Application of planning models in the agri-food supply chain: A review

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Abstract

The supply chain of agricultural products has received a great deal of attention lately due to issues related to public health. Something that has become apparent is that in the near future the design and operation of agricultural supply chains will be subject to more stringent regulations and closer monitoring, in particular those for products destined for human consumption (agri-foods). This implies that the traditional supply chain practices may be subject to revision and change. One of the aspects that may be the subject of considerable scrutiny is the planning activities performed along the supply chains of agricultural products. In this paper, we review the main contributions in the field of production and distribution planning for agri-foods based on agricultural crops. We focus particularly on those models that have been successfully implemented. The models are classified according to relevant features, such as the optimization approaches used, the type of crops modeled and the scope of the plans, among many others. Through our analysis of the current state of the research, we diagnose some of the future requirements for modeling the supply chain of agri-foods.

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Keyword: OR in agriculture

1. Introduction

The supply chain practices of agricultural food products are currently under public scrutiny. This is the result of several factors, such as the national attention given to recent cases of fresh produce contamination (van der Vorst, 2006), the changing attitudes of a more health conscious and better informed consumer who wants to have precise information about the farming, marketing, and distribution practices used to bring the agricultural products into the shelves of the neighborhood supermarket. This scrutiny will undoubtedly translate into additional regulations and market driven standards that will affect the design and operation of an already complex supply chain. This complexity is particularly critical in the case of perishable agricultural commodities where the traversal time of the products through the supply chain and the opportunities to use inventory as a buffer against demand and transportation variability are severely limited. This complexity is compounded when the supply chain encompasses two or more countries. Thus, the opening of domestic markets to international competition throughout the world will undoubtedly result in shifting the focus from a single echelon, such as the farmer, to the efficiency of the overall supply chain. In order to meet these new challenges, it is necessary to take a critical look at the current supply chain practices to determine the best strategies to accommodate the new global conditions. In particular, it is necessary to investigate if there exist better ways to design and operate a supply chain that is increasingly globally integrated. In this paper we focus primarily on planning models used in the different aspects of the supply chain of agricultural food products obtained from crops, or agri-food products. This review does not include the supply chains of other products such as cattle, meats, and other agricultural products not directly related to crops.

The term agri-food supply chains (ASC) has been coined to describe the activities from production to distribution...
A tactical model for planning the production and distribution of fresh produce

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Abstract We present an integrated tactical planning model for the production and distribution of fresh produce. The main objective of the model is to maximize the revenues of a producer that has some control over the logistics decisions associated with the distribution of the crop. The model is used for making planning decisions for a large fresh produce grower in Northwestern Mexico. The decisions obtained are based on traditional factors such as price estimation and resource availability, but also on factors that are usually neglected in traditional planning models such as price dynamics, product decay, transportation and inventory costs. The model considers the perishability of the crops in two different ways, as a loss function in its objective function, and as a constraint for the storage of products. The paper presents a mixed integer programming model used to implement the problem as wells as the computational results obtained from it.

Keywords Production and distribution planning · Perishable products · Linear programming

1 Introduction

In recent years, a renewed interest on the application of advanced planning tools for fresh agricultural supply chains has emerged. However, adapting existing planning techniques to fresh agricultural supply chains is a task whose complexity is compounded by the perishable nature of these products. Among the critical issues in the planning of growing perishable products we can mention the long supply lead times, the short shelf lives, as well as significant supply and demand uncertainties (Lowe and Preckel 2004). These peculiarities call for planning models that incorporate decisions regarding harvesting, market access, method-of-sale, logistics, vertical coordination, and risk management (Epperson and Estes 1999). In this paper we present an integrated modeling approach for the tactical planning of the production and distribution of perishable agricultural products. Tactical decisions include those
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Estudio de Capacidad Logística del Corredor Guaymas-Tucson

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Tactical planning of the production and distribution of fresh agricultural products under uncertainty

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A B S T R A C T

We present a stochastic tactical planning model for the production and distribution of fresh agricultural products. The model incorporates the uncertainties encountered in the fresh produce industry when developing growing and distribution plans due to the variability of weather and demand. The main motivation for building this model is to make tools available for producers to develop robust growing plans, while allowing the flexibility to choose different levels of exposure to risk.

The modeling approach selected is a two-stage stochastic program in which the decisions in a first stage are designed to meet the uncertain outcomes in a second stage. The model developed is applied to a case study of growers of fresh produce in Mexico and in a simulation of various scenarios to test the robustness of the planning decisions. The results show that significant improvements are obtained in the planning recommendations when using the proposed stochastic approach as compared to those rendered by deterministic models. For instance, for the same level of risk experimented by the producer, planning based on the proposed stochastic models rendered increases of expected profit of over 50%. At the same time when risk aversion policies were implemented, the expected losses decreased significantly over those recommended by deterministic planning models.

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1. Introduction

Growers of perishable agricultural products, such as fresh fruits and vegetables, very often face complex planning problems such as deciding how much of a particular crop to plant, the timing of planting, and harvesting. The complexity of this problem and its importance for securing the food supply chain has prompted several applications. For instance, Ahumada and Villalobos (2011) presented a deterministic tactical model for planning the production and distribution of fresh agricultural products. Given that experience indicates that some parameters used in deterministic planning models are highly dependent on weather and market conditions (Lowe and Preckel, 2004), it is necessary to develop models that capture this variability. In particular, it is necessary to capture the uncertainty on price and yield which are very important for those growers that operate under open-market conditions. For these growers, the prices of their products vary along the harvesting season due to the combined effects of supply and demand and the lack of storage opportunities because of the perishability of these crops. For this reason, models that capture these uncertainties are needed to find more robust tactical solutions that are adaptable to the situations experienced by the different types of growers and their tolerance to risk.

In this paper, we develop a model that deals with the uncertainties mentioned above for the fresh produce industry. The model builds on the work introduced by Ahumada and Villalobos (2011), by adding random variables, to better reflect the variability experienced by producers. The main motivation for building this model is to develop planting and distribution plans that are robust to the uncertain effects of markets and weather. From the perspective of the growers, the model should help them achieve their goals in the fresh produce supply chain, whether these goals include maximizing the expected income of growers, also known as risk neutral approach, or at reducing the probability of experimenting a loss, which is also known as the risk-averse approach. For the development of this project, growers were involved on providing data and validating the results found.

The present work follows a similar approach to the one presented in Ahumada and Villalobos (2011), which consisted of designing a model with tactical decisions such as planting, labor planning, harvesting and distribution decisions that could be applied to any fresh agricultural problem, and then demonstrating its applicability by applying this methodology to a real case study of fresh produce growers located in Mexico.

The approach selected for improving the deterministic model is to use a two-stage stochastic program (Birge and Louveaux, 1997).
Operational model for planning the harvest and distribution of perishable agricultural products

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A B S T R A C T
This paper presents an operational model that generates short term planning decisions for the fresh produce industry. In particular, the application developed helps the grower to maximize his revenues by making production and distribution decisions during the harvest season. The main motivation for this model comes from the fact that the profitability of producers is highly dependent on the handling of short term planning in the harvest season. Some of the factors affecting profitability include the management of labor costs, the preservation of the value of perishable crops, and the use transportation modes that provide the best trade-off between time (quality of products) and cost. These issues are interrelated, and their judicious management is fundamental for attaining good financial results. The results of the proposed planning model indicate that significant savings can be obtained by managing the trade-off of the freshness at the delivery of the product with the added labor and transportation cost at the grower’s side. Moreover, the results also show that dynamic, information-based, management practices might be preferred over traditional practices based on fixed labor allocation and distribution practices.

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1. Introduction

Growers of perishable agricultural products, such as fresh fruits and vegetables, very often face complex planning problems such as deciding the level of technology to use, how much of a particular crop to plant, the timing of planting and harvesting. The problem becomes even more complex if conflicting objectives are involved, for instance a grower could try to maximize total production, or minimize the labor used to grow and harvest the crops, or minimize the losses due to sending an over-ripe product to the market. From a traditional planning perspective the grower faces planning problems at different levels. For instance, the farm location and other infrastructure decisions can be considered strategic level planning problems. Those decisions that are made each year, such as the timing of planting and resource allocation among competing crops can be considered tactical level problems. Once the crop is planted and short term decisions are made regarding its cultivation, harvest and distribution; then operational planning is applied (Ahumada and Villalobos, 2009). In this context, the current paper aims to assist the farmer by providing him with a decision model that generates operational, short term, planning decisions. In particular, the operational model to be introduced assists in making production and distribution decisions during harvesting with the objective of maximizing the revenue obtained by the grower.

The main underlying motivation for developing a model that handles harvesting decisions is that the profits and losses observed by growers of fresh perishable crops are highly dependent on these short-term decisions. Among the most important issues in short-term harvesting planning are the management of labor costs, preserving the value of perishable crops, and using efficient transportation modes that provide the best trade-off between time to reach the market (quality of products) and cost. For example, the consumer demands that a certain quality attributes be present in fresh produce at the time of sale. However, to preserve these attributes the growers might incur in higher costs in terms of labor and transportation. This paper addresses this trade-off by developing a planning model that quantifies and balances the loss of value due to the perishability of the crops and the costs incurred to prevent that loss, such as increasing the number of harvests in a given time period.

To show the applicability of the proposed model, this paper presents a case study based on two products: bell peppers and tomatoes. These crops were selected because of their economic importance (Johnson et al., 2006) and their modeling complexity. Another advantage of using tomatoes in the case study is that the tools developed can be easily adaptable to other fresh crops such as cucumbers, and eggplants (Marcelis, 2001).