Effective algorithm for optimization of constrained delivery problem with time windows

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1 Introduction and related work

Productivity is an objective concept, where it measures how efficiently resources are used in the production process [3]. For the industrial era, productivity is expressed by the efficiency to transform inputs to products. Other parameters can affect this equation such as delivery system efficiency. In this context, logistics flexibility is required and it expresses the ability of the company to effectively respond to customer requirements for delivery.

Recently, Bushuev et al. [2] propose a strategy for two-stage supply chain delivery improvement. The latter is based on a mathematical cost model that decreases untimely cost penalties with optimal position delivery window. Meta-heuristics are also used to optimize delivery problems with time windows [1] such as Genetic Algorithm [5], Tabu Search and Ant Colony.

This work is driven from an industrial case study and aims to introduce an effective algorithm for optimization of constrained delivery problem with time windows towards productivity improvement, on which a decision-maker can rely to efficiently allocate resources.

2 Problem statement

2.1 Scope definition

This study is related to companies that cannot follow conventional customer pick up strategy or last mile delivery strategy due to the commercialised products. They have to deliver products from the production plant to end customers following the Order-To-Delivery process.

Let us consider a company that has to schedule O daily customer orders, using M vehicles of capacity C. Each customer order $i \in O$ has a product volume v_i, hence r_i is the needed number of round trip to fulfil order i. Additionally, each order i has a desired delivery time d_i within a time window $[d_i^{min}, d_i^{max}]$. Furthermore, a delivery round trip is composed of four steps : 1) product loading ; 2) vehicle outward trip ; 3) product unloading ; 4) finally, vehicle return trip. We assume that the loading time is constant, the outward trip time is equal to the return trip time and the unloading time is proportional to v_i. The objective is to assign the minimum number of vehicles to schedule all the orders while minimizing vehicle idle times.

2.2 Constraints

Restrictive constraints are considered making the studied delivery problem more difficult :
- unicity : only one order delivery can be carried out by a vehicle round trip ;
- loading : it is possible to load only one vehicle at a time ;
- continuity : a continuous goods flow is ensured for all round trips of the same order ;
- unavailability : each vehicle must have a break during an idle interval.

3 Proposed effective algorithm

3.1 Encoding

The idea behind is to allow delivery time shifting for each order within its time window $[d^{min}, d^{max}]$ that one may reach a high schedule compactness reducing the number of vehicles. Indeed, a $|O|$ sized array is used, where each gene represents a delivery of an order i and takes its allele from the time window representing the time in minutes of the time lag, see Figure 1.

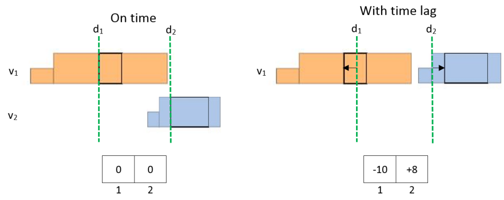

FIG. 1 – Chromosome encoding examples

3.2 Fitness function

Fewer vehicles are used for a delivery schedule, better the solution is. One question remains unanswered : How to assign vehicles to orders ? Theorem 1 answers to this questions.

Theorem 1 *For any chromosome of EA, the optimal number of utilized vehicles is obtained in linear time by always choosing the first available vehicle with the smallest index $j \in M$.*

The minimum vehicles assignment problem can be reduced to the interval graph colouring problem where each round trip represents an interval. Indeed, finding the chromatic number χ would thus finding the minimum vehicle number. The optimal algorithm consists in assigning the smallest indexed colour, which is feasible with respect to its neighbourhood [4]. For our problem, it is equivalent to assign the first available vehicle with the smallest index $j \in M$. □

4 Discussion and perspectives

The proposed algorithm provides very promising solutions in a short computation time. The results show an improvement of productivity with a better use of resources and effortless logistics management, which reduces the manager's workload. As perspective, it would be interesting to consider online delivery optimization without any prior knowledge on orders.

Références

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