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Reliable Distribution Network Design with Link Disruption Using Cross Decomposition

Vijay Kumar[a,*], Rimmi Anand[a]

[a] *Computer Science and Engineering Department, Thapar University, Patiala, Punjab, India*

Abstract

This paper proposes a model for reliable facility location with distribution protection. The proposed model utilizes site-dependent failure probabilities and random link disruptions. It uses both proactive and reactive measures when a customers primary facility fails. The proactive mitigation strategy is implemented for reliable distribution centers during the design phase. It uses single-level backup mechanism as reactive measure that will increase facility availability. It can simultaneously determine both optimal number and location of capacitated distribution centers. The formulation of proposed model uses the concept of cross decomposition approach. The proposed model is implemented in IBM CPLEX 12.6.3. It is tested on randomly generated datasets for 180 customers and 30 distribution centers. Experimental results reveal that the proposed model provides optimal solution in a reasonable time.

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Keywords: Distribution network design; Facility location; Reliability; Disruption; Cross Decomposition.

1. Introduction

Establishing a distribution network for an organization involves an ample capital investment to ensure the distribution of products. For this, the key factor is to determine success or failure of the related business in a long run. The success of an organization depends upon the location of distribution centers that will maximize their profits and minimize their transpiration costs. These are dependent upon tangible or intangible factors. However, the major cost component of an organization is the establishment of distribution center [1]. It is very crucial for companies to take a right decision for distribution center. In past years, organizations assumed that once the distribution center is established, then the facilities in distribution center never fail and they were always in operational mode. However, in real-life scenarios, the facilities may fail occasionally due to random disruptions [2].

The disruptions in a supply chain network are very rare. The disruptions in distribution facilities may lead to additional

* Corresponding author
** Corresponding author. Tel.: +91-7073169619.
E-mail address: vijaykumarchahar@gmail.com

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costs. Therefore, the main goal of an organization is to minimize the transportation costs, with possibility of disruptions. Hence, there is a need to develop an efficient mathematical model that can increase the systems' performance and reliability in all conditions, both normal and disruption [3].
The main contribution of this paper is to formulate problem as a mixed integer linear programming model that minimize the transportation cost. The proposed model uses both proactive and reactive measures when a customers primary facility fails. It uses single-level backup mechanism that will increase availability of facility. It can simultaneously determines both optimal number and location of capacitated distribution centers.
The reminder of this paper is structured as follows. Section 2 describes the mathematical model of reliable facility location. The proposed methodology is presented in Section 3. Experimental results and discussions are described in Section 4. The concluding remarks are drawn in Section 5.

2. Problem Description

This paper studies a reliable facility location problem with distribution protection, henceforth abbreviated RFLDP, that aims to increase the reliability of a facility network by both protecting some facilities and assigning customers to backup facilities [8]. In RFLDP, the facilities may fail with site-specific failure probabilities but their reliability can be protected through extra investments. Each customer is assigned to a primary facility. The primary facility can be reliable or unreliable facility. If the primary facility is unreliable, then the customer should be assigned to a backup facility. The backup facilities ensure that the customers are served during the failure of some facilities. The main aim of RLPDP is to determine the location of distribution centers and protection mechanisms to minimize the opening costs and excepted transportation cost. To formulate the problem as an integer programming model, the following notations are used [5]:

Notations

I Set of customer sites, indexed by i
J Set of potential sites for distribution centres, indexed by j
M Set of available investment levels for opening unreliable distribution centres, indexed by m
L Set of available disrupted links between distribution centres and customers, indexed by l
C_j Capacity of potential facility j
D_i Demand of customer i
H_j Holding cost per product unit in distribution centre j
f_j^R Fixed cost of opening and operating reliable DC j
f_{jm}^U Fixed cost of opening and operating unreliable DC j with investment level m
S_{jil}^U Cost for transporting products from unreliable DC j to customer i through unreliable link l
S_{ji}^P Cost for transporting from primary facility j with reliable link to customer i
S_{ji}^B Cost for transporting from secondary facility j with reliable link to customer i
Pb_j Failure probability of the unreliable facility opened at site j
Ω_{jm} Percentage of capacity in disrupted unreliable DC j with investment level m
T_{jk} Transportation cost from unreliable DC j to reliable DC k
θ_{jil} Failure probability between DC j and customer i due to unsafe transportation link l
.

Decision variables

X_j^R The value is set to 1 if a reliable DC is opened at site j; Otherwise, 0
X_j^U The value is set to 1 if a unreliable DC is opened at site j; Otherwise, 0
Y_{ij} The value is set to 1 if customer is assigned to an unreliable DC opened at site j; Otherwise, 0
Z_{ij} The value is set to 1 if customer is assigned to a reliable DC j; Otherwise, 0
YU_{ijl} The value is set to 1 if customer is assigned to an unreliable DC j through unsafe link l; Otherwise, 0
A_{jk} Amount of products shipped from reliable DC j to unreliable DC k