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# Holding cost determination: An activity-based cost approach

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**Abstract**

We consider the problem of choosing the holding cost in inventory models. Traditionally, the cost of holding inventory is assumed to increase linearly with a rate that is equal to a percentage of the product value. This since the capital cost is believed to make up the main part of the cost. However, recent research indicates that this is not necessarily the case.

In the present work, we present a more general model of the cost of holding inventory based on a microeconomic framework. A method for determining a suitable holding cost per unit and time unit, $h$, which can be used in existing heuristics/formulas is derived. The method is based on the ideas behind activity-based costing (ABC).

The suggested method works well in the considered numerical examples (maximum and average cost increase is 1.78% resp. 0.08%). There exist situations where the traditional approach, i.e., setting $h$ as a percentage of the product value, gives rise to a significant cost increase (>15%).


*Keywords:* Holding cost; Activity-based cost; Inventory control

## 1. Introduction

Appropriate cost determination is important in the implementation of efficient inventory control systems. Through the years, several methods have been developed to determine an optimal or close to optimal inventory policy and the methods are constantly being refined. However, surprisingly little effort has been put into finding ways for accurately determining the cost parameters used for inventory control, i.e. the holding cost, the ordering cost, etc., although such costs are used as inputs in nearly all existing methods and heuristics.

The present work focuses on the holding cost, i.e., the cost associated with physically having inventory in stock. Such a cost arises due to the capital invested in the inventory (capital cost), and to rent/write-offs on warehouses, salaries to warehouse staff, etc. (out-of pocket costs). Traditionally, one has assumed that the capital cost makes up the main part of the cost. Therefore, it is commonly assumed that the cost per time unit associated with having goods on stock can be expressed as a constant holding cost, $h$ (€/unit/time unit), times the amount of inventory on hand, where $h$ is obtained as a percentage of the product value. The percentage suggested in textbooks ranges according to Lambert and Stock (1993) between 12% and 34%, depending on the industry/field.

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Recent research by Berling and Rosling (2005) indicates that the capital cost might very well not make up the main part of the holding cost, though. Based on real option theory and empirical data they show that the capital cost varies considerably among goods. For some goods, it will make up the dominating part of the holding cost, while for others the capital cost might even be negative. Furthermore, they put forward a hypothesis suggesting that, on average, the capital cost will be close to the product value times the real risk-free interest rate (typically estimated to be around 1% see, e.g., Brealey and Myers, 1996, Chapter 7). This hypothesis is supported by the business-cycle literature on aggregate inventory (Romer, 1996).

In this paper, we present a more detailed model for the cost per time unit associated with having inventory on stock. We use a general microeconomic framework where cost is not necessarily a linear function of the amount of inventory on hand. Furthermore, we develop a method for determining a holding cost per unit and time unit, $h$, which can be used in existing heuristics and formulas, generally with good results. This method is based on the ideas behind activity-based costing (ABC), the now well-accepted cost allocation system for product costing that arose during the late 1980s (Cooper and Kaplan, 1987; Johnson and Kaplan, 1987).

The outline of the paper is as follows. In Section 2, we present the model for the cost per time unit associated with having inventory on stock and derive an expression for the average cost per time unit. Section 3 is devoted to the development of the method for determining a holding cost per unit and time unit, $h$. A numerical evaluation of the suggested method for determining $h$ is presented in Section 4 along with a comparison between the suggested method and the traditional method where $h$ is set equal to a percentage of the product value. Finally, we give some concluding remarks in Section 5.

## 2. Model

The cost of holding inventory at an installation is presumed to be caused by resources purchased to produce activities needed to store the goods. Examples of such activities are "providing suitable warehouse space" and "providing capital" and the resources could include "surveillance equipment" and "personnel".

Before the cost associated with holding inventory can be determined, we must establish the relationship between the inventory kept, the activities needed and the resources used. Let us introduce the following notation:

| | |
|---|---|
| $\mathrm{IL}_k^+$ | inventory on hand of product $k$ ($k = 1, 2, \ldots, K$) |
| $E[\mathrm{IL}_k^+]$ | average amount of product $k$ on hand |
| $H(\mathbf{IL}^+)$ | total cost per time unit for holding $\mathbf{IL}^+ = (\mathrm{IL}_1^+, \mathrm{IL}_2^+, \ldots, \mathrm{IL}_K^+)$ on stock |
| $\bar{H}$ | average total cost per time unit for holding inventory on stock |
| $H_{\mathrm{trad}}(\mathbf{IL}^+)$ | total cost per time unit for holding $\mathbf{IL}^+ = (\mathrm{IL}_1^+, \mathrm{IL}_2^+, \ldots, \mathrm{IL}_K^+)$ on stock computed in accordance with traditional models |
| $\bar{H}_{\mathrm{trad}}$ | average total cost per time unit for holding inventory on stock computed in accordance with traditional models |
| $h_k$ | product $k$'s holding cost per unit and time unit |
| $O_i$ | required output level of activity $i$ ($i = 1, 2, \ldots, M$) |
| $\mathrm{AC}_i(O_i)$ | cost to provide $O_i$ units of activity $i$ for one unit of time |
| $\overline{\mathrm{AC}}_i$ | average cost per time unit for activity $i$ |
| $x_{i,j}$ | amount of resource $j$ ($j = 1, 2, \ldots, J$) used to produce activity $i$ |
| $p_j$ | price for resource $j$ per unit and time unit |
| $\lambda_{i,k}$ | amount of activity $i$ needed to store one unit of product $k$ |
| $f_i(\mathbf{x}_i)$ | the production function for activity $i$, $\mathbf{x}_i = (x_{i,1}, x_{i,2}, \ldots, x_{i,J})$ |

The required output levels of the activities are assumed to be linear functions of the amount of inventory on hand,

$$O_i = \sum_{k=1}^{K} \lambda_{i,k} \mathrm{IL}_k^+, \tag{2.1}$$

where $K$ is the number of products stored at the installation and $\lambda_{i,k}$ are non-negative product-specific constants.

The production of the activities is governed by convex monotonically increasing production functions

$$O_i \leqslant f_i(\mathbf{x}_i) \tag{2.2}$$

where $\mathbf{x}_i = (x_{i,1}, x_{i,2}, \ldots, x_{i,J})$, $x_{i,j} \geqslant 0$, are the amount of the resources $1, 2, \ldots, J$ used to produce activity $i$.