

# The impact of lot-sizing on net profits and cycle times in the $n$ -job, $m$ -machine job shop with both discrete and batch processing

George Kenyon<sup>a,\*</sup>, Cem Canel<sup>b</sup>, Brian D. Neureuther<sup>c</sup>

<sup>a</sup>Department of Management and Marketing, College of Business, Lamar University, Beaumont, TX 77710, USA

<sup>b</sup>Department of Information Systems and Operations Management, Cameron School of Business,  
University of North Carolina at Wilmington, Wilmington, NC 28403-3297, USA

<sup>c</sup>Analytical Department, School of Business, Indiana State University, Terre Haute, IN 47809, USA

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## Abstract

One of the key factors for productivity growth in the semiconductor industry is the improvement in overall equipment effectiveness (OEE). In order for the industry to meet its future goals it must find methods to continuously improve its OEE. This study assesses the impact that lot sizes can have on the operational variables that most influence OEE, net profits, cycle-time, throughput, work-in-process, and operating expenses. In a multiple operation system, where both discrete and batch processing is utilized, the interactions among products, product lot sizes, and equipment load capacity affect the arrival and service rates of all operations. As a result, cycle time and its components, throughput and work-in-process, are affected. This study shows that progressively smaller lot sizes do not provide continuous improvements in cycle time, throughput, work-in-process inventories, operating expenses, or net profits. Furthermore, we show that the impact of lot sizes on cycle times is not significantly related to setup times.

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## 1. Introduction

Historically, the semiconductor industry has maintained a steady 25 to 30 percent productivity

growth per year, as measured in the reduction of wafer production cost per function (SIA, 1997). This growth has occurred despite the escalating factory costs of approximately 20 percent per year (SIA, 1997). Due to diminishing annual gains in yield and wafer size, there is a greater emphasis being placed upon factory productivity. A key element in the strategy to remain on its historic improvement curve is the continuous improvement

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\*Corresponding author.

*E-mail addresses:* [george.kenyon@lamar.edu](mailto:george.kenyon@lamar.edu) (G. Kenyon), [canelc@uncw.edu](mailto:canelc@uncw.edu) (C. Canel), [sdbrian@isugw.indstate.edu](mailto:sdbrian@isugw.indstate.edu) (B.D. Neureuther).

in operating expenses per centimeter square of wafer production.

The Semiconductor Industries Association (SIA) recognizes that in order to meet its future goals, improvements are needed in developing, purchasing and operating equipment and reductions in feature size, and increases in wafer diameter are no longer sufficient. Improvements in this area are measured in overall equipment effectiveness (OEE). Overall equipment effectiveness is a measure that can lead to improvements in net profit and in cost reduction. OEE can be improved by eliminating what has been termed the six big losses of a production setting (Nakajima, 1998). These include losses from (1) poor productivity and lost yield due to poor quality, (2) setup and adjustment for product mix change, (3) production losses when temporary malfunctions occur, (4) differences in equipment design speed and actual operating speed, (5) defects caused by malfunctioning equipment, and (6) start up and yield losses at the early stage of production.

In support of OEE improvement, some complex job shop industries, such as the semiconductor industry, have realized that greater emphasis must be placed on factory productivity (due to diminishing annual gains in yield and wafer size). According to the SIA (1997), these OEE measurements are complementary to cost-of-ownership and throughput measurements. The SIA (1997) also has recognized that in order to exceed the 65 percent OEE barrier, improvements in factory planning and scheduling, and better modeling tools for assessing and optimizing capacity are needed. This has led the semiconductor industry to seek new ways to get more productivity from its fab investments by developing equipment and processes that improves the economics of production (Douglas, 1999).

Throughout most of this century, firms produced finished goods that were stored in inventory until they were sold to the customers. In the current business environment, where speed and flexibility are key competitive factors, maintaining large inventories is unacceptable. The current trend in manufacturing has been to migrate from produce-to-stock strategies to produce-to-order and engineer-to-order strategies that curtail over-

head costs, especially for finished inventory. In order to support organizational goals, operations managers have to decide how to minimize product cycle times and maximize net profits.

As competition in the global marketplace increases and customers continuously demand for higher quality levels and shorter cycle times, management's decisions must focus upon quality, speed, flexibility, revenue generation, and cost reduction. Buffa (1984) stated that day-to-day operating decisions, such as lot sizing, have major strategic implications for the firm. Thus, optimally sized production lots can help meet these strategic needs. This study assesses the impacts that lot sizes and material release rates can have on net profits and cycle times, as well as, the operational variables that most influence them: throughput, work-in-process, and operating expenses. Furthermore, this study shows that contrary to conventional wisdom; setups are not the principle driver of production cycle time in the multiple product, multiple operation job shop, and that progressively smaller lot sizes do not assure cycle time or cost improvements. The next section provides an overview of the literature in this area. Section three presents an analytical model that has the objective of maximizing net profits through selection of an optimal lot size for each product. Section four describes the experiment, section five provides an analysis of the results, and section six presents the conclusions.

## 2. Literature review

There have been extensive studies on issues related to lot sizing since lot sizing is affected by several operations decisions, and capacity planning decisions are affected by lot sizing decisions. Karimi et al. (2003) present an extensive survey on single-level lot sizing problems, their variants, and exact and heuristic solution approaches. Drexel and Kimms (1997) provide a survey for the capacitated, dynamic, and deterministic lot sizing problems, where continuous time models and multi-level lot sizing and scheduling are discussed. Ramasesh et al. (2000) present an economic production lot size model that minimizes the total

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