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Lot sizing with learning and forgetting in set-ups and in product quality

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Abstract

Managers at manufacturing firms make every effort to improve the performance of their operations through the adoption of continuous improvement programmes, e.g. reducing set-ups times, increasing production capacity and eliminating rework. The learning curve can be used to describe and predict such improvements.

This paper investigates the effects that learning and forgetting in set-ups and product quality have on the economic lot-sizing problem. Two quality-related hypotheses were empirically investigated: (1) The time to rework a defective item reduces if production increases conform to a learning relationship, and (2) quality deteriorates as forgetting increases due to interruptions in the production process. Mathematical models are developed and numerical examples illustrating the solution procedure are provided.

Keywords: Learning; Forgetting; Set-up reduction; Lot sizing; Product quality

1. Introduction

Learning curves provide a means to quantify, observe and predict ongoing improvement in manufacturing and service organisations. Similarly, forgetting curves track decay in organisational knowledge. The strategic importance of learning and forgetting curves has been observed by many scientists and practitioners, and the learning–forgetting process has been used when developing training programmes, setting time standards, improving work methods, measuring productivity, managing transfer of knowledge, bidding for contracts, deciding whether to make or buy, planning production, enhancing process capability, product and quality improvement and setting manufacturing strategies.

The competitive advantage that one organisation has over another arises from its ability to become a learning organisation. Continuous improvement programmes, e.g. associated with just-in-time production, aim to provide consumers with high-quality products at competitive prices. To ensure low inventory levels, items are often produced in small lots. For this to be economic requires set-up, production and rework costs to be

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reduced. This paper investigates the effects of learning and forgetting in set-ups and product quality.

Many researchers have investigated reduction in set-ups. Porteus (1985) developed an extension of the economic order quantity (EOQ) model in which the set-up cost is viewed as a decision variable, rather than as a parameter. Replogle (1988) presented a revised EOQ model that recognised the effect of learning on set-up costs, and permitted the calculation of lot sizes that minimise total inventory cost over any period. Cheng (1991) argued that Replogle's model seems to over estimate the reduction in lot size and savings in total inventory cost due to the way in which he defines the learning curve, which is different from the traditional definition. In a subsequent article, Cheng (1994) considered learning in batch production and set-ups in determining the economic manufacturing quantity (EMQ). His numerical results indicated that the assumption of equal manufacturing lot sizes simplifies the process of determining optimal solutions. Li and Cheng (1994) studied the effect of learning in set-ups and learning and forgetting in production on the economic production quantity in batch production systems. Their results strongly indicated that the assumption of equal lot sizes not only simplifies the determination of the optimal solutions, but also provides close approximations to the optimal solutions. Rachamadugu (1994) set a myopic policy – Part Period Balancing – such that the current set-up cost equals the holding cost for the current lot. Her computational experiments revealed that its average performance is good even for horizons as short as eight times the initial reorder interval. In a following paper, Rachamadugu and Schriber (1995) provided heuristic and optimal methods for determining lot sizes when set-up cost reductions occur over time whether arising from continuous improvement, learning effects or incremental process changes. Pratsini et al. (1994) investigated how the reduction of set-up time through learning affects the optimal production schedule in the capacity constrained lot-sizing problem. Their results indicated that reduction of set-up time (cost) could cause an increase in the prescribed number of set-ups, resulting in lower inventories. Hong and Hayya (1993) pointed out that the benefits of reducing set-up costs are reduced lead times, improved process quality, increased production capacity and reduced investment in storage space. In a later article, Hong et al. (1996) examined three production policies under non-constant, deterministic demand and dynamic set-up cost reduction, where a decision to invest in set-up reduction is made at the beginning of each period of a planning horizon. Diaby (1995) proposed a dynamic programming procedure for solving the problem of set-up reduction with logarithmic and power cost functions.

The aforementioned works did not consider improvement in process quality. Porteus (1986) extended his earlier work in Porteus (1985) by incurring an extra cost for reworks as a result of the process being out of control. Karwan et al. (1988) proposed a model for joint worker/set-up learning. Chand (1989) permitted learning in process quality in addition to learning in set-ups, but no learning in processing times as in Karwan et al. (1988). Chand (1989) showed that, including the expected cost of defective units and the effect of learning in set-ups in the total cost to be minimised may lead to significant reduction in the optimal lot sizes. Further discussion of the relationship between learning and quality is provided in Section 3 of this paper.

With the exception of Karwan et al. (1988) and Chand (1989) who suggested accounting for forgetting in set-ups as an extension to their work, none of the works surveyed above investigated the effects on the lot size problem of learning and forgetting in set-ups and in process quality, either separately or simultaneously. This paper extends the work of Chand (1989) by assuming learning and forgetting to occur simultaneously in set-ups and in process quality, with the later characterised by reworking defective items.

2. The mathematics of learning–forgetting process

Many researchers believe that Wright (1936) was the first to formulate the relation between learning variables in a quantitative way Yelle