Ant Colony Algorithm for Single Stage Supply Chain

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INTRODUCTION

The solution approaches adopted to solve distribution-allocation problem can be broadly categorized into exact approach and approximation approach. Meta-heuristic belongs to the class of approximation method. In recent years, researchers have given prominence to the development of evolutionary meta-heuristics to solve optimization problems. According to Dorigo and Stützle (2004), a meta-heuristic is a set of algorithmic concepts used to define a heuristic method applicable for solving combinatorial optimization problems. In other words, a meta-heuristic provides a general-purpose algorithmic framework to be applied to obtain a solution for an optimization problem. Khalili-Damghani, Abtahi and Tavana (2013) state that the application and the development of meta-heuristic procedures are useful to properly solve NP-hard problems. In addition, so as to escape from local optima in the search process, a meta-heuristic uses some basic heuristic(s) such as a constructive heuristic starting from a null solution and adding elements to build a better complete solution, or a local search heuristic starting from a complete solution and iteratively modifying some of its elements to achieve a better one.

Recently, swarm intelligence has emerged as an approach in developing meta-heuristics for solving combinatorial optimization problems (Marinakis & Marinaki, 2013; Drias, Sadeg, and Yahi, 2005). The methodology takes inspiration from social behaviours of insects and of other animals. Genetic Algorithm (GA) is the most popular technique based on evolutionary computation research using the operators inspired by natural genetic variation and natural selection (Gen and Cheng, 2000). Particle Swarm Optimization (PSO) developed by Eberhart and Kennedy (1995) is an example for a methodology inspired by the social behavior of bird flocking or fish schooling. Ant Colony Optimization (ACO) is another evolutionary optimization algorithm inspired by the natural ability of colonies of ants to find the shortest path between their nest and food places by pheromone trail (Arnaout, 2013; Dorigo & Gambardella, 1997). Besides these well-known methods, investigations are still being done on nature-inspired optimization algorithms.

In ACO algorithm, ants communicate information among themselves by leaving a trail using a chemical substance called pheromone. When more ants are following a path, the path becomes more attractive for the successor ants. Thus, the probability with which an ant chooses a path increases with the number of ants that previously chose the same path. This concept in the ant's behavior has led to the development of ACO by Marco Dorigo in 1992. This chapter introduces the development of an ACO-based heuristic for distribution-allocation problem with fixed cost for transportation routes in a single-stage supply chain.

The rest of the chapter is organized as follows. The following section describes the background for the present research. Then, a brief introduction to the distribution-allocation problem in a supply chain, and the modeling and analysis of distribution-allocation problem in a single-stage

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supply chain are presented. The penultimate section provides directions for further research. The last section concludes the chapter.

BACKGROUND

A distribution-allocation problem is one of the most comprehensive decision issues that need to be solved for a long term efficient operation of the whole supply chain. The problem involves determining the best way to transport goods and services from the supply point to the demand point minimizing the overall cost of the supply chain operation.

In a supply chain, the product reaches the end customer passing through several facilities such as manufacturing plants, wholesalers or distributors and retailers. An efficient allocation and integration of the geographically dispersed facilities can support supply chains in gaining competitive advantage. Most of the supply chain distribution models reported in the literature take into account a unit transportation cost only, which is directly proportional to the shipment quantity (Safi and Razmjoo 2013; Sajjadi and Cheraghi 2011; Manimaran, Selladurai, Rajesh and Sasikumar, 2011). However, in real-life situations, there is always a fixed cost associated with the distribution which is independent of the shipment quantity; for example, the toll fee paid on highways, the premium paid for insurance, the reward given to the driver, the landing fee paid at the airport etc. When fixed cost is also taken into account, the transportation problem is known as fixed charge transportation problem (Adlakha and Kowalski, 1999). The distribution-allocation models discussed in this chapter take into account both the fixed cost for a transportation route and a unit transportation cost. Thus, a fixed charge transportation problem (FCTP) consists of two cost components: (1) a continuous cost (unit transportation cost) that linearly increases with the amount shipped between a source and a destination and (2) a fixed charge which is incurred whenever a non-zero quantity is shipped between a source and a destination. The fixed costs cause discontinuities in the objective function. This leads to the solution procedures becoming non-deterministic polynomial (NP) hard.

MAIN FOCUS OF THE CHAPTER

Distribution-Allocation Problem

This work deals with modeling and analysis of the distribution-allocation problem in a single-stage supply chain with a fixed charge for a transportation route. The model deals with a single-stage of a supply chain involving m suppliers (or manufacturing plants) and n customers (or distribution centers). Each of the m suppliers can ship to any of the n customers at a transportation cost per unit c_{ij} (unit cost for transporting from supplier i to customer j) plus a fixed cost f_{ij} incurred in opening this route. The objective is to determine which customers are to be supplied from which suppliers so that the total cost of meeting the customers' demand is minimum.

An FCTP is often formulated and solved as an integer linear programming problem. Any general integer linear programming solution method such as the branch-and-bound method and the cutting plane method can be used to solve the FCTP. Xu, Liu and Wang (2008) formulate a fuzzy multi-objective mixed-integer non-linear programming model for the supply chain network of a Chinese industry. Zakir (2009) proposes a primal decomposition algorithm namely, Benders decomposition to solve a multi-commodity, multi-mode capacitated distribution network planning problem. As observed by Sun, Aronson, Mckeown, and Drinka (1998), exact algorithms are generally inefficient and computationally expensive since they do not take advantage of the special network structure of the FCTP. Hence, heuristic methods and meta-heuristic methods are proposed in the literature for solving FCTP (Gottlieb & Paulmann (1998).

Heuristic methods are based on relatively simple common sense ideas for guiding the search