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Integrated network design of wheat supply chain: A real case of Iran



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ABSTRACT

This study proposes designing the integrated supply chain of wheat products that includes long-term decisions of supplier selection and locating new silos and mid-term decisions of assignment and distribution of the wheat and its products. The proposed model aims at selecting the suppliers, determining amount of the import, distribution of wheat, and production of its products. The model is developed by considering blending of different types of the wheat for producing different products, locating new silos and different modes of transportation in all levels of the chain, and also adding the export sector. Unlike the most of previous researches, the current research proposes an integrated planning model that is able to consider all effective levels and factors on the chain. The application of this model is surveyed in a case study for Iran that demonstrates considerable cost savings. By solving the model, the results illustrate the significant reduction in transportation costs. Meanwhile, the sensitivity analysis has been performed on changing of the most important parameter values of the model to show the effect of them on objective function. Finally, practical suggestions from the output results are brought in conclusion.

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1. Introduction

Considering the strategic importance and position of the wheat and its products in the consumable commodities basket, planning for its supply and management of its supply chain is undoubtedly one of the important country's needs. The motivation of this work comes from real requirements as mentioned below:

- 1- Iran buys millions of tons of wheat from other countries, such that the wheat was the main imported commodity to the country in year 1393. Therefore, selecting the suppliers that impose the minimum purchase and transportation costs is of great importance.
- 2- The wheat and its products are among the commodities with the most transportation within the country. The lack of storage space as the problems facing the wheat chain that must be resolved with the construction of new warehouses to the needy regions.
- 3- The diversity of climate in Iran makes the different time of harvest in different regions of the country, such that the wheat harvesting starts from early-spring and ends in mid-autumn.

- 4- The production amount of each province is not proportional to its population. Hence, the produced wheat should be moved from a province to another. Considering the vast territory of the country and number of the provinces, these movements require accurate management; it is necessary to plan methodically for this domain.
- 5- Wheat with different qualities makes much difference in quality of wheat flour. Generally the quality of wheat flours should be enhanced by blending low quality wheat with high quality ones.
- 6- Finally, Given the proper and strategic position of the country in the Middle East and being among producers and consumers of wheat, becoming the commercial hub of wheat and its products through the export has always be considered.

So, the wheat supply chain can be studied in both strategic (long-term) and tactical (mid-term) aspects. For example, Weintraub and Romero (2006) reviewed and also analyzed OR (i.e. operations research) applications in all aspect levels of agriculture and forestry resources. But specially, strategic studies concern the supply chain structure/configuration (e.g. facility location decisions) with long-lasting impacts, generally over several years (Cordeau et al., 2006; Aryanezhad et al., 2010; Bashiri et al., 2012). Tactical studies determine an outline of the regular operations, in particular the flow quantities for a given supply chain configuration (Fahimnia et al., 2013). Unfortunately, previous

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researchers have concentrated on only one aspect and so a part of motivations has been attended in their works. A number of research studies, directly and indirectly, develop a model to solve this problem.

In transportation issues, [Sheikhi and Nazeman \(2004\)](#) determined how much wheat in which month and from which country should be purchased and in which custom should be delivered and then to which province should be sent. [Koopahi and Kiani \(2006\)](#) proposed a mathematical model using linear programming to determine the optimal transportation plan of the wheat from center of provinces and import points (customs) to the storage centers and from storage centers to consumption areas. The objective of their research was to find a logical pattern to reduce domestic transportation and movement costs of the wheat. [Zanjirani Farahani et al. \(2009\)](#) developed a mathematical model to optimize the wheat storage and transportation between provinces at each month. The distribution network is intended only for direct transportation. [Mahmoudinia \(2012\)](#) formulated the wheat distribution in Iran as a mathematical model with the objective function of minimizing the transportation costs and axis establishment costs. He believed that the current wheat distribution system, which uses direct shipment, is not desirable with respect to high volume of the wheat movements in different months. For this reason, he utilized the axis points to distribute this product in his study. [Paksoy et al. \(2012\)](#) proposed a fuzzy multi-objective linear programming model to simultaneously minimize transportation costs between the suppliers and the silos and between the producers and the warehouses. [Asgari et al. \(2013\)](#) investigated and researched a real case of logistics management problem. They proposed an integer programming model and determined the optimal amount of the wheat that should be transported from each producer province to each consumer province in each month of the year. As recent works, it should be mentioned to [Mogale et al. \(2017\)](#) which developed a multi-period multi-model for bulk wheat supply chain with the aim of minimizing transportation, storage and operational costs.

In blending issues, [Bilgen and Ozkarahan \(2007\)](#) surveyed the wheat blending and transportation problem and formulated the problem as a mixed integer program. Also, [Bilgen \(2007\)](#) developed a multi-period and multi-mode blending model with fuzzy objective function. The objective function in this research includes blending, holding and transportation costs in fuzzy uncertainty form. The model is first transformed into crisp multi-objective linear programming and then solved using Zimmermann's fuzzy programming method. Meanwhile, [Bilgen \(2008\)](#) extended the work by considering marine transportation. In a different approach, [Wang et al. \(2009\)](#) used bill of materials (BOM) as a measure of blending finished products from raw materials and components. The concept is used in incorporating traceability factor in a food supply chain as recall cost. Similar research findings are available for concept and structure of modelling. [Franca et al. \(2010\)](#) proposed a model for supply chain in stochastic states to confront the risk of low quality products. [Li et al. \(2013\)](#) developed a hybrid evolutionary algorithm and linear programming in order to solve the Australian wheat blending problem. As recent works, [Ge et al. \(2016\)](#) developed an agent based model for identifying wheat quality in a wheat delivery and handling system.

In designing issues, [Apaiah and Hendrix \(2005\)](#) designed an integrated network model for seeding, harvesting, transportation, and processing the pea-based products. Their modeled supply chain was divided into three phases: production (seeding and harvesting), preparation (grinding and doping), and processing of the product. These phases were connected to each other using transportation links along with using different methods of transportation. The objective of their research was to minimize the total costs of the supply chain including activities of production and

transportation for achieving the final product. [Fahimifar \(2006\)](#) developed a bi-objective model that maximizes total internal collectable wheat for storage and minimizes transportation cost from production centers into storages. He divided the country into 7 regions and determined type, capacity and location of silos in each region. [Zanjirani Farahani \(2008\)](#) studied network design of wheat supply chain by suggesting three issues: (1) wheat production forecasting in different province using regression method, (2) determining the wheat strategic reserve at each province and (3) determining the wheat transport and distribution systems between provinces. [Zhao and Wu \(2011\)](#) proposed a mathematical model for coordinating the supply chain of agricultural products with respect to uncertain conditions in production of the agricultural products and probable problems of the commercial contracts. [Zokaei et al. \(2014\)](#) proposed a robust optimization model for designing the bread supply chain with considering demand uncertainties, supply capacity, transportation costs, and shortage. Their model aimed at determining the optimal location of facilities and optimal assignment in a 4-level supply chain. [Janova \(2014\)](#) proposed a stochastic programming model to optimize seeding planning by considering risk and uncertainty in amount of production of products. Also, a scenario-based two stage stochastic programming model was used by [Wiedenmann and Geldermann \(2015\)](#) regarding the growing and selling seasons of agricultural raw materials. The model was developed to reduce the risk of brokers in a three level supply chain including farmer, broker (i.e. processor) and customer by adding optional supply along with contract farming. Recently, [Govindan et al. \(2015\)](#) surveyed supplier selection and orders assignment problem in the robust model of the supply chain in the terms of network design with stochastic demands.

This paper answers the following question: "How can we maximally utilize the wheat imported and produced so that the network overall costs are minimized during a year?" The model includes custom ports, silos, milling factories and flour factories. This is a real-world case to determine when and where the imported and produced wheat should be transported and/or stored. The developed model is flexible and is applicable for other agricultural products with similar features and conditions. [Tables 1 and 2](#) respectively represent the subjective and objective comparison of this work with previous works that are specifically in connection with Iran's wheat supply chain.

The paper is organized as follows [Section 2](#) explains the characteristics of the problem and assumptions; in [Section 3](#), the mathematical model is developed. The computational results and a discussion are included in [Section 4](#); and finally, the conclusions and recommendations for further research are presented in [Section 5](#).

2. The problem definition

Now, the consumed wheat of the country is supplied from two sources of domestic productions and imports. The government purchases the most of the domestic productions of wheat, holds it in the warehouses of each province, and then enters it to the supply chain. The imported wheat is transported to different provinces and is stored as domestic wheat. Every year, considerable amounts of wheat are shipped from domestic purchasing centers and import points to the storage centers of the country, and then are distributed among the flour factories and the consumption centers. Here, the limitation of wheat storage spaces is one of the problems of this chain that should be fixed by construction of new warehouses in needful areas. With respect to diversity of climate in 31 provinces of the country, the domestic wheat harvesting continues from early-spring to mid-autumn. On one hand, the production

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