



A heuristic framework based on linear programming to solve the constrained joint replenishment problem (C-JRP)

Ciro Alberto Amaya*, Jimmy Carvajal, Fabian Castaño

Department of Industrial Engineering, Universidad de los Andes, Kr. 1E No. 19A-40, Bogotá, Colombia

ARTICLE INFO

Article history:

Received 1 February 2013

Accepted 12 February 2013

Available online 28 February 2013

Keywords:

Constrained joint replenishment problem

Inventory policies

Linear programming

CRAND heuristic

ABSTRACT

This paper presents a new approach to solve the joint replenishment problem under deterministic demand and resource constraints (C-JRP). To solve the problem, a heuristic framework based on linear programming is presented. The proposed method can be extended to solve different versions of the problem and can be extended with linear programming modeling. This method is analyzed and some tests are performed, the results of which show that the proposed algorithm outperforms other well-known algorithms in total cost.

© 2013 Elsevier B.V. All rights reserved.

1. Introduction

Coordinated procurement policies have shown great potential to save companies money by reducing costs in logistical operations. In environments in which a set of products are obtained from one vendor, it is advantageous to exploit the economies of scale that result from coordinating transportation, production runs or item replenishment. However, warehouse capacities, budget limitations and other factors often create resource constraints. The problem of obtaining a common replenishment period under resource constraints is known as the joint replenishment problem with resource constraint (C-JRP).

Many efforts have been made to solve the unconstrained joint replenishment problem (JRP), which involves obtaining coordinated replenishment policies without regard for resources constraints. However, given the complexity of the problem, most authors work on the development of heuristic methods to obtain approximated solutions instead of the optimal one. An overview of approaches used to solve this problem can be found in Viswanathan (1996), Silver (1976), Kaspi and Rosenblatt (1991), Viswanathan (2002), and Li (2004), who have developed different methods and models that allow for obtaining near-optimal solutions.

Silver (1976) presents a simple non-iterative method to solve the C-JRP based on solving the differential equation system. The results show that the solutions are near optimal and with low penalties associated with use. Nilsson and Silver (2008) have

updated the Silver method with an improved routine that allows for significant outperformance of the previous results. On the other hand, the RAND heuristic (Kaspi and Rosenblatt, 1991) and the subsequent changes made by Viswanathan (1996) and Viswanathan (2002) have proven to be successful at finding near-optimal solutions in less computational time than the counterparts. Porras and Dekker (2008) improve upon the results obtained by Viswanathan (2002) through the inclusion of a correction factor at the objective function. However, the algorithms presented above have been applied to the constrained version of the problem and may not be useful when applied to systems with limited resources different from the original constraint. (Hoque, 2006; Porras and Dekker, 2006; Khouja and Goyal, 2008; Moon and Cha, 2006; Goyal and Giri, 2003).

Several authors propose solution methods to deal with the constrained version of the joint replenishment problem (C-JRP). Most of the research into C-JRP is centered on the inclusion of constraints like transportation, budget and physical space. Proposed methods are usually only useful for solving specific versions of the problem and cannot be extended to other variations. The new proposals in the literature have included different constraints on the JRP, such as minimum-order constraints, storage constraints, purchase-budget constraints and transportation constraints. This shows that the solution methods must still be improved, so that coordinated replenishment policies may be obtained in real environments. The JRP has recently been used as a basis to propose a model for supply-chain distribution problems, including those involving freight consolidation, full truckloads and joint delivery orders (Goyal, 1975; Kiesmüller, 2009; Cha et al., 2008; Moon et al., 2011).

Goyal (1975) proposed a heuristic based on the Lagrangian Multipliers method to solve the C-JRP. Moon and Cha (2006) use

* Corresponding author. Tel.: +57 13394949.

E-mail addresses: ca.amaya@uniandes.edu.co (C.A. Amaya), ja.carvajal911@uniandes.edu.co (J. Carvajal), fa.castano47@uniandes.edu.co (F. Castaño).

Goyal's algorithm as a basis to modify the RAND heuristic and proposed the C-RAND heuristic to solve the C-JRP. His experimental results showed that their new method outperforms the results obtained by using Goyal's heuristic. Furthermore, the C-RAND was compared with an evolutionary algorithm (GA) proposed to solve the C-JRP (Khouja et al., 2000) showing that the results are favorable to the former.

The aim of this paper is to propose a solution method based on linear programming that can be used to solve a general version of the constrained joint replenishment problem. The proposed method can be extended to solve the joint replenishment problem under different constraints, depending on the context in which it is used.

This paper is organized as follows. Section 2 presents the nomenclature used in the paper and a non-linear version of the mathematical model for the JRP and C-JRP. Section 3 presents the structure of the algorithm. Section 4 describes the way in which the instances were designed and the parameters used as an input this process. Sections 5 and 6 evaluate the algorithm and compare them with the obtained by using the C-RAND heuristic to present the advantages and disadvantages of the proposed approach.

2. Problem formulation

Several assumptions were proposed and used to develop the proposed method. First, lost sales and backorders were not allowed. This is a typical assumption in the JRP that is extended to the context of the constrained resources. In addition, replenishment policies were assumed not to show any changes during the planning horizon, so the replenishment policy is stationary, as is the product demand. Last, we assumed that replenishment is instantaneous, so the lead time is zero. The holding and order costs are linear.

Let I be the set of n items to be replenished. For each item there exists a constant demand D_i and an annual holding cost h_i associated with each stocked unit. There exists a major ordering cost S for each order independently of the ordered items and a minor ordering cost related to the items involved at each order. For each unit of each item, there also exists a unitary cost b_i . The total cost CT is the sum of the holding and ordering costs. There also exists a limit B of money spent on each order; this is a budget constraint that limits the order size.

For this problem, it is necessary to define a common replenishment period T , equal to the length of time in which one order of the unit arrives that is, for each item an order of Q_i units arrives each $k_i T$ time units.

2.1. Nonlinear model

Assuming that each item has a separate order policy and has the same replenishment time T , as shown in Eq. (1), the minimum time (T) can be obtained through the optimization model (M1) (Nilsson and Silver, 2008; Wang and Cheng 2008; Khouja and Goyal, 2008; Hoque, 2006; Moon and Cha, 2006).

$$T_i = Tk_i \tag{1}$$

$$Q_i = d_i T_i \tag{2}$$

In Eq. (1) k_i is a decision variable that represents the number of periods T in which the product i is replenished, k_i is a integer number which multiplies of the basic cycle time.

$$\min : TC(T_i) = \frac{S}{T} + \frac{\sum_{i=1}^n s_i}{T_i} + \frac{\sum_{i=1}^n h_i Q_i}{2} \tag{3}$$

S.t:

$$T_i = k_i T \forall i = 1 \dots n \tag{4}$$

$$\sum_{i=1}^n Q_i b_i \leq B \tag{5}$$

$$T_i; T; k_i \geq 0 \tag{6}$$

$$k_i \in +$$

Model M1: Non-linear version of the C-JRP.

Including Eqs. (1) and (2) in the model (M3), then the model M2 is:

$$\min : TC(T_i) = \frac{S + \sum_{i=1}^n (s_i/k_i)}{T} + \frac{\sum_{i=1}^n h_i d_i k_i T}{2} \tag{7}$$

S.t:

$$T_i = k_i T \forall i = 1 \dots n \tag{8}$$

$$\sum_{i=1}^n d_i k_i T b_i \leq B \tag{9}$$

$$T_i; T; k_i \geq 0 \tag{10}$$

$$k_i \in + \tag{11}$$

Model M2: non-linear version of the C-JRP.

Eq. (7) shows the total cost, which is the sum of the ordering and inventory holding costs. In addition, a budget constraint is added Eq. (9). The cost function is expressed in monetary units per year and the aim is to find the set of values and the optimal that minimizes Eq. (7) (Moon and Cha, 2006).

3. Solution algorithm

To deal with the C-JRP a math-heuristic is proposed in which a linear model is solved. The linear model assumes that the time between replenishments (T) is known and therefore it is a parameter. The nonlinear model presented in the previous section is therefore transformed in the following linear programming (LP) model.

Eq. (12) shows the linear objective function. The set of constraints (13) shows that the variables are limited to integer values. The set of constraints (14) ensures that the model only has one policy for each product, and (15) guarantees that the maximum product budget is not exceeded. In the LP model it is possible to eliminate the set of constraints expressed in (13), because the set of constraints in Eq. (14) is dominant over Eq. (13), making the formers redundant.

When the LP model is solved using T as a parameter, an expression for $TC(k_i^* s | T)$ is obtained. This is the minimal total cost, using the set of coordination constants found with the LP. The value of T can be changed within a lower and an upper bound to find the best total cost can be found. The function $TC(k_i^* s | T)$ is strictly decreasing in the interval $[0, a']$ where $a' \in T$ and is strictly increasing in the interval $[b', T']$ as demonstrated by Viswanathan (1996). Then, the search area is restricted to the interval $[a', b']$.

$$\min : TC(T_i) = \frac{S}{T} + \sum_{j=1}^J \sum_{i=1}^n \frac{s_i l_{ij}}{jT} + \sum_{j=1}^J \sum_{i=1}^n \frac{h_i d_i l_{ij} jT}{2} \tag{12}$$

S.t:

$$\sum_{j=1}^J j l_{ij} = k_i \forall i = 1 \dots n \tag{13}$$

$$\sum_{j=1}^J l_{ij} = 1 \forall i = 1 \dots n \tag{14}$$

متن کامل مقاله

دریافت فوری ←

ISIArticles

مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات