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Application of network flow models for the cash management of an agribusiness company

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ABSTRACT

In this study, we apply network flow models with gains and losses to deal with the cash flow management problem of a typical Brazilian company which produces frozen concentrated orange juice. The aim is to maximize the cash return of the financial resources at the end of a multi-period and finite planning horizon. Two real-life situations are analyzed: in the first, the network flow model in Golden, Liberatore, and Lieberman (1979) is used to support operational cash flow decisions and in the second, the model is extended to cope with tactical planning of loan payments. The corresponding linear programming models representing these situations were solved using a solver tool available in well-known spreadsheet software, which is of wide applicability for analytical work in business. The numerical results obtained show that the models are flexible and effective to support the decisions involved, being able to generate solutions as good as or better than the ones of the treasury of the citrus company.

1. Introduction

Cash management deals with the efficient use of the firm's liquid assets and it was one of the first areas of application in mathematical programming and operations research (Mulvey, 1994). Some reviews of problems and deterministic models for cash management can be found, for example, in Gregory (1976) and Srinivasan and Kim (1986). Other reviews and annotated bibliographies of applying operations research techniques for financial engineering and cash management are found in Ashford, Berry, and Dyson (1988), Mulvey and Vladimirou (1992), Steuer and Na (2003), Geunes and Pardalos (2003), Gupta and Dutta (2011) and the references therein. The problem of managing the cash flow of a company is a financial problem that involves considerable complexity to cope with short-term investments, receipt and expenditure of cash and short-term debts of the company, in order to maximize the financial cash return at the end of a planning horizon. Besides dealing with the supply of financial resources that are required by the operating activities of the company, the cash flow management problem includes the formulation of decision rules to control the level of cash balance and the administration of a set of facts structured in time (Brigham & Houston, 2004; Gitman, 1987; Sethi & Thompson, 1970; Van Horne, 1995; Welsch, Hilton, & Gordon, 1988).

When optimizing financial processes, the similarities with flow networks is natural due to their systems of inter-related cash flows and elements that entertain numerous, diverse and complex relationships (Crum, Klingman, & Travis, 1979; Geunes & Pardalos, 2003). In particular, cash flow management models can be formulated as flow models in generalized networks, where the flows in the arcs of the network can either have gains or losses, as in some pipeline networks which lose flow due to leakage or some manufacturing networks which gain flow due to certain chemical reactions (Golden et al., 1979; Srinivasan & Kim, 1986). These models are used in situations containing the characteristics presented by Mulvey and Vladimirou (1992) in the definition of financial planning problems. A better ability to generate cash resources promotes, among other benefits to the company, less needs for financing investments in turn, therefore reducing their costs. A flexible and effective tool for managing the cash flow, able to deal with the problems faced by financial managers in making decisions and to scale the flow of monetary resources, provides an improvement in the process of optimizing the cash management.

In this study, our aim is to propose and apply a tool that optimizes the financial management of the cash flow in a typical Brazilian company which produces frozen concentrated orange juice. For this, we use network flow models with gains and losses to represent the major decisions involved in the problem. We analyze the viability of applying the models and evaluate their performance in the practice of the company's treasury. Although our focus is on a citrus company, we believe that with minor modifications the approach may also be applied to other agribusiness and non-agribusiness companies. The planning horizon is the time period when the company plans its cash operations and the concept of rolling horizon is often applied to the practice of managing the cash flow.

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Given a finite multi-period planning horizon, it is updated as soon as the first period is carried out by considering the decisions taken in the first period and reviewing the expected values for the next periods. The first period is then removed from the planning horizon and a new period is added to the end of it, and so on. This process of analysis is repeated period by period in each new (rolling) planning horizon.

Analyzing the conditions of the present study and its organizational environment, although the Brazilian rate of inflation and the interest rates are relatively high, there is a high degree of certainty in the expected inflows and outflows of cash of the company studied. Some discussions about the utility of cash flow forecasts are found in Gormley and Meade (2007). The cash inflows of the company are derived from sales in the short term to other companies, which buy orange juice as raw materials for their processes. The regularity and uniformity of customer orders allow the treasury of the company to accurately forecast the cash inflows in the near future. With regards to cash outflows, also there is no major difficulty in forecasting them in the near future, as negotiations with suppliers have set deadlines in contracts typical of the Brazilian agribusiness systems.

In this paper, we study two examples of cash flow management: the first involves the direct application of the optimization model in Golden et al. (1979) to support operational decisions in managing the company's cash, while the second involves an adaptation of the model to cover the depreciation of tactical planning funding in cash management. These network flow models are tested in real situations of the treasury practice and solved by the solver tool of spreadsheet software, which is widely used in the financial environments of the companies (Grossman, 2007; Martin-Vega & Carlo, 1986). The flexibility of the optimization models to handle different situations and their ability to produce solutions as good as or better than those used by the company treasury can be observed by means of some numerical experiments.

This study is organized as follows: in Section 2, we briefly review some models in the finance literature to represent problems of cash flow management and, for having the text self-contained, the network flow model in Golden et al. (1979) is presented briefly. In Section 3, we study the application of this model to support operational decisions of cash management, where the periods of the planning horizon are days. In Section 4, we extend and apply the model to a case using amortization scheduling to support tactical decisions of cash management, where the periods of the planning horizon are months. Finally, in Section 5, we present the final considerations of this study and some perspectives for future research.

2. Cash flow management and network flow model

As pointed out in Geunes and Pardalos (2003), the first network approaches to cash flow management problems focused on solving deterministic network flow problems. Then researchers increasingly focused on treating these problems in a stochastic network optimization framework. In the following we briefly review some deterministic cash management models. A comprehensive review of stochastic network optimization problems in financial engineering, including managing cash flows, can be found in Mulvey and Vladimirou (1992). Other studies applying dynamic programming techniques and other approaches for cash balance problems under uncertainty environments can be found, for example, in Elton and Gruber (1974), Lam, Runeson, Tam, and Lo (1998), Hinderer and Waldmann (2001), Premachandra (2004), Yao, Chen, and Lu (2006), Gormley and Meade (2007), Baccarin (2009), Bensoussan, Chutani, and Sethi (2009) and Nascimento and Powell (2010).

The recognition of the trade-off between maintaining high levels of cash and converting them into more profitable assets was first studied in Baumol (1952), adapting the concept of economic order quantity for cash management. The objective that guides this approach is the adoption of a certain level of cash that the company should keep as a reference to its financial operations. This approach can involve different methods for calculating the amount that the company's cash should accomplish (Opler, Pinkowitz, Stulz, & Williamson, 1999). Robichek, Teichroew, and Jones (1965) developed a model for making decisions in short-term financing using linear programming to determine how and, where to obtain resources from a group of alternative sources of funding. The optimal financial strategy is obtained for each period of the planning horizon by solving a multi-period linear programming model. The optimal amounts of each source and the excess of cash to invest are defined for each period. Orgler (1969) noted that the decisions of the cash flow management are not only interrelated between successive periods of time, but also within each time interval. Orgler (1969) addressed the management of cash flow through a multi-period linear programming model which includes four main types of decisions: schedule of payments, short-term financing, cash balance and transaction titles for which both the amount and maturity are explicitly defined.

Rutenberg (1970) was one of the first studies to exploit the network structure of a set of financial decisions for maneuvering liquid assets, where the network flows are subject to gains and losses. Sethi (1971) developed a mathematical programming model for cash management with minimum transaction cost as the objective function. Srinivasan (1974) formulated the cash flow problem as a transshipment model, where the deposits were treated as origins of resources and the markets as applications. The transshipment model was applied to minimize the total cost allocation of renewable resources to different applications, with the possibility of transferring cash between sources. Golden et al. (1979) formulated the problem of managing the cash flow as a generalized network flow model with gains and losses. The losses and gains are, respectively, the conversion rates between assets and interest income. The arcs of the network have specific weights or multipliers acting to increase or decrease the arc flows. Crum and Nye (1981) developed a set of generalized network flow models tailored to the management of cash flow of an insurance company. Other related studies dealing with the generalized network flow structure are found in Crum et al. (1979), Christofides, Hewins, and Salkin (1979), McBride and O'Leary (1997) and Barbosa and Pimentel (2001).

Mulvey and Vladimirou (1992) pointed out that the generalized network models cope with a common theme: the allocation of funds of different asset classes and in different periods. Kornbluth and Salkin (1987) presented some numerical examples of these allocations, where exchange rates, return rates and loan rates are shaped by the arc multipliers in the network structure. Nonlinear generalized network models for asset allocation and other related problems in finance were also studied in the literatura, for example, in Golden and Keating (1982), Dembo, Mulvey, and Zenios (1989) and Mulvey and Vladimirou (1992). Jorjani and Lamar (1994) proposed incorporating the concept of discount based on quantity to the cash flow problem, depending on the amount of money that is being negotiated. Quantity discounts can also be incorporated into the linear network flow model in Golden et al. (1979). However, depending on the type of discount, the resulting model is either a convex piece wise linear program or an integer linear program.

As aforementioned, in the present study we are particularly concerned with the model in Golden et al. (1979). While addressing the problem deterministically, this model proved to be particularly suitable for providing flexibility and effectiveness for solving the cash flow management. For instance, it considers several assets of different levels of liquidity and possible conversions between