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Strategic design of competing supply chain networks with foresight

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ABSTRACT

We consider models for duopolistic competitive supply chain network designing with sequential acting and variable delivered prices. These models design a multi-tier chain operating in markets under deterministic price-depended demands and with a rival chain present. The existing rival chain tends to open some new retailers to recapture some income in a near future. These rival chains' structures are assumed to be set "once and for all" in a sequential manner but further price adjustments are possible.

This problem is modeled for each of the following two strategies: (1) the *von Stackelberg strategy* in which we assume the existing chain will choose its future entry sites in the way to optimize its market share. This problem is modeled by a linear binary bi-level program and solved by a combinatorial meta-heuristic. (2) the *minimum regret strategy* in which we assume the existing chain's future entry sites are totally unpredic, it is playing a "game against nature". This problem is modeled by linear binary programs.

1. Introduction

With development, the globalization of the economy, and unpredictable customer behavior, competition is evolving from competition among firms to competition among supply chains [10,51,52]. According to the Deloitte Consulting's [18] report which is based on a survey of more than 200 large manufacturers and distributors in the United States and Canada, (including aerospace, automotive, consumer products, high-tech, etc. industries) "no longer will companies compete against other companies, but total supply chains will compete against other supply chains." Today's firms no longer compete as independent entities with unique brand names, rather as integral parts of supply chains. For example, Microsoft (software supplier) and HTC (device manufacturer) constitute a supply chain that competes with the supply chain consisting of Symbian (software supplier) and Nokia (device manufacturer) [51]. This requires better management of inventories and material flows and all the associated costs throughout an efficient supply chain network structure. It is therefore not surprising that supply chain tablenetwork design is viewed as the primary source of reducing costs and consequently increasing profit by many chains. The physical network structure of a supply chain completely influences its performance, and is one of the important factors impacting chain's competitiveness [45]. These reasons motivate us to develop models for competitive supply chain network design.

Many supply chain network design models are available in the literature [17,43,46,47,49]. They vary in the ingredients which form the model. They may consider only strategic locating cost in their modeling or also consider operational transportation and inventory holding cost in their designing model. As you know, failure to take the related inventory and shipment costs into consideration when deciding the locations of facilities in the supply chains' networks can lead to sub-optimality. We refer the reader to Shen [45] for a review of supply chain network design literature. Many factors must be taken into account when designing a new chain which provides goods or a service to the customers of a given area. One of the most important factors is the existence of rivals in the market providing the same goods/service. When no other rival exists, the new chain will have the monopoly of the market in that area. However, if in that area already exist other chains offering the same goods/service, the new chain will have to compete for the market. For simplicity, all of the works have been done until now in supply chain network design ignored the existing rivals in the markets [45]. However in B2B settings, applications of competitive supply chain network design are very obvious: network designing of fast food retailers, gas stations, high-tech products retailers and other producers in highly competitive industries. Due to the importance of competitive network design in today's B2B settings and lack of these kinds of problems in the literature, here we consider models for duopolistic competitive supply chain network designing in markets under deterministic price-depended demands.

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In supply chain context there are three kinds of competitions: competition among the firms of one tier of a supply chain [7,11,12,16,19–21,33,36–40]; competition among the firms of different tiers of a supply chain [8,31,35,41]; and competition between rival supply chains [10,51,52]. There is little analytic work in the literature that studies the interaction of multiple supply chains and particularly, supply chain versus supply chain competition. In this paper, we consider the supply chain network design problem anticipating later competition with the existing rival chain in the markets.

Three types of analysis have been carried out about competition in the literature: The competition may be "static" which consists of solving an optimization problem in a scenario in which one new entrant has to make decision about its facilities, taking into account that other rivals already exist and the new entrant knows their characteristics (see for instance [1,5,23,25,32,53], or "with foresight", in which the rivals are not in the market yet but they will enter soon afterwards [14,42,48]. In this case it is necessary to make decisions with foresight about this competition, leading to a Stackelberg type model. Also there is a "dynamic" competition, which is on the existence of Nash equilibriums in a scenario described as a game, in which rivals simultaneously compete in prices, locations, qualities, etc. In this case the competitors can change their decisions [2,3,6–11,16.22,28,44,50]. Most of these works are related to competitive locating of facilities. Also there are some not quite so obvious applications of competitive location models, such as brand positioning, in which decision makers have the task to position their brands in some "feature space" so as to optimize the firm's objective and in the positioning of political candidates in an "issue space" with the objective of the maximization of voters [24].

Competition with foresight (usually modeled as a Stackelberg game) helps industries in anticipating later reaction of existing or new rivals to keep their market shares and incomes ([26,42]). It might be interesting for the industries not to needlessly invest in a region in which investment will be lost anyway to the followers. The situation becomes quite different when a market is entered in the knowledge that other rivals will enter it soon afterwards. It will then be necessary to make decisions with foresight about this competition, which itself will enter a market where competition is already present. The ensuing Stackelberg-type models, where each evaluation of the main objective involves the solution of the competitor's nontrivial optimization model, quickly become extremely complex. These games have potential applications for network routing and pricing in transportation systems, competitive designing with foresight, and many others.

In this paper, we consider a model for duopolistic competitive supply chain network designing with sequential acting and variable delivered prices. This paper develops a model to design a multi-tiered and single-product supply chain network operating in markets under deterministic price-dependant demands and with a rival chain present. We adapt the supply chain network design model to include the presence of an existing competitor chain and the knowledge that existing competitor chain will open some new retail facility in the market later. When new chain comes into the markets, choose its network structure and prices, might anticipate later reaction of existing rival chain in opening new retailers to keep its market shares and incomes. The objective is to design the new chain under a budget constraint in order to maximize the remaining income after the existing competitor chain's later retailers' entry. The structure of the network of these rival chains is assumed to be set "once and for all" in a sequential manner but further price adjustments are possible (Nash equilibrium in prices is reached). In contrast to the long-term supply chain network design decision, setting prices is a short-term decision. Thus we define decisions on two different stages [24]: first strategic supply chain network design decisions are made, then on operational stage, prices are chosen. The rival chains' strategies do not only consist of locations and flows but also of prices. In this work, two new sequential two-stage models for duopolistic competitive supply chain network designing are proposed. We develop programming formulations for each of the following two strategies: (1) the "von Stackelberg strategy" in which we assume the existing chain will choose its future entry sites in the way to optimize its market share and (2) the "minimum regret strategy" in which we assume the existing chain's future entry sites are totally unpredictable, it is playing a "game against nature".

This paper contributes to supply chain network design in three ways. First, in today's fierce competitive markets, instead of unrealistic monopoly assumption, our supply chain network design models consider the existing rivals offering the same or substitutable products or services in the markets. Second, this paper develops multi-tiered competitive supply chain network design models with the knowledge that existing competitor chain might open some new retail facility in the market later to recapture its market shares. Third, strategic and operational decisions of the new chain are defined on two different stages which makes our models so realistic.

This paper is organized as follows: In Section 2, we describe our problem and the method will be used to solve it. In Section 3, we describe the von Stackelberg competition Model and present the mathematical supply chain network design model in this strategy. In Section 4, we describe the minimum regret competition Model and present the mathematical supply chain network design model in this strategy. In Section 5, we present the solving approach of the presented models. We conclude the paper with Section 6.

2. Problem definition

We consider new sequential two-stage models for duopolistic competitive supply chain network designing with sequential acting and variable delivered prices. This paper develops models to design a multi-tiered and single-product supply chain network operating in markets under deterministic price-dependant demands and with a rival chain present. When a new chain comes into the markets, choose its network structure and prices, might anticipate later reaction of existing rival chain in opening new retailers to keep its market shares and incomes.

The problem environment and assumptions of this study are as follows:

2.1. Demand of markets

- The demand of customers is concentrated in several discrete points called markets.
- The demand of markets is elastic and depends on the price of good in those markets. It can be supposed that at the limit price, demand of markets decrease to zero and there is a maximum demand in each market that occurs if nothing is charged for the good.
- "Special price discrimination" is used as pricing policy here (compared with other policies lead to the highest profit).
- Customers always buy from the chain which charges the lowest price (due to the assumption of goods homogeneity).

2.2. Specification of facilities in these chains

- The available candidate locations for locating the DCs of the new chain are known. The new chain wants to find the best places to locate the DCs.