Computers & Industrial Engineering 104 (2017) 80–97

Contents lists available at ScienceDirect

Computers & Industrial Engineering

journal homepage: www.elsevier.com/locate/caie

Bulk wheat transportation and storage problem of public distribution system

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ARTICLE INFO

Article history:
Received 7 July 2016
Received in revised form 17 December 2016
Accepted 21 December 2016
Available online 24 December 2016

Keywords:
Transportation-storage problem
Food grain supply chain
Public distribution system
Mixed integer non-linear programming
Chemical reaction optimization

ABSTRACT

This research investigates the multi-period multi-modal bulk wheat transportation and storage problem in a two-stage supply chain network of Public Distribution System (PDS). The bulk transportation and storage can significantly curtail the transit and storage losses of food grains, which leads to substantial cost savings. A mixed integer non-linear programming model (MINLP) is developed after studying the Indian wheat supply chain scenario, where the objective is to minimize the transportation, storage and operational cost of the food grain incurred for efficient transfer of wheat from producing states to consuming states. The cost minimization of Indian food grain supply chain is a very complex and challenging problem because of the involvement of the many entities and their constraints such as seasonal procurement, limited scientific storages, varying demand, mode of transportation and vehicle capacity constraints. To address this complex and challenging problem of food grain supply chain, we have proposed the novel variant of Chemical Reaction Optimization (CRO) algorithm which combines the features of CRO and Tabu search (TS) and named it as a hybrid CROTS algorithm (Chemical reaction optimization combined with Tabu Search). The numerous problems with different sizes are solved using the proposed algorithm and obtained results have been compared with CRO. The comparative study reveals that the proposed CROTS algorithm offers a better solution in less computational time than CRO algorithm and the dominance of CROTS algorithm over the CRO algorithm is demonstrated through statistical analysis.

1. Introduction

The population of India is continuously increasing because of that demand of wheat is also growing. Therefore, for fulfilling the ever-growing demand of wheat there is a necessity of more production, more procurement and proper storage and transportation methods. The wheat production in India has steadily increased due to the use of advanced agricultural production technologies. Food grain is distributed to weaker and vulnerable sections of society at reasonable prices through PDS which is the national food security system of India. Transportation and storage system of food grain become very complex because of the 4, 89,000 Fair Price shops (FPS) located at different parts of the country. Furthermore, it is the largest retail system of its type in the world. The higher losses of wheat occurred during transit and storage because of improper storage and conventional method of transportation through gunny bags.

The various operations of Food Corporation of India (FCI) comprises of procurement, storage, transportation and distribution of food grains on behalf of the Government of India (GOI). FCI is a central nodal agency responsible for the execution of all these activities. The Fig. 1 shows the detail operations of FCI from procurement at minimum support price (MSP) from farmers to the sale of food grains to consumers at a central issue price (CIP). The procurement is carried out in two stages, i.e. centralized and decentralized procurement. In the centralized procurement, FCI along with state government agencies (SGAs) procures the wheat for the central pool from the farmers in the procurement centers at MSP. Procured wheat is stored in the FCIs warehouses, including State Warehousing Corporation (SWC) and the Central Warehousing Corporation (CWC) warehouses of producing states. In decentralized procurement (DCP), SGAs procures food grains but they directly store into their warehouses and distribute under PDS based on the allocation of GOI. In a centralized system after procurement, the goal is to transfer the wheat to deficit states warehouses from producing state warehouses. The GOI makes the allocation to the respective states based on the demand of that states and offtakes in the previous period. Distribution of food grains to consumers is totally handled by respective consuming states. The transportation of food grains in intrastate is mostly carried out by road and interstate movement through rail in

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http://dx.doi.org/10.1016/j.cie.2016.12.027
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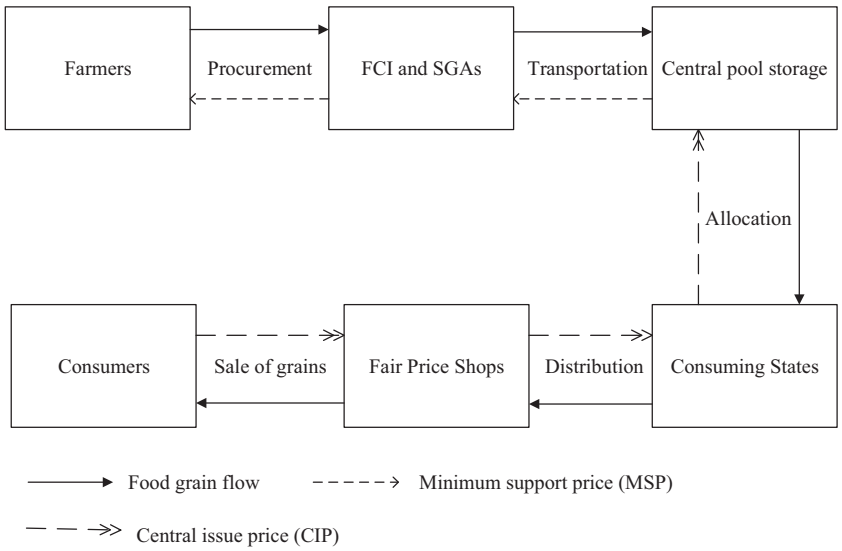

Fig. 1. FCI operations.

conventional gunny bags. Furthermore, primarily the wheat supply chain involved the transportation, handling and storage cost and to reduce these costs, it needs the efficient movement of food grains from producing to consuming states.

At present, FCI is facing several major issues and challenges with food grain storage, transportation and distribution. FCI daily transports an average 2 million bags (50 kg per bag) of food grains through rail, road and waterways from producing to consuming states covering an average 1500 km distance. The annual transportation cost incurred for this movement was 47.2737 billion INR mentioned in Comptroller and Auditor General of India (CAG, 2013) report. According to the Report of Institution of Mechanical Engineers (2013), India every year losses wheat near about 21 million tons, which is equivalent to the total wheat production of a country like Australia. As per CAG 2013 report, overall 45% food grains are getting wasted from the post-harvest to distribution stage due to lack of proper handling, transportation and infrastructure. The monetary value of these losses amounts to more than Rs 50,000 crores per year (Singh, 2010). There is a significant discrepancy in the procured quantity and storage capacity available with FCI. As mentioned in the CAG 2013 report, the food grains stock in the central pool as on 1st June 2012 was 667.89 Lakh Metric Tonne (LMT) barring the DCP against the aggregate FCI capacity of 491.86 LMT including SWC and CWC capacities. This wide gap of 176.03 LMT stockpiling limit shows the requirement of more storage capacity to cope with growing procurement. Generally, procurement of wheat is carried out during Rabi marketing season (April-June) by SGAs, therefore, more storage capacity requires during this peak period. FCI needs to assume control over the stock from SGAs toward the end of June, but unfortunately, because of the absence of available storage capacity, FCI can't lift the stock from SGAs and for keeping this stock beyond the time limit FCI gives the carry over charges to SGAs. FCI has given the Rs 175 crore in 2006–07 and Rs 1635 crore for the period of 2011–12 as a carryover charges to various SGAs across the country. The above-discussed issues can be addressed through bulk storage and transportation of food grain instead of conventional gunny bags. However, in the present situation FCI and all other agencies have less number of scientific storages in each state. Therefore, proper planning and management of bulk wheat transportation and storage reduces the food grain supply chain cost.

In this paper, we consider the real problem of bulk wheat transportation and storage in India. Generally, wheat transportation has been carried out from producing states to consuming states. The main focus of this paper is on the development of a mathematical model for cost minimization considering bulk wheat transportation and storage with deterministic demand and procurement. The transportation of food grain from producing state to consuming state become the challenging task because of the limited number of steel silos. Apart from this issue, other constraints which make the problem very complex such as the availability of various capacitated vehicles, fixed cost associated with each vehicle, operational cost, and optimal inventory level. Indian food grain supply chain is categorised into four stages. The primary stage includes transportation of food grains from procurement centers to silos in producing states and shipment from these silos to consuming states silos is the second stage. The subsequent stages include grain shipment up to block level and from block level to fair price shops. There are some major important issues which affects the transportation and distribution cost of wheat such as "how much quantity, from which origin node, when and where to transport". Besides, inventory and operational cost of wheat inside the silos play the vital role in the food grain supply chain cost. Generally, interstate food grain transportation is carried out by rail mode, but in some cases, it transports through road mode also if economical. Hence, selection of the mode of transportation is also a crucial aspect of the food grain supply chain.

The remainder of the paper is structured as follows. Section 2 provides the details of existing available literature of transportation problem, food supply chain, and Evolutionary Algorithms (EAs). Section 3 gives the description of the considered problem. Section 4 shows the mathematical model formulation of the problem. Section 5 describes the solution methodology used in the paper. Results and analysis of the paper are presented in Section 6. Section 7 concludes the paper and gives the future direction of the research.

2. Literature review

The inventory transportation problem of supply chain network is an interesting topic and a plethora of literature available on the same. The literature review has been divided into two sections. The initial section covers the literature related to transportation and storage problem and subsequent section focuses mainly on the various solution approaches used in literature for solving these problems.