Available online at www.sciencedirect.com

SCIENCE DIRECT®

Applied Mathematical Modelling 30 (2006) 867–883

APPLIED MATHEMATICAL MODELLING

www.elsevier.com/locate/apm

A thermodynamic approach to modelling the economic order quantity

M.Y. Jaber [a,*], R.Y. Nuwayhid [b], M.A. Rosen [c]

[a] Department of Mechanical and Industrial Engineering, Ryerson University, 350 Victoria Street, Toronto, Ont., Canada M5B 2K3

[b] Department of Mechanical Engineering, American University of Beirut, P.O. Box 11-0236, Riad El-Solh, Beirut 1107 2020, Lebanon

[c] Faculty of Engineering and Applied Science, University of Ontario Institute of Technology, 2000 Simcoe Street North, Oshawa, Ont., Canada L1H 7L7

Received 9 July 2004; received in revised form 31 May 2005; accepted 27 June 2005
Available online 25 August 2005

Abstract

Ever since its introduction in the second decade of the past century, the economic order quantity (EOQ) model has been the subject of extensive investigations and extensions by academicians. Although the EOQ formula has been widely used and accepted by many industries, some practitioners have questioned its practical application. Accounting for holding and order/set-up costs, as has traditionally been the case for the economic order quantity, can distort the scenario. There are hidden costs not accounted for when modelling inventory systems. This paper postulates that some of these costs, which we refer to as the entropy costs, may be estimated using the principles of thermodynamics. Firstly, a new mathematical model is developed and considered as an enhancement to the EOQ model. Secondly, the developed model is investigated in a two-level (supplier–retailer) supply chain coordination context. Numerical examples are presented and results discussed.

Keywords: Economic order quantity; Thermodynamics; Entropy cost; Price dependent demand; Constant commodity flow; Supply chain coordination

* Corresponding author. Tel.: +1 416 979 5000x7623; fax: +1 416 979 5265.
E-mail address: mjaber@ryerson.ca (M.Y. Jaber).

0307-904X/$ - see front matter
doi:10.1016/j.apm.2005.07.001

1. Introduction

The basic principles of thermodynamics have been finding increased application in many non-energy areas. Thus, the principles of conservation of energy and non-conservation of exergy have been found to be useful in providing tools for the analysis of various other systems undergoing processes. The two principles stated above, which correlate with the first and second laws of thermodynamics, provide the basis for quantitative and qualitative assessments and comparisons of systems. Disciplines now exist which merge costs and thermodynamics. Some of the more notable of these are the field of thermoeconomics [1] and the associated concepts of extended exergy analysis [2]. One of the present authors has investigated the linkages between exergy and economics [3,4].

Many researchers have attempted to bridge their fields with others to gain insight into their own, benefiting from the synergies of such processes. As markets have become more and more competitive, disorder has become a prevailing characteristic of modern productive systems that are operating in complex, dynamic and uncertain environments. Some researchers in the discipline of management science/operational research have applied information theory and entropy approaches to account for disorder when modelling the behaviour of productive systems. However, few have applied classical thermodynamics reasoning to modelling such systems, e.g., [5,6].

Inventory theory and management has been one of the focus research areas in the discipline of management science/operational research for decades. The economic order quantity (EOQ) model developed by Harris [7] is regarded as the first scientific approach to analysing inventory. Since its introduction the EOQ model has undergone extensive investigations and extensions by academicians. Although the EOQ formula is mathematically rigorous and correct, and has been widely used and accepted by many industries [8], some practitioners have questioned its practical application.

Adkins [9] argued that the "True" value of the holding cost is not necessarily the best one to use in the EOQ equation. Instead, he suggested that the proper question to ask when seeking the parameters for the EOQ equation is: "what values will provide the proper lot size to meet aggregate inventory investment objectives?" Brown et al. [10] showed that, under certain conditions, even relatively small lot-size errors could be extremely costly to a firm. They claimed that their result is important to theoreticians and practitioners due to the importance of lot sizing in computer-based production and inventory control systems. Selen and Wood [11] cautioned that substantial miscalculations or misinterpretations during parameter input determination often lead to poor results. They added that such a problem might occur because financial accounting does not accumulate carrying and order costs, the necessary inputs for EOQ lot sizing. Woolsey [12] severely critiqued the use of the EOQ model, arguing that the assumptions (i.e., constant demand, constant carrying capacity, constant price, and unlimited storage capacity) necessary to justify the use of this model are not met. Woolsey [12] attributed the popularity of the EOQ among academicians and business people to the ease of manipulation and calculation. Jones [13] cautioned that most manufacturers, who use the EOQ formula to minimize relevant annual costs, end up over estimating their lot sizes. This was attributed to the fact that most accountants fail to identify which costs are relevant.

In summary, there is no doubt that the proper estimation of the EOQ model input parameters, which are the order cost, carrying (holding) cost and the demand rate, are essential for producing reliable results. However, properly estimating and monitoring these costs is often not an easy task.