destination. We associate to each segment (i,j) two values (\( \tau_{ij}, \eta_{ij} \)) defined as:

* \( \tau_{ij} \): the pheromone trail left by the ants in the segment (i,j)
* \( \eta_{ij} \): the segment “attractivity” which, in our case, equals to the inverse of the delivery time at street j. The previous delivery time being the sum of:
  1. the time of the trip from street i to street j
  2. the sum of the time required to service the customers at street j
4. The algorithm to solve the problem

For each segment, set $\tau_{ij}$ to $\tau_0$
Randomly allocate an ant to each street
For $t=1$ to $t_{\text{max}}$
  For $k$ from 1 to $m$
    For each non-visited street
      Select a destination street, within the remaining streets $J_i^k$, according to the formula:

\[
j = \begin{cases} \arg \max_{\text{unvisited}} \{ \tau_{iu}(t) \eta_{iu}^\beta \} & \text{if } q \leq q_0 \\ J & \text{else} \end{cases}
\]

Where $j$ is chosen according to the probability

\[
p_{ij}(t) = \frac{(\tau_{0}(t))^\beta(\eta_j)^\beta}{\sum_{l \neq j}(\tau_{0}(t))^\beta(\eta_j)^\beta}
\]

\[
\tau_{ij}(t) \leftarrow (1 - \rho)\tau_{ij}(t) + \rho \tau_0
\]

End for
Calculate the length $L_k$ for each trip cycle of the ant $k$
If ant $k$ totals the shortest length then store it in $T^+$
  For each segment $(i,j) \in T^+$, calculate $\tau_{ij}(t) \leftarrow (1 - \rho)\tau_{ij}(t) + \rho / L^+$
End-For
Return $T^+$ and its length $L^+$
End-For
5 Illustration with an example

Current Situation
The graph below summarizes a real case of a delivery itinerary used by our courier business.

Fig 2: existing delivery itinerary

Where R₀ is the warehouse; R₂, ..., R₉ designate the streets; and the values 1 to 18 designate the order of the trips between those streets. The itinerary is:

R₀→₁ R₃→₂ R₁→₃ R₉→₄ R₂→₅ R₃→₆ R₇→₇ R₄→₈ R₅→₉ R₆→₁₀ R₃→₁₁ R₅→₁₂ R₇→₁₃ R₄
→₁₄ R₂→₁₇ R₁→₁₈ R₉

We notice that the driver goes through a street for more than once (example: R₂ is visited three times). This redundancy generates an additional cost, a waste of time and lack of productivity, and probable late deliveries which might entail a customer non satisfaction.
Solution suggested by our algorithm

We took the previous case and applied to it our algorithm to develop an optimized solution that we represent in Fig 3. As parameters, we took $m = 10$, $\alpha = 1.0$, $\beta = 2.0$, $\rho = 0.5$ and $t_{\text{max}} = 10$ A;

Fig3: delivery itinerary suggested by our algorithm

Our solution suggests the following itinerary: $R_0\rightarrow R_7\rightarrow R_4\rightarrow R_5\rightarrow R_1\rightarrow R_8\rightarrow R_3\rightarrow R_5\rightarrow R_9$.

The current solution does respect the criteria previously outlined and most notably gives a better itinerary to use for the delivery trip. In fact,

1. the total time is reduced by $35.75\%$ from 2h45 to 1h46
2. the total distance is reduced by $30.48\%$ from 16.4 km to 11.4 km

6 Conclusion

Our solution enables the company to reduce its cost, to be more productive, and yet, to better serve its customers mainly by respecting the delivery timings. These enhancements and gains made at the level of the distribution will have a direct and immediate positive impact (in terms of cost reduction, productivity and customer satisfaction) at the macro level of the supply chain as the distribution is one link of the entire value chain.
References


Received: November, 2008