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# A sensitivity analysis of solving joint replenishment problems using the RAND method under inaccurate holding cost estimates and demand forecasts

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**Abstract**

This paper presents a study of solving the joint replenishment problem (JRP) by using the RAND method, a heuristic approach that has been proven to find almost as good as optimal solutions, under uncertain customer demands and inaccurate unit holding cost estimation. The classical JRP deals with the issue of determining a replenishment policy that minimizes the total cost of replenishing multiple products from a single supplier. The total cost considered in the JRP consists of a major ordering cost independent of the number of items in the order, a minor ordering cost depending on the items in the order, and the holding cost. There have been many heuristic approaches proposed for solving the JRP. Most of the research work was done under the assumptions that the demand for each item type and the unit holding cost are known and constant. However, in the real world accurately forecasting customer demands and precisely estimating the unit holding cost are both difficult. Besides, the real values of the demands and the unit holding cost may change over the replenishment horizon. The present study addresses the issue of the uncertain demands and the unit holding cost to the JRP and investigates how misestimates of these demands and holding costs may influence the replenishment policy as determined by the famous JRP heuristic, the RAND method.


*Keywords:* Joint replenishment problems; RAND; Customer demands; Unit holding costs

## 1. Introduction

Over the past few decades the joint replenishment problems (JRP), sometimes called coordinated replenishment problems, have received a lot of attention since the JRP is not only a multi-item inventory problem but its concepts can also be applied to lot sizing problems in manufacturing applications. For a practical supply chain system, there are several reasons to grouping items into the same order when making replenishment decisions. When a group of items is ordered from the same vendor, a quantity discount may be offered by

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the vendor if the order amount is greater than a certain quantity. Ordering this much of a single item may not be economical, but it could certainly make sense to coordinate several items to achieve a total order size as large as the breakpoint quantity. In addition, for the cases where the fixed cost of placing a replenishment order is high, it is reasonable to put several items on a single order to reduce the total of these fixed costs. However, a possible disadvantage may be caused by using joint replenishment procedures. When items are grouped into the same order, some items will be reordered earlier than they were treated independently. This may result in elevating the buyer's inventory level. The total cost considered in inventory control problems usually consists of three components: the ordering costs, the costs of the ordered items, and the inventory holding costs. Since an order may consists of multiple items in JRP, the ordering costs are composed of a major ordering cost which is independent from the ordered items and the quantity and a minor ordering cost which depends on the ordered items and the quantity in the order. The ordering cost in a supply chain inventory system is sometimes also referred to as the manufacturing set-up cost in manufacturing applications. The basic idea of the JRP is to save costs by coordinating items when making replenishment decisions, since the items ordered in the same order share the major ordering cost. Some common assumptions usually made for the classic JRP include:

- The demand rate of each item is deterministic and constant.
- The unit cost of each item is known and constant.
- The unit holding cost of each item is known and constant.
- The major ordering cost incurred for an order is known and constant.
- The minor ordering cost incurred for a specific ordered item is known and constant.
- Shortage is not allowed.
- No quantity discount.
- Order lead time is zero.

There have been many heuristic approaches proposed for solving the JRP (Aksoy & Erenguc, 1987). These approaches can be classified into two different strategies: Direct grouping strategy and indirect grouping strategy. With the direct grouping strategy, items are divided into a predetermined number of groups, and the items within the same group are jointly replenished. An individual cycle time is determined for each group. Each item in the group is replenished every group cycle time. In contrast to the direct grouping strategy, the indirect grouping strategy uses a basic cycle time for each order, although not all products are necessarily ordered every basic cycle time. Some items might have a replenishment quantity to last for exactly one basic cycle time period, but others might have a replenishment quantity to last for several basic cycle time periods. The main difference between the direct grouping strategy and the indirect grouping strategy is that the replenishment cycles for groups in the direct grouping strategy are independent, while the cycles determined by the indirect grouping strategy are multiple integers of some basic cycle time. A detailed comparison between the class of indirect grouping and direct grouping strategies was made by Van Eijs, Heuts, and Kleijnen (1992). They found that there is a threshold value for the major ordering cost above which the indirect grouping strategies outperform the direct grouping strategies. The indirect grouping strategy for the JRP can be classified into the category of the periodic review inventory models since this kind of approach is to search for the optimal value of the ordering cycle time and an integer number for the ordering cycle frequency for each item (Goyal & Satir, 1989).

The present study focuses on the well known heuristic, the RAND method, an indirect grouping strategy for solving the classic JRP. To present the total cost model of the classic JRP, the following notation is used:

| | |
|---|---|
| $n$ | Number of items ($i = 1,2,\ldots,n$, the index of an item). |
| $D_i$ | Annual demand for item $i$. |
| $h_i$ | Annual holding cost per unit of item $i$. |
| $m_i$ | The minor ordering cost of item $i$. |
| $M$ | The major ordering cost for each replenishment. |
| $T$ | Basic cycle time of the replenishment. |
| $k_i$ | An integer multiple of a basic cycle $T$ for item $i$. |
| TC | The total annual cost including the annual ordering cost and holding cost is given by |