Designing Supply Chains Using Optimization

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INTRODUCTION

This chapter studies the strategic decision making problem regarding the design of a distribution network and the definition of material flows. In particular, we consider the Two-Echelon Uncapacitated Facility Location Problem (TUFLP). In a general case, the problem is defined as follows. A firm may have relatively few products and a number of plants. Products are shipped from plants to markets via a set of warehouses. The key issues we are concerned with are: how many warehouses to have, where to locate them, and how the products should flow through the system. Implicit in the product flow decision are other decisions about which products should be produced at which plants for which markets. Figure 1 is a schematic of such a system.

This problem is known to NP-hard (Cornuejols, Nemhauser, & Wolsey, 1990), which means that approximate algorithms are required in order to find good solutions in a reasonable amount of time for big data sets. Various solution approaches have been considered in the literature, including heuristics (e.g., Pirkul and Jayaraman, 1998; Cohen and Lee, 1989; Zuo, Kuo, & McRoberts, 1991; Chen and Wang, 1997), and meta-heuristics to solve similar, but not identical, problems (Klose, 2000; Syarif, Yun, & Gen, 2002; Syarif and Gen, 2003; Zhou, Min, & Gen, 2003; Gen, Kumar, & Kim, 2005; Gen and Syarif, 2005; Gen, Altiparmak, & Lin, 2006; Amiri, 2006; Adlakha and Kowalski, 2003; Kowalski and Lev, 2008; Adlakha, Kowalski, & Lev, 2010; Jawahar and Balaji, 2009; Zegordi, Kamal Abadi, & Beheshti Nia, 2010).

The same problem studied here is considered by Montoya-Torres, Aponte, Rosas, & Caballero-Villalobos (2010) and Montoya-Torres, Aponte, & Rosas (2011). These authors propose the use of the meta-heuristic Greedy Randomized Adaptive Search Procedure (GRASP). This chapter is an extension of their work. We present a greedy heuristic, as well as a Tabu Search meta-heuristic algorithm in order to solve the TUFLP. Our goal is to propose more effective and easy to implement algorithms. We also aim to provide the readers a rigorous experimental analysis of both deterministic and probabilistic algorithms to handle this complex problem.

SOLUTIONS USING APPROXIMATE ALGORITHMS

Using approximate algorithms is usually the main alternative to solve large number of real-life optimization problems in economics and business. Talbi (2009) classifies these approaches in two classes:

- **Dedicated Heuristics:** These are problem-dependent and are designed and applicable to a particular problem, and
- **Meta-Heuristics:** More general approximate algorithms applicable to a large variety of optimization problems.

A Greedy Procedure

This subsection describes the proposed greedy heuristic procedure (see Figure 2). Four parameters

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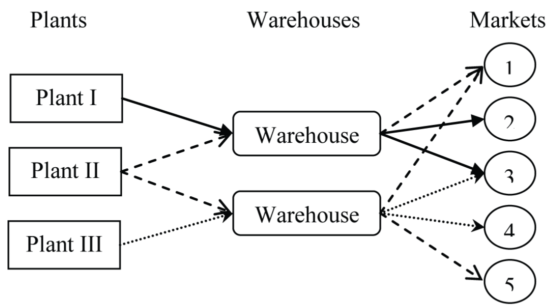
Figure 1. Representation of the TUFLP



define a problem instance: the number of products (k), the number of manufacturing plants (m), the number of warehouses (j), and the number of clients (i). The greedy heuristic uses the First-Fit strategy commonly employed to solve the well-known Bin Packing problem. This is a very simple, useful and efficient heuristic for such problem (De Castro Silva, Soma, & Maculan, 2003). In order to adapt this heuristic to solve the TUFLP, the strategy consists on sending the higher quantity of a product to a given market via a warehouse at the lowest possible cost. All this has to be done by locating the fewer number of warehouses (Silva and Montoya-Torres, 2013).

It is important to note that the design of this Greedy First-Fit heuristic allows it to be easily implemented in any structured or object-oriented programming language: it only considers very simple concepts concerning conditional statements, cycles and ordering of vectors. Its complexity is $O(n^4)$, which means that its computational time will not highly increase for large instances, as observed later.

A Greedy Randomized Adaptive Search Procedure (GRASP)

One of a number of successful meta-heuristics appearing in the late years of the last century is the Greedy Randomized Adaptive Search Procedure (GRASP), proposed by Feo and Resende (1989, 1995). In its basic version, each iteration consists of two phases: (i) a constructive phase whose product is a good but not necessarily locally optimal solution, and (ii) a local search procedure, during which, neighborhoods of the solution is examined until a local optimum is attained. The iterations proceed, keeping the best found solution, until a stopping criterion is reached. One of the great advantages of this meta-heuristic is its easiness to be implemented since only two parameters have to be: the maximum number of iterations to stop running the algorithm, and the value of the (noted as α) which is a parameter used to randomly generate the list of candidate solutions. The GRASP presented here was firstly proposed by Montoya-Torres et al. (2010, 2011). We now explain these two parts more in details:

Construction Phase: This is the first step of the procedure, which intends to obtain feasible solution. For the problem under study, this phase starts with the selection, one by one, of clients according with their demand, by increasing order, given by parameter h_i^k. In order to evaluate other candidates and their contributions to the objective function, transportation costs and fixed location costs of warehouses are taken using parameters c_{ijm}^k and f_j. Such candidates give the different options to satisfy market demand already selected. It is necessary to evaluate all possible combinations of plants and warehouses, using a greedy strategy, which will give the values of decision variables Y_{ijm}^k. The restricted candidate list (RCL) is built based on the value of the seed which determines the acceptance bound of candidates. Each candidate have assigned a probability according to its contribution to the objective function to be later possibly added to the solution. When a candidate is added to the partial solution, a value is given to decision variable $Y_{i'j'm'}^{k'}$ and values of parameters demand ($h_{i'}^{k'}$), plant capacity ($S_{m'}^{k'}$) and fixed cost ($f_{j'}$) are updated. Values of these parameters will depend on the value of $Y_{i'j'm'}^{k'}$ according to the following rules:

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