

# Ant Colony Algorithm for Two Stage Supply Chain

**A****R. Sridharan***National Institute of Technology Calicut, India***Vinay V. Panicker***National Institute of Technology Calicut, India*

## INTRODUCTION

Ant Colony Optimization (ACO) is an 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). In ACO algorithm, ants communicate information among themselves by leaving a trail using a chemical substance called pheromone. This chapter introduces the development of an ACO-based heuristic for distribution-allocation problem with fixed cost for a transportation route in a two-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 two-stage supply chain, and the modeling and analysis of distribution-allocation problem in a two-stage supply chain are presented. The penultimate section provides directions for further research. The last section concludes the chapter.

## BACKGROUND

A distribution-allocation problem in a two-stage supply chain involves determining the optimal number of manufacturing plants and distributors to be opened, the allocation of retailers to distributors and the allocation of distributors to manufacturing plants depending on supply chain stages. 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. Jawahar and Balaji (2009) state that distribution cost expenditures are about 30% of the product costs. In particular, with a GDP of over US\$ 474.3 billion, the Indian industry spends 14% of its GDP on logistics (Srikantha Dath, Rajendran, and Narashiman, 2010). Hence, distribution plays a crucial role in the success of a supply chain.

The distribution-allocation problem in a two-stage supply chain model discussed in this chapter takes into account both the fixed cost for a transportation route and a unit transportation cost. 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 two-stage supply chain with a fixed charge for a transportation route. The model considers a two-stage supply chain consisting of  $m$  suppliers,  $d$  distribution centers and  $n$  customers. The objective of the problem is to allocate the customers to the dis-

tribution centers and the distribution centers to the suppliers, minimizing the total cost of supply chain operation. In this chapter, an ACO-based heuristic has been developed.

Recently, Jawahar and Balaji (2009) propose a two-stage distribution-allocation model in a supply chain with a fixed cost for a transportation route. GA-based heuristic is proposed for solving the model. A matrix-based representation is used to code a candidate solution in the proposed GA-based heuristic. The same researchers present a simulated annealing-based heuristic for solving a two-stage FCTP in Balaji and Jawahar (2010). Later, Panicker, Vanga and Sridharan (2013) develop an ACO-based heuristic for solving a distribution-allocation problem in a two-stage supply chain.

### Modeling and Analysis of Distribution-Allocation Problem in a Two-Stage Supply Chain

The two-stage supply chain includes entities such as suppliers, distributors, and customers. The mathematical formulation for this two-stage supply chain with a set of  $m$  suppliers ( $i = 1, 2, \dots, m$ ), a set of  $d$  distributors ( $j = 1, 2, \dots, d$ ), and a set of  $n$  customers ( $k = 1, 2, \dots, n$ ) is described in this section. The total cost in each stage includes a unit transportation cost and a fixed cost for a distribution route. The objective of this formulation is to minimize the cost incurred in transporting the goods from the supplier to the customer considering the possible combination of routes.

#### Assumptions

The following are the assumptions made:

- The demand for a single-product for a single-period is considered.
- The number of suppliers and their capacities are known.

- The number of customers and their demand are known.
- The number of distributors is known and each has a large capacity of  $M$  units;  $M$  takes a large number (infinite capacity).
- Customers can be supplied with products from more than one distributor.
- Transportation damages or losses are not considered.

#### Indices

**$I$** : Set of suppliers ( $i = 1, 2, \dots, m$ )

**$J$** : Set of distributors ( $j = 1, 2, \dots, d$ )

**$K$** : Set of customers ( $k = 1, 2, \dots, n$ )

#### Decision Variables

$x_{ij}$ : Number of units shipped from supplier  $i$  to distributor  $j$

$z_{jk}$ : Number of units shipped from distributor  $j$  to customer  $k$

$y_{ij}$ : Binary variable to describe the transportation activity from source  $i$  to destination  $j$

$y_{jk}$ : Binary variable to describe the transportation activity from source  $j$  to destination  $k$

#### Cost Parameters

$c_{ij}$ : Unit cost of transportation from supplier  $i$  to distributor  $j$

$e_{jk}$ : Unit cost of transportation from distributor  $j$  to customer  $k$

$f_{ij}$ : Fixed transportation cost from supplier  $i$  to distributor  $j$

$g_{jk}$ : Fixed transportation cost from distributor  $j$  to customer  $k$

#### Capacity and Demand Parameters

$S_i$ : Capacity of supplier  $i$

$D_k$ : Demand of customer  $k$

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