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Modeling of financial supply chain

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ABSTRACT

The research work on supply-chain management has primarily focused on the study of materials flow and very little work has been done on the study of upstream flow of money. In this paper we study the flow of money in a supply chain from the viewpoint of a supply chain partner who receives money from the downstream partners and makes payments to the upstream partners. The objective is to schedule all payments within the constraints of the receipt of the money. A penalty is to be paid if payments are not made within the specified time. Any unused money in a given period can be invested to earn an interest. The problem is computationally complex and non-intuitive because of its dynamic nature. The incoming and outgoing monetary flows never stop and are sometimes unpredictable. For tractability purposes we first develop an integer programming model to represent the static problem, where monetary in-flows and out-flows are known before hand. We demonstrate that even the static problem is NP-Complete. First we develop a heuristic to solve this static problem. Next, the insights derived from the static problem analysis are used to develop two heuristics to solve the various level of dynamism of the problem. The performances of all these heuristics are measured and presented.

1. Introduction

Supply-chain management revolves around coordination and cooperation among several business partners that are linked through flows of material, money and information. These partners include suppliers of basic raw materials and component parts, manufacturers, wholesalers, distributors, transporters, retailers, banks and financial institutions. In general the materials, component parts and finished goods flow downstream although the returned merchandise flows upstream. The money flows upstream in a supply chain whereas the information flows in both directions (Fig. 1). For an effective supply chain system, the management of upstream flow of money is as important as the management of downstream flow of goods.

The problem of flow of goods in supply chains has been studied widely (Kouvelis et al., 2006). Research on supply chain systems has focused on inventory cost, transportation cost and cost related to goods procurement. However, there has been very little research work that focuses on the upstream flow of money.

There are several fundamental differences between the downstream flow of goods and materials and upstream flow of money. In downstream flow, holding of goods and materials increases the inventory holding cost whereas in upstream flow of money, holding of money earns interest which is a completely opposite situation to that of downstream flow of goods. Further, the amount of goods and materials to be delivered downstream depends on the orders placed from the downstream partner and remains constant if the order size is not changed. However, in upstream flow of money, the amount to be paid to an upstream partner will depend on the terms of payment that may include penalty for late payments and/or discounts for early payments. Trade credit policies are well researched in the finance literature, for example, see Borde and McCarty (1998). These differences make the management of upstream flow of money an important and distinct research problem.

The motivation for studying the problem proposed in this paper emerged through our discussions with Sukrit Agrawal (2008), CEO, American Medical Depot, a distributor of medical and surgical supplies in Miami, Florida, USA. According to Agrawal, his company at any time has close to 500 invoices to be paid; and almost the same number of accounts receivables. An optimization model to schedule payments can definitely benefit the company.

This research problem of managing the flow of money is computationally complex for several reasons. First, the inflows and outflows of cash are continuous throughout an organization‘s life span. These flows never cease to exist and, therefore, the problem is dynamic in nature. Second, future cash inflows and outflows are mostly unknown, because such inflows and outflows depend on movement of goods which again depends on market demand. Third, even if the future values of such inflows and outflows are known before hand the problem is computationally NP-Complete. We demonstrated this by first developing a static version of the

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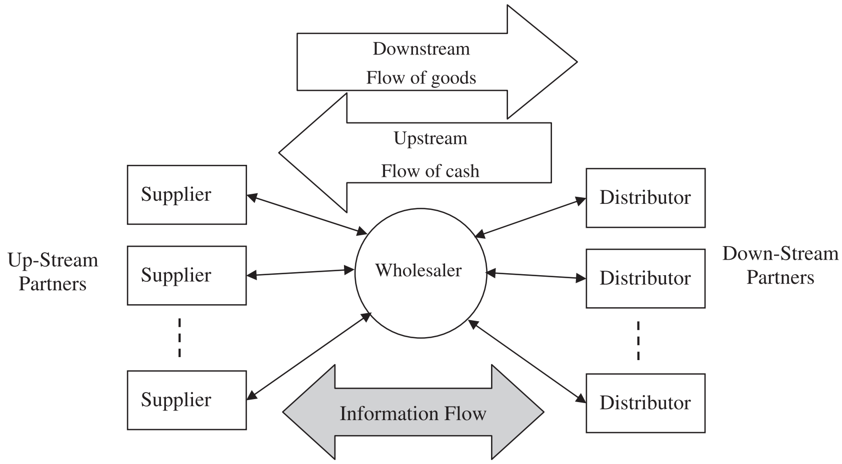

Fig. 1. Supply chain of goods and cash for a wholesaler.

problem. So the problem requires focused study and development of appropriate quality heuristic, which is the main objective of this paper.

To illustrate the complexity of the problem, let us consider a very simple case of a wholesaler, who receives $100 each day from his distributors; and has to pay two invoices in the amounts of $1000 and $2000 from two of his suppliers respectively. Let us assume that the deadline for paying the $1000 to supplier A is within the next 10 days; and the deadline for paying the supplier B is within the next 15 days. Penalties are to be paid if the payments are made after the deadlines. Suppose the penalties per day are 1.0% and 1.5%, respectively, for the two suppliers. Obviously, payments to the two suppliers cannot be made within the deadlines and the wholesaler needs to decide the order in which the two suppliers will be paid. If the wholesaler decides to pay supplier A first and then supplier B, then the total cash outflow will be $3859 by 39th day. In this decision the payment to supplier A is made on the 10th day without a penalty; and the payment to supplier B is made on 39th day with penalty. If the wholesaler decides to pay supplier B first and then supplier A, then the total cash outflow is $3549 by 36th day. In this decision, the payment to supplier B is made on 23rd day and the payment to supplier A is made on 36th day. This decision involves paying penalties to both suppliers but entails a smaller cash outflow; and is the preferred choice. This is a very non-intuitive solution even for such a small scenario. Deriving the optimal scenario for this simple case requires solving multiple non-linear equations. Real life situations are much more complex; and involve multiple suppliers and multiple distributors. The terms and conditions for making payments to various suppliers vary from each other. The real problem is also not static because new invoices continue to arrive while the old invoices still need to be paid. The cash inflow rate may not be continuous and uniform each day. The wholesaler may use rudimentary heuristics such as "first come first served", or "least penalty", which may only result in suboptimal decisions. Finding optimal solution to such problem is computationally complex.

In this paper first we develop an integer programming model for the static case where the future receipts from distributors, and the payment terms and amounts of all suppliers are known. We prove that the problem is NP-Complete. Next, we present a heuristic approach where the cash in-flows from distributors are known but the amounts and payment terms from suppliers are unknown. Lastly, we present a dynamic solution where both the future cash in-flow from distributors and upcoming payment terms (invoices) from the suppliers are unknown. In both the cases, we determine the quality of the heuristic solutions by comparing it with the optimal and lower bound solution of the problem. Lastly we present our managerial implications on applicability of different solution techniques in various real life situations.

2. Related work

The flow of money in a supply chain has not yet attracted the attention of main stream POM and MS/OR researchers even though the problem is important and bears a great resemblance to flow of material. The money flow problem has primarily been studied as the problem of cash circulation, cash management and cash balance. Based on the available literature, the research work under the rubric of financial supply chains can be divided into the following three categories.

- Cash flow systems analogous to ERP systems.
- Models for cash management based on inventory concepts.
- Cross functions models that integrate manufacturing and finance decisions.

2.1. Cash flow systems analogous to ERP systems

There is a pleothra of literature on financial supply chains that has primarily focused on the use of technology in improving the cash flow process similar to that of ERP in a manufacturing environment. The examples include Hausman (2005), Killen (2002) and SAP (2005). The main focus of these studies is on the improvement of actual business process interactions across multiple organizations in financial supply chain systems. For example, Hausman (2005) has studied the process of monetary flow in complex financial relationships involving banks, financial institutes, vendors and retailers. A quantitative measure of the efficiency of cash flow processes can be found in research papers that are termed as "Cash-to-Cash" (C2C) studies. The "Cash-to-Cash" is defined as "the average days required to turn a dollar invested in a raw material into a dollar collected from a customer," Farris and Hutchison (2002, 2003). Farris and Hutchison (2002) has shown the importance of C2C as a metric in the supply chain system. More recently, Ozbayrak and Akgun (2006) focused on cash conversion cycle which is the time elapsed between the time a purchase or investment is made and the time of sales revenue received from goods produced by that purchase or investment. This approach of cash management may not be applicable in value-added-service operations where it is very difficult to pin point the exact return for each and every purchase and investment. In many cases such purchase