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A century of evolution from Harris's basic lot size model: Survey and research agenda

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ABSTRACT

Determining the economic lot size has always represented one of the most important issues in production planning. This problem has long attracted the attention of researchers, and several models have been developed to meet requirements at minimum cost. In this paper we explore and discuss the evolution of these models during one hundred years of history, starting from the basic model developed by Harris in 1913, up to today. Following Harris's work, a number of researchers have devised extensions that incorporate additional considerations. The evolution of EOQ theory strongly reflects the development of industrial systems over the past century. Here we outline all the research areas faced in the past by conducting a holistic analysis of 219 selected journal papers and trying to give a comprehensive view of past work on the EOQ problem. Finally, a new research agenda is proposed and discussed.

1. Introduction

The economic order quantity (EOQ) model is undoubtedly one of the oldest models in the inventory analysis literature. The first who tackled the problem of determining the economic lot size in production systems was Ford Whitman Harris, born on August 8, 1877, and who passed away on October 27, 1962. In February 1913 at the age of 35, he proposed his formulation of this problem under the assumption of a continuous constant rate for demand and his recognition of the need to balance intangible inventory costs against tangible costs for ordering. Harris's solution has become the well-known "Square root formula". Even though its wide circulation, Harris's original paper was apparently unnoticed before its rediscovery in 1988 (Erlenkotter, 1989, 1990). In the first decades of the last century a large number of researchers formulated their own models, so that nowadays Harris's formula is also known as the "Wilson lot size formula" (Wilson, 1934) or "Camp's formula" (Camp, 1922), or the "Barabas formula". Erlenkotter, 1989, 1990 provides an interesting historical account of the formula's early life including a biography of F.W. Harris.

The second major contribution focussing on this problem was authored by Taft (1918), who incorporated a finite production rate and developed the classical Economic Production Quantity (EPQ) model, the first in a long sequence of generalisations to come.

As reported by Best (1930) an EOQ formula was used at Eli Lilly and Company from 1917 onwards. The EPQ/EOQ inventory control models are still widely accepted by many industries today for their simplicity and effectiveness. However, these simple models have several weaknesses. The obvious one is the number of simplifying assumptions. In these traditional inventory models in fact the sole objective is to minimise the total inventory-related costs, typically holding cost and ordering cost. For this reason many researchers studied the EOQ extensively under real-life situations and provided mathematical models that more closely conform to actual inventories and respond to the factors that contribute to inventory costs. The result was a very vast literature on inventory and production models generalising the economic order quantity model in numerous directions, a major example being the famous *dynamic lotsizing* algorithm devised by Wagner and Whitin (1958) for solving the problem, in the case when requirements may vary between different discrete points in time, and this formulation has gained many followers.

The large number and broad range of papers using the EOQ inventory model have also raised important concerns about the state of the lot sizing literature stream. It is unclear what this large stream of papers has collectively accomplished. Now, after one century from the first EOQ model, there is a need to assess what our collective understanding of lot sizing appears to be at this point in time, and what directions might be fruitful for future research. We here explore how lot sizing research has built on Harris's basic model idea by analysing a selection of 219 papers published in relevant peer-reviewed management journals between 1913 and 2012 (see Table 1). We organise them in a

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Table 1
Review methodology: keywords and the 11 search steps adopted.

Step	Years	Keywords	Exclusion criteria	Selection criteria	Papers found
1	1996–2009	Title="EOQ" or Title="EPQ or Title="Economic Order Quantity" or Title="Economic Production Quantity"			352
2	1996–2009		And not Title="Review" and not Title="Survey" and not Title="Case Study"		349
3	1996–2009			LIMIT-TO Subject Area="Decisions Science" or "mathematics" or "engineering" or "business management and accounting" or "economic econometrics and finance" or "multidisciplinary"	311
4	1996–2009		LIMIT-TO document type=Article		259
5	1996–2009			Citation number: papers contributing to the 90% of total citations	***95***
6	2010–2012	Title="EOQ" or Title="EPQ or Title="Economic Order Quantity" or Title="Economic Production Quantity"			208
7	2010–2012		and not Title="Review" and not Title="Survey" and not Title="Case Study"		181
8	2010–2012			LIMIT-TO Subject Area="Decisions Science" or "mathematics" or "engineering" or "business management and accounting" or "economic econometrics and finance" or "multidisciplinary"	169
9	2010–2012		LIMIT-TO document type=Article		133
10	2010–2012			Papers classification applying a 4 point scale evaluation according to the level of centrality of the "EOQ/EPQ construct" (according to Lane et al. (2006))	***49***
Total 1996–2012					***144***
11	1913–2012	Title="Title 1", "Title 2", "Title 3", …all belonging to the reference lists of the 144 selected papers	none	Citation number and journal relevance (Impact Factor)	***75***
Total 1913–2012					***219***

*From Scopus: steps 1–10, from Google Scholar: step 11.

new literature framework schema and we analyse how the EOQ/EPQ concept has been used by researchers. Second, we examine how cohesive the Lot Sizing research community is. This paper is organised as follows. In Section 2 we state the basic problem and in Section 3 the literature research methodology is explained. A new framework able to map Lot Sizing theory across the century 1913–2012 is proposed and discussed in Section 4. In order to complete the literature analysis, in Section 5 we report on the citation network analysis of the selected papers. Finally, Section 6 includes a background discussion on different topics related to lot-sizing, not covered or extracted from our survey, in particular (i) the possibility of including transportation cost considerations in inventory replenishment decisions, (ii) sustainable lot sizing procedures, and (iii) developing the NPV methodology for lot size decisions. This section ends with a summary of proposals for future research directions. Our conclusions are reported in Section 7.