A Dissertation

entitled

The Impact of Time-Based Accounting on Manufacturing Performance

by

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Submitted as partial fulfillment of the requirements for
the Doctor of Philosophy degree in
Manufacturing Management & Engineering

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College of Graduate Studies

The University of Toledo
December 2007

An Abstract

of

The Impact of Time-Based Accounting
on Manufacturing Performance

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December 2007

Advanced manufacturing strategies are often undermined by the legacy control mechanisms of another era. In response to today's hypercompetitive global business environment, many manufacturing firms have adopted new business strategies such as time-based manufacturing (TBM). While some firms credit their success in the marketplace to TBM and other advanced manufacturing strategies, still more have realized little or no improvement in performance. Post-implementation failures often find their root not in the manufacturing strategy itself, but in the lack of congruent control mechanisms. One of such important control mechanism is the firm's managerial accounting system (MAS).

Despite evident appeal to both managerial accounting and manufacturing management, few managerial accounting innovations have developed at this interface. There is increasing recognition amongst managerial accounting scholars of the need for innovative studies to fill in the knowledge gaps and provide normative solutions for managerial accounting practice that has increasingly lost its relevance to modern manufacturing.

This study demonstrates that the design of the MAS can significantly affect key manufacturing performance measures. Market, operational, and financial performance measures are utilized in this study in terms of demand fulfillment rate (DFR), cycle-time (CT), and net operating income (NOI) respectively. Three MAS alternatives – traditional costing systems (TCS), activity-based costing systems (ABC), and the newly proposed time-based accounting (TBA) methods – are all examined. This study employs a computer simulation methodology, which presents an opportunity for the direct comparison and quantitative measurement of this impact. The choice of methodology allows for the controlled introduction of supply and demand stochasticity along with differing levels of product mix complexity, modeled in environments with differing levels of manufacturing overhead burden.

The results provide significant evidence of the importance of MAS design vis-à-vis manufacturing strategy. No single MAS outperformed all others along all performance measures, indicating the need to align the MAS to the manufacturing strategy. While MAS design alone may not ensure the success of an advanced manufacturing strategy, this study clearly demonstrates that it should be considered an integral part of the initiative. The introduction of TBA demonstrates how MAS design can better support a TBM strategy and regain lost relevance.

For Mariana

All thanks be to God

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Chapter One

Introduction

Today's advanced manufacturing strategies are often undermined by legacy control systems designed in another era. In response to today's hypercompetitive global business environment, many manufacturing firms have adopted new business strategies such as time-based manufacturing (TBM) and invested heavily in advanced manufacturing technologies in order to maintain their market position over competitors. While some firms credit their success in the marketplace to TBM and other advanced manufacturing strategies, still more have realized little or no improvement in performance. In some cases, implementation has been reported to have had a negative effect on the performance, and, in extreme pathological cases, some firms have even blamed such strategies for complete demise of the company. Quite often, the failure can be traced back not to the manufacturing strategy and/or technologies, but to the lack of appropriate control systems post-implementation (Womack & Jones 1996).

One of the most crucial control systems is the firm's internal managerial accounting system (MAS), which plays a decisively important role in supporting manufacturing strategy. Yet the blatant insignificance conferred upon it by a great number of academic researchers and practitioners remains paradoxical. Empirical research suggests that MAS design rarely reflects differences in manufacturing strategy, operating environment, or competitive pressures (Hughes & Paulson-Gjerde 2003).

Rather than suggest ways to better incorporate strategic measures within the existing managerial accounting framework, many consultants and researchers have advocated an increased use of non-financial measures, i.e. operational measures, in lieu of traditional cost measurers (Chenhall 1997, Sim & Killough 1998, Hoque 2003). The so called 'balanced scorecard' has thus become a popular topic for researchers seeking to restore relevance for cost accounting. Still others believe that in order to influence managers to do the right things, traditional manufacturing cost accounting systems may need to be abandoned altogether (Womack & Jones 2003). Regardless of cost accounting's potential flaws, the bottom line – pun intended – on solutions that would marginalize or even eliminate financial measures is that few manufacturing managers can simply ignore product cost. This presents a real conundrum to manufacturing mangers as strategic non-financial performance measures have increasingly come into direct conflict with legacy cost measures that are artifacts of another era of manufacturing.

What is really needed is not a complete abandonment of manufacturing cost accounting systems, but an adaptation that directly links strategic success measures, such as time-based performance measures, to product cost. Alternatives to financial measures, such as the balanced scorecard, remain an enigma for researchers as they are often firm-specific and are seldom identified in practice. The fatal flaw for is that they fail to build on the strengths of manufacturing cost accounting. In the words of Peter Drucker (1990), the world's preeminent authority on management theory:

> Cost accounting's strength has always been that it confines itself to the measurable and thus gives objective answers. But if intangibles are brought into its equations, cost accounting will only raise more questions. How to proceed is thus hotly debated, and with good reason. Still, everyone agrees that these business impacts have to be integrated into the measurement of factory performance, that is, into manufacturing accounting.

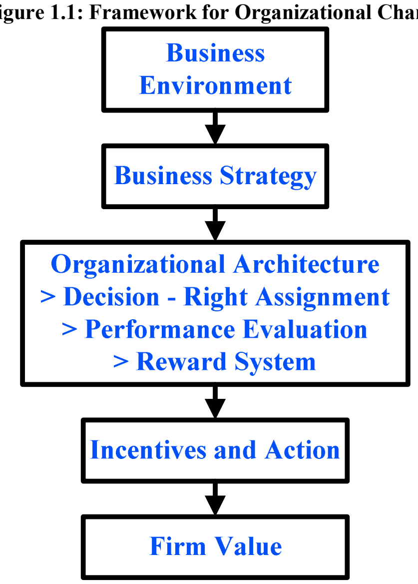
Managerial Accounting Function

Although not usually ranked high in organizational priorities or in academic research models, a firm's MAS provides the ultimate scorecard for management. It is critical that the MAS exhibit the following characteristics (Zimmerman 2003):

1. Provide the information necessary to identify the most profitable products and the pricing and marketing strategies to achieve desired volume levels.
2. Provide information to detect production inefficiencies to ensure that the proposed products and volumes are produced at minimum cost.
3. When combined with the performance evaluation and reward systems, create incentives for managers to maximize firm value.
4. Support the financial accounting and tax accounting reporting functions.
5. Contribute more to firm value than it costs.

The objectives of the managerial accounting function are to assist managers and to influence their behavior in a way that results in goal congruent actions (Anthony 1989). Figure 1.1 below presents a framework for organizational change and managerial accounting's role in driving the action that leads to firm value.

Figure 1.1: Framework for Organizational Change

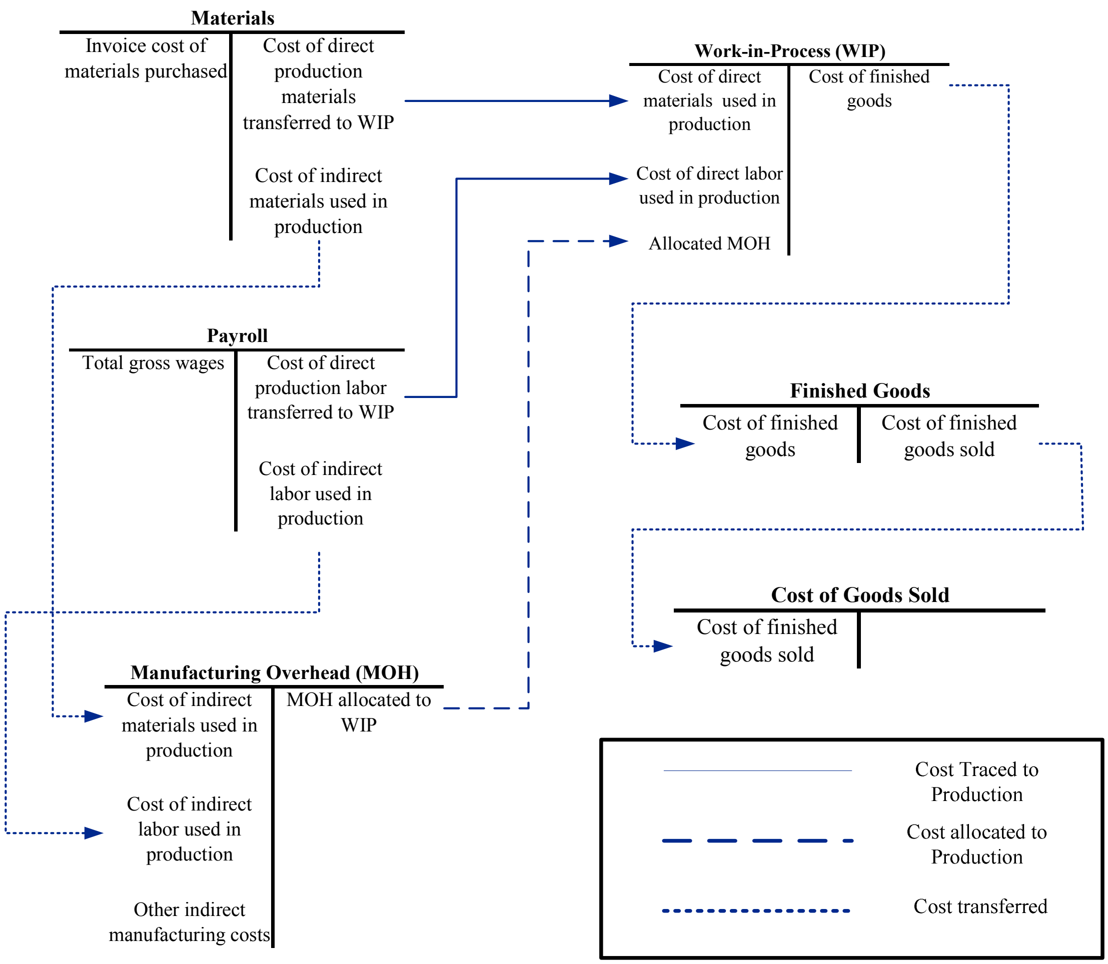


Changes in business environment should lead to the evolution of new strategies and ultimately to changes in the firm's organizational architecture, including changes in the

MAS to better align employee incentives to the objectives of the organization (Zimmerman 2003). The MAS is critical in setting profit goals, establishing departmental targets in the form of budget plans, evaluating the effectiveness of resource usage against those plans, investigating successes and failures in terms of specific manufacturing processes and support tasks, and taking action on adjustments and improvements necessary to keep the entire manufacturing enterprise moving towards the established strategic objectives. This raises the question in today's increasingly time-based competitive environment; to what extent do managerial accounting practices incorporate the strategic importance of time into product cost? The answer for many manufacturing firms is that MAS congruence is an afterthought to strategy, if given any consideration at all (Hughes & Paulson-Gjerde 2003).

Perhaps one of the reasons MAS alternatives are rarely considered in conjunction with implementation of TBM or any other advanced manufacturing strategy, may be a general lack of understanding, particularly for non-accountants, as to the fundamental differences between these alternatives. Essentially, the differences between most MAS alternatives come down largely to how manufacturing overheads are allocated or 'absorbed' into product cost. It is often relatively easy to trace costs such as direct materials, direct labor, and certain conversion costs – such as utilities – to particular products. However, in most modern manufacturing facilities, the proliferation of advanced manufacturing strategies and technologies make it difficult, if not impossible, to trace manufacturing overhead burden directly to any particular product or product class. Figure 1.2 below illustrates the typical flow of material, labor, and overhead costs through the work-in-process and finished goods accounts ending in cost of goods sold.

Figure 1.2: Cost Flow Diagram



For all intents and purposes, the MAS may be thought of as nothing more than a methodology for capturing and allocating costs to products, with the defining difference between alternatives being how manufacturing overhead are allocated. The basic difference then becomes the basis for allocating manufacturing overheads. While this may seem simple enough in concept, in reality it becomes a major issue as direct costs, particularly manual labor, have become increasingly insignificant in relation to manufacturing overheads driven by increasing capital investments in advanced manufacturing strategies and technologies.

With the widespread adoption of advanced manufacturing strategies and technologies, many managers have questioned the ability of traditional cost systems

(TCS) to achieve its objectives of strategic planning, budgeting and cost control, product pricing, profit determination, and especially employee motivation. In fact, TCS has often been charged as one of the major obstacles to the success of any advanced manufacturing strategy. Goldratt, whose 'theory of constraints' manufacturing has developed a worldwide cult following, labeled TCS "enemy number one to operational productivity" (Goldratt & Cox 1992). Despite evidence heaped against it from academics and management consultants, most firms in practice continue to use TCS (Garg et al. 2003). Ittner and Larcker (2003) contend that managerial accounting researchers themselves hold much of the responsibility for the failure of managerial accounting practice to effectively adapt.

> Kaplan's (1983) call for greater emphasis on manufacturing performance measurement spurred considerable enthusiasm for research on this topic in the managerial accounting community. Notwithstanding this initial enthusiasm and the potential contribution both to scholarly research and practice, the pursuit of new 'hot' topics quickly and substantially reduced research at this interface of accounting and operations management… We are left with an underdeveloped body of [manufacturing accounting] research that fails to build on prior studies to increase our understanding of the topic, leaving many important research topics unexplored, and lacks the critical mass of related studies needed to reconcile conflicting results.

TCS has lost its relevance to the dynamic and fast advancing nature of the modern manufacturing enterprise (Johnson & Kaplan 1987). Nevertheless, case studies suggest that cost remains the primary, and in the majority of cases the only, decision criterion in manufacturing (Veen-Dirks 2006). Continued debate on balancing cost and non-financial measures is of dubious practical value to operations management. The overarching question for research is what effect, if any, different MAS alternatives, with differing methodologies for allocating manufacturing overhead burdens, have on manufacturing system performance. A particular challenge for management accountant researchers today is developing MAS alternatives for practice that directly link manufacturing strategic measures to product cost.

The Productivity Paradox

Beginning in the 1980s, American industry invested heavily in advanced manufacturing strategies and technologies in order to regain competitive advantage lost to Japanese manufacturers. The majority of manufacturers found implementation of these advanced manufacturing systems problematic and realized that fundamental changes in production must be coupled with corresponding changes in control systems. In particular, managerial accounting research began to consider the 'perverse' management incentives created by TCS. Skinner (1986) termed this type of perverse behavior the 'productivity paradox', where manufacturing managers strive to better their measure of productivity rather than making true productivity improvements.

Fry and others (1993) contend that continued reliance on TCS may result in dysfunctional behavior vis-à-vis time-based strategic objectives including:

- Batching of orders to minimize setups at the expense of higher priority orders
- Production overruns and excess inventory to create favorable variances
- Cherry picking easy orders at the expense of higher priority orders
- Delaying preventive maintenance to increase machine utilization
- Understaffing in departments to increase worker productivity
- Delay operator training and cross training to prevent under-utilization
- Building a buffer of backorders to ensure that an adequate level of work exists

In their well-known book, *Lean Thinking*, Womack and Jones (1996) combined the core practices of several advanced manufacturing strategies under a broad conceptual umbrella, which they termed ‘lean manufacturing’. They examined the application of the key practices of lean manufacturing across the value chains of many global manufacturing companies. The authors found commonalities between those companies that were successful not only in implementing a lean initiative but also in sustaining the initiative. The following is a list of the critical success factors they observed at firms that successfully implemented and sustained lean manufacturing programs:

1. *Institutionalizing change* – organizations that accept change as continuous process are more successful in their pursuit of lean manufacturing. Constant change becomes part of the organizational culture, and employees not only accept it as necessary to doing business, but embrace it as a competitive weapon.
2. *Find a leverage point* – organizations on the brink of failure are more likely to accept the radical changes (item 3) in business practices and processes needed to save the company. It gives the employees a sense of urgency knowing that failure of the ‘lean’ program is not an option.
3. *Radical change* – organizations that begin the ‘lean’ process with a complete reengineering of their business systems and processes are more likely to succeed in instituting lasting change throughout the organization. If the firm is on a course of bankruptcy only a 180 degree turn will save it from destruction.
4. *Continuous improvement* – once the firm has set a course for improvement, change must focus on continuous and incremental improvement of business processes.
5. *Install business support systems* – once continuous improvement and change has been institutionalized, support systems must be adjusted to support and encourage a continuation of the program.
   a. *Accounting systems* – those firms that change their accounting systems to better reflect the goals of the ‘lean’ organization are more likely to succeed. Leaving the legacy accounting system, with its focus on past goals, can create perverse incentives for managers.
   b. *Compensation systems* – incentives should be given based on performance according to the goals of the company.
6. *Educate* – as part of the system of continuous improvement and employee empowerment, education becomes critical to continued success.
7. *Create transparency* – business systems need to be designed to create transparency throughout the organization, and information should be shared freely among the various organizations and functional departments.

Womack and Jones stressed the importance of installing appropriate business systems (item 5) to the long-term, continued success of lean manufacturing initiatives, yet this is often forgotten or ignored after the hype of installation on the plant floor. Legacy accounting systems, many of which were developed and widely adopted before World War II, when average cost of production was primary focus of manufacturing, remain in common use and may create perverse incentives for managers that undermine the continued performance of the lean system. It is for this reason that managerial accounting plays a critical roll in lean initiatives, and, according to the authors, the fact that it is often ignored may explain a great number of failures cited by companies that have tried to implement some form of advanced manufacturing strategy.

Sustained success of any advanced manufacturing strategy repeatedly comes down to having goal-congruent support systems, such as the MAS, in place post-implementation. Unfortunately, in many cases these 'backroom' processes are forgotten or simply ignored after the hype of installation on the plant floor. A recent study of three flexible manufacturers similarly found general incongruence of managerial accounting practices with operational strategy. At one particular facility, only one of the sixteen initiatives being reviewed by management was not considered a cost-reduction, despite a supposed emphasis on manufacturing flexibility measures (Veen-Dirks 2006). Again, this suggests an inherent weakness to the 'balanced' scorecard in that cost measures nearly always trump operational measures when they come into conflict.

Managerial accounting plays a critical roll in any advanced manufacturing strategic initiative, and the fact that it is often ignored may explain the great number of failures. The poor performance of many new manufacturing initiatives is due, in part, to continued reliance on an MAS alternative that fails to provide appropriate goals, performance measures, rewards systems (Kaplan 1983, 1993). Performance measures directly related to business goals are required to ensure that manufacturing processes are in control and continuously improved (Kaplan 1983, Drucker 1990).

Research Objectives, Questions, and Framework

The relationship between time-based manufacturing practices and manufacturing performance is well established in the operations management literature and therefore will not be the focus of this study. However, the strategic importance of time is acknowledged *a priori* as the contextual milieu for this research. *The primary objectives of this study are (1) to examine the impact of different managerial accounting system (MAS) alternatives on manufacturing performance measures and (2) to propose an MAS alternative that better links time-based strategic measures to product cost.* The resultant research questions and a testable research framework are developed along with clearly defined experimental factors, performance measures, and a simulation research methodology is developed in subsequent chapters.

The four managerial accounting systems considered in this study are traditional costing systems (TCS), activity-based costing (ABC), throughput accounting (TA), and the proposed time-based accounting system (TBA). The study is specifically concerned with the impact of various MAS alternatives on production mix decisions (PMD), with the effect of these decisions on manufacturing performance measures (MPM), analyzed in terms of average demand fulfillment rate, throughput-time, and net operating income.

These manufacturing performance measures were chosen because they represent both financial and non-financial and operational and market measures of performance.

In addition, this study examines the impact of MAS choice under varying levels of manufacturing overheads (MOH) and product mix complexity (MIX). Product mix complexity is a multidimensional variable measured through the depth of the bill of material for various products and the variability of demand for those products at a single supply point. The width of a bill of material has been defined within the operations management literature as the maximum number of dependent relationships in a product structure (Veral & Laforge 1985, Sum et al. 1993). Product mix complexity is widely acknowledged in operations management research as one of the primary factors in determining a product cost under different MAS alternatives and has been a primary variable in studies of lot sizing (Blackburn and Millen 1980; 1982a & b, Veral and LaForge 1985, Benton and Srivastava 1985, LaForge 1985), system nervousness strategy (Blackburn et al. 1986), and in capacity control policy (Gutzmann and Wysk 1986).

Product mix complexity defined as the demand variability for different products produced within the same facility has long been acknowledged in the managerial accounting literature as one of the primary drivers of manufacturing cost and may significantly contribute to cost distortions under traditional managerial accounting scenarios (Cooper 1988a , Brimson 1991). Many researchers have posited that TCS may under allocate MOH burden to the low volume, complex products and may over allocate manufacturing overhead burden to the high volume, simple products when both types of products are manufactured in the same facility, because manufacturing overheads are most often allocated on direct labor hours, machine hours, or some other measure of production volume (Johnson 1991b, Chalos 1992, O'Guin 1991).

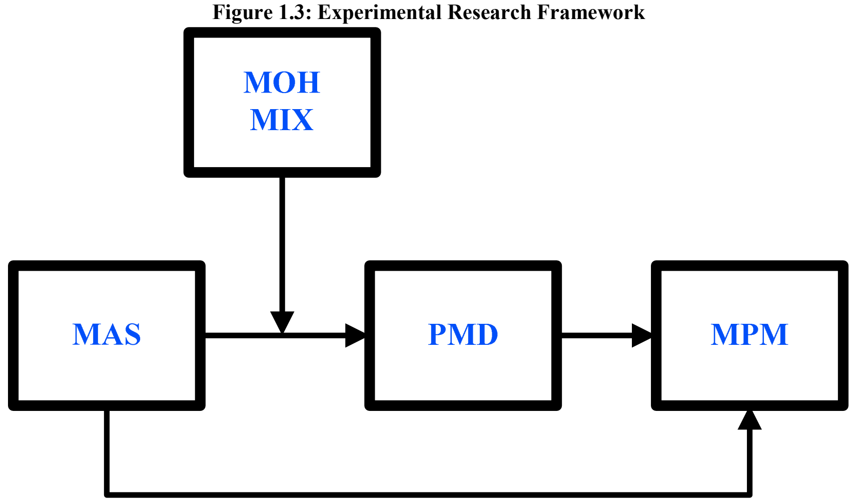
Theory in both managerial accounting and operations management has predicted that producing a heterogeneous product mix within a single facility may increase total cost and reduce operating performance (Skinner 1974, Hayes & Wheelwright 1984, Hill 1985, Johnson & Kaplan 1987, Banker et al. 1988). Empirical studies would later confirm the impact of product variety on manufacturing costs (Anderson 1995, Fisher & Ittner 1999, Randall & Ulrich 2001, Pil & Holweg 2004, Peacock 2005). Yet few studies have integrated these factors from managerial accounting and operations management within a single research model.

The experimental framework below in figure 1.3 shows the hypothesized relationship between the managerial accounting system alternative and the production mix decision. This relationship is mediated by the level of manufacturing overhead and product mix complexity. The production mix decision and the managerial accounting system alternative then together affect the manufacturing performance measures. The following research questions will be answered through the experimental research framework presented bellow in figure 1.2:

1. Does the use of different managerial accounting systems in production decisions result in differences in average demand fulfillment rate, cycle-time, and/or net operating income?
2. What effect does manufacturing overhead level have on average demand fulfillment rate, cycle-time, and/or net operating income?
3. For a given level of manufacturing overhead level does the use of different managerial accounting systems in production decisions result in differences in average demand fulfillment rate, cycle-time, and/or net operating?
4. What effect does product mix complexity have on average demand fulfillment rate, cycle-time, and/or net operating income?

5. For a given level of product mix complexity does the use of different managerial accounting systems in production decisions result in differences in average demand fulfillment rate, cycle-times, and/or net operating income?
6. For a given level of product mix complexity does manufacturing overhead level affect result in differences in average demand fulfillment rate, cycle-time, and/or net operating income?
7. For a given level of product mix complexity and a given level of manufacturing overhead level does the use of different managerial accounting systems in production decisions result in differences in average demand fulfillment rate, cycle-time, and/or net operating income?

Figure 1.3: Experimental Research Framework



Research Methodology

The impact of various managerial accounting systems on manufacturing performance vis-à-vis a time-based manufacturing strategy is of primary importance to this study and will be tested via computer simulation, an emergent and increasingly accepted methodology in industrial engineering and operations management research. This methodology was chosen for several reasons, not the least of which the fact that few examples of firms utilizing innovative MAS alternatives are to be found in practice.

> Traditional or [positivist] social science research methods, such as empirical analysis of large data sets, analytic models of accepted and understood phenomena, and cross-sectional field research, can be effective for studying the universe as it now exists, for understanding "what-is". But these normal science methods are less helpful for managerial accounting research where major social structural changes are occurring in organizations and in the roles performed by managerial accounting systems within these organizations (Kaplan 1993)

There has been an increasing recognition amongst some of the prominent scholars in the managerial accounting field of the need for innovative studies borrowing novel methodologies from other disciplines to fill in the knowledge gaps in the literature (Kaplan 1993, Ittner & Larcker 2001, 2003, Zimmerman 2001). As has been suggested, at the heart of the problem rests the wider accounting academic community that has largely fortified itself in its accepted research methodologies and avoided the interface with other research traditions altogether.[1] A full decade after his seminal article that questioned the relevance of managerial accounting practice and research to the modern manufacturing, Kaplan surveyed the managerial accounting field finding many opportunities remain undeveloped in relation to operations management (1993):

> Managerial accounting scholars, unlike their counterparts in operations management (OM), could not easily find widespread adopters of innovative practices. Our OM colleagues could look to leading Japanese manufactures in the automobile, machine tool, and electronics industries for observable examples of total quality management, just-in-time production, computer-integrated manufacturing, and design for manufacturability… But no 'Japan' existed for learning about or studying innovative managerial accounting practices. Therefore, standard cross-sectional field research studies would largely capture traditional managerial accounting systems operating in environments radically different from the ones for which the systems were designed.

[1] It is interesting to note that many of the preeminent scholars in the field of managerial accounting, such as Robert S. Kaplan, H. Thomas Johnson, Robin Cooper, and Eliyahu M. Goldratt, have not been trained as accountants at all. Rather their educational backgrounds include such diverse fields as electrical engineering, operations research, industrial engineering, chemistry, and physics.

Finding few examples of manufacturing organizations exhibiting innovative managerial accounting practice, accounting researchers have largely remained on the sidelines of the cutting edge, leaving the little literature existing on the subject to operations management. Zimmerman (2001: 422) argues that the current research focuses almost exclusively on describing practice rather than testing theories. In his view, managerial accounting field research has become completely descriptive with accounting researchers "wondering the hallways of corporations and manufacturing plants searching for facts unguided by tentative hypotheses."

Kaplan (1993) predicts that new research in high-payoff managerial accounting topics would likely have to be done in the field with innovative organizations requiring a very different set of research methods than have been used in the past, because of the loss of credibility of managerial accounting researchers amongst practitioners. "Traditional empirical analyses in managerial accounting research is not useless, it's just difficult to do without credibility."

Referring back to the research objectives of this study, it is desired not only to better understand the impact of existing managerial accounting practice on manufacturing performance, but also to develop an innovative alternative to traditional cost accounting systems that links time-based manufacturing strategy to product cost. To this end, it becomes necessary to go beyond the positivist tradition of managerial accounting research and its established empirical methodologies and instead take a normative approach employing quasi-experimental methodologies as an active participant. In a substantial departure from the passive, observational role for researchers that has become sacrosanct in the social sciences, and in managerial accounting research in particular since the 1950s, scholars must become active participants in the change process (Argyris et al. 1985, Argyris 1993, Kaplan 1993).

Contributions of this Research

1) *This study integrates theory and methodologies from industrial engineering, operations management, and managerial accounting within a single research model and directly compares the performance of different MAS alternatives in a controlled environment.* Managerial accounting has yet to produce an integrated set of theories and empirical results as the field is in a somewhat early stage in its evolution (Zimmerman 2001, Ittner & Larcker 2001). As evident in the review of the managerial accounting and POM literature, managerial accounting systems, product complexity, scope of product mix, and manufacturing overhead levels all play a major role in the manufacturing performance of a firm in a time-based competitive environment, yet little research to date has considered all these variable in a single study. Managerial accounting alternatives are seldom considered as a factor in operations management literature, despite the fact that management accountants have received a great deal of criticism from operations managers. In response, managerial accounting researchers have proposed novel alternatives to traditional costing systems. Each alternative has been examined against traditional accounting systems and claims that it will perform better; however, seldom has the manufacturing environment been considered. In the research that has included the manufacturing environment as a factor, it has been difficult to determine whether improvement is due to the new managerial accounting systems or to the new manufacturing system, e.g. Drugdale and Jones (1996) compared traditional costing

systems in an MRP manufacturing environment to throughput accounting in a theory-of-constraints environment.

Managerial accounting has a long tradition of utilizing all types of research methodologies including archival, field studies, case studies, survey, experimental, and even simulation to a limited extent; however, there remains a strong need for the development of interdisciplinary work employing methods such as simulation. Controlled experimentation, such as simulation studies, offers a means for filling in many of the research gaps and for supporting existing theories drawn from theoretical inference, field observations, case studies, and surveys of different companies. Unfortunately, direct comparisons of MAS alternatives are often made across entirely different industries with unique manufacturing settings. Often times it is even difficult to truly determine the extent to which alternatives to TCS have been implemented.

2) This study considers the interaction effects of the various MAS alternatives with factors from operations management. The existing research in both managerial accounting and in production operations management often ignores the interrelationships among important factors. For example, most managerial accounting researchers are in agreement that activity-based costing provides more accurate product cost information than TCS, and most managerial accounting research makes the assumption that more accurate product costs will improve the quality of product mix decision thereby improving firm performance (Brimson 1991). However, this assumption is made without examining important factors such as product complexity, scope of product mix, and manufacturing overhead levels, which in the real world application are as important as managerial accounting alternatives on product costing and product mix decisions.

Cooper and Kaplan (1992) remind us that the measure of an improved managerial accounting system is increased profits, not more accurate product costs.

3) This study goes a long way towards bridging this gap that has long existed between managerial accounting and operations management and between academic research and practice. A number of surveys have indicated that potentially up to 90% of all manufacturing companies are considering changes to their internal managerial accounting systems, yet fewer than 20% have actually done so. One possible reason is the lack of knowledge about the various managerial accounting alternatives and their potential impact within various manufacturing environmental settings (Walley et al. 1994). Through evaluating these MAS alternatives with environmental factors that were previously studied separately within a controlled simulation environment, results should create common ground for communication between management accountants and operations mangers.

4) *This study goes beyond the more conventional deterministic managerial accounting research with the incorporation of demand and supply stochasticity within the simulation model.* The existing managerial accounting literature often draws conclusions about the performance of managerial accounting alternatives assuming a deterministic manufacturing environment setting such as fixed processing times, no demand uncertainty, and no forecasting error (Goldratt 1986, Bakker and Hellberg 1991, Low 1992). Even simplistic models of pull production systems become extremely difficult to analyze mathematically as the assumptions needed for a closed-loop solution often require deterministic assumptions (Leitch 2001). The production operations management

literature has recognized that most manufacturing operations face considerable uncertainty and should be considered stochastic due to:

1. uncertainty in the timing customer orders,
2. variability in the processing time, rework, and scrap rate,
3. inaccuracy of demand forecasting, and,
4. uncertainty of equipment failure.

For example, Wemmerlov (1979) investigated the effects of forecast errors on inventory and found that it leads to an increased number of stock-outs, declining service levels, increased inventories, and increased ordering activities. He concluded that the manufacturing environments where demand uncertainty is present are fundamentally different from those where there is no uncertainty. He recommended that future experimentation should consider demand uncertainty since it is a more realistic representation of real life settings.

The production operations management literature has accepted stochasticity in most of its research design and has explored how different manufacturing systems cope with and react to stochasticity. However, despite the fact that stochasticity involved in manufacturing operations may cause product cost and performance measurement fluctuations, it has not been generally included in managerial accounting studies. The fact that the robustness of managerial accounting alternatives to uncertainty is largely emergent remains presents a major opportunity for contribution to the literature.

Simulation modeling allows for a direct comparison of alternative managerial accounting schemes under different levels of product complexity and scope and different levels of manufacturing overhead. Simulation modeling makes these complex comparisons in a controlled quasi-experimental setting possible and allows for the collection and measurement of quantitative data. This is something that empirical methodologies, such as cross sectional surveys and case studies, have not been able to do. Moreover, simulation allows for examination of these factors over an extended, albeit compressed, time period; not just as a snapshot in time. The primary purpose of this study is to examine the four managerial accounting allocation schemes listed above under the exact same environmental settings so that a direct comparison can be made.

Incorporation of supply and demand complexity into the model through stochasticity helps to create a dynamic environment in which to test the robustness of various managerial accounting allocation schemes and provides useful information about its behavior. This will help to bridge the gap between managerial accounting theory often created in academic isolation and real-world practitioners who want to know how these accounting schemes will hold up in practice.

5) *This study goes beyond conventional positivist managerial accounting research by taking an active role in developing an innovative alternative to traditional accounting practice, i.e. the proposed time-based accounting system.* As was pointed out by Zimmerman (2001), managerial accounting researchers may have lost some credibility in the field because of a failure to positively impact managerial accounting practice. This study addresses the deficiency of simply "describing management consulting practice" as suggested by Zimmerman (2001) and Ittner & Larcker (2001), and may provide helpful and quantifiable information to help struggling manufacturing firms and industries regain their competitive advantage through a better understanding of productivity and profitability. The results of this study will provide useful insights for both the fields of managerial accounting and production operations management research, making

significant contributions both to theory and practice. The introduction of throughput-time accounting demonstrates that, when it comes to managerial accounting schemes in an ever more diverse competitive field of manufacturing, the one-size-fits-all mentality will no longer suffice. Managerial accounting systems are an important consideration with regards to the design and implementation of any manufacturing strategy, if it is to be leveraged to the maximum competitive advantage.

Managerial accounting systems alone may not lead directly to the failure of advanced manufacturing strategies nor will assure its success. However, managerial accounting systems should be viewed as an integral part of the manufacturer's response today's competitive environment (Kaplan 1991). The results of this study will help managers to identify appropriate managerial accounting alternatives, specifically in conjunction with a time-based manufacturing strategy, to evaluate the actual profitability of products and to provide the right motivation for production given product complexities, scope of product variety, and manufacturing overhead levels.

The remaining chapters describe the specifics of this study. Chapter 2 begins with a historiography of the development, evolution, and the more recent stagnation of managerial accounting practice. It later reviews relevant literature on the evolution of time-based competition and managerial accounting alternatives and their potential impact on operations management. In addition, this chapter reviews the literary support from both managerial accounting and operations management on the impact of increasing manufacturing overhead levels and product mix complexity on production mix decisions and ultimately on manufacturing performance. Chapter 3 further develops and operationalizes the experimental factors within the research framework and presents the statistical hypotheses and methodologies for testing. Chapter 4 addresses the assumptions that were made in the simulation model as well as the issues relating to model verification and validation. Chapter 5 reviews and statistically analyzes the results of the simulation study and the performance of the MAS alternatives. Chapter 6 provides conclusions, applications to practice, limitations of this study, and suggestions for further research at this fertile interface of managerial accounting and operations management.

Chapter Two

Literature Review

The Evolution of Managerial Accounting

The practice and theory of accounting has been in existence for over 6,000 years, even if only in rudimentary form until the late 15^{th} century. A Franciscan Friar, Luca Bartolomeo de Pacioli is considered the father of modern double-entry accounting, known at the time as the Venetian method. The only date during Pacioli's life that is known with absolute certainty is 1494, when nearly fifty years of age, he published the first known work on accounting theory. His famous book was titled *Summa de Arithmetica, Geometria, Proportioni et Proportionalita* – The Collected Knowledge of Arithmetic, Geometry, Proportion and Proportionality. Pacioli wrote the *Summa* in an attempt to redress the poor state of mathematics education at the time, but it is one rather small and obscure section of the book that would make Pacioli famous. This section, a treatise on accounting and reconciliations, was titled *Particularis de Computis et Scripturis* – The Particulars of Reckonings and Writings (Bishop 1995).

His system, a compilation of accounting practices employed by Venetian merchants at the time, included most of the accounting cycle as we know it today. For example, he described the use of journals and ledgers, and he even warned that an accountant should not go to sleep at night until the debits equaled the credits! His ledger included assets – including receivables and inventories, liabilities, capital, income, and expense accounts. He demonstrated year-end closing entries and proposed that a trial balance be used to prove a balanced ledger. Also, his treatise discussed a wide range of related topics from ethics to cost accounting (Bishop 1995).

This new system of financial accounting was state-of-the-art, and literally revolutionized business and economics of the day. The *Summa* made Pacioli an immediate celebrity throughout the Western World and insured him a place in history as the 'Father of Double-Entry Accounting'. The *Summa* was the most widely read mathematical work of its day in all of Italy, and became one of the first books published on the Gutenberg press.

The *Summa* remained the only published work on accounting and mercantile mathematics for almost a century, providing a solid financial foundation for a period of rapid globalization and economic expansion. The Venetian merchant marine would trade goods as far as the seas would take them, making Venice one of the richest principalities in the world. With this new system of accounting, merchants and venture capitalists could compute profitability on their various ventures upon their completion with little disagreement as to the disposition of cargo, profits, and the ship itself at the end of the voyage. From these early mercantilist beginnings, the generation of standard firm-level accounting information became the practice for most all venture enterprises to this day.

It would be nearly four centuries before cost/managerial accounting would begin to develop as a separate field of study. There exist three major paradigms of contemporary historiography in regards to the origins and evolution of managerial accounting as practice and theory; the economic rationalist, Marxian, and Foucauldian schools (Fleischman 2000). However, most all industrial historians recognize Garcke and Fells (1887) as the first published accounting text to integrate cost accounts into the double-entry system (Littleton 1933, MacDonald 2002). It became widely accepted that cost/managerial accounting developed as a practice in the latter part of the 19th century to provide information to managers in large capital-intensive firms (Littleton 1933, Johnson 1981). The escalating investments in fixed assets created complex control problems that relatively simplistic 18th century accounting systems could not solve (Garner 1954).

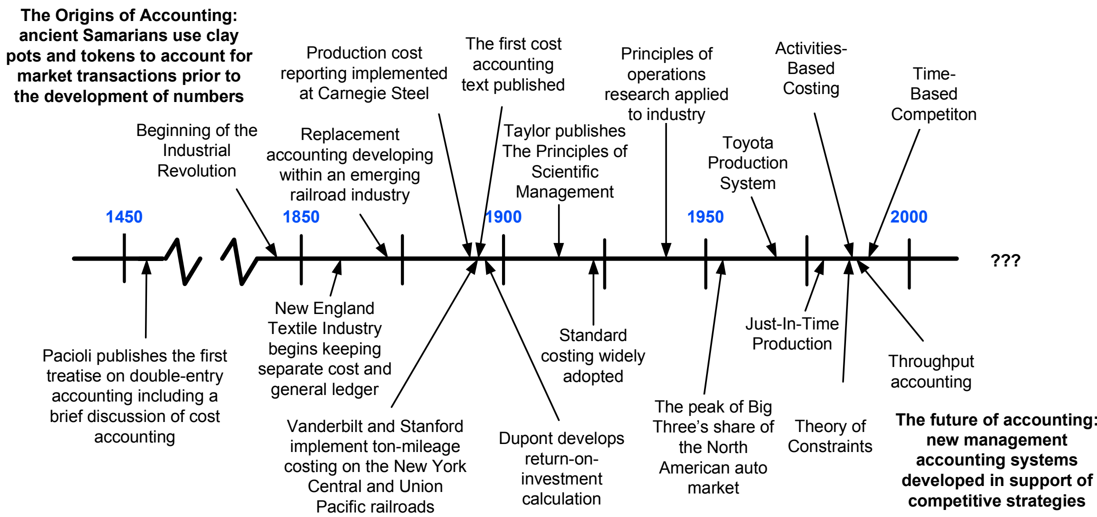
The well-known industrial historian, Alfred Chandler (1966), widened the traditional approach of accounting historiography, with its exclusive reliance on 'hard, objective' evidence such as archival artifacts, by considering the development of managerial accounting within its broader historical context. American businesses prior to 1840 were well served by the double-entry mercantile bookkeeping procedures that were introduced a half century earlier. By 1850, however, the technology of production was changing as companies moved from the craft age and adopted factory production systems with increased throughput and fewer workers, resulting in significant productivity gains. Chandler (1977) notes that by the 1880s the focus of managerial accounting systems was prime costs, without any known records of depreciation or overhead costs in most process industries. Johnson (1981) found historical artifacts suggesting that cost accounting may have developed even earlier in the 19th century in certain industries. In his review of records from Lyman Mills and the Boston Manufacturing Company dating back to 1856, he found that management had already developed regular production cost reports to augment the general factory ledger.

Applying Chandler's broad historical context approach, Johnson (1981) contends that cost accounting likely developed in conjunction with the development of textile mills around the very turn of the 19th century. Despite the lack of hard evidence to substantiate this theory, it seems quite probable given the dramatic paradigm shift of the textile industry at that time. Prior to the development of multi-purpose and mechanized mills, the textile industry operated under a ‘domestic’ or ‘putting-out’ business model in which merchant-entrepreneurs provided the raw materials to home-based artisans who received a market-determined piece rate for their production. Accounting records to this time were only utilized to track exchanges and inventories.

Kaplan (1984) attributes the development of modern managerial accounting techniques to the growth of large transportation, production, and distribution enterprises during the period between 1850 and 1925. These enterprises encountered new information needs as they implemented new methods of industrial organization and production. Initially the railroads would provide the greatest source of innovation in managerial accounting as the early tycoons, such as Commodore Cornelius Vanderbilt of the New York Central Railroad and Amasa Leland Stanford of the Central Pacific Railroad, consolidated their power and would seek to gain efficiency in large scale, capital intensive, and geographically dispersed operations (MacDonald 2002).

Sometime between 1870 and 1900, the advent of scientific management ushered in modern manufacturing accounting complete with standard costs, allocation of factory overheads to products, and unit product costing. By 1910 all modern manufacturing accounting was in place with the exception of depreciation accounting, as replacement cost was still being used for book value of plant and equipment in most industries (Chandler 1977). Figure 2.1 below presents a rough time-line of major developments in managerial accounting and industry.

Figure 2.1: A Time-Line of Managerial Accounting and Industrial Developments



<u>Relevance Lost</u>

Traditional managerial accounting practice did not loose relevancy overnight, but progressively over the past century. Many industrial historians claim that managerial accounting practice did not develop as a result of industrialization; rather it was the development of managerial accounting practice that enabled the rapid expansion of industrial production. The relevance of managerial accounting practice was not lost on the industrialists near the turn of the 20th Century, who would leverage the innovative managerial accounting practices of the day to extend their control over vast empires. Many of those methods, such as DuPont's 'return-on-investment', or Carnegie's 'job-costing', and Vanderbilt's 'ton-mileage' calculation, are still widely practiced used control mechanism in industry.

Kaplan (1984) concluded that virtually all of the accounting practices employed by firms today had been fully developed by 1925, and, despite considerable changes in the nature of organizations and the dimensions of competition during the past 60 years, there has been little innovation in the design and implementation of cost accounting. After a stream of several sole-authored papers, Johnson (1972, 1981, 1983) and Kaplan (1983, 1984) collaborated to provide a more complete picture of the development and stagnation of managerial accounting practice, as summarized in their controversial 1987 book, *Relevance Lost: The Rise and Fall of Managerial accounting*. This book brought into focus a stream of literature begun on the ever widening dissonance between managerial accounting practice and actual operational practices on the production floor. This historiography was yet another call for managerial accounting research to focus its efforts on the increasingly important interface with operations. The authors even suggested that the accounting process has becomes so detached from the operations of the business that often the accountant can work despite being completely ignorant of the nature of core business processes. The *Relevance Lost* historiography of accounting remains contentious to this day and keeps open the call for an interdisciplinary approach to accounting theory (MacDonald 2002).

The world economy would change for ever on Black Thursday, October 24, 1929, when the world financial markets collapsed. In response to the stock market crash of 1929 and the Great Depression that followed, the accounting establishment in the United States shifted from concern for cost management and operational efficiency to financial accounting and external reporting. Per Zimmerman (2003), supporting the financial accounting and tax accounting reporting functions is one of the primary functions of a managerial accounting system; however, far too often the other functions become subservient to the public reporting needs. Many operations managers have been forced to base decisions on external financial reporting requirements rather than internal operational performance criteria such as throughput time, inventory turnover, number of defects, or customer service (Fry et al. 1998).

Accountants became overly concerned with the valuation of inventory and not the management of cost (Fry et al. 1993). This concern led to the development of standard absorption costing, as is prevalent today in most industry. Managers began comparing actual results to budgeted figures to assess manufacturing performance, leading to the calculation and development of budget variances. Management by exception became the standard practice, which made sense during this period of mass production with long production runs of standardized products. However, according to Womack and others (1990) the heyday of mass production in America was 1955, when 95 percent of the market of America's largest industry – the automobile industry – was controlled by the Big Three: General Motors, Ford, and Chrysler. The authors point out that 1955 was the year that mass production business model began a steady downhill slide that continues today in the face of advanced manufacturing strategies coupled with flexible automation.

Despite radical changes in modern production strategies and technologies, legacy accounting systems, i.e. TCS, remain firmly in place. Under absorption costing, determining product cost involves adding the costs of direct materials, direct labor, and some percentage of factory overheads. The addition of allocating factory overheads came to be standard practice as United States Generally Accepted Accounting Principals (US GAAP) required that these overheads be allocated to products in inventory valuation for public financial and tax accounting reporting.

Whatever the MAS alternative, US GAAP requires:

> In keeping with the principle that accounting is primarily based on cost, there is a presumption that inventories should be stated at cost… It should also be recognized that the exclusion of all overheads from inventory does not constitute an accepted accounting procedure. The exercise of judgment in an individual situation involves a consideration of the adequacy of the procedures of the cost accounting system in use, the soundness of the principles thereof, and their consistent application. (Accounting Research Bulletin No. 43)

Because US GAAP requires some form of absorption costing for inventory valuation – both for public financial and tax reporting – and most companies see maintaining two separate systems as cost prohibitive, variable costing is very seldom used in practice. Most firms began to use the same method of full-absorption costing for both internal management decision making and external reporting.

The most common method of absorption utilizes direct some measure of production volume as a basis for MOH allocation. A study by Price Waterhouse (1989) found that roughly 80% of their American manufacturing clients surveyed continue the use of standard absorption costing with direct labor content as the primary allocation method of overhead costs. Drury and Tayles (1997) conducted a survey with the purpose of investigating the claims of Johnson and Kaplan (1987) that managerial accounting has become subservient to financial accounting. They found 73% of the non-automated and 68% of the automated manufacturers used labor hours as a base for allocations, even though other systems, with claims of better accuracy exist. Only 9% of the surveyed companies had plans or were in the process of implementing some form of ABC, with only 4% having an operational ABC system. The authors concluded that simplistic methods, designed primarily for meeting financial accounting requirements, are being widely used for decision making. A similar survey by Fry and others (1998) of 110 manufacturing companies supported this figure with 75% using TCS with direct labor hours as an allocation basis. An even more recent survey of 131 manufacturing firms shows that little has changed with 88% of firms stilly relying on TCS at least to some degree (Hughes & Paulson-Gjerde 2003).

Supporting the assessment of the chasm between managerial accounting and operational decision making are numerous articles finding that nothing is wrong with the design of cost systems. The authors of these studies argue that the system is simply being misused in that it was never designed for internal reporting, but rather for external reporting documents to be used in valuing inventory and calculating profits and losses (Baker 1989, Edwards 1985, 1984). These authors suggest that operations managers should not use variance reports against standards as the primary tool for control, but rather something more indicative of the actual manufacturing task, e.g. throughput-time for a time-based manufacturer.

The Dawn of Time-Based Competition

"The way I sell investment in innovation is as a time reduction, not a cost reduction" (Schafrik 2005). This proclamation by the General Manager of GE Aircraft Engines at the International Workshop on Accelerated Radical Innovation underscores both the increasing importance of time and the decreasing relevancy of traditional cost measures in modern manufacturing. Indeed, many managers competing in time-based industries realize that advance manufacturing strategies are often undermined by traditional cost systems developed for another era.

Time is fast becoming the next competitive battleground for American industry (Blackburn 1991). Those manufacturing firms that survive face a major shift in paradigm from mass production systems driven solely by cost efficiency to advanced manufacturing systems driven by quick response to customer demands for a much greater variety of high-quality products (Doll & Vonderembse 1991). A distinctive characteristic of globalized markets has been an increase in customer requirements for ever faster delivery of high quality products without corresponding increases in price (Drucker 1990). This heightened competition has forced most companies to adopt some form of advanced manufacturing strategy in order to remain a viable competitor in the long-term.

The evolution of time-based competition follows a continually evolving global manufacturing environment, where the order winners quickly become order qualifiers. Hayes and others (2005:19) describe this dynamic and evolving basis for competition in the new millennium. According to the authors, "American manufacturers have struggled to keep up with the global competition since the age of mass production, as the basis of competition has shifted from cost, to quality, to variety, and now to speed. It has come to the point where, as one CEO so succinctly stated, 'time accounting is more important [for us] than cost accounting'".

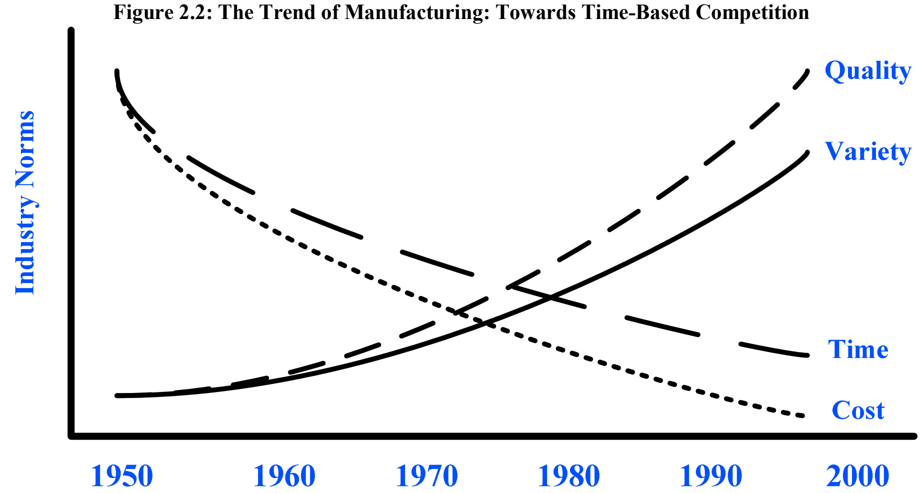
The first major shift in the basis of competition from mass production and its cost efficiencies came with the advent of Total Quality Management (TQM). TQM evolved first as a philosophy in manufacturing that stresses improved quality through continuous process improvement, employee empowerment, and data-based decision making. Closely related to TQM, and evolving shortly thereafter, is the concept of Just-In-Time (JIT) production, which focuses on lot size reductions, minimizing inventory levels, increasing flexibility, and elimination of all waste in manufacturing and distribution. The relationship between TQM and JIT is very strong, and, although their infrastructural practices have been proven beneficial in isolation, there is an evident synergistic effect in implementing both programs together. TQM delivers the quality levels necessary to support JIT measures for reducing lot sizes and inventory levels, and reduced inventory levels reciprocally expose opportunities for process improvements (Flynn et al. 1995).

The TQM/JIT movement in manufacturing has been described as the genesis of TBM (Blackburn 1991). The first time-based competitors were innovators that applied the TQM/JIT tools and concepts beyond the factory walls and across the entire value chain (Stalk 1988). TBM promises increased customer satisfaction through faster service times and higher quality levels. Time-based competitors found that speed and quality not only allow for premium pricing of products in the marketplace, but it also often leads to reduced internal costs over the long-run and greater profitability.

Figure 2.2 below illustrates long-term trends in manufacturing, adapted from Blackburn (1991: 295-96). Graphing the 1950s, 60s, 70s, 80s, 90s, 2000 and beyond on the x-axis and plotting lines roughly indicating how industry norms have changed form decade to decade during that period presents a revealing picture of the evolution towards time-based competition almost universally across all industries. According to the author:

> In most industries – industries as diverse as eyeglasses, package delivery, wholesale distributions, consumer electronics, motorcycles, and automobiles – the patterns are identical. The graph tends to show quickening market response time, improving standards of quality, and increasing product variety… These trends suggest strongly that time-based competition, like quality, is not a fad… Unless a fundamental change occurs in consumer behavior, competition will become increasingly time-based.

Figure 2.2: The Trend of Manufacturing: Towards Time-Based Competition



Hout & Stalk (1993) present case studies reaffirming Blackburn's hypothesis that across almost every industry time has become the basis for competitive advantage. According to the authors, "time-based competition is a reality, not just a concept. It is rapidly becoming the baseline, not the exception."

Time-based competition focuses on reducing response time to customer demand by squeezing time from every facet of the value-delivery system from research and development, to product development, to manufacturing, to marketing and delivery. TBM is a natural evolution of the TQM/JIT philosophy, albeit with a slightly broader scope of application. Suffice to say that time-based manufacturing is an externally focused production system that emphasizes quick response to changing customer needs and to this end seeks to reduce the end-to-end (throughput) time in manufacturing (Stalk and Hout 1990, Blackburn 1991). According to Blackburn (1991), a clear distinction must be made between TBM and JIT strategies. Time reduction, not inventory reduction, is the real underlying driving force behind the TQM/JIT revolution and naturally leads a firm to become a time-based competitor:

> Inventory reduction is a small part of the story; a benefit of JIT, but not the *raison d'etre*… Cycle-time compression translates in to faster asset turnover, increased output and flexibility, and satisfied customers. Thus, the diminished inventory often associated with JIT is more of a side benefit than a driving force.

Similarities between JIT and TBM sometimes make it difficult to distinguish the two, and it may be debatable as to whether inventory and cycle-time reductions represent two sides of the same coin. Figure 2.3 below summarizes some of the key conceptual differences between these two strategies described in the literature:

Figure 2.3: A Comparison of the Key Distinctions Between JIT and TBM

	JIT	**TBM**
	Internal (Operations)	External (Customer)
Focus	Inventory, batch size reduction, and elimination of waste	Time compression and product mix
Scope	Narrowly applied to manufacturing	Broadly applied to value chain
Key Metric	Inventory cost	Throughput time

There are many case studies where American manufacturing firms have redesigned their processes to compress time and improve performance (Stalk 1988, Stalk & Hout 1990, Blackburn 1991). These firms achieved higher productivity, increased market share, charged premium prices, reduced risk, and improved customer service. Substantial and sustainable competitive advantage is the prize when firms achieve speed in all facets of the value-deliver system, and all aspects of the business from accounting to engineering to manufacturing to marketing should be aligned towards this strategic goal.

Despite significant conceptual contributions and numerous case study examples, it would be nearly a decade before empirical studies would identify the key practices of time-based manufacturers. Koufteros and others (1998) identified the following specific manufacturing practices that focus on time compression:

(1) *Shop-floor employee involvement in problem solving*: first level employees participate in activities to define and solve problems.
(2) *Reengineering set up*: efforts are taken to reduce setup time.
(3) *Cellular manufacturing*: units are produced in a product oriented layout
(4) *Quality improvement efforts*: methods are developed and used to reduce defects and enhance quality.
(5) *Preventive maintenance*: equipment is routinely maintained on a proactive basis.
(6) *Dependable suppliers*: suppliers facilitate customer needs for service quality.
(7) *Pull production*: production is driven by demand from the next work station and ultimately from the customer.

The results of this study found a statistically significant relationship between the composite measure of these time-based manufacturing practices with reduced throughput-time. Throughput time is the ultimate measure of performance for the time-based competitor, and that is determined by how well an organization is able to move materials to, through, and off the shop floor into finished goods inventory and how well that organization is able to minimize finished goods (Fry et al. 1993). Time-based manufacturing requires an emphasis on time measures, such as throughput-time, inventory turnover, on-time shipments, new product introduction time, and quoted delivery times. Managerial accounting systems that fail to emphasize throughput-time may act as a fetter to sustained TBM practices.

Stalk (1989) points out that although time is a more critical competitive yardstick than traditional financial measures, management seldom monitors its consumption explicitly – almost never with the same precision accorded to sales and cost. Older, cost-based strategies require managers to do whatever is necessary to drive down costs: move production to, or source from, a low-wage country; build new facilities or consolidate old plants to gain economies of scale; or focus operations down to the most economic subset of activities, all at the expense of responsiveness.

Blackburn (1991) postulates that time-based competition will eventually come to all industries in due time, even those industries that seem to compete on an entirely different basis. It appears that certain industries are immune to or simply resisting time-based competition, such as plastic injection mold producers. The typical mold builder is a small, privately-held machine shop with fewer than 20 employees. Many of these small shops appear to compete for small jobs based mainly on price and the reliability of delivery lead-time, albeit rather long. However; further study in the industry revealed that it would not remain immune to time-based competition for long. Zahorik and others (1989) presented evidence that end users of the molds are increasingly driven by time and willing to pay a premium. According to one manufacturing manager from an IBM plant that is a major consumer of such plastic injection molds, "Time is everything. It's well worth it to pay double to cut production time in half".

Stalk and Blackburn bring to light an interesting paradox for TBM that has largely been ignored by research, as many managers see throughput-time and product cost as an unavoidable tradeoff. This is especially true with regards to traditional managerial accounting systems that often come into conflict with time-based performance measures. While the Koufteros (1998) study provides a firm foundation for research in time-based manufacturing, it focused solely on the plant floor practices of a time-based manufacturer. While it does conclude with suggestions for future research in time-based practices in the areas of product development and marketing, it completely ignores the question as to whether a particular MAS alternative would also be associated with reduced cycle-times.

The Impact Increasing Manufacturing Overhead Burdens

Adoption of advanced manufacturing strategies, such as TBM, have often been made in conjunction with increased investments in flexible automation, bringing fundamental and lasting change to the modern factory floor. For those successful manufacturing firms, implementation of these advanced manufacturing systems have brought positive changes including lower inventories, reduced production lead times, shortened product lifecycles, and an emphasis on quality. Probably most obvious of these changes has been the movement of the human production interface from the plant floor to the back office. These trends in modern manufacturing result in corresponding changes in manufacturing cost characteristics, including dramatically reduced direct labor costs with correspondingly greater levels of manufacturing overhead (MOH) burden.

The higher levels of capital investment inherent in flexible technologies drive the need for more accurate tracing of costs to individual work centers and products along with more detailed analyses in both capital authorization and recovery decisions. The failure to recognize the impact of these manufacturing trends on managerial accounting information has resulted in inaccurate product costing/pricing, inadequate operations/cost control, poor inventory management, unnecessary capital investments, and poor strategic decision making. An overemphasis on traditional cost-based performance measurement systems, encourage resource utilizations rather than other time-based competitive practices (Fry et al. 1993). The older cost-based strategies require total management concentration on minimization of costs in an attempt to maximize profits, often in exclusion of other more meaningful performance criteria (Kaplan 1984).

While many managerial accounting researchers have logically inferred the impact of increasing MOH burdens, given outmoded overhead allocation practices left from the mass production era, few have ventured to quantify the level of manufacturing overheads at which TCS begins to grossly misallocate costs. Vokurka and Lummus (2001) performed a simple scenario analysis to determine at what level of manufacturing overhead burden level does the implementation of an ABC system make a significant difference compared to TCS. In this study they compare four fictitious companies producing the same five products all with differing levels of MOH burden, ranging from 6.2% to 40% of total product cost. There findings were that in general the higher the overhead rate, the greater the difference between traditional and activity-based costing approaches. Given the rather high cost of implementing an ABC system, they conclude that any company with an overhead burden of less than 15% should probably not consider the effort.

A Taxonomy of Managerial Accounting Systems

A firm's MAS is called upon both in strategic and tactical planning, as well as providing support to financial and tax reporting systems. A major concern of management, therefore, is to select the appropriate MAS alternative that would provide accurate product cost information, derive the most profitable production mix decisions, minimize throughput, and maximize capacity utilization in a given manufacturing context.

Most MAS alternatives fall under two broad categories, based on method of inventory valuation; they are absorption and variable costing. The distinction between absorption and variable costing is based on the treatment of overheads. Under absorption costing, fixed overhead is assigned to units of inventory and shows up in the income statement as part of the cost of goods sold when the units are sold. When the units are produced, but not yet sold, allocated MOH stays in finished goods inventory. Under variable costing, no MOH is allocated to inventory. Fixed overhead is treated as a period expense which enters the income statement on a line-item every period regardless of the number of units sold.

Absorption costing makes a primary classification of costs according to manufacturing and non-manufacturing functions, emphasizing the gross margin – sales less cost of goods sold (CGS) – available to cover all fixed and variable selling, general, and administrative expenses (SG&A). Variable costing makes a primary classification of costs into variable and fixed categories, emphasizing the contribution margin (sales less variable costs) available to cover all fixed costs. Figure 2.4 demonstrates how the formats for profit reporting under absorption and variable costing differ:

Figure 2.4: A Comparison of Profit Reporting under Absorption and Variable Costing

Absorption Costing	**Variable Costing**
Revenues	Revenues
Less: Cost of Goods Sold	Less: Variable Manufacturing

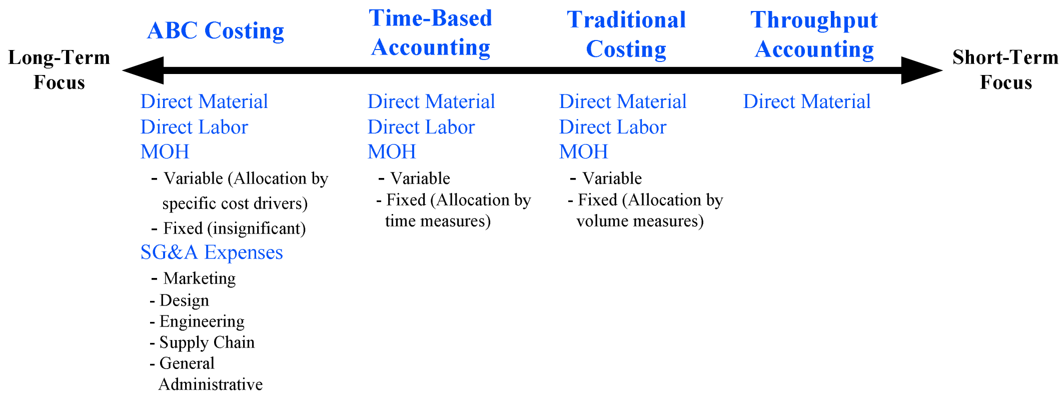
Gross Margin	Less: Variable S&A

Less: Variable S&A	Contribution Margin
Less: Fixed S&A	
-----------------	Less: Fixed Manufacturing
Profit	Less: Fixed S&A
=======	-------------------
	Profit
	========

The difference between the two income measurement approaches is essentially the difference in the timing of the charge to expense for fixed factory overhead costs. In the absorption costing method, fixed factory overhead is first charged to finished goods inventory; thus, it is not charged to expense until the period in which the inventory is sold and included in cost of goods sold. In contrast, under the variable costing method, fixed factory overhead is expensed immediately, and only variable manufacturing costs are included in finished goods inventory. Therefore, if inventories increase during a period, i.e. production exceeds sales, the variable costing method will generally report less operating income than will the absorption costing method. When inventories decrease, the opposite effect occurs with variable costing reporting great operating income than absorption costing.

The four specific managerial accounting systems considered in this research include traditional cost systems (TCS), activity-based costing (ABC), throughput accounting (TA), and the proposed time-based accounting (TBA). A comparison of product costing under these four alternative managerial accounting schemes is presented in figure 2.5. As illustrated, the four accounting alternatives inherently have a different focus in terms of decision making, with the major difference being whether and how overhead costs are allocated to products. Managerial accounting researchers tend to criticize variable costing methods such as throughput accounting for being short-term in their focus, since no attempt is made to allocate manufacturing overheads to product cost.

Figure 2.5: Product Costing Under Different Managerial accounting Schemes



Traditional Costing Systems

Using a TCS, management assigns the rates at which products will 'absorb' direct material, direct labor, and MOH. Unlike direct materials and direct labor, MOH is not broken down by actual activity drivers, and is instead assigned through a simple calculation of dividing the total MOH burden by some known allocation basis. Typically, the allocation basis is some quantifiable measure of volume, such as direct labor hours or direct machine hours.

Though widely used today by roughly three quarters of manufacturing firms, a TCS is most appropriate in specific manufacturing environments (Price Waterhouse 1989, Fry et al. 1998). In particular, standardized processes, similar and limited product lines, high direct cost, and a mature stage in the product cycle all lend themselves to the use of a TCS (Kaplan 1983, Baker 1989, Fry et al. 1998). At the zenith of the industrial age, when labor and materials represented 70-80 % of total production costs, the use of direct labor to allocate overhead seemed logical. Regardless of the apparent logic, if MOH burden was a negligible portion of total production costs, misapplication would not be a concern (Ruhl & Bailey 1994).

This stands in stark contrast to the manufacturing paradigm of today, where overheads, driven by large investments in advanced manufacturing technologies, may represent the single largest percentage of manufacturing costs. Labor, conversely, often represents the smallest share of total costs in most modern manufacturing plants at 10 % or less (Seed 1984, Turk 1990). The allocation of MOH by means of direct labor content or labor dollars has led managers to focus strict attention on direct labor variances, not to control direct labor costs but rather to control the allocation of overhead costs to each product (Fry et al. 1993). Fundamental changes in production also mean that the occurrence of overheads is no longer proportional to production volume. Traditional cost accounting practices tend to influence overproduction, as managers feel the need to maximize standard labor hours in order to spread out MOH (Womack & Jones 2003).

Activities-Based Costing

The increased magnitude of MOH burden and the corresponding decrease of direct labor component in advanced manufacturing facilities have led practitioners and researchers alike to search for a more relevant alternative to TCS to reflect the fundamental changes in manufacturing. The time was ripe for any alternative to established accounting techniques, and activity-based costing (ABC) quickly became a popular focus for consultants and researchers in the early 1990s. ABC was introduced as an alternative to traditional accounting techniques by Cooper and Kaplan (1988) and quickly became a popular focus for both practitioners and researchers alike. ABC proposes that all activities in the organization exist to support the production and distribution of goods and services and that activities consume resources and that products consume activities.

Conceptually, ABC is not radically different from the TCS it is meant to replace. It simply accumulates MOH and SG&A into ‘activity pools’ and then allocates them to products by specific individual cost drivers as opposed to a single generic and often irrelevant drivers such as direct labor hours or machine hours. ABC attempts to better model the relationships between the final product and all the resources used at all stages in its manufacture, thereby, tying the activity costs to the appropriate activity driver. Many managerial accounting scholars consider ABC superior to TCS because it provides a more accurate and consistent method for calculating manufacturing costs (Andrea et al. 1999). The result of this detailed system is a more accurate cost calculation, which may better highlight the constraints driving costs on the manufacturing floor (Kee & Schmidt 2000).

Although it is conceptually easy to understand and is intuitively logical, actual implementation often proves difficult. Many ABC systems introduced in recent years have been regarded as failures (Cooper et al. 1992, Argyris & Kaplan 1994). In most cases the effort required in identifying and modeling all the individual cost-driving activities within a manufacturing process and back office support functions from beginning to end does not justify the cost. The ability to fully and accurately allocate all overheads, or at least a significant portion, remains a major problem for implementing ABC. According to Johnson (1992), advocates of ABC tell companies that are unable to fully allocate all manufacturing overheads, in effect, to cost products differently for financial reporting purposes than for management purposes, such as planning and decision-support. For financial reporting, the ABC advocates recommend that companies continue allocating overheads using the volume sensitive drivers they have used since the early years of the past century. The need for maintaining the TCS is that for inventory valuation purposes, US GAAP requires that all overhead costs be fully absorbed into either cost of goods sold or into inventory. The ability to fully allocate all MOH remains the Achilles' heal for ABC advocates.

Kaplan and Anderson (2004) acknowledge that part of the failure of ABC comes from the inability to fully and accurately trace all overhead activities to all products, often leaving large amounts of overhead unallocated. On the other side, they point out an even more sinister demon in the ABC system, that when industrial engineers or management accountants survey individuals in overhead support functions to determine how they spend their time it almost always adds up to 100%. Few people, if any, report any significant amount of their time is spent idly or unproductively. Managers do not typically look favorably on work time that cannot be directly allocated to any particular cost pool, but – as we all know – most operations in the real world run considerably lower than their capacity.

Other factors hypothesized as contributing to the failure of ABC may include the failure to truly leverage all the benefits due to lack of sufficient information system infrastructure and the general resistance or simple lack of appreciation by decision makers (Malmi 1997). Hiromoto (1988) points out another flaw of ABC; that is the failure to leverage the motivational aspects of the MAS. While Japanese companies are well aware of the principle that an allocation system should capture as precisely as possible the reality of shop floor costs, they are more concerned with the motivational potential of the accounting system used in terms of long-term manufacturing strategies than with precise data on costs, variance, and profits.

Johnson (1992) agreed with Hiromoto's assessment of ABC and broke with Kaplan to write a new book entitled *Relevance Regained: From Top-Down Control to Bottom-Up Empowerment*. In this book he was equally critical of ABC as he had been of TCS, describing it as "relevance lost déjá vu". According to Johnson, "the pathway to global competitive excellence is not reached by doing better what we should not be done at all" (1992:149). The point the author makes is that ABC, while certainly potentially more accurate in product costing than TCS, does little to motivate employees towards strategic goals. Johnson follows with two case studies of manufacturing companies,one in the automotive market and one in the electronics market, where ABC information prompted managers to reduce costs and improve short-term profits by altering product mix or process mix, not by altering the way work is performed and the customer is served.

Throughput Accounting

Throughput as the most important measure of manufacturing performance was originally proposed by Eliyahu Goldratt through the concept of "theory of constraints" (TOC) in his 1992 book *The Goal*. TOC has had a significant impact on production scheduling theory and has many similarities with JIT production – with the emphasis of stock reduction and on 'pulling' production only as needed, but TOC advocates stock buffers to protect bottleneck facilities (Drugdale & Jones 1996). TOC also shares many similarities with TBM in that both emphasize the reduction of throughput-time. Goldratt recognized the inherent perversity of TCS that rewarded manufacturing managers for overproduction, while the shop floor and warehouse back up with WIP and aging finished goods inventory. He argued on many occasions that cost accounting is 'enemy number one of productivity', through sub-optimal behavior driven by local efficiency and utilization measures along with the standard accounting practice of 'recovering' overhead into stocks as goods are produced – not sold. According to Goldratt & Cox (1992: 91-92):

> The goal of a plant is to make money, and the measurements we are seeking should measure progress towards that goal…The result is that our cost accounting measurement have caused either a loss in throughput or an increase in inventory or operating expense – not consistent with the goal of the organization. Measurements should provide incentives for the plant to run more smoothly, but these cost accounting measurements seem to have the opposite effect.

Throughput accounting advocates that only direct materials are included in product cost and all other costs are fixed and not identifiable with products (Goldratt & Cox 1992). The earliest reference to 'throughput accounting' can be traced to a series of four articles written by Galloway and Waldron beginning in 1988. Waldron worked for Goldratt's consulting firm, and contributed to the development of TOC, but would later diverge from Goldratt in attempting to reconcile its principles with more traditional accounting analyses. Throughput accounting (TA) began to appear in some textbooks and has been incorporated into the UK's Chartered Institute of Management Accountants (CIMA) syllabi. Figure 2.6 below compares TCS with TA:

Figure 2.6: A Comparison of Traditional Cost and Throughput Accounting

Traditional Cost Accounting	Throughput Accounting
There are direct (variable) and indirect (fixed) costs	Distinguishing between direct and indirect costs is impossible and unproductive
Summing component costs to derive product cost and subtracting the result from the sales price used to determine product profitability	It is the rate at which the factory earns money that determines profitability, the the contribution of each product
Inventory is an asset and working on material increases its value	Inventory is not an asset! It is the result of unsynchronized manufacturing and stands in the way of profits
Reducing component cost directly increases profits	Profit is a function of material cost, total factory cost, and throughput

Throughput, inventory, and operating expense are the three terms used in TOC as well as TA. Because some textbooks may not define these terms exactly as they have been defined by Goldratt & Cox (1992), it is necessary to provide some definitions. "*Throughput* (T) is the rate at which the system generates money through sales". As interpreted by throughput accounting, it is equivalent to contribution margin, defined as the selling price minus the total variable cost. That is to say that under throughput accounting, product cost is equivalent to variable costs only. From an economic standpoint, the category of variable cost is dependent on the chosen time horizon. As described by Goldratt (2002) in one of his "late night discussions":

> We recognize that at the beginning of the century vast majority of costs were totally variable. You see, I don't think that differentiating between variable and fixed costs is very useful. At the end, the difference is based on an arbitrary decision. Even the building is not a fixed cost, it can be sold. Look at industry in the past ten years. Overall, what we call variable costs have stayed the same, while during the same time, fixed costs have doubled. So variable is fixed, and fixed is changing.

Under short-term conditions, only material costs, utilities, etc. are variable. Under longer-term horizons all costs are potentially variable (Bakke & Hellberg 1991). Under TA, all costs except material costs are considered fixed and therefore excluded from product costs. This means that only the material costs should be included in the product costs and that labor costs and factory overheads are considered to be part of operating expenses (Miller & Vollmann 1985)

"*Inventory* (I) represents all the money the system invests in purchasing things the system could or intends to sell". This is the total amount of investment in the system, including things as buildings, equipment, vehicles, and raw material inventory. This does not, however, included added value for labor or factory overheads in the inventory. This view of inventory not as an asset, as is traditional for accounting, rather as a 'money pit' is not entirely new. Drucker (1990) had also challenged manufacturing accountants to develop new cost concepts redefining costs and benefits in the manufacturing context.

> In the traditional cost accounting system, [inventory] is treated as an asset. In the new manufacturing accounting, however, inventory of finished goods is a 'sunk cost' (an economist's, not an accountant's term). Stuff that sits in inventory does not earn anything. In fact, it ties down expensive money and absorbs time. As a result, its time costs are high. The new accounting measures these time costs against the benefits of finished-goods inventory (quicker customer service for instance).

"*Operating expense* (OE) is all the money the system spends in turning inventory into throughput". This is all the money constantly poured into the system to keep it operating, i.e. expenses for labor, supplies, maintenance, depreciation, advertising, etc.

TA is a new tool for managerial accounting that was initially developed to support the TOC. The basic philosophy is that profit is a function of manufacturing response to time and that the long-term objective of management must be to maximize profit. TA has been offered as an alternative to absorption accounting systems such as TCS and ABC systems, for which TOC advocates have little use. The TA measurements provide a method of operationalizing the key concepts of TOC – throughput, inventory, and operating expense – into a functional accounting system (Ruhl 1997). Throughput accounting states:

$$\textit{Net Profit} = \textit{Throughput} - \textit{Operating expenses}$$

When:

$$\textit{Throughput} = \textit{Sales} - \textit{Total variable costs}$$

Then:

$$\textit{Return on investment} = \frac{\textit{Net profit}}{\textit{Inventory}}$$

Proponents of TA laud its simplicity while opponents criticize its complete disregard for fully capturing detailed product costs. Critics point out that TA is short-term focused and does not provide adequate product costing information for long-term decision making. Short-term variable cost may not reflect the true product cost because the decision to make a product creates a long-term commitment to manufacturing, marketing, and post sales support, thereby resulting in an increase in fixed cost (Cooper & Kaplan 1988). TA is not very helpful to strategic decision making, which typically requires the investment of significant capital over a long period of time and is concerned with more than just throughput (Ruhl 1997).

Goldratt and Cox counter these arguments by pointing out that the long-term is nothing more sophisticated than a series of short-terms. According to them, the only relevant element for product cost decisions is variable costs, because all fixed costs have already been incurred, or have been committed to be incurred, and cannot be changed in the short-run. This is the same argument that economists have long made for marginal analysis, i.e. all decisions should be made on the margin.

Despite criticisms from established scholars, the simple lack of novel alternatives to TCS drove some to operationalize TA. Galloway and Waldron (1988a) in their first article on TA claimed that a new language for manufacturing is needed to replace traditional concepts such as direct/indirect costs, economic batch sizes, and the idea of adding value to stock. They later develop a series of articles which make operational the concepts of TOC through development of management tools.

In the second article (1988b) they develop the ‘TA ratio’, which they suggest can be used to rank individual products.

If:

$$\textit{Return per factory hour} = \frac{\textit{Sales price - Material cost}}{\textit{Time on key resource}}$$

And:

$$\textit{Cost per factory hour} = \frac{\textit{Total factory cost}}{\textit{Total time on key resource}}$$

Then:

$$\textit{TA Ratio} = \frac{\textit{Return per factory hour}}{\textit{Cost per factory hour}}$$

The third article (1989a) introduces the 'primary ratio', where instead of defining profit as throughput less operational expense, they prefer a ratio:

$$\textit{Primary ratio} = \frac{\textit{Throughput}}{\textit{Total factory cost}}$$

Recognizing a need for local measures to drive 'throughput thinking' on the plant floor, they develop a set of time-based measures. This is opposed to measures based on departmental sales, which would imply some form of transfer pricing between departments.

$$\textit{Departmental throughput} = \textit{Standard minutes of throughput} \; x \; \textit{Budgeted departmental cost per minute}$$

Waldron (1994) continued to show his commitment to developing departmental measures within the context of TOC.

$$\text{Departmental ratio} = \frac{\text{Throughput}}{\text{Total facility cost}}$$

In their fourth article (1989b), Galloway and Waldron note that in complex manufacturing environments, there are often several manufacturing facilities, and within each facility, the 'focal' point needs to be identified.

$$\text{Cost per focal point minute} = \frac{\text{Total facility cost}}{\text{Focal point capacity (minutes)}}$$

In conclusion, product costs can be computed on TA principles:

$$\text{Product cost} = \text{Time required on focal point} \times \text{Cost per focal point minute} + \text{Material cost}$$

Throughput-based product costs would therefore penalize products that make heavy use of focal points while products not routed through focal points would be cost as materials only, creating a new set of perverse incentives. Waldron (1994) would later agree that TA principles are not conducive to product costing, and he later would propose that ABC is more appropriate for product costing (Drugdale & Jones 1996). He would go on to suggest that companies need both ABC for product costing and TA to tell how many products can be made and how fast. According to Waldron:

> Some sectors in the accounting world would want to set TA against ABC… that's a whole lot of junk, because you need the added information and they're both adding something… [ABC] doesn't tell you anything about how the business can make money… It doesn't tell you how many [products] I can make, or how fast… [but] TA will never tell you the right price to go to the market with for a product. So you need both… TA is not a product costing system.

Given the already low success rate of ABC systems due to the cost and complexity of implementation, adding yet another MAS alternative on top does not present a practical solution. Moreover, careful analysis of the entirety of Waldron and Galloway's ratios reveals that they are in fact analogous to familiar concepts of maximizing contribution per unit of limiting factor. If materials were the only variable cost, contribution and throughput would be identical and there would be no difference between traditional contribution analysis and 'throughput' analysis, therefore there is nothing new in throughput accounting (Willett 1989). Maximizing throughput per bottleneck minute, in the guise of 'contribution per unit of limiting factor', has been standard textbook material for many years, and although he may not succeed in destroying the 'cost world thinking', Goldratt may have succeeded in reinvigorating debate on historical issues such as relevant cost, contribution, and variable cost analysis (Drugdale and Jones 1996).

Furthermore, the debate as to whether to use absorption or variable costing appears to have long been settled by government regulations and the costs of maintaining two separate accounting systems. Because of the US GAAP requirement that some form of absorption costing be used for inventory valuation and tax reporting purposes, TA does not present a viable alternative for most manufacturing firms. Although several studies have included TA or other forms of direct costing, and it is an interesting alternative from an academic standpoint, this study will compare only the three forms of absorption costing that are most likely to be used in practice. To be included in this study are the previously mentioned TCS and ABC system as well as the following proposed TBA system, which does incorporate the same importance of throughput-time in manufacturing that the TA system does.

Time-Based Accounting

Drucker (1990) predicted that managerial accounting would play an even bigger role than in the past in the American factory of the future, and that time – not labor – would be the critical driver of costs by 1999.

> Labor costs are clearly the wrong unit of measure in manufacturing. But – and this is a new insight – so are all the other elements of production. The new measurement unit has to be time. The costs for a given period of time must be assumed to be fixed; there are no 'variable' costs. Even material costs are more fixed than variable, since defective output uses as much material as good output does. The only thing that is both variable and controllable is how much time a given process takes. And 'benefit' is whatever reduces that time. In one fell swoop, this insight eliminates cost accounting's traditional limitations.

Unfortunately, managerial accounting practice has failed to advance vis-à-vis Drucker's prediction. One often cited reason for the lack of innovation in managerial accounting practice is that no 'Japan' exists for learning about or studying innovative managerial accounting practices as is the case in operations management (Kaplan 1993). While there may be no example of a single wide-spread managerial accounting development in Japanese industry for cross-sectional study, this is more a reflection of the nature of Japanese managerial accounting practice, which tends to be firm-specific. There are many known case studies of Japanese companies that utilize the allocation of factory overheads to motivate employees towards long-term strategic goals (Hiromoto 1988). For example, a Hitachi factory producing refrigeration and air-conditioning equipment employs an overhead allocation technique based on the number of parts in product models in order to influence product design decisions towards reducing the number of parts per product.

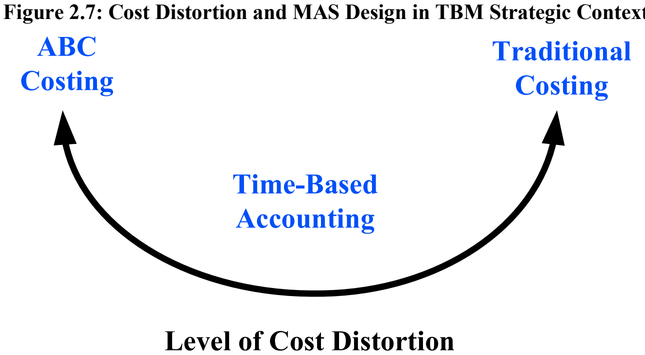
In large part, Japanese companies have rejected ABC as providing little if any marginal value for management decision making and control.

While Japanese management is well aware of the guiding principle that an allocation system should capture as precisely as possible the reality of shop floor costs, they are more concerned with the motivational potential of the MAS in terms of long-term strategy than with absolute precision of cost, variance, and profit data. The allocation basis used commonly in Japan is primarily determined by the activity or resource usage that management wants to minimize. In the case of a time-based competitor, the resource usage to be minimized is time itself – throughput time in manufacturing terms.

One possibility for the time-based manufacturer is to simply change the allocation method to reflect TBM strategy, i.e. time-based accounting (TBA). Rather than volume measures such as direct labor, throughput-time could be used as a basis for allocating overheads. As a time-based manufacturer competes on time, using product throughput time as an allocation basis would encourage managers to constantly reduce time in order to reduce product cost. Since this modification would not violate any aspect of US GAAP or compromise public reporting, TBA could be readily implemented. A simple numerical example of TBA allocations is provided in Appendix B.

TBA accounting would be much easier to implement than ABC, as it does not require radical change in the entire accounting system. However, the real advantage in using product throughput-time to allocate overheads for a time-based manufacturer is that any investment initiatives are ultimately justified in terms of expected time reductions via product cost. Under TCS justifications on improvements are often made via reduction in labor content that is really *de minimus* in terms of overall product cost (Fry et al. 1993). TBA maintains the strategic decision making strength inherent to absorption costing systems, in that it fully allocates manufacturing overheads to products thereby supporting long-term investment strategy. TBA has the tactical decision making strengths of TA, in that it motivates turning inventory quickly into throughput, i.e. into cash. Furthermore, it presents none of the organizational complexity and cost found in ABC implementations; possibly its greatest strength. Although many accounting experts agree that ABC can generate more accurate cost information, with low manufacturing overhead or a single product line, the cost to implement and adopt ABC may exceed the benefits (Vokurka & Lummus 2001). TBA supports 'the Goal' as articulated by Goldratt and Cox (1992) "to make money in the present as well as in the future". Most importantly, in linking throughput-time directly to product cost, TBA mitigates cost distortions and serves to eliminate potential dysfunctional behavior in terms of TBM strategy (figure 2.7).

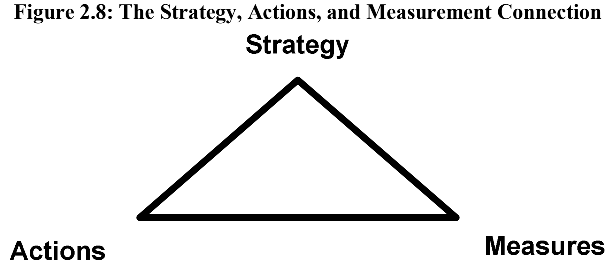
Figure 2.7: Cost Distortion and MAS Design in TBM Strategic Context



Interface of Managerial Accounting and Operations Management

The potential of any advanced manufacturing systems is greatly enhanced by the use of appropriate manufacturing performance measures reflected in the MAS. Hiromoto (1988) points out that a central principle guiding managerial accounting in Japan is that accounting policies should be subservient to corporate strategy, not independent of it. Nanni and others (1992) support the belief that performance measurement, i.e. MAS, is of equal importance to management strategy and actions (figure 2.8). The relationship between strategies and actions is fairly obvious. An organization's actions should be taken to support strategies, but the role played by measures in supporting strategies and actions should be equally obvious.

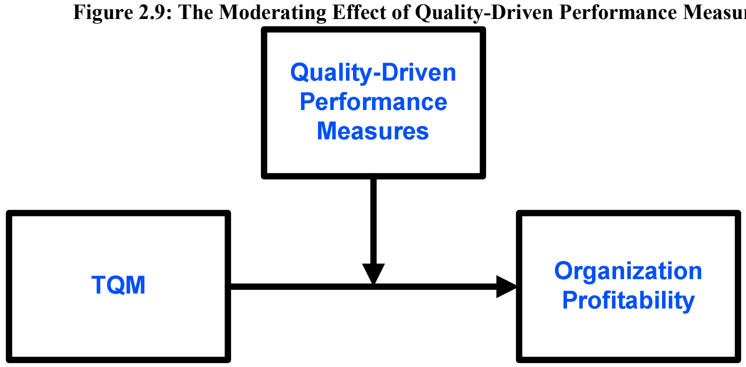
Figure 2.8: The Strategy, Actions, and Measurement Connection



This belief that MAS congruence with manufacturing strategy would lead to higher levels of firm performance has been touted by academic researchers and consultants ever since Kaplan's (1983) seminal article. While very little has been written on MAS congruence in terms of a time-based manufacturing strategy, there have been a handful of studies linking performance of other advanced manufacturing systems with appropriate accounting measures. These empirical studies suggest the need to develop an innovative MAS alternative for a TBM strategy.

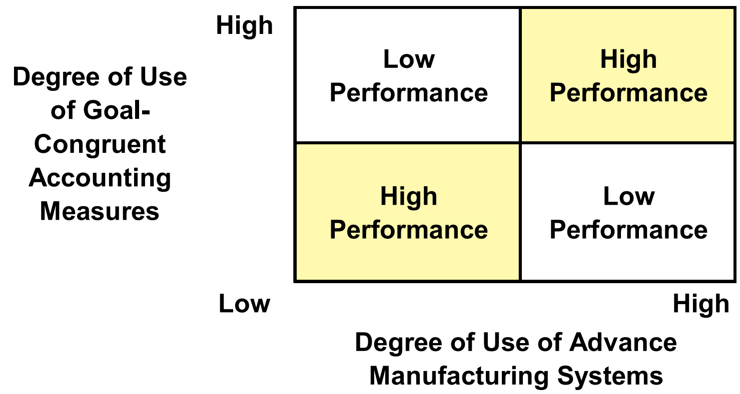
Chenhall's (1997) study of 39 manufacturing organizational units exemplifies the reliance on manufacturing measures and its impact on the potential increased organizational profitability of TQM. Given the nature of advanced manufacturing philosophies, such as TQM, those firms whose MAS focuses on key measures of customer satisfaction, on-time delivery, and quality production measures – such as throughput-times, defect rates, and inventory levels – show greater organizational profitability. Figure 2.9 below shows moderating effect of quality-driven performance measures on the relationship between TQM and organizational profitability.

Figure 2.9: The Moderating Effect of Quality-Driven Performance Measures



Firms utilizing an MAS alternative geared towards corporate goals show highest performance. Sim and Killough (1998) showed a disordinal interaction between advanced manufacturing systems, such as TQM/JIT, and the appropriateness of manufacturing performance measures, i.e. the firm's MAS. As seen in figure 2.10 below, those companies demonstrating high levels of TQM/JIT practices and utilizing appropriate performance measures related to customer quality along with performance contingent rewards showed the highest performance. One interesting result was that firms utilizing a low degree of TQM/JIT also performed well as long as their accounting measures also reflected a law degree of TQM/JIT congruent measures. This would indicate that mass production industries may perform best using traditional cost systems.

Figure 2.10: Disordinal Interaction of the Goal-Congruent Measures and Performance



This empirical evidence indicates that a firm's MAS should be designed contingent on characteristics of the production system, or that the characteristics of the production and managerial accounting systems should be simultaneously designed. It further suggests the possibility that an important reason some firms have not experienced performance gains from implementing advanced manufacturing systems is a reliance on an inappropriate MAS alternative. The following matrices illustrates the match between goal-congruent accounting measures and the degree of use of advanced manufacturing systems as adapted from the findings of Sim & Killough 1998 and clearly reinforces the need for congruence between the manufacturing practices and the performance measures utilized in the form of managerial accounting systems.

Using a survey of top manufacturing executives at 253 US firms, Fullerton and McWatters (2002) found a relationship existed between the level of JIT manufacturing practices implemented and the performance measures and incentive systems inherent to the managerial accounting system. Specifically, the use of non-traditional measures such as bottom-up measures, product quality, and vendor quality, as well as incentive systems of employee empowerment and compensation rewards for quality production are positively related to the degree of JIT manufacturing practices implemented. The factors which emerged as critical for performance measures and incentive systems and are associated with a high degree of JIT manufacturing practices are:

- The frequency with which quality issues are measured and reported to management strata.
- The importance of quality and teamwork in determining compensation.
- The use of bottom-up data gathering techniques such as Pareto analysis, histograms, and cause-and-effect diagrams to evaluate operations
- The importance of adherence to budget items in determining compensation
- The use of benchmarking to evaluate operations.
- The use of performance measure related to waste and inefficiency in evaluating the manufacturing system.
- The extent to which employees understand the firm's strategic plan.
- The use of performance measures related to timeliness and vendor performance in evaluating the manufacturing system.
- The use of non-financial measures to determine compensation.
- The extent to which line managers and non-management personnel are empowered to make decisions.

The authors suggest that in order to build and strengthen long-term competitive advantage, firms must provide low-cost, high-quality products under time-based demands. The results of this study demonstrate that successful implementation of JIT practices also requires a complementary decision making and control system.

It is clear that the selection of an appropriate accounting system is critical to the performance of the manufacturing system. The question is which accounting system to use, given several options. The answer is to choose the accounting system that best depicts the manufacturing reality. In the cases where manufacturing overhead was high in relation to direct labor and material costs and product variety is high, ABC outperformed the other two systems. In cases where a 'push' manufacturing strategy is used for long production runs of standardized products, in conjunction with centralized resource management systems such as manufacturing resource planning (MRP), MRP II, or enterprise resource and planning systems (ERP), TCS outperformed the other two accounting systems (Lea & Min 2003).

Other variations of MAS alternatives have been proposed and have shown positive results when applied in the appropriate manufacturing environment. One of these is the so called 'balanced score card', which focuses on four key performance measures: customer, financial, learning, and internal processes (Hoque 2002). Another variation proposed is one of integrated performance measures, which is based on a continuous process of developing performance measures. Based on case studies observed by Nanni and others (1992) propose an 'Integrated Performance Measurement System', which balances cost and other performance knowledge and employs it operationally at every step in the strategic management cycle. The utility of the MAS in supporting advanced manufacturing systems diminishes as the variety of cost data needed increases, the emphasis on future cost increases, and the importance of non-financial measures increases. In a dynamic manufacturing environment, in which the process is continuously changing, dynamic performance measures give the best results.

Although rarely seen in practice, the pathologic case of abolishing the MAS altogether has also been proposed by some researchers and practitioners, citing the fact that in many cases factory managers ignore internal accounting reports all together. It seems that production managers have come to realize that the performance measures being generated by the MAS more often than not reflect little more than a distorted view of shop floor reality. Neely (1999) found much the same reaction in his case study research of UK manufacturing, as he watched a production manager of a small manufacturing business through a freshly-delivered 200 page performance report straight into the waste bin. The response of the manager to Neely's puzzled look; "we measure everything that walks and moves, but nothing that matters." In their book, *The Race*, Goldratt and Fox (1986) share their experiences consulting to many manufacturing companies and finding that managers often used a combination of cost and intuition in deciding what actions to take, where cost is trumped by intuition.

> Currently we are using both cost and intuition to determine what actions to take. The mere fact that we override the cost recommendations so frequently already tells us that cost procedures are not adequate. Intuition often helps to improve the cost recommendation, but unfortunately intuition is not a basis for good communication. Even though this combination of cost and intuition were not sufficient in the past, this new competitive race has now made them totally obsolete.

The Impact of Product Mix Complexity on Manufacturing

Product mix complexity has been a focus of study in both the managerial accounting and the production operations management literature for some time now. Product complexity is commonly defined along two dimensions, breadth complexity and depth complexity (Bentorn and Srivastava 1985). Breath complexity is represented by the number of components in the parent product (Bentorn and Srivastava 1985). Depth complexity is defined as the maximum number of dependent relationships in a product structure (Veral and Laforge 1985, Sum et al. 1993).

Product mix complexity has commonly been found as a primary variable in various POM studies such as in lot sizing studies (Blackburn and Millen 1980; 1982a & b, Veral and LaForge 1985, Benton and Srivastava 1985, LaForge 1985), in system nervousness strategy studies (Blackburn et al. 1986), and in capacity control policy studies (Gutzmann and Wysk 1986). In all studies it has been shown as a primary driver of cost as the number of levels in the product BOM increases. In addition, some researchers have shown that JIT strategies work better with a flat BOM structure, while MRP performs better with a deep structure (Vollmann et al. 1992).

Product mix complexity has also been reported as an important factor in product costs amongst various managerial accounting alternatives. Many researchers have suggested that product complexity increases cost distortions under traditional managerial accounting scenarios (Cooper 1988a , Brimson 1991). Their research has shown that the manufacturing of complex products with many part numbers and complex functions places far greater demands on overhead support activities such as production planning, engineering, purchasing, quality control, and logistics than do more simple products. When the quantity of volume-related resources that a product consumes does not vary in direct proportion to the quantity of volume-unrelated resources consumed, a volume-based cost system such as traditional absorption-based costing systems will report distorted product costs (Cooper 1988a). Many researchers in managerial accounting have posited that traditional absorption-based costing systems may under allocate manufacturing overhead costs to the low volume, complex products and may over allocate manufacturing overhead costs to the high volume, simple products when both types of products are manufactured in the same facility, because these manufacturing overheads are most often allocated on direct labor hours, machine hours, or some other volume basis (Johnson 1991b, Chalos 1992, O'Guin 1991).

> Increasing complexity is the bane of a factory manager's life. With increasing complexity comes and increased number of parts, greater material handlings and inventories, more diverse process flows, higher supervision requirements, an increase of errors and defects, and smaller batches produced in shorter runs. (Abegglen & Stalk 1985, pg. 81)

Henry Ford was possibly the first industrialist to realize the full cost of variety on operations when he famously ruled that “the American can have a Ford in any color as long as it is black”. Closely related to product complexity is the impact of demand variability production operations. Theories in economics, operations management, and managerial accounting have long predicted that producing a heterogeneous product mix increases costs and reduces operating performance (Skinner 1974, Hayes & Wheelwright 1984, Johnson & Kaplan 1987, Banker et al. 1988, Anderson 1995) as a result of transactions caused by complex material flows, capacity balancing, quality control, and change (Miller & Vollmann 1985).

The impact of product mix complexity has become of increasing importance to researchers in both managerial accounting and production operations management as producers have struggled to cope with the ever increasing demands of consumers for greater product variety in the post-industrial age (Doll & Vonderembse 1991). The scope of product mix complexity is defined as the breadth of product offerings produced at a single facility; the wider the breadth of product offerings, the greater the complexity of the factory operations.

> As factory complexity increases, greater overhead resources must be committed to ensure smooth operations. For example, the scheduling, material handling, and expediting efforts required to support a line on which only one product is assembled are significantly lower than the efforts required to support a line on which ten or twenty products are assembled… The more variety of products fabricated or assembled on a line, the less focused, the more difficult to manage, and the greater the required overhead support will be. By inference, the more products a factory manufactures, the less focused, the greater the overhead requirements and costs and the higher its total production costs will be. (Abegglen & Stalk 1985: 81-83)

Theory in both managerial accounting and operations management has predicted that producing a heterogeneous product mix increases costs and reduces operating performance (Skinner 1974, Hayes & Wheelwright 1984, Hill 1985, Johnson & Kaplan 1987, Banker et al. 1988). Later empirical studies confirm the impact of product variety on manufacturing costs (Anderson 1995, Fisher & Ittner 1999, Randall & Ulrich 2001, Pil & Holweg 2004, Peacock 2005). Numerous operations management and accounting studies indicate that product variety's greatest impact may be on indirect and overhead costs rather than on direct labor productivity, yet little attention has been given to the impact of product variety in mixed-model assembly operations (Fisher & Ittner 1999).

Under TCS, the addition of greater product offerings can place an unfair burden on older, less complex products, which often require far less overhead support activities than the newer, more complex products.

> Complexity can also be substantially increased when a new product line is introduced, but the older product line is continued for parts or to keep a valued customer. In the early stages of product line expansion, the savings from the product redesigns and from the incremental volume often offset the costs and aggravation of the factory's increased complexity. However, as the expansion continues, the factory becomes increasingly less efficient, more costly, and less profitable. Because most management [accounting] and [financial] accounting systems are used as score cards rather than to demonstrate cause and effect, they are unlikely to show why the performance of the factory is deteriorating. (Abegglen & Stalk 1985, pg. 81)

Simulation Methodologies in Managerial Accounting Research

There has been an increasing recognition amongst some of the top scholars in the managerial accounting field of the need for innovative methodologies to fill in the knowledge gaps (Kaplan 1993, Zimmerman 2001, Ittner & Larcker 2001, 2002). Ittner and Larcker (2001) highlight that managerial accounting research has developed a somewhat faddish nature and has yet to produce an integrated, substantive body of knowledge. Zimmerman (2001: 422) is even more critical of the state of managerial accounting research and its over reliance of empirical methods. He argues that the state of affairs described by Ittner & Larcker (2001) is caused by a focus of describing practice rather than testing theories. In his view, managerial accounting research has become completely descriptive, and he believes that nothing more substantial can be learned from continued field research. He describes accounting field researchers as "wandering the hallways of corporations and manufacturing plants searching for facts unguided by tentative hypotheses".

Since this dialogue was brought back to the forefront of managerial accounting research, there has been a renewed interest in looking outside the more established empirical methods, towards other fields. Since managerial accounting interfaces with operations management, it makes sense that it should borrow some of the more established methodologies such as mathematical modeling and linear programming and emerging methodologies such as simulation modeling.

Figure 2.11 below has a listing of recent studies from operations management, industrial engineering, and managerial accounting which have employed some form of simulation methodology within the past ten years. As evident from this listing, with only one journal article greater than five years old, and the rest within the past five years, this methodology is gaining acceptance within the research community.

Figure 2.11: Select Managerial Accounting Studies Using Simulation Methodologies (2001-2006)

No.	Author	Date	Title	Publication	Methods	Findings
1.	Vokurka & Lummus	2001	At What Overhead Level Does Activity-Based Costing Pay Off?	Production & Inventory Management Journal	Scenario analysis with four fictional companies with identical production but different OH levels comparing TCS and ABC	Companies should examine their overhead levels to determine whether ABC is valuable to them. Companies with high overhead levels and companies with a wide product mix and identifiable activities may benefit. Companies with lower overhead and static product mix may find it cost prohibitive to implement.
2.	Boyd & Cox	2002	Optimal Decision Making Using Cost Accounting Information	International Journal of Production Research	Simulation in a resource constrained environment (TOC) compares TCS, ABC, direct costing, and TA.	TA produced the same results linear programing. All others produced suboptimal results. For cost accounting systm to provide information for optimal decisions it must be aware of production constraints and not use allocated cost.
3.	Özbayrak et al.	2004	Activity-Based Cost Estimation in a Push/Pull Advanced Manufacturing System	International Journal of Production Economics	Uses mathematical modeling and simulation to compare TCS and ABC in an automated manufacturing setting.	Pull strategy gives consistantly better results under both TCS and ABC, but the optimum is using ABC.
4.	Lea & Fredendall	2002	The Impact of Management Accounting, Product Structure, Product Mix Algorithm, and Planning Horizon on Manufacturing Performance	International Journal of Production Economics	Large-scale simulation examines TCS, ABC, and TA in two shops, one with a flat and one with a deep product structure, in a highly automated industry (high overhead).	No single shop setting is best of all perfomance measures. The manager must determine which performance measures are most important when chosing an MAS, product mix algorithm, or product structure.
5.	Lea & Min	2003	Selection of Management Accounting Systems in Just-In-Time and Theory of Constraints-Based Manufacturing	International Journal of Production Research	Large-scale simulation examines TCS, ABC, and TA in highly automated JIT and TOC environments with different planning horizons.	The management accounting system that best depicts the manufacturing process provides better product cost information and results in better system performance.
6.	O'Brian & Sivaramakrishnan	1996	Coordinating Order Processing and Production Scheduling in Order Initiated Production Environments	Journal of Management Accounting Research	Simulation model of order initiated environment compares cost (TCS) and cycle time in as order cutoff criteria for coordinating order processing.	A simple cycle-time cutoff decision rule outperforms a cost decision rule.
7.	Leitch	2001	Effect of Stochasticity, Capacity and Lead Time Cost Drivers on WIP and Throughput in a Pull Production Environment	Management Accounting Research	Simulation examines the tradeoffs of cost drivers and its effects on strategic cost management.	The effects of these cost drivers are much different than traditional push manufacturing systems and management may need to model these and other cost drivers to assess their impact on performance.
8.	Burrows et al.	2001	Real-Time Cost Management of Aircraft Operations	Management Accounting Research	Uses flight simulation to model cost impact of pilot inflight decisions on entire flight network.	Provides a unique and detailed description of cost-drivers and cost-behavior information for a non-manufacturing environment.
9.	Balakrishnan & Sivaramakrishnan	2002	A Critical Overview of the Use of Full-Cost Data for Planning and Pricing	Journal of Management Accounting Research	Uses mathematical modeling and simulation in conjunction to determine the relationship between product pricing and product, capacity, and allocation decisions.	Flexible capacity mitigates the potential perverse incentives of full-costing on product, capacity, and capacity allocation decisions.
10.	Banker & Hansen	2002	The Adequacy of Full-Cost-Based Pricing Heuristics	Journal of Management Accounting Research	Uses mathematical modeling and simulation in conjunction to compare three pricing heuristics in a service operation.	Full costing provides optimal performance when demand is greater than capacity in a service operation where there is 'soft' capacity in the form of backorderd service.
11.	Leitch et al.	2005	Opportunity Costing Decision Heuristics for Product Acceptance Decisions	Journal of Management Accounting Research	Uses simulation to evaluate full-cost heuristics under different levels of stochastic demand, lead-time, cost structur, and workstation capacity.	Full costing works well when lead times are long and shop capacity is balanced. Deviations reduce its performance over other heuristics.
12.	Meade	2004	Modeling the Strategic Impact of Management Accounting Methods on the Implementation of Lean Manufacturing	Doctoral Disseration: Western Michigan University	Evaluates lean implementation ex post facto through the lens of differing MAS alternatives.	Focus on short-term impact (6 month simulation) limited the generalizability of findings.
13.	Whittenberg	2004	Decision Usefulness of Management Accounting Information Systems in Constraints-Based Manufacturing Operations	Doctoral Disseration: Nova Southeastern Unviversity	Human experiment using masters of accountancy students to determine impact of MAS design on decision making.	Results inconclusive as time allowed for only two iterations and difficult to determine if improvements were due to changes in MAS design or simply learning to better play the game.

Vokurka and Lummus (2001) use a simple scenario analysis with a spreadsheet of four fictional companies with identical production and differing levels of factory overhead (6%, 18%, 31%, and 40%) to compare TCS and ABC. The results suggest that companies need to examine their overhead levels in order to determine whether implementing ABC will be valuable. Companies with high levels of manufacturing overhead, wide product mixes, and clearly identifiable activity drivers may benefit, while companies with lower levels of manufacturing overhead and a static product mix may find it cost prohibitive to implement.

Boyd and Cox (2002) use simulation software in a resource constrained environment (TOC) comparing TCS, ABC, direct costing, and TA. They found that TA produced the same results as a linear programming model, while all others produced suboptimal results. In the TOC environment, for a cost accounting system to provide information for optimal decision making it must be based on production constraints and not use allocated costs.

Özbayrak and others (2004) use a combination of analyticall and simulation modeling to compare TCS and ABC in a highly automated manufacturing setting. They found that a pull strategy gives consistently better operational results, regardless of accounting scheme, but is optimized in conjunction with ABC.

Lea and Fredendall (2002) use a large-scale simulation model to examine TCS, ABC, and TA in a highly automated manufacturing environment, i.e. manufacturing overhead. They compare these accounting schemes under different product structures finding that no one performs best under all shop settings. The manager must determine which performance measures are most important when choosing an MAS. Lea and Min (2003) repeated this simulation comparing the same managerial accounting schemes in both a JIT and TOC environment with different planning horizons. The found that the MAS that best depicts the manufacturing process provides better product cost information and results in better system performance.

This research follows a similar methodology as that used in Lea and Fredendall (2002) including two of the same input variables, i.e. MAS alternatives and product mix complexity. The current study develops an additional MAS alternative and addresses another limitation of the Lea and Fredendall (2002) study – namely that it only considered an environment with a high level of manufacturing overhead. One additional limitation, from an accounting standpoint, is that TCS is not operationalized as is most common in practice, with direct labor hours as an allocation basis. Rather, they use direct machine hours, which would be consistent with a highly automated environment. They note that this may be the reason why their anomalous results were inconsistent with other researchers (Cooper & Kaplan 1992, Johnson 1991 & 1992, Kaplan 1989, O'Guin 1991).

O'Brian and Sivaramakrishnan (1996) used a simulated order initiated environment to compare financial and operational cutoff criteria under a TCS for coordinating order processing. They found that a simple throughput-time cutoff decision rule outperforms a cost decision rule. Although this study is not concerned with different account schemes, the use of throughput-time for the decision rule further supports the use of throughput-time as an allocation basis within the managerial accounting scheme.

Leitch (2001) used a simple simulation model of a pull-production environment to examine the tradeoffs between various cost drivers (stochasticity, capacity, and lead-time constraints) and its effects on strategic cost management. He notes that even relatively simple simulated pull-production environments can offer much complexity and difficulty in analysis. He found that the effects of these cost drivers are much different than in traditional push manufacturing systems, and that management needs to consider the impact of these and other cost drivers on performance. This study supports the use of simulation in accounting studies, so that stochasticity may be introduced to the experimental environment.

Burrows and others (2001) accessed a flight-simulator and utilized its 'real-time' operational data to model the impact of pilot in-flight decisions on the entire network. This research provided a unique and detailed description of cost-drivers and cost-behavior in a non-manufacturing environment.

Balakrishnan and Sivaramakrishnan (2002) used analytical and simulation modeling to determine the relationship between product pricing, production capacity and allocation decisions in a fictional organization. They found that flexible capacity mitigates the potential perverse incentives of full-costing on production capacity and allocation decisions.

Banker and Hansen (2002) used analytical and simulation modeling in order to compare three pricing heuristics in a fictional service operation. They found that full costing provided optimal performance when demand is greater than capacity in a service operation where there is soft capacity in the form of backordered service.

Leitch and others (2005) used simulation modeling to evaluate full-cost heuristics under different levels of stochastic demand, lead-time, cost structure, and work station capacity. They found that full costing works well when lead ties are long and shop capacity is balance. Deviations from this ideal scenario reduce its performance over other heuristics.

A search of doctoral dissertations/theses involving managerial accounting (including the terms managerial accounting, cost accounting, costing, and accounting) and simulations was performed in ProQuest since 2000 returning two such dissertations. Meade (2004) uses simulation to model the short-run (six months) impact of the implementation of lean manufacturing on financial performance measures through different managerial accounting methods. The focus of this research was not on how the MAS alternatives affect manufacturing operations, but rather how the view of manufacturing operations is changed through the lenses of different accounting schemes during the implementation phase of lean manufacturing. Although this study provided a useful look at the impact of lean manufacturing through various accounting treatments, its short-term view did little to show the system-dynamic relationship of managerial accounting on the success of lean initiatives. The author provided some useful suggestions for future research that are incorporated into the study at hand including expansion of the time horizon, incorporation of customer service measures, use of income measures, and the addition of non-normal distributions in supply and demand.

Whittenberg (2004) compared the decision usefulness of various managerial accounting schemes in a constraints-based manufacturing environment. This study utilized a scenario experiment where human participants made production decisions based on information provided, both operational and financial. Although this was a novel approach to introducing 'real' human decision making into the simulation game model, it had a number of limitations due to its nature. First, because of time constraints and the attention span of participants, the simulation could only be run in two iterations, one without the accounting information and one with the accounting information. Even then, the two or three hours needed to play the game precluded most of the operations and accounting professionals originally targeted for the study.

In the end, a group of 159 participants, including 15 industry professionals, was assembled mainly from accounting undergraduate and graduate students. Since time only allowed for two iterations of the game, it was difficult to determine whether improvements in system performance are due to improved decision making or simply to the learning curve of the game itself. In the end, the author notes that the variability introduced by allowing human subjects, from many backgrounds and experience levels, the freedom to make decisions tends to limit the conclusions that can be drawn form the results. The author suggests that future research would add controls to limit the decision making alternatives; however, this would obviate the purpose of having real human subjects. This conclusion supports the use of integer linear programming in conjunction with the simulation model, which would allow for a realistic decision making process without the inherent variability.

Chapter Three

Research Design

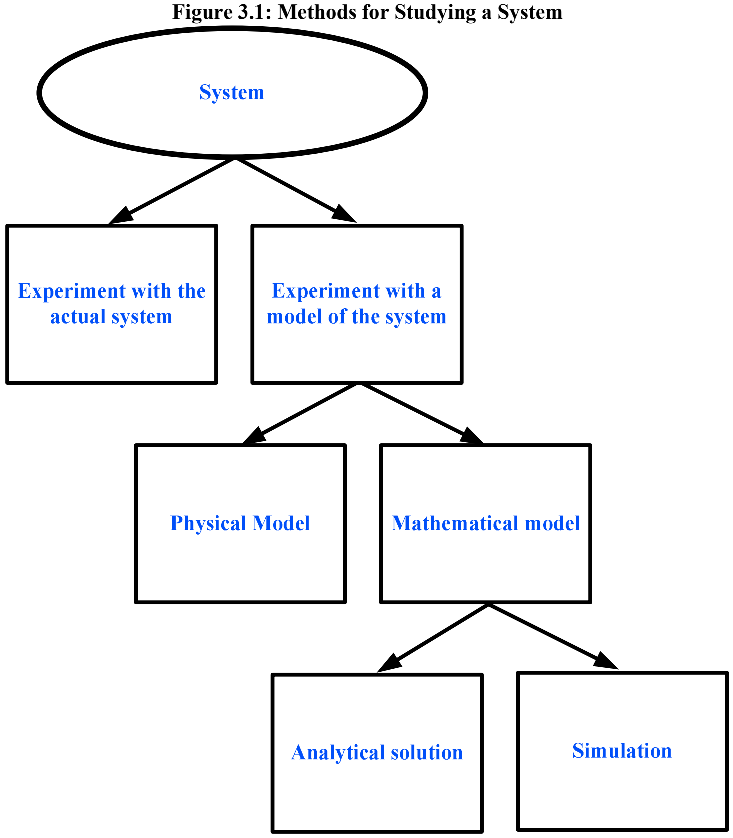
This chapter describes the development of an experimental research design that utilizes a simulation modeling methodology to examine the impact of different MAS alternatives on production decision making and ultimately on manufacturing performance in the context of a TBM strategy. The simulation model is developed and executed within Rockwell Automation Corporation's ARENA software, one of the most powerful commercially available simulation tools on the market today. ARENA is a highly flexible and endlessly reconfigurable tool that allows the research analyst to create an animated simulation model representing virtually any system, build in complex underlying costing and decision logic sub models, and statistically analyze the results of system input modifications.

Increasingly researchers are giving less credence to the pejorative old saw often describing simulation as a 'method of last resort'. In fact, researchers are increasingly looking to simulation methods as a method of first resort, in most cases due to the sheer complexity of systems of interest and the models necessary to represent them in a credible and valid way (Law & Kelton 2000). To observe real manufacturing systems is often very expensive and sometimes cumbersome; a simulation model is an easier way to build up models representing real-life scenarios (Ali et al. 2005).

Despite the fact that simulation is an emergent field of research, it has already become foe of the most widely used in techniques in industrial engineering and operations research. There have been several meta-analytic studies that support this claim. Lane and other (1993) reported that from 1973 through 1988 that simulation was ranked consistently as on of the three most important operations research techniques. The other two were math – a catch all category as simulation is itself a form a modeling – and linear programming. Gupta (1997) analyzed 1,294 papers from 1970 through 1992 in the journal *Interfaces* – one of the leading journals highlighting real world applications of operations research theory – finding simulation only second to 'math' programming out of the 13 research methodologies utilized.

Since the impact of the introduced TBA method of accounting is of primary interest, the scope of this study is limited to experimental methodologies. Law and Kelton (2000) describe the various options to the researcher in terms of experimental methodologies. Figure 3.1 below presents experimental options for studying a system.

Figure 3.1: Methods for Studying a System



Unlike case studies that examine actual companies, simulation studies use hyperphysical companies in purposefully designed experimental environments. The scale, processing times, decision criteria, and other settings are usually carefully designed to examine extreme pathological settings as well as normal settings. Therefore, results from the simulation model demonstrate patterns and trends over a decision space, but managers need to interpret the results carefully to ensure they correspond to their own manufacturing environment (Lea & Fredendall 2002). However, the use of longitudinal data from a single [simulated] plant avoids differences in production functions and other correlated omitted variables that may bias cross-sectional studies (Fisher & Ittner 1999). All other variables can be controlled through the use of simulation, and a sufficiently large sample of outcomes can be obtained to achieve significant comparisons between production systems with differing degrees of variation and levels of stress due to capacity and service constraints (Leitch 2001).

Simulation modeling is becoming a widely used tool in particularly in service operations management studies, where the behavior of human participants in the service system both as servers and customers can be erratic. According to Metters and others (2006), simulation offers several advantages over some more traditional OM techniques such as analytical (mathematical) modeling. One of the biggest advantages is that it allows for the compression of years of experience into just a few seconds or minutes of computer possessing time. While it may take multiple simulation runs and scenarios to evaluate a system, with no guarantee of an optimal solution, the results of simulation modeling are far more general than mathematical models. Although both simulation and mathematical approaches require assumptions, a simulation model can deal with complexity better and a mathematical model affords greater precision (Leitch 2001).

The remainder of this chapter is organized as follows: the first section describes the experimental design, statistical hypotheses, and decision logic foundation of this study. The second section describes the design and parameters of the simulation model and experiment. The third section defines the experimental factors and performance measures used to evaluate the various managerial accounting systems.

Experimental Design

The experimental research design used to address the research questions posed in Chapter 1 includes three experimental factors; the various levels of management accounting system alternatives(MAS), three levels of product mix complexity (MIX), and three levels of manufacturing overhead (MOH). According to Kleijnen (1995) most simulation analysts apply an inferior design of experiments, changing one input at a time as opposed to factorial (2^{K-P}) designs, which controls estimated effects of input changes and shows the importance of interaction effects. For each performance measure the experimental design is a 3 X 3 full factorial with 60 replications, thus resulting in a total of 1620 (3x3x3x6) observations.

The experimental design is then:

$$Y_{aom} = \mu + MAS_a + MOH_o + MIX_m \quad \text{(Main Effect)}$$
$$+ MAS_a * MOH_o + MAS_a * MIX_m + MOH_o * MIX_m \quad \text{(Two-Way Interaction)}$$
$$+ MAS_a * MOH_o * MIX_m \quad \text{(Three-Way Interaction)}$$
$$+ e_{aom}$$

Where: Y_{aom} = Performance Measurements

μ = Mean Effect

MAS_a = Management Accounting System Effect, a = 1, 2, 3
MAS_1 = TCS
MAS_2 = ABC
MAS_3 = TBA

MOH_o = Manufacturing Overhead Level Effect, o = 1, 2, 3
MOH_1 = Low
MOH_2 = Medium
MOH_3 = High

MIX_m = Product Mix Complexity Effect, m = 1, 2, 3
MIX_1 = Narrow
MIX_2 = Medium
MIX_3 = Wide

e_{aom} = Random Effect

Statistical Hypotheses

Research Questions		**Null Hypotheses**
RQ1: Does the use of different managerial accounting systems in production decisions result in differences in average demand fulfillment rate, cycle-time, and/or net operating income?	→	**$H_0$1**: The use of different managerial accounting systems has no effect on average demand fulfillment rate, cycle-time, and/or net operating income.. $MAS_a = 0$
RQ2: What effect does manufacturing overhead level have on average demand fulfillment rate, cycle-time, and/or net operating income?	→	**$H_0$2**: Manufacturing overhead level has no effect on average demand fulfillment rate, cycle-time, and/or net operating income. $MOH_o = 0$
RQ3: For a given level of manufacturing overhead level does the use of different managerial accounting systems in production decisions result in differences in average demand fulfillment rate, cycle-time, and/or net operating income?	→	**$H_0$3**: The use of different managerial accounting systems has no effect on average demand fulfillment rate, cycle-time, and/or net operating income for a given level of manufacturing overhead. $MAS_a * MOH_o = 0$
RQ4: What effect does product mix complexity have on average demand fulfillment rate, cycle-time, and/or net operating income?	→	**$H_0$4**: Product mix complexity has no effect on average demand fulfillment rate, cycle-time, and/or net operating income. $MIX_m = 0$

RQ5: For a given level of product mix complexity does the use of different managerial accounting systems in production decisions result in differences in average demand fulfillment rate, cycle-time, and/or net operating income?

→

$H_0$5: The use of different managerial accounting systems has no effect on average demand fulfillment rate, cycle-time, and/or net operating income for a given level of product mix complexity.

$$\mathbf{MAS_a * MIX_m = 0}$$

RQ6: For a given level of product mix complexity does manufacturing overhead level affect result in differences in average demand fulfillment rate, cycle-time, and/or net operating income?

→

$H_0$6: Manufacturing overhead level has no effect on average demand fulfillment rate, cycle-time, and/or net operating income for a given product mix complexity.

$$\mathbf{MOH_o * MIX_m = 0}$$

RQ7: For a given level of product mix complexity and a given level of manufacturing overhead level does the use of different managerial accounting systems in production decisions result in differences in average demand fulfillment rate, cycle-time, and/or net operating income?

→

$H_0$7: The use of different managerial accounting systems has no effect on average demand fulfillment rate, cycle-time, and/or net operating income for a given level of product mix complexity and a given manufacturing overhead level.

$$\mathbf{MAS_a * MOH_o * MIX_m = 0}$$

Experimental Factors

The three **managerial accounting system (MAS)** alternatives investigated in the simulation model are a traditional costing system (TCS), activity-based costing (ABC), and time-based accounting (TBA). Figure 3.2 below summarizes the product and period cost classifications under these various MAS alternatives:

Figure 3.2: Product and Period Cost Classifications by MAS

Cost Classification		Amount			ABC	TBA	TCS
Manufacturing Direct:							
Direct materials		Varied with production volume and collected from simulation			P (actual cost)	P (actual cost)	P (actual cost)
Direct labor					P (actual cost)	P (actual cost)	P (actual cost)
Depreciation (machinery)					P (actual cost)	P (actual cost)	P (actual cost)
Manufacturing Overhead Costs:		**LOW**	**MED**	**HIGH**			
Depreciation (other)		12,000	18,000	24,000	P [1]	throughput time)	MOH (by labor hours)
Data entry		2,200	4,400	8,800	P [1]	throughput time)	MOH (by labor hours)
Cost analysis		4,800	7,200	9,600	P [1]	throughput time)	MOH (by labor hours)
Production engineering		3,200	4,800	6,400	P [1]	throughput time)	MOH (by labor hours)
Scheduling		2,200	3,300	4,400	P [1]	Period cost	Period cost
Quality control		1,340	1,444	1,653	P [2]	throughput time)	MOH (by labor hours)
Production supervision		4,200	6,300	8,400	P (time/product)	throughput time)	MOH (by labor hours)
Utilities		4,500	6,750	9,000	P (actual usage)	throughput time)	MOH (by labor hours)
Miscellaneous		1,000	1,000	1,000	P (sales volume)	throughput time)	MOH (by labor hours)
Selling, General, & Adminsitrative							
R&D - Basic				1,200	P (time/product)	Period cost	Period cost
Customer support				7,400	P [3]	Period cost	Period cost
General administration				3,000	P (sales volume)	Period cost	Period cost
Advertising costs - general				1,200	P (sales volume)	Period cost	Period cost
Advertising costs - product	A			1	P (actual cost)	Period cost	Period cost
	B			2	P (actual cost)	Period cost	Period cost
	C			4	P (actual cost)	Period cost	Period cost
Commision	A			5	P (actual cost)	Period cost	Period cost
	B			10	P (actual cost)	Period cost	Period cost
	C			20	P (actual cost)	Period cost	Period cost

The first column identifies the common manufacturing and selling, general, and administrative (SG&A) activities. The second column shows the cost associated with each activity followed by the classification and basis for absorption under each of the

MAS alternatives. These classifications are consistent with prior research (Brimson 1991, O'Guin 1991, Low 1992, Lea & Fredendall 2002).

As discussed in the literature review in Chapter 2, manufacturing activities such as raw material purchases, direct labor, and direct manufacturing costs, i.e. machine depreciation, are all likely to vary with production volume and are therefore considered variable. These costs will be collected over the course of the simulation runs. Most of the other costs in manufacturing are generally considered fixed or semi-variable in nature, and these make up the classifications of MOH and SG&A. As seen in figure 12 above, the use of different MAS alternatives entails a different treatment of these costs, either as product or period costs. These activities listed are consistent with the activities studied in the literature (Low 1992, Brimson 1991, O'Guin 1991, Lea & Fredendall 2002).

As the main focus of this research is to make a direct comparison of the various MAS alternatives, budgeting and cost control is not of interest in this study. Therefore, in order to simplify the accounting complexity at the end of each period and avoid tracking variances and adjustments, an actual costing methodology is utilized in this research. The accounting period for this study will be set to one month, i.e. 4 weeks, as this is common practice in industry. All performance measures will be collected at the end of each period.

The direct materials, labor, and manufacturing, as well as the ordering costs, are treated as product costs under each MAS. The cost of raw materials is designed to reflect the greater percentage of standardized and non-standardized parts used in high-volume, simple products and low-volume, complex products respectively. Figure 3.3 below outlines the costs for the individual parts used in this study.

Figure 3.3: Material Purchase Prices

Item No.	Associated with Product(s)	Cost/Unit
110	B & C	$ 20
220	A & B	$ 10
230	C	$ 25
240	C	$ 25
250	C	$ 25
260	C	$ 25

Brimson (1991) indicates that manufacturing overheads are frequently accumulated by department and then allocated to products using a predetermined allocation rate. In this study, TCS and TBA will allocate these costs based on the percentage of total direct labor hours and total cycle-time to each product class respectively. ABC, on the other hand, treats all costs as product costs, attempting to fully allocate all overhead costs by their individual actual activity drivers. Since it is rarely possible to accurately trace 100% of MOH to specific activity drivers and then allocate it to specific products by those drivers (Vokurka & Lummus 2001, Kaplan & Anderson 2004), miscellaneous MOH will be allocated by a single generic basis, the measure of an individual product class' percentage of total production volume.

Under TCS and TBA all SG&A are treated as period costs, i.e. expensed within the period the actually occur. Under ABC, these costs are also treated as product costs and are allocated to the product classes by their individual activity drivers. Again, because it is nearly impossible, in most cases, to accurately trace all overhead costs to individual activity drivers, general administrative costs are allocated by a single generic basis, the measure of an individual product class' percentage of total production volume.

Under ABC, for the sake of simplicity and generalizability, it is necessary to make certain assumptions in the cost model. It is assumed in this experiment that all the activities shown in figure 12 are primary activities that already reflect all the costs of any secondary activities. Following a similar methodology as Lea & Fredendall (2002) and Lea & Min (2003), the following formula is used to absorb the manufacturing overhead costs to an individual product:

$$R_{k,i} = C_k \frac{Q_i * N_i}{\sum_{i=1}^{m} Q_i * N_i} \qquad [P1]$$

Where: $R_{k,i}$ - amount of cost k allocated to product i, i = 1, 2, 3;
C_k - k = 1 (finished goods storage), 2 (depreciation), 3 (data entry), 4 (cost analysis), 5 (production engineering), 6 (scheduling)
Q_i - production quantity of product i
N_i - total number of parts in product i
m - number of products, m = 3

Quality control costs per period include prevention, appraisal, and internal failure costs. For the purposes of this study, it is assumed that all products passing inspection are good products and therefore the external cost of failure is irrelevant. The activity driver associated with quality control under ABC is the actual number of occurrences weighted by a product's predetermined quality multiplier. The multiplier is selected to reflect the average time needed to inspect and either repair or reject the final product. The following formula is used to absorb the cost of quality control to an individual product:

$$X_i = Quality\ Cost * \frac{A_i * AQ_i}{\sum_{i=1}^{m} \left(A_i * AQ_i\right)} \qquad [P2]$$

Where:

X_i - quality control cost allocated to product i

AQ_i - number of defects for product class i

A_i - quality multiplier for product i

m - number of products, m = 3

Customer support is the general cost of providing service to customers after the sale, and this cost varies by product classification. Similar to the quality control costs, the activity driver associated with service under ABC is the actual number of occurrences weighted by a product's predetermined service multiplier. The multiplier is selected to reflect the average time needed to service a customer by product class. The following formula is used to absorb the service costs to an individual product:

$$X_i = Service\ Cost * \frac{B_i * AQ_i}{\sum_{i=1}^{m} \left(B_i * AQ_i\right)} \qquad [P3]$$

Where:

Y_i - service cost allocated to product i

BQ_i - actual service calls for product class i

B_i - service multiplier for product i

m - number of products, m = 3

Ever rising **manufacturing overhead levels (MOH)** have long been considered the primary amplifier of cost distortion and have led to the development of ABC. If manufacturing overhead were a negligible portion of total product cost, misapplication of manufacturing overhead would not be a concern (Ruhl & Baily 1994). However, this does not reflect reality, as MOH has grown to become the single largest product cost component in most modern manufacturing plants. In general, the higher the overhead rate for a company, the greater the amplification of the difference in costs between TCS and ABC approaches. Likewise, the lower the overhead level, the smaller the cost difference between TCS and ABC. Vokurka & Lummus (2001) show an example where the same product manufactured in two different plants with differing levels of overhead burden is costed significantly different under TCS and ABC as the overhead burden increases from 6% to 40% of cost. The difference in product cost between the two MAS alternatives was only 4.1% in the former and 26.1% in the latter.

ABC has been purported to be an overall better manufacturing overhead allocation technique, but many management accounting researchers believe that this is largely contingent upon the percentage of MOH in total production costs and the percentage of that which can be allocated by specific activities or cost drivers. Per Vokurka & Lummus, companies above a certain ratio of overhead to total cost may benefit from adopting ABC; however, it may not be wise for a company with a low overhead burden or a single product line to adopt ABC because of the cost of implementation. The higher the percentage of MOH not allocated by assigned activities, the more the allocation will reflect what could have been calculated through an existing TCS. As a general guideline, the authors suggest that at least 70-75% of total overheads should be assigned by specific activities if ABC is to provide real value in decision making over TCS.

The Vokurka & Lummus study suggests that MOH begins to drive significantly different product costing under TCS and ABC at levels greater than 15%. Using a similar methodology, total MOH burden will be set at three levels – low (roughly 10 %), medium (roughly 20%), and high (roughly 40%). As in the aforementioned study, any statistically significant trend towards greater cost distortions will be assumed to continue as MOH percentage increases.

Product mix complexity (MIX) is defined as the breadth of different products – with varying levels of width in the bill of materials (BOM) for each product – produced at one factory, i.e. narrow, medium, or wide. Product mix complexity has been generally acknowledged as one of the primary drivers of manufacturing cost and a primary cause of cost distortions (Kaplan 1983, Cooper 1988a). Product mix complexity will be examined via three different products under differing levels of demand variability. The three products examined are (A) a high volume product with a narrow BOM structure, (B) a mixed volume product with a mixed BOM structure, and (C) a low volume product with a wide BOM structure.

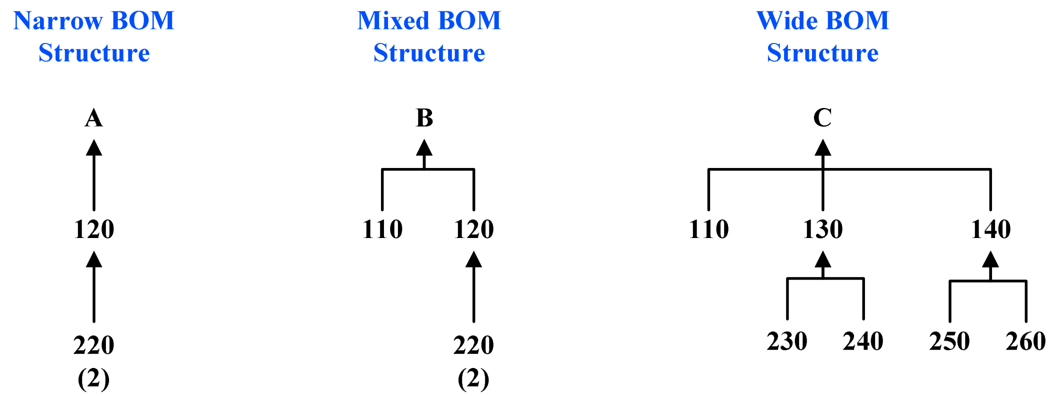
It is not uncommon in today's competitive environment for a firm's product line to contain a mix of both high and low volume products produced within a single facility. In most cases, the high volume products tend to have a steady demand, utilize cheaper standardized parts, require little marginal overhead support, and traditionally have had lower profit margins reported under TCS. Alternatively, low volume products tend to have higher demand variation, utilize more expensive and specialized parts, require a great deal of overhead support, and traditionally have had higher profit margins under TCS (Bakke and Hellberg 1991). The three products examined in this study are designed to reflect these characteristics in both their demand variability and BOM structures. Figure 3.4 below summarizes the characteristics of the products used in this study:

Figure 3.4: Product Characteristics

	A	B	C
Volume	High	Medium	Low
Demand variation	Low	Medium	High
Overhead usage	Low	Medium	High
Main type of parts used	Standard	Mixed	Non-Standard
Profit margin under TCS	Low	Medium	High

Based on the literature review in Chapter 2, the BOM levels in this study are set two levels. This treatment is consistent with the Lea and Fredendall (2002) study. The mix of differing levels of BOM structure is designed to examine the frequent claims in the management accounting literature that high-volume, simple products often subsidize low-volume, complex products under TCS. As discussed previously in the literature review in Chapter 2, traditionally, high-volume products typically are allocated a greater share of manufacturing overhead than what they marginally drive. This is due mainly to the use of volume measures such as direct labor hours or machine hours. Conversely, low-volume products often bear a share of manufacturing overhead burden considerably less than what they marginally contribute (Johnson 1991 & 1992, Chalos 1992). Figure 3.5 below shows the BOM structures of the product produced in this study:

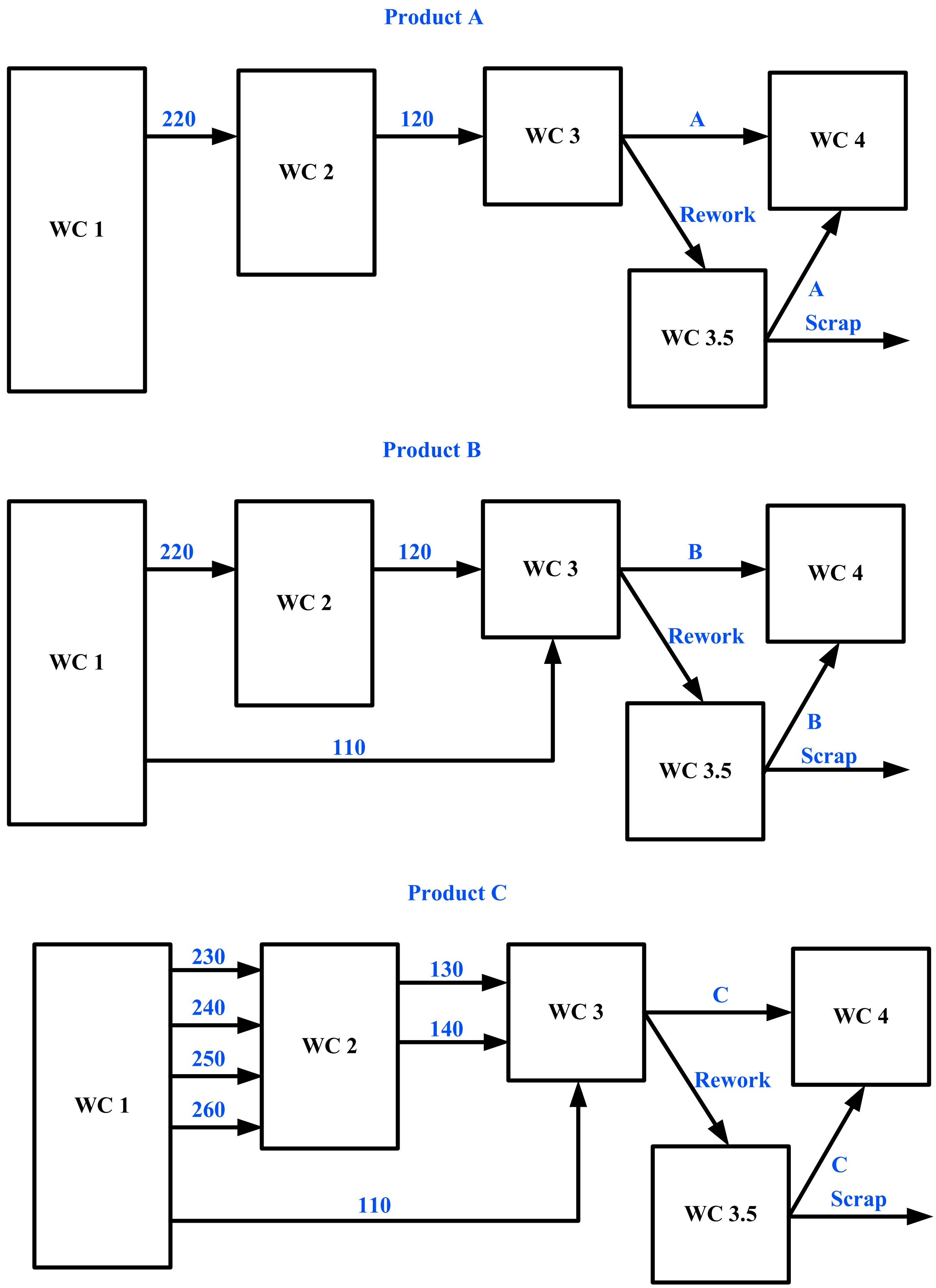
Figure 3.5: BOM Structure by Product



For the purposes of this study, we assume that the market is nearly perfectly competitive, i.e. there are many producers and sellers and total industry capacity is roughly equal to total demand. In this scenario, prices are market driven and any individual firm cannot affect the overall market price. In economic terms, the firm is a 'price taker'. The selling price in this study is set at $100 for product A, $160 for product B, and $360 for product C. However, at a micro level the individual firm operates in a constrained environment where it has insufficient production capacity to meet its individual market demand. Demand not satisfied by the individual firm is immediately lost to other firms in the market. In this environment variations in product cost caused by different MAS alternatives my result in different product mix decisions that in turn lead to different manufacturing performances (Bakke and Hellberg 1991).

The plant routings for the three products are can be seen in figure 3.6 below:

Figure 3.6: Product Routings



Performance Measures

The impact of MAS alternatives on manufacturing performance is evaluated using both internal and external criteria. The internal system performance measurement is the average throughput time and capacity utilization rate. The primary external system performance measure is net operating income.

Demand Fulfillment Rate is the primary customer service measure used in this study. It is defined as the percentage of demand for the three individual products that is accepted for production. It has been used in similar simulation studies (Lea & Min 2003, Lea & Fredendall 2002). This represents one of two non-financial measures for manufacturing performance and the primary market measure used in this study.

Cycle-Time is the primary measure of success for a time-based competitor (Koufteros 1998). In the case of a time-based competitor, the resource usage to be minimized is time itself – throughput time in manufacturing terms. Throughput time is the ultimate measure of performance for the time-based competitor, and that is determined by how well an organization is able to move materials to, through, and off the shop floor into finished goods inventory and how well that organization is able to minimize finished goods (Fry et al. 1993). Time-based manufacturing is an externally focused production system that emphasizes quick response to changing customer needs. Its primary purpose is to reduce end-to-end time in manufacturing (Stalk & Hout 1990, Blackburn 1991, Koufteros 1998).

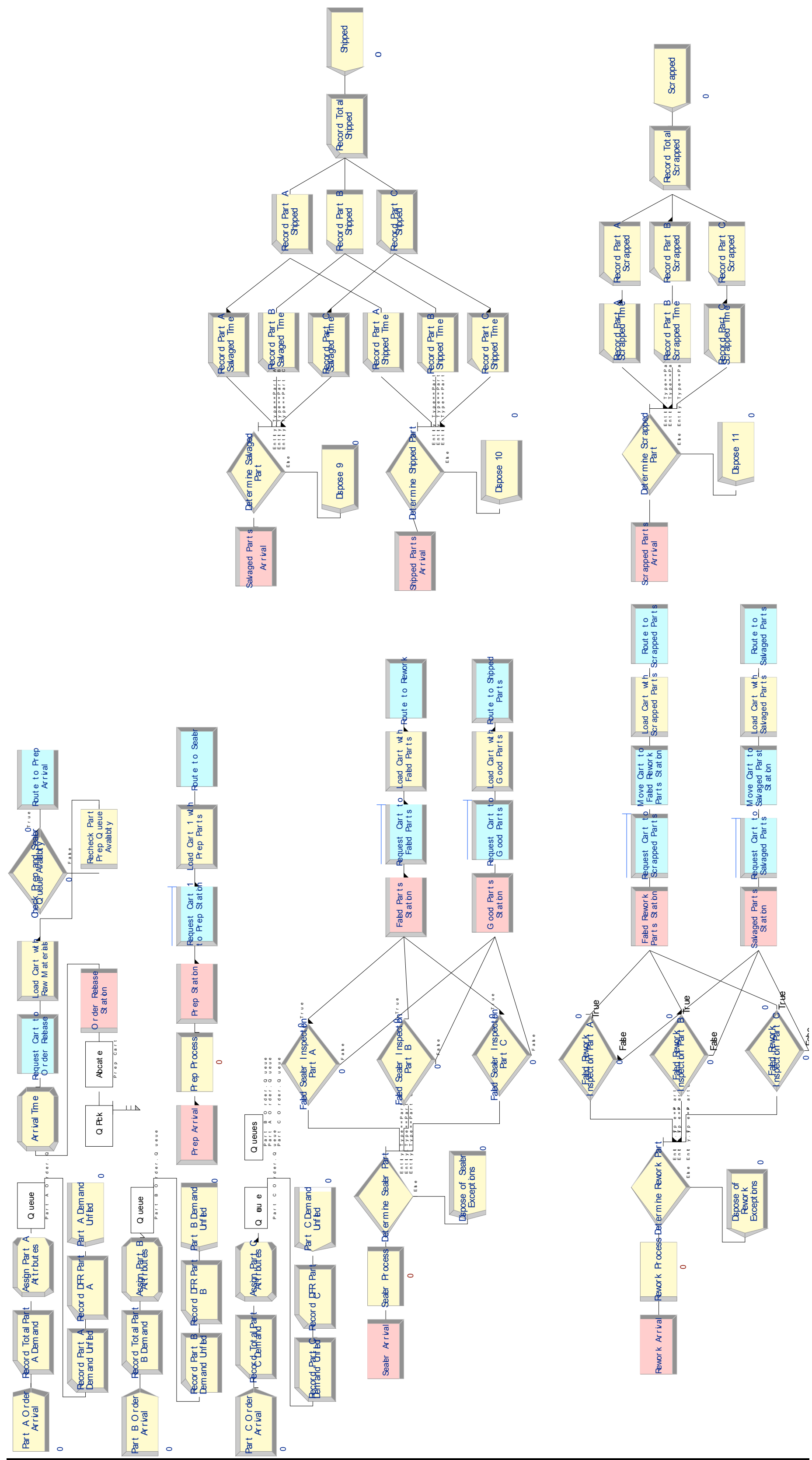
Net operating income (NOI) is utilized often in the accounting literature to measure performance (Bakke & Hellberg 1991, Low 1992, Dugdale & Jones 1996, Lea & Fredendall 2002, Lea & Min 2003). Regardless of industry type or manufacturing environment, NOI is the bottom line for most organizations and certainly for publicly-held companies. For the purposes of this study, regardless of MAS alternative, NOI is defined as revenues or sales from operations for the accounting period less all operating expenses, including CGS and SG&A. As this study will simulate a make-to-order shop, i.e. with no stocking on finished goods inventory, there is no concern for short-term timing differences between the various MAS alternatives under examination.

Chapter Four

Simulation Design

This study will utilize a modified version of ARENA's existing "Electronic Assembly and Test System with Part Transfers" as a baseline model. The final model used for data generation is shown in figure 4.1 below. This system represents the final operations of the production of different sealed electronic units. The arriving parts are cast metal cases that have already been machined to accept the electronic parts. In the prep area, the cases are machined to ensure a good seal, after which they are deburred, cleaned, and transferred to the sealer. At the sealer operation the electronic components are inserted, the case is assembled and sealed, and the sealed unit is then sent to bet quality control tested. At quality control testing the finished part either passes directly to finished goods to be shipped or is rejected and rerouted to the rework station. After rework, the part is again tested to ensure quality and is either passed, routed to finished goods inventory, and shipped or rejected for a second time and scraped.

Figure 4.1: Simulation Model



The decision logic sub model in ARENA will utilize the following maximization formulation, which includes all constraints for the resources and market demand, in order to determine optimal product mix for the master production schedule:

$$\text{Maximize } Z = \sum_{j=1}^{n} c_j^{l,k} x_j$$

$$Z = \sum_{j=1}^{n} a_{ij} x_j \le b_i \quad i = 1, 2, 3, \ldots, m \qquad \text{(Resource/ Capacity Constraint)}$$

$$x_j \le d_j \qquad \text{For every } j,\ j = 1, 2, 3, \ldots, n \quad \text{(Market Demand Constraint)}$$

$$x_j \ge 0$$

Where:

x_j - is the number of product j produced

b_i - is the maximum amount of resource i available

d_j - is the market demand for product j

a_{ij} - is the amount of resource i required to produce product j

$c_j^{l,k}$ - is the contribution margin of product j, with complexity k, under MAS l

With m + n constraints for this model

Model Assumptions

Based on other simulation studies discussed in Chapter 2, and specifically on the Krawjewski and others (1987) study, the following assumptions are necessary:

1. No preemption of jobs once work has begun
2. No alternative routings
3. Zero setup times
4. Jobs are not split in the shop. All jobs are moved to the next work center or buffer area when the current work center operation is complete.
5. No backorders. Demand that cannot be filled is lost to the perfectly competitive market.
6. The first work center is never starved for work because raw material supply is not constrained.

Technical Details of Simulation Model

Most simulation models can be classified as either terminating or steady state. This is primarily a methodological issue of intent or goal of the study rather than and issue of internal model logic or construction. Kelton and others (2002) define these two classifications of simulation models according to its fitness for purpose. A terminating simulation is one in which the model dictates specific starting and stopping conditions as a natural reflection of how the target system actually operates.

For the purposes of this study, on the other hand, steady-state determination is used for analyzing the results. A steady-state simulation is one in which the quantities to be estimated are defined in the long-run, i.e. over a theoretically infinite time frame. People often assume that a long-run, steady-state simulation is the thing to do. This largely depends on whether the starting and stopping conditions are part of the essence of the research model, in which case a terminating analysis is probably more appropriate.

In principle, the initial conditions of the simulation are not of interest to this research, but even a steady-state simulation has to stop at some point. Each simulation run is in fact truncated, i.e. the simulation run does end. N.B., there is no 'natural' event that occurs within the simulation model to signal the end of one run and the beginning of another. Rather each simulation run has been programmed to end after 3 years. Buffer size between stations is unbounded, i.e. there is no blocking or balking within the system that may cause bias in certain performance measures.

Steady-state determination addresses one weakness, from an analytical perspective. This is the fact that each simulation run begins in the 'empty' or 'idle' state and this may cause statistical bias especially during the transient priming process. From an analytical perspective, it is preferable to initiate the collection of statistical data only after the transition from the priming process to a steady state has been accomplished. According to Pritsker (1986), unless the startup behavior is a focus of the research, the analysis of data under a steady state determination leads to an improved mean estimate for performance measures.

According to Kelton and others (2002), there are several ways to achieve a steady-state determination. One cumbersome method would be to place entities in the system at time 0 and start the model. Another, maybe unrealistic, method would be to run the model for sol long that any bias at the beginning is overwhelmed by the amount of later data. However, a more commonly used procedure for steady state determination of a stochastic process is observing the behavior of the system and only begin statistical accumulation of data after a certain warm-up period. Work center queue lengths are often used as an indicator of steady-state operation, because queue lengths will continue to increase or decrease before reaching a steady state. Several pilot runs may be executed to establish the steady state for each experimental combination. Fortunately, ARENA has a built-in option for steady-state analysis using a specified warm-up period. Every replication of the model starts as it did before – independent and identical, all statistical accumulators are cleared, and the performance metrics only reflect what happened after the warm-up period ended.

Replications and Variance Reduction

One of the key advantages of simulation modeling is the ease with which experimental conditions may be repeated or reproduced. Replication of the simulation model run is used to capture the variance of dependent variable means. The number of replications can be estimated via a formula provided by Pritsker (1986) based on a 90% confidence interval for the variance of sample means.

$$I = [\ (t_{\alpha/2,\ I-1}\ S_x)/g\ ]$$

Where:

- I - number of independent replications
- $t_{\alpha/2,\ I-1}$ - t value with I-1 degrees of freedom
- S_x - sample standard deviation of the dependent variable
- g - half-width confidence interval for the sample mean

The g can be specified in relative terms of σ_x, that is, let $g = v\sigma_x$ for any $v>0$. In this case, I can be computed with knowledge of σ_x (Pritsker 1986: 754). A 90% confidence interval is desired such that μ_x is within ($\overline{X}_I - 0.8\sigma_X$, $\overline{X}_I + 0.8\sigma_X$). Thus, the above equation requires that at least 6 replications be performed, when in fact this study performs 60 replications.

Verification and Validation

Simulation remains a relatively new field for researchers, and unfortunately standards and consensus amongst researchers on the question of verification and validation (V&V) of simulation models remains a fundamental, albeit emergent aspect. In the words of Elmaghraby (1968), "It is well to remember the dictum that nobody solves the problem. Rather, everybody solves the model that she [or she] has constructed of the problem".

According to Law and Kelton (2000: 265,275), one must always keep in mind with any simulation study that the simulation model itself can only be an approximation to an actual system, no matter how much effort is spent on model building. In fact,

> Increasing the validity of a model beyond a certain level might be quite expensive, since extensive data collection may be required, but might not lead to significantly better insight or decisions… There are several techniques for increasing a simulation model's validity and credibility, which include building the model based on existing theory, relevant results from similar simulation studies, and the experience and intuition of the simulation modeler.

Regarding the experience and intuition of the modeler, as Law and Kelton point out, the United States Department of Defense was an early adopter and innovator of simulation techniques. This included strategic analyses of the complex interactions of men, technologies, and tactics in future battles against enemies with technologies and tactics yet to be developed. It is therefore often necessary to build hypotheses based on the researchers experience or intuition, to be substantiated later in a simulation study.

The whole process of simulation modeling research has elements of art as well as science, as articulated by the title of one of the first published text books on simulation *The Art of Simulation* (Tocher 1963). According to Balci (1989),

> Simulation modeling is an art. Give a set of objectives, if ten economists are asked to build a simulation model of the U.S. economy, each one will come up with a model which will produce a different set of results. The differences in the results are considered normal and as expected under the paradigm of the art of modeling… Modeling is an artful balancing of opposites. On the one hand, a model should not exclude the essential elements of the system, and on the other hand, it should not include unnecessary details. Missing an essential element may invalidate model representation. Inclusion of unnecessary details would only make the model unnecessarily complex and difficult to analyze. A model is an abstraction of the reality and it is built for a specific purpose. The level of representativeness of a model must be judged with respect to that purpose.

While there are no perfect solutions to V&V, there is increasing agreement on the broader terminology. V&V in the operations research literature has come to be defined by one of the classic simulation textbooks by Law and Kelton (2000:299) now in its third edition since 1983: "Verification is determining that a simulation computer program performs as intended, i.e. debugging the computer program… Validation is concerned with determining whether the conceptual simulation model (as opposed to the computer program) is an accurate representation of the system under study." Validation determines whether the conceptual simulation model, as opposed to the computer program, is an accurate representation of the system under study. Model formulation is the process by which a conceptual model is envisioned to represent the system under study (Balci 1989). The conceptual model is the model which is formulated in the mind of the modeler (Nance 1981). In a similar vein, Sargent (1991:38) states that:

> The conceptual model is the mathematical/logical/verbal representation (mimic) of the problem entity developed for a particular study, and the computerized model is the conceptual model implemented on a computer. The conceptual model is developed through analysis and modeling phase, the computerized model is developed through a computer programming and implementation phase and inferences about the problem entity are obtained by conducting computer experiments on the computerized model in the experimentation phases.

Kelton and others (2002: 42-43) point out that while no simulation study will follow a cut-and-dried formula, there are few key aspects that need to be addressed:

- *Understand the system*. Whether it exists or not, the simulation analyst must have a down-to-earth feel for what is going on.
- *Be clear about your goals*. Understand what can be learned from the study and expect no more.
- *Formulate the model representation*. What level of detail is appropriate to the goals of the study.
- *Verify the model.* A faithful representation of the conceptual model.
- *Validate the model*. While statistical tests can be carried out here, a good dose of common sense is also valuable.
- *Document what you have done*.

Kleijnen (1995) surveys the literature from several fields using simulation methodologies in research in order to document various approaches to V&V. There are several techniques commonly used in verification of simulation models, and – while individually none is perfect – the author points out that general good programming practice can go a long way in verifying the computer model performs as intended. Borrowing largely from software engineering research, the author suggests: (1) modular programming, (2) checking intermediate simulation outputs through tracing and statistical testing, (3) comparing final simulation results with analytical results, (4) animation.

Assessment of accuracy (i.e. verification and validation) must be done right after completing each phase of a simulation study (Balci 1989). One of the powers of ARENA is that it has the built-in diagnostic capability for verification that can be applied at each stage of the model development. Through this capability, this study applies several of the verification techniques described above to ensure the simulation program performs as intended. Modular programming is used to model this research, utilizing an existing ARENA model as the baseline for this study. In addition, ARENA has the built-in diagnostic capability to self-check intermediate simulation outputs ensuring that all modules are performing as intended.

According to Kelton and others (2002), one easy verification method using ARENA is to allow only a single entity to enter the system and follow that entity to be sure that the model logic and data are correct. This is easily accomplished using the 'step' feature found as a 'run' option on the tool bar. This allows the simulation analyst to advance step-by-step through the simulation modules. The authors also suggest what they term 'performance estimation'. Borrowing the logic of the engineering slide rule, which in an era before calculators and computers represented a relatively quick way for the engineer to check the reasonability of estimates, performance estimation essentially entails logically predicting what the model will do and comparing this to how one entity advances through the system.

Multifaceted and multidisciplinary knowledge and experience are required for a successful simulation study (Balci 1989). Kleijnen makes special note of the power of animation in debugging the program. Face validation is useful as a preliminary approach to validation (Baci 1989). The simulation analyst is most familiar with the corresponding conceptual model, which means they can often easily detect programming errors through dynamic displays. Because ARENA has a very powerful and easy to use animation capability, animation is use to debug the simulation module by module and throughout the simulation assuring face validation. Intermediate simulation outputs are also checked through computer tracing, manual calculation, and statistical testing, module by module, to ensure that orders are created exactly as planned, and that the flow of orders through the shop is correct. When this is done, actual utilization rates are equal to the calculated utilization rates.

Validation of a simulation model posses a unique problem for many researcher. Since a model is an abstraction of reality, we cannot talk about absolute accuracy (Balci 1989). Validation can never be assumed to result in a perfect model, since the perfect model would be the real system itself and, by definition, any model is a simplification of reality (Kleijnen 1995). Kelton and others (2002:119) emphasize that this may be nearly impossible even in instances where a real system exists for comparison.

> Although verification can be very difficult, complete validation (the next activity) can sometimes be almost impossible. That's because validation implies that the simulation is behaving just like the real-world system, which may not even exist. And even if the system does exist, you have to have output performance data from it, as well as convince yourself and other nonbelievers that your model can really capture and predict the events of the real system.

The clear advantages of using a simulation model are that the normal transience present in a real manufacturing environment can be eliminated along with exogenous events and that the same data collection and analysis procedures can be used for each replication. Holding all exogenous inputs constant, several replications of a stochastic model are made to determine the amount of stochastic variability in the model. The unexplained variance between these replications would provide a measure of internal validity (Hermann 1967, Balci 1989). Therefore the internal validity of the simulation model can be assured without further testing.

Hypothesis and construct validation is achieved through careful literature review and analysis to ensure that the treatment effect being measured is caused by experimental factors. Kleijnen (1991) reminds the simulation analyst that the model need only be 'good enough' as determined by the goals of the model. "For example," the author states, "some applications need only relative, not absolute, simulation responses corresponding to different scenarios." Again, based on the goals of this research to directly compare different MAS treatments in the same manufacturing environment, a relatively simple simulation model will be adequate for obtaining meaningful data.

According to Balci (1989) sometimes due to the lack of data, we may not be albe to characterize and input variable or parameter. In this case, a heuristic procedure such as one based on a triangular or beta probability distribution (Law & Kelton 2000) may be used. Kleijnen (1991) agrees, as the system concept implies that the analyst must subjectively decided on the boundary of that system and the attributes to be quantified in the model. He points out that sometimes it is difficult, impossible, or simply undesirable to obtain relevant data, such as in simulation studies of nuclear war, quite fortunately. In such cases, the analyst may show logically that that exact values of input data are not critical. Moreover, in some cases the marginal value of available 'real world' data is *de minimus* in terms of the goals of the study.

Borrowing from all fields of scientific research, Karplus (1983) classifies mathematical models (including simulation models) as ranging from black box (non-causal) model in the social sciences through grey box models in ecology to white box (causal) models in physical sciences. Balci (1989) classifies simulations models broadly as either self-driven or trace-driven. A self-driven (distribution-driven or probabilistic) simulation model is the one which is driven by input values obtained via sampling from probability distributions using random numbers. A trace-driven (or retrospective) simulation model, on the other hand, is driven by input sequences derived from trace data obtained through measurement of the real system.

Again, the uniqueness of this study is that it takes a causal (normative) approach in proposing and testing the impact of a new time-based MAS alternative and then tests the hypothesized relationships with a self-driven simulation model. The author points out that a typical aspect of many white box simulation studies is that the conceptual models are based on common sense and understand of real systems. Two additional techniques proposed by Kleijnen (1991) in validating causal simulation models are animation for face validity (discussed earlier also as a model verification technique) and sensitivity analysis for construct validity.

Models and sub models with unobservable inputs can be subjected to sensitivity analysis in order to determine whether the model's behavior agrees with the judgment and knowledge of the simulation analyst (Kleijnen 1991). Unexpected effects may reveal invalidity (Balci 1989). Sensitivity analysis is a systematic investigation of the reaction of model outputs to drastic changes in model inputs and model structure. An often ignore aspect of simulation studies, the magnitudes of the sensitivity estimates show which inputs are important (Law & Kelton 2000:144). The input/output behavior of the model may be approximated through the meta model:

$$y_i = \beta_0 + \sum_{k=i}^{K} \beta_k x_{ik} + \sum_{k=1}^{K-1} \sum_{k'=k+1}^{K} \beta_{kk'} x_{ik} x_{ik'} + e_i$$

Where:

y_i - denotes the simulation response in replication i

i - the number of simulation replications, i = 1, …, n

k - simulation input, k = 1, …, K. of the K simulation

x_{ik} - the value of simulation input k in combination with i

β_k - the main or first order effect of input k

$\beta_{kk'}$ - the interaction between inputs k and k'

e_i - the approximation error in run i

So this simulation model is valid within a certain area of its inputs only; the area defined as a K-dimensional hypercube formed by the K input ranges. Within that area the simulation model's input/output behavior may vary. The first order meta model presented above is a good approximation of the input/output behavior.

Statistical conclusion validity determines whether the sample size is large enough to detect a treatment effect, and whether a desired alpha level is obtained (Cook & Campbell 1979). As discussed earlier, if the simulation model is carefully programmed and controlled, all treatments and replications are implemented in the same way and independently, the sample size is computed to be large enough to detect treatment effect, then the statistical conclusion validity of the simulation model can be obtained. As concluded by Kleijnen (1991), regardless of developments vis-à-vis V&V techniques, simulation will remains both an art as well as a science.

Chapter Five

Results

This chapter presents the results and statistical analyses of the data collected in the ARENA simulation experiment described previously in Chapter 3. The initial data were downloaded into Excel and then uploaded into SPSS for statistical analysis. After screening the data for missing data and outliers, Multivariate Analysis of Variance (MANOVA) was performed to determine whether or not a factor and/or its interaction is statistically significant in determining overall performance. The results were further analyzed using a more detailed Univariate Analysis of Variance (ANOVA) post-hoc tests. The remainder of this chapter is organized as follows: the first section presents the raw data collection and descriptive statistics, the second section presents the assumption testing for MANOVA, the third section presents the results of MANOVA and individual ANOVOA, the fourth section presents a discussion of the hypothesis testing, and the fifth section discusses the results by experimental factor and its implications for management accounting research and practice.

Raw Data and Descriptive Statistics

As demonstrated in Appendix B, the product costs were first determined in the simulation model by using different management accounting alternatives: traditional costing systems, activities-based costing, and throughput accounting. The product cost data were then input into the integer linear programming (ILP) model to determine the optimal product mix, which was then input into the simulation model for use in the product mix decision. Average performance data were collected for 60 replications of 30 days each for 27 experimental condition groups, representing three different management accounting systems (traditional costing systems, activities-based costing, and time-based accounting), three levels of manufacturing overhead (low, medium, high), and three levels of product mix complexity (low, medium, high) for a total of 1620 data points. Figure 5.1 below show the number of observations by experimental factor.

Figure 5.1: Total Number Between-Subjects Factors

		N
MAS	1	540
	2	540
	3	540
MOH	1	540
	2	540
	3	540
MIX	1	540
	2	540
	3	540

Data Screening and Assumption Tests

Prior to the actual multivariate statistical analysis, the data were screened and its quality assessed. According to Mertler and Vannatta (2002: 25), there are four main purposes for screening data prior to conducting a multivariate analysis. The first of these deals with the accuracy of the data collected, the second deals with missing data and the pattern of missing data, the third deals with assessing the effect of extreme values, i.e. outliers, and finally the fit between the data and the assumptions of the specific procedure must be assessed. Because the data were generated through an ARENA simulation model and manually entered into an Excel spreadsheet for sorting and financial calculations uploading into SPSS, the possibility of researcher error in transferring the data exists. The raw data uploaded into SPSS can be seen in Appendix C. Figure 5.2 below shows that there were in fact no missing data at the time of the initial upload into SPSS. For each dependent variable there are exactly 1620 observations.

Figure 5.2: Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
DFR_2	1620	100.0%	0	.0%	1620	100.0%
CT_2	1620	100.0%	0	.0%	1620	100.0%
NOI_2	1620	100.0%	0	.0%	1620	100.0%

A visual review of the data prior to uploading into SPSS revealed no missing data, and any unrealistic values were checked against the original ARENA data reports and corrected as necessary. With regards to the accounting calculation for net operating income (NOI), there were occasional offsetting extreme values between replications (accounting periods) due simply to timing differences. In these instances, which numbered no more than three instances per experimental condition group, the extreme values were replaced with the average net value of the two points.

Multivariate outliers consist of unusual combinations of scores on two or more variables and are often subtle and more difficult to detect than univariate outliers. Therefore, the univariate outliers were identified for each group using box plots and stem and leaf plots. Univariate outliers are defined as cases with unusual or extreme values one or both ends of the a sample distribution. There are three fundamental causes for outliers: 1) data entry errors were made by the research, 2) the subject is not a member of the population for which the sample is intended, or 3) the subject is simply different from the remainder of the sample (Tabachnick & Fidell 1996).

It is important to note that both ANOVA and MANOVA are robust to moderate violations of normality, provided the violation is created by skewness and not by outliers (Tabachnick & Fidell 1996). The real danger of outliers is that they can significantly distort the results of statistical tests, due to the fact that many statistical procedures rely on squared deviations from the mean (Aron & Aron 1997). Therefore, an observation falling far from the rest of the distribution mean could potentially exert a great deal of influence on the results of the statistical test. A single outlier, if extreme enough, according to Mertler and Vannatta (2002: 27), could influence a false significance or insignificance as well as seriously affect the values of correlation coefficients.

Appendix B presents the results of the univariate outlier screening for each dependent variable within each group. Univariate outliers can be detected by means of graphical methods (Tabachnick & Fidell 1996). Since the number of outlying cases for each variable in each group was fairly small, i.e. less than 5 in all groups, and the sample size is relatively large, i.e. 60 replications, the outliers can either be deleted or altered to a value that is within the extreme value of the tail of the accepted distribution (Mertler & Vannatta 2002: 40). In order to ensure the equality of sample size between experimental condition groups, and robustness to minor violations of normality and homoscedasticity, the latter option was chosen.

There are three general assumptions of multivariate statistical testing. The first of these assumptions is that of a normal sample distribution. Prior to examining multivariate normality, one should first assess univariate normality (Mertler & Vannatta 2002: 30). Multivariate normality is a difficult concept to describe, much less to test. Suffice to say, normality on each of the variable separately is a necessary condition for multivariate normality to hold (Stevens 1996: 245). According to Mertler & Vannatta (2002: 31) characteristics of multivariate normality include:

1. Each of the individual variables is normally distributed;
2. Any linear combination of the variables is normally distributed; and
3. All subsets of the set of variables, i.e. every pairwise combination, have a multivariate normal distribution (bivariate normality).

Moreover, because data were collected for 60 replications for each of the 27 experimental groups (3 experiment factors with 3 levels each), there are a total of 1,620 data points utilized for this analysis. With equal or unequal samples sizes and only a few DVs, a sample size of 20 in the smallest cell should be sufficient to ensure robustness to violations of univariate and multivariate normality (Mertler & Vannatta 2002: 124) Therefore, given equal sample sizes of 60 in each group, normality may be assumed under the central limit theorem.

Univariate normality refers to the extent to which all observations in the sample for a given variable in a given group are distributed normally. Among the non-graphical test that can be used are the chi-square goodness of fit and the Kolmogorov-Smirnov test. The chi-square test suffers from the defect of depending on the number of intervals used for the grouping. Therefore, the Kolmogorov-Smirnov statistic with Lilliefos significance level was utilized to test univariate normality for each dependent variable in each group. The Kolmogorov-Smirnov statistic tests the null hypothesis the population is normally distributed and an associated significance level serves as an indication that the variable is not normally distributed (Mertler & Vannatta 2002: 30). Appendix C presents the Kolmogorov-Smirnov test statistics for each variable in each experimental condition group, with insignificance in all cases indicating normality of distributions.

The second assumption, linearity, presupposes that there is a straight line relationship between any two variables. It is a critical assumption in multivariate analyses due to the fact that many of the techniques are based on linear combinations of the variables. The Pearson correlation coefficient (*r*) is the most commonly used bivariate correlation technique, measuring the association between two quantitative variables. Figure 5.3 below shows significance of this measure for all bivariate combinations of the dependent variables, indicating a significant linear relationship.

Figure 5.3: Correlations

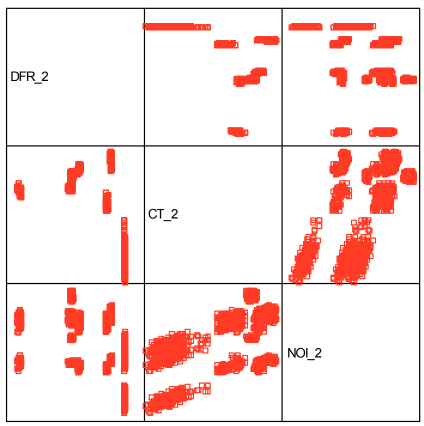
		DFR_2	CT_2	NOI_2
DFR_2	Pearson Correlation	1	-.578**	-.406**
	Sig. (2-tailed)	.	.000	.000
	N	1620	1620	1620
CT_2	Pearson Correlation	-.578**	1	.590**
	Sig. (2-tailed)	.000	.	.000
	N	1620	1620	1620
NOI_2	Pearson Correlation	-.406**	.590**	1
	Sig. (2-tailed)	.000	.000	.
	N	1620	1620	1620

**. Correlation is significant at the 0.01 level (2-tailed).

The final assumption of homoscedasticity is that the variability in scores for one continuous variable will be roughly the same across all values of another continuous variable. This concept is analogous to the univariate assumption of homogeneity of variance. Homoscedasticity is closely related to the assumption of normality, because if the assumption of multivariate normality is met, two variables must be homoscedastic (Tabachnic & Fidell 1996). Although subjective in nature, homoscedasticity is sometimes best assessed through the examination of bivariate scatterplots.

Figure 5.4 below presents the bivariate scatterplots for the three dependent variables. The output four the three dependent variables indicates a non-elliptical shapes between DFR_2 and the other two variables CT_2 and NOI_2. The bivariate scatterplots between CT_2 and NOI_2, on the other hand, show a somewhat elliptical pattern. Sine the use of bivariate scatterplots is fairly subjective in examining linearity (Mertler & Vannatta 2002: 55), we will not place reliance on this test. However, reliance can be placed on the Pearson's correlation coefficients above, indicating that a linear relationship does indeed exist.

Figure 5.4: Bivariate Scatterplots



In multivariate cases, homoscedasticity may be assessed statistically using Box's M test for equality of variance-covariance matrices. This test evaluates the hypothesis that covariance matrices are equal, and if the observed significance level for the Box's M test is small, i.e. $p<.05$, one should reject H_0. Highly sensitive to violations of normality, Box's Test should be interpreted with caution (Mertler & Vannatta 2002: 125).

It is important to note that violations of homoscedasticity, similar to a violation of homogeneity in univariate analysis, will not prove fatal to the analysis so long as the linear relationship between the variables can still be established (Tabachnick & Fidell

1996, Kennedy & Bush 1985). Wilk's Lamda is the most commonly reported MANOVA statistic; however, Pillai's Trace statistic is most often used in instances where homogeneity of variance-covariance is in question (Mertler & Vannatta 2002: 125). Box's test in figure 5.5 below is significant, so Pillai's Trace statistic will be used in evaluating the multivariate tests.

Figure 5.5: Box's Test of Equality of Covariance Matrices

Box's M	5136.282
F	32.294
df1	156
df2	1173890
Sig.	.000

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept+MAS+MOH+MIX+MAS * MOH+MAS * MIX+MOH * MIX+MAS * MOH * MIX

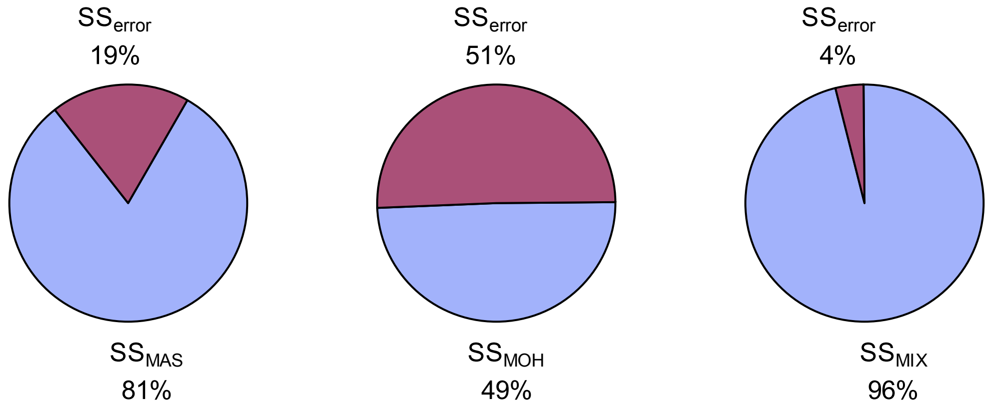
MANOVA Results

The collected experimental data were first analyzed using a factorial MANOVA procedure. This analysis is meant to determine if the combination of dependent variables – the performance measures discussed in Chapter 3: demand fulfillment rate (DFR_2), average cycle time (CT_2), and net operating income (NOI_2) – is significantly effected by the independent variables. The experimental factors, discussed in Chapter 3, include management accounting system (MAS), product mix complexity (MIX), and manufacturing overhead levels (MOH). As shown in figure 24 below, the treatment effects are all significant as are all the bivariate interactions. Moreover, the effect sizes are generally very high.

Measures of effect size in MANOVA and ANOVA are measures of the degree of association between the effect, either the main effect or any interactions, and the dependent variable(s). It is the proportion of variance in the dependent variable that is attributable to each effect. There are several commonly used measures for effect size, the most common being Eta Squared ($ή^2$) and Partial Eta Squared ($ή_p^2$). One of the problems with $ή^2$ is that the values of each effect are dependent upon the number of other effects an the magnitude of those effects. Partial Eta Squared presents an alternative computation of Eta Squared for each individual effect (Tabachnick & Fidell 1989). Partial Eta Squared is defined as: $ή_p^2 = SS_{effect} / (SS_{effect} + SS_{error})$, and is a standard output in SPSS.

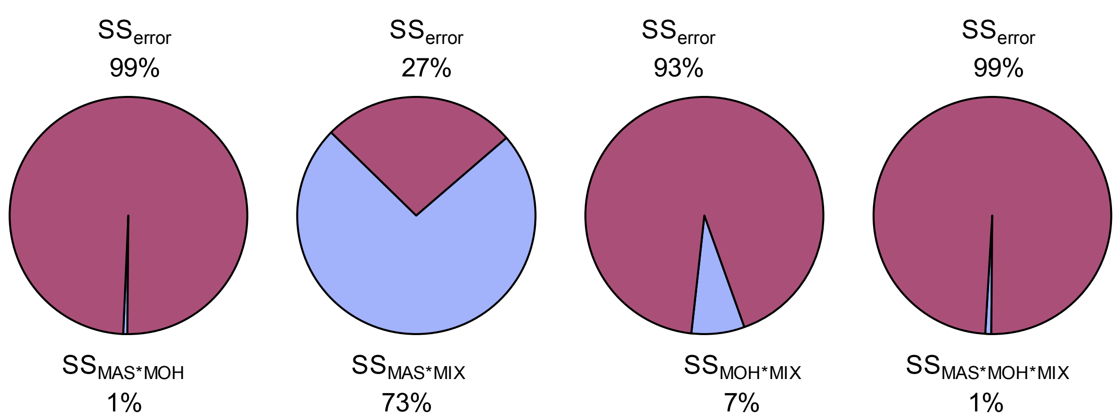
It should be noted that sums are $ή_p^2$ values are not additive, i.e. they do not sum the amount of dependent variable variance accounted for by the independent variables, and therefore it is possible for the sum of $ή_p^2$ values to be greater than zero. The $ή_p^2$ values presented below in figure 5.6 clearly show high effect size for all three experimental factors (main effects), especially for management accounting system and product mix complexity, which explains 81% and 96% of the variability in the dependent variable combination respectively. Manufacturing overhead level was associated with 49% of the variability in the dependent variable combination. Although it is low when compared with the other two main effects, it still shows a high relationship.

Figure 5.6: Partial Eta Squared Values for MAS, MOH, and MIX Effects



The $\acute{\eta}_p^2$ values presented below in figure 5.7 clearly show high effect size for the two-way interaction of management accounting system and product mix complexity and a significant, albeit it rather low, effect size for manufacturing overhead level and product mix complexity. The amount of variance in the dependent variable combination explained by these interactions was 73% and 7% respectively. The two-way combination of management accounting system and manufacturing overhead level as well as the three-way interaction of management accounting system, manufacturing overhead level, and product mix complexity was insignificant with less than 1% in effect size.

Figure 5.7: Partial Eta Squared Values for MAS, MOH, and MIX Interaction Effects



MANOVA results in figure 5.8 below indicate that management accounting system (Pillai's Trace=1.62, $F(6, 3184)=2268.712$, $p=.000$, $ή_p^2=.810$), manufacturing overhead level (Pillai's Trace=.984, $F(6, 3184)=514.306$, $p=.000$, $ή_p^2=.492$), and product mix complexity (Pillai's Trace=1.925, $F(6, 3184)=13603.070$, $p=.000$, $ή_p^2=.962$) significantly affect the combined DV of demand fulfillment rate, average cycle time, and net operating income. In addition, the bivariate combinations of management accounting system and manufacturing overhead levels (Pillai's Trace=0.019, $F(12, 4779)=2.52$, $p=.000$, $ή_p^2=.006$), management accounting system and product mix complexity (Pillai's Trace=2.20, $F(12, 4779)=1095.489$, $p=.000$, $ή_p^2=.733$), and manufacturing overhead level and product mix complexity (Pillai's Trace=0.220, $F(12, 4779)=31.495$, $p=.000$, $ή_p^2=.073$) are all found to significantly affect the combined DV of demand fulfillment rate, average cycle time, and net operating income. However, multivariate effect sizes are small for the combinations of management accounting system and manufacturing overhead level as well as the combination of manufacturing overhead level and product mix complexity. The three-way interaction of management accounting system, manufacturing overhead level, and product mix complexity were not found to have a significant affect on the combined DV of demand fulfillment rate, average cycle time, and net operating income.

Figure 5.8: Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	1.000	23118783.276[a]	3.000	1591.000	.000	1.000
	Wilks' Lambda	.000	23118783.276[a]	3.000	1591.000	.000	1.000
	Hotelling's Trace	43592.929	23118783.276[a]	3.000	1591.000	.000	1.000
	Roy's Largest Root	43592.929	23118783.276[a]	3.000	1591.000	.000	1.000
MAS	Pillai's Trace	1.621	2268.712	6.000	3184.000	.000	.810
	Wilks' Lambda	.001	16101.286[a]	6.000	3182.000	.000	.968
	Hotelling's Trace	370.873	98281.457	6.000	3180.000	.000	.995
	Roy's Largest Root	369.217	195931.096[b]	3.000	1592.000	.000	.997
MOH	Pillai's Trace	.984	514.306	6.000	3184.000	.000	.492
	Wilks' Lambda	.016	3703.096[a]	6.000	3182.000	.000	.875
	Hotelling's Trace	62.719	16620.609	6.000	3180.000	.000	.969
	Roy's Largest Root	62.719	33283.011[b]	3.000	1592.000	.000	.984
MIX	Pillai's Trace	1.925	13603.070	6.000	3184.000	.000	.962
	Wilks' Lambda	.000	83260.044[a]	6.000	3182.000	.000	.994
	Hotelling's Trace	1872.499	496212.261	6.000	3180.000	.000	.999
	Roy's Largest Root	1860.086	987085.721[b]	3.000	1592.000	.000	.999
MAS * MOH	Pillai's Trace	.019	2.552	12.000	4779.000	.002	.006
	Wilks' Lambda	.981	2.566	12.000	4209.682	.002	.006
	Hotelling's Trace	.019	2.579	12.000	4769.000	.002	.006
	Roy's Largest Root	.019	7.702[b]	4.000	1593.000	.000	.019
MAS * MIX	Pillai's Trace	2.200	1095.489	12.000	4779.000	.000	.733
	Wilks' Lambda	.001	5231.569	12.000	4209.682	.000	.913
	Hotelling's Trace	213.949	28342.331	12.000	4769.000	.000	.986
	Roy's Largest Root	210.259	83735.577[b]	4.000	1593.000	.000	.995
MOH * MIX	Pillai's Trace	.220	31.495	12.000	4779.000	.000	.073
	Wilks' Lambda	.780	34.513	12.000	4209.682	.000	.079
	Hotelling's Trace	.282	37.330	12.000	4769.000	.000	.086
	Roy's Largest Root	.282	112.208[b]	4.000	1593.000	.000	.220
MAS * MOH * MIX	Pillai's Trace	.020	1.343	24.000	4779.000	.122	.007
	Wilks' Lambda	.980	1.350	24.000	4614.985	.118	.007
	Hotelling's Trace	.021	1.358	24.000	4769.000	.114	.007
	Roy's Largest Root	.020	4.049[b]	8.000	1593.000	.000	.020

a. Exact statistic

b. The statistic is an upper bound on F that yields a lower bound on the significance level.

c. Design: Intercept+MAS+MOH+MIX+MAS * MOH+MAS * MIX+MOH * MIX+MAS * MOH * MIX

Univariate ANOVA and Scheffé post hoc tests were conducted as follow-up tests. ANOVA results indicate that demand fulfillment rate differs significantly for management accounting system ($F(2, 1593)=290159.67$, $p=.000$, $\acute{\eta}_p^2=.997$), product mix complexity ($F(2, 1593)=1471806.2$, $p=.000$, $\acute{\eta}_p^2=.999$), and the two-way interaction of management accounting system and product mix complexity ($F(2, 1593)=82837.12$, $p=.000$, $\acute{\eta}_p^2=.995$). Average cycle-time differs significantly for management accounting system ($F(2, 1593)=960.591$, $p=.000$, $\acute{\eta}_p^2=.547$), product mix complexity (F(2, 1593)=20756.710, p=.000, $\acute{\eta}_p^2$=.963), and the two-way interaction of management accounting system and product mix complexity (F(2, 1593)=591.132, p=.000, $\acute{\eta}_p^2$=.597).

Net operating income differs significantly for management accounting system (F(2, 1593)=1704.381, p=.000, $\acute{\eta}_p^2$=.682), manufacturing overhead level (F(2, 1593)= 31768.716, p=.000, $\acute{\eta}_p^2$=.976), and product mix complexity (F(2, 1593)=20449.024, p=.000, $\acute{\eta}_p^2$=.963); the two-way interactions of management accounting system and manufacturing overhead level (F(2, 1593)=5.061, p=.000, $\acute{\eta}_p^2$=.013), management accounting system and product mix complexity (F(2, 1593)=679.384, p=.000, $\acute{\eta}_p^2$=.630), and manufacturing overhead level and product mix complexity (F(2, 1593)=71.264, p=.000, $\acute{\eta}_p^2$=.152); and moderately in the three-way interaction of management accounting system, manufacturing overhead level, and product mix complexity (F(2, 1593)=2.49, p=.011, $\acute{\eta}_p^2$=.012).

As expected, manufacturing overhead level had an amplification effect and only significantly affected the performance measure of net operating income. As shown in figure 5.9 below, post-hoc Scheffé tests show significant differences between the three levels of manufacturing overhead and net operating income. This effect presents some interesting implications for management accounting practice, which will be discussed in greater detail in the final section of this chapter. As well, the amplification effect of manufacturing overhead level can be seen on the charts of cumulative net operating income at the very end of this chapter.

Figure 5.9: Net Operating Income Post-Hoc Test

Scheffe[a,b,c]

MOH	N	Subset 1	2	3
3	540	68.81071		
2	540		92.52141	
1	540			98.55130
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 4.201.

a. Uses Harmonic Mean Sample Size = 540.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Manufacturing overhead level did not have a significant impact on demand fulfillment rate ($F(2, 1593)=.038$, $p=.962$, $ή_p^2=.000$) or average cycle-time ($F(2, 1593)=.014$, $p=.986$, $ή_p^2=.000$), nor do any of its interactions significantly affect demand fulfillment rate or average cycle-time. The two-way interactions of management accounting system and manufacturing overhead level have an insignificant impact on demand fulfillment rate ($F(2, 1593)=.056$, $p=.994$, $ή_p^2=.000$) and average cycle-time ($F(2, 1593)=.006$, $p=1.000$, $ή_p^2=.000$). The interactions of manufacturing overhead level and product mix complexity also have an insignificant effect on demand fulfillment rate ($F(2, 1593)=.012$, $p=1.00$, $ή_p^2=.000$) and average cycle-time ($F(2, 1593)=.005$, $p=1.000$, $ή_p^2=.000$). Finally, the three-way interactions of management accounting system, manufacturing overhead level, and product mix complexity had an insignificant affect on demand fulfillment rate ($F(2, 1593)=.057$, $p=1.00$, $ή_p^2=.000$) and average cycle-time ($F(2, 1593)=.008$, $p=1.000$, $ή_p^2=.000$). Figure 5.10 below presents the summary of the between-subjects effects for this model.

Figure 5.10: Test of Between Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	DFR_2	62.838[a]	26	2.417	148280.04	.000	1.000
	CT_2	45262856.302[b]	26	1740879.089	1761.510	.000	.966
	NOI_2	465888.411[c]	26	17918.785	4264.884	.000	.986
Intercept	DFR_2	1053.052	1	1053.052	64607878	.000	1.000
	CT_2	466080178.4	1	466080178.361	471603.69	.000	.997
	NOI_2	12157090.348	1	12157090.348	2893532.4	.000	.999
MAS	DFR_2	9.459	2	4.729	290159.66	.000	.997
	CT_2	1898679.810	2	949339.905	960.591	.000	.547
	NOI_2	14321.816	2	7160.908	1704.381	.000	.682
MOH	DFR_2	1.254E-06	2	6.272E-07	.038	.962	.000
	CT_2	27.157	2	13.578	.014	.986	.000
	NOI_2	266950.628	2	133475.314	31768.716	.000	.976
MIX	DFR_2	47.978	2	23.989	1471806.2	.000	.999
	CT_2	41027206.507	2	20513603.254	20756.710	.000	.963
	NOI_2	171831.926	2	85915.963	20449.024	.000	.963
MAS * MOH	DFR_2	3.661E-06	4	9.152E-07	.056	.994	.000
	CT_2	23.795	4	5.949	.006	1.000	.000
	NOI_2	85.047	4	21.262	5.061	.000	.013
MAS * MIX	DFR_2	5.401	4	1.350	82837.117	.000	.995
	CT_2	2336834.240	4	584208.560	591.132	.000	.597
	NOI_2	11417.652	4	2854.413	679.384	.000	.630
MOH * MIX	DFR_2	7.801E-07	4	1.950E-07	.012	1.000	.000
	CT_2	21.054	4	5.264	.005	1.000	.000
	NOI_2	1197.652	4	299.413	71.264	.000	.152
MAS * MOH * MIX	DFR_2	7.380E-06	8	9.225E-07	.057	1.000	.000
	CT_2	63.738	8	7.967	.008	1.000	.000
	NOI_2	83.690	8	10.461	2.490	.011	.012
Error	DFR_2	2.596E-02	1593	1.630E-05			
	CT_2	1574342.494	1593	988.288			
	NOI_2	6692.942	1593	4.201			
Total	DFR_2	1115.916	1620				
	CT_2	512917377.2	1620				
	NOI_2	12629671.701	1620				
Corrected Total	DFR_2	62.864	1619				
	CT_2	46837198.796	1619				
	NOI_2	472581.353	1619				

a. R Squared = 1.000 (Adjusted R Squared = 1.000)

b. R Squared = .966 (Adjusted R Squared = .966)

c. R Squared = .986 (Adjusted R Squared = .986)

Hypothesis Testing

The specific research questions and corresponding statistical hypotheses were posited previously in Chapter 3. In this section, the results of the univariate testing above are further summarized in relation to these statistical hypotheses. These hypotheses along were as follows:

> **$H_0$1**: The use of different managerial accounting systems has no effect on average throughput-time, demand fill rate, and/or net operating income.

$$\mathbf{MAS_a = 0}$$

As shown in figure 5.10 above, the main factor for the management accounting system was fond to significantly affect all three manufacturing performance measures. Therefore it is necessary to reject **$H_0$1**.

> **$H_0$2**: Manufacturing overhead level has no effect on average throughput-time, demand fill rate, and/or net operating.

$$\mathbf{MOH_o = 0}$$

As shown in figure 5.10 above, the main factor for the manufacturing overhead level was fond to significantly affect net operating income, but not the other two manufacturing performance measures. Therefore it is necessary to accept **$H_0$1** as it relates to demand fulfillment rate and average cycle time and to reject **$H_0$1** in regards to net operating income.

> **$H_0$3**: The use of different managerial accounting systems has no effect on average throughput-time, demand fill rate, and/or net operating income for a given level of manufacturing overhead.

$$MAS_a*MOH_o = 0$$

As shown in figure 5.10 above, the interaction for the management accounting systems and manufacturing overhead level was fond to significantly affect net operating income, but not the other two manufacturing performance measures. Therefore it is necessary to accept $\mathbf{H_0 1}$ as it relates to demand fulfillment rate and average cycle time and to reject $\mathbf{H_0 1}$ in regards to net operating income.

> $\mathbf{H_0 4}$: Product mix complexity has no effect on average throughput-time, demand fill rate, and/or net operating income.

$$MIX_m = 0$$

As shown in figure 5.10 above, the main factor for product mix complexity was fond to significantly affect all three manufacturing performance measures. Therefore it is necessary to reject $\mathbf{H_0 1}$.

> $\mathbf{H_0 5}$: The use of different managerial accounting systems has no effect on average throughput-times, demand fill rates, and/or net operating income for a given level of product mix complexity.

$$MAS_a*MIX_m = 0$$

As shown in figure 5.10 above, the interaction for the management accounting systems and product mix complexity was fond to significantly affect all three manufacturing performance measures. Therefore it is necessary to reject $\mathbf{H_0 1}$.

> $\mathbf{H_0 6}$: Manufacturing overhead level has no effect on average throughput-time, demand fill rate, and/or net operating income for a given product mix complexity.

$$MOH_o*MIX_m = 0$$

As shown in figure 5.10 above, the interaction for the manufacturing overhead level and product mix complexity was fond to significantly affect net operating income, but not the other two manufacturing performance measures. Therefore it is necessary to accept **$H_0$1** as it relates to demand fulfillment rate and average cycle time and to reject **$H_0$1** in regards to net operating income.

> **$H_0$7**: The use of different managerial accounting systems has no effect on average throughput- time, demand fill rate, and/or net operating income for a given level of product mix complexity and a given manufacturing overhead level.

$$\mathbf{MAS_a * MOH_o * MIX_m = 0}$$

As shown in figure 5.10 above, the interaction for the management accounting system, manufacturing overhead level, and product mix complexity was fond to significantly affect net operating income, but not the other two manufacturing performance measures. Therefore it is necessary to accept **$H_0$1** as it relates to demand fulfillment rate and average cycle time and to reject **$H_0$1** in regards to net operating income.

Practical Implications

Because the primary focus of this study is to examine the impact of different management accounting systems – traditional costing systems (TCS), activities-based costing (ABC), and time-based accounting (TBA) – on manufacturing performance in the context of a time-based competitive environment, it is necessary to take a more detailed look at this impact on each individual performance measure. The three performance measures were chosen because they represent both internal and external and financial and non-financial measures of performance. Figure 5.11 below presents a summary of the results in performance measures by management accounting system alternative.

Figure 5.11: Multiple Comparisons by MAS

Scheffe

Dependent Variable	(I) MAS	(J) MAS	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
DFR_2	1	2	-.16799907*	.000245697	.000	-.16860104	-.16739710
		3	-.15545861*	.000245697	.000	-.15606058	-.15485664
	2	1	.16799907*	.000245697	.000	.16739710	.16860104
		3	.01254046*	.000245697	.000	.01193849	.01314244
	3	1	.15545861*	.000245697	.000	.15485664	.15606058
		2	-.01254046*	.000245697	.000	-.01314244	-.01193849
CT_2	1	2	-29.211410*	1.91319765	.000	-33.89883996	-24.52397938
		3	53.468745*	1.91319765	.000	48.78131487	58.15617545
	2	1	29.211410*	1.91319765	.000	24.52397938	33.89883996
		3	82.680155*	1.91319765	.000	77.99272454	87.36758512
	3	1	-53.468745*	1.91319765	.000	-58.15617545	-48.78131487
		2	-82.680155*	1.91319765	.000	-87.36758512	-77.99272454
NOI_2	1	2	-6.3592155*	.124743740	.000	-6.66484388	-6.05358703
		3	-.10501750	.124743740	.702	-.41064593	.20061092
	2	1	6.35921545*	.124743740	.000	6.05358703	6.66484388
		3	6.25419795*	.124743740	.000	5.94856952	6.55982637
	3	1	.10501750	.124743740	.702	-.20061092	.41064593
		2	-6.2541979*	.124743740	.000	-6.55982637	-5.94856952

Based on observed means.

*. The mean difference is significant at the .05 level.

Demand fulfillment rate represents an external (market) non-financial measure of manufacturing performance. It represents the percentage of demand that is ultimately fulfilled by the production system. As presented in figure 5.12 below, the highest performance in terms of this measure was activities-based costing (MAS_2) with a rate of 86.6% of demand filled and time-based accounting (MAS_3) with 85.4% of demand filled. The worst performance was traditional costing systems (MAS_1) with 69.8% of demand filled. Although the difference between ABC and TBA in terms of demand fulfillment rate was statistically significant, from a practical perspective, this difference may not justify the high cost of implementing an ABC system.

Figure 5.12: Demand Fulfillment Rate by MAS

Scheffe[a,b,c]

MAS	N	Subset 1	2	3
1	540	.69842651		
3	540		.85388512	
2	540			.86642558
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 1.630E-05.

a. Uses Harmonic Mean Sample Size = 540.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

As discussed at length in Chapters 1 and 2, the primary non-financial measure of success for a time-based manufacturer is cycle-time, or the total time from receipt of an order to the shipment of the product to the customer. Reducing cycle-time is the primary focus of time-based competition, and is therefore a key internal measure of success. As presented in figure 5.13 below, the best performance was TBA with an average cycle time of 491.00 minute. The second best performance along this key measure was TCS with an average cycle-time of 544.47 minutes, followed by ABC with an average cycle-time of 573.68 minutes.

Figure 5.13: Cycle-Time by MAS

Scheffe[a,b,c]

MAS	N	Subset 1	2	3
3	540	490.9973		
1	540		544.4661	
2	540			573.6775
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 988.288.

a. Uses Harmonic Mean Sample Size = 540.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Net operating income represents the primary internal measure of financial performance. As presented in Figure 5.14 below, the best performance in terms of this performance measure was ABC with an average net operating income of 90.83 (thousands) per accounting period (replication). It should be noted that TBA performed slightly better than TCS over the long run, 84.58 and 84.47 respectively, but the difference was not statistically significant.

Figure 5.14: Net Operating Income by MAS

Scheffe[a,b,c]

MAS	N	Subset 1	2
1	540	84.47306	
3	540	84.57808	
2	540		90.83228
Sig.		.702	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 4.201.

a. Uses Harmonic Mean Sample Size = 540.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

As shown in the figure 5.15 (Tests of Between-Subjects Effects) above, product mix complexity and its combination with management accounting system has a significant affect on all three of the performance measures. As summarized below in figure 31, product mix complexity has a significant impact on all three performance measures.

Figure 5.15: Multiple Comparisons by Product Mix Complexity

Scheffe

Dependent Variable	(I) MIX	(J) MIX	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
DFR_2	1	2	.15082359*	.000245697	.000	.15022161	.15142556
		3	.41631103*	.000245697	.000	.41570906	.41691300
	2	1	-.15082359*	.000245697	.000	-.15142556	-.15022161
		3	.26548745*	.000245697	.000	.26488548	.26608942
	3	1	-.41631103*	.000245697	.000	-.41691300	-.41570906
		2	-.26548745*	.000245697	.000	-.26608942	-.26488548
CT_2	1	2	-352.30321*	1.9131977	.000	-356.990639	-347.615779
		3	-320.63793*	1.9131977	.000	-325.325364	-315.950503
	2	1	352.30321*	1.9131977	.000	347.6157787	356.9906393
		3	31.665276*	1.9131977	.000	26.97784547	36.35270605
	3	1	320.63793*	1.9131977	.000	315.9505030	325.3253636
		2	-31.665276*	1.9131977	.000	-36.35270605	-26.97784547
NOI_2	1	2	-18.783746*	.124743740	.000	-19.08937396	-18.47811711
		3	-23.975737*	.124743740	.000	-24.28136503	-23.67010817
	2	1	18.783746*	.124743740	.000	18.47811711	19.08937396
		3	-5.1919911*	.124743740	.000	-5.49761949	-4.88636264
	3	1	23.975737*	.124743740	.000	23.67010817	24.28136503
		2	5.19199106*	.124743740	.000	4.88636264	5.49761949

Based on observed means.

*. The mean difference is significant at the .05 level.

As presented in figure 5.16 below, product mix complexity has a significant affect on the demand fulfillment rate measure. Average demand fulfillment rate was 99.5% under a love level of product mix complexity and drops to 84.5% under medium level and 57.9% under a high level of product mix complexity.

Figure 5.16: Demand Fulfillment Rate by MIX Level

Scheffe[a,b,c]

MIX	N	Subset 1	2	3
3	540	.57897957		
2	540		.84446702	
1	540			.99529061
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 1.630E-05.

a. Uses Harmonic Mean Sample Size = 540.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

As presented in figure 5.17 below, product mix complexity has a significant affect on the average cycle-time measure. Average cycle-time was 312.1 minutes under a low level of product mix complexity and increases to 632.7 minutes under medium level and 664.4 minutes under a high level of product mix complexity.

Figure 5.17: Cycle-Time by MIX Level

Scheffe[a,b,c]

MIX	N	Subset 1	2	3
1	540	312.0666		
3	540		632.7045	
2	540			664.3698
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 988.288.

a. Uses Harmonic Mean Sample Size = 540.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

As presented in figure 5.18 below, product mix complexity has a significant affect on net operating income. Average net operating income was 72.37 (thousands) under a low level of product mix complexity and increases to 91.16 under medium level and 96.35 under a high level of product mix complexity.

Figure 5.18: Net Operating Income by MIX Level

Scheffe[a,b,c]

MIX	N	Subset 1	2	3
1	540	72.37465		
2	540		91.15839	
3	540			96.35038
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 4.201.

a. Uses Harmonic Mean Sample Size = 540.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Summary of Research Results

This study applied a simulation modeling methodology to examine the impact of different management accounting system alternatives, manufacturing overhead levels, and product mix complexity levels on manufacturing performance measures. The manufacturing performance measures examined included both internal and external as well as financial and non-financial measures of success. These measures were demand fulfillment rate, cycle time, and net operating income. Figure 5.19 below summarizes the results of this study in terms of these three manufacturing performance measures by management accounting system alternative and combined weighted score.

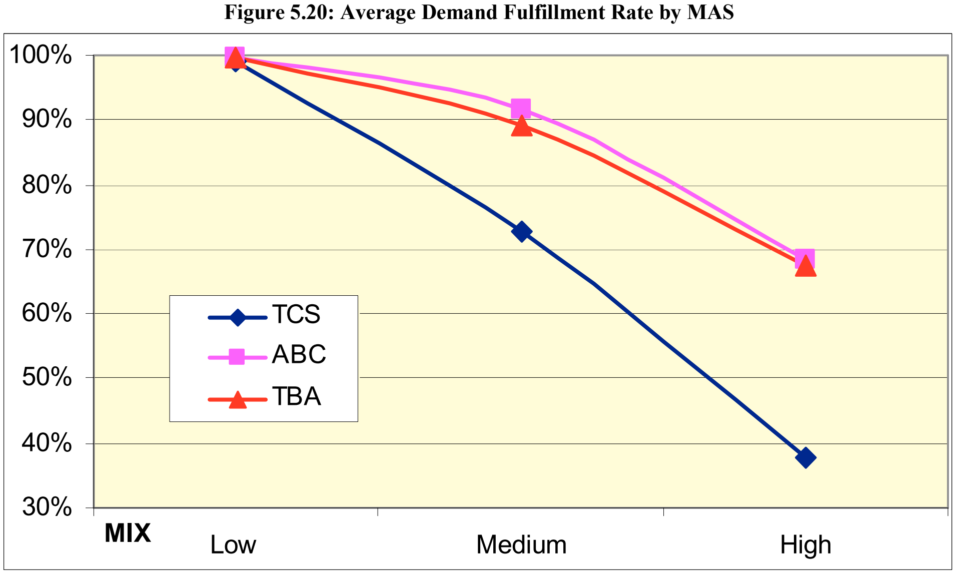
Figure 5.19: Summary of MAS Performance by Experimental Condition Group

MOH Level	MIX Level	Performance Measure: Demand Fulfillment Rate			Cycle Time			Net Operating Income			Combined Weighted Score (Maxium 6)		
Low	Low	1	ABC	99.8%	1	TBA	304.91	1	ABC	86.188	1	ABC	5
		2	TBA	99.6%	2	ABC	305.13	2	TCS	85.660	2	TBA	3
		3	TCS	99.2%	3	TCS	326.38	3	TBA	85.603	3	TCS	2
	Medium	1	ABC	91.6%	1	TBA	549.88	1	ABC	105.922	1	ABC	4
		2	TBA	89.1%	2	TCS	698.46	2	TCS	101.416	2	TBA	3
		3	TCS	72.6%	3	ABC	745.55	3	TBA	101.405	3	TCS	2
	High	1	ABC	68.5%	1	TCS	608.89	1	ABC	115.412	1	ABC	4
		2	TBA	67.5%	2	TBA	619.20	2	TBA	103.579	2	TBA	3
		3	TCS	37.7%	3	ABC	670.13	3	TCS	101.771	3	TCS	2
Medium	Low	1	ABC	99.8%	1	TBA	304.91	1	ABC	78.087	1	ABC	5
		2	TBA	99.6%	2	ABC	305.13	2	TCS	77.803	2	TBA	3
		3	TCS	99.2%	3	TCS	325.38	3	TBA	77.480	3	TCS	1
	Medium	1	ABC	91.6%	1	TBA	548.21	1	ABC	100.462	1	ABC	4
		2	TBA	89.1%	2	TCS	698.46	2	TCS	95.799	2	TBA	3
		3	TCS	72.6%	3	ABC	745.55	3	TBA	95.319	3	TCS	2
	High	1	ABC	68.5%	1	TCS	608.89	1	ABC	112.319	1	ABC	4
		2	TBA	67.5%	2	TBA	619.15	2	TBA	98.462	2	TBA	3
		3	TCS	37.7%	3	ABC	670.13	3	TCS	96.620	3	TCS	2
High	Low	1	ABC	99.8%	1	TBA	304.91	1	ABC	53.781	1	ABC	5
		2	TBA	99.6%	2	ABC	305.46	2	TCS	53.507	2	TBA	3
		3	TCS	99.2%	3	TCS	326.38	3	TBA	53.258	3	TCS	1
	Medium	1	ABC	91.6%	1	TBA	548.88	1	ABC	76.283	1	ABC	4
		2	TBA	89.1%	2	TCS	698.46	2	TCS	72.467	2	TBA	3
		3	TCS	72.6%	3	ABC	745.89	3	TBA	71.352	3	TCS	2
	High	1	ABC	68.5%	1	TCS	608.89	1	ABC	89.038	1	ABC	4
		2	TBA	67.5%	2	TBA	618.94	2	TCS	74.866	2	TCS	3
		3	TCS	37.7%	3	ABC	670.13	3	TBA	74.744	3	TBA	2

The combined weighted score is a composite measure of the three primary manufacturing performance measures, whereby two points are assigned to the best performing management accounting system, one point to the second best performance, no points to the worst performance. Therefore a perfect score of 6 would indicate that the management accounting system scored the highest along all three manufacturing performance measures. As can be seen in figure 5.19 above, no single management accounting system excelled across all three measures, indicating that each alternative has its own limitations in terms of performance that must be considered in decision making. This is an important point to note, especially for management accounting practitioners.

As can be seen in figure 5.20 below, all three management accounting alternatives performed nearly equally well when the product mix complexity (MIX) was low. As product mix complexity increased, all three saw a decrease in demand fulfillment rate. However, the falloff in demand fulfillment rate occurred at a far greater rate under traditional costing systems as compared to the two other management accounting system alternatives. Although activities-based costing performed the best across all levels of product mix complexity, time-based accounting performed nearly as well along this crucial customer service measure.

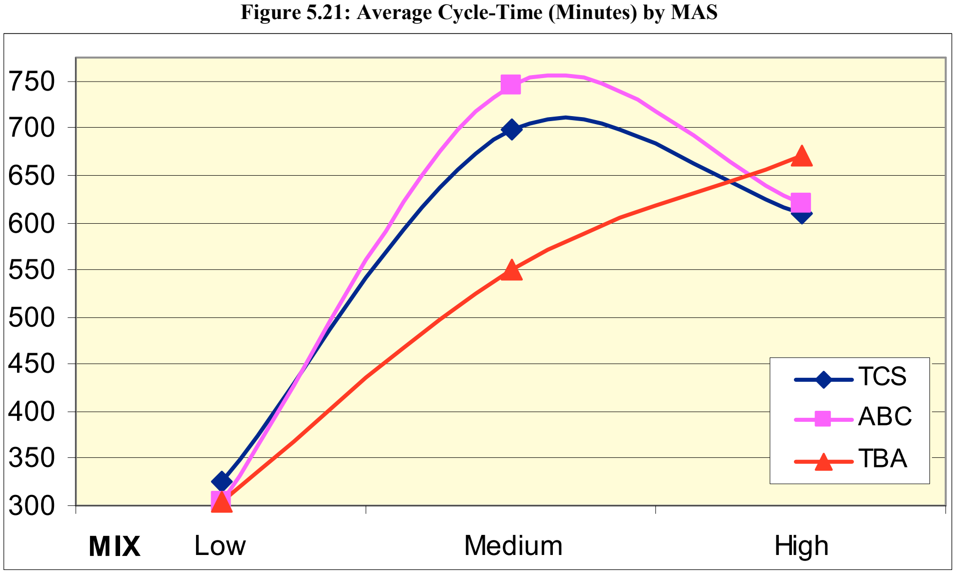
Figure 5.20: Average Demand Fulfillment Rate by MAS



Because a major focus of this study was to examine the impact of management accounting system alternatives within the context of today's increasingly time-based competitive environment, the internal manufacturing performance measure of cycle time is of primary importance. As discussed in previous chapters, cycle-time is the primary success measure for a time-based competitor. In terms of this strategic measure, time-based accounting performed the best at nearly all setting of product mix complexity.

Time-based accounting drove a product mix decision that better balanced the manufacturing line and resulted in the lowest average cycle-times for all products. It is interesting to note that activities-based costing, which generally outperformed vis-à-vis the other two manufacturing performance measures, was least effective in terms of cycle-times. It is important to note that the variability of cycle-times across the various levels of product mix complexity was much less than the variability under the traditional costing and activities-based costing systems. This may have important implications for the time-based manufacturer that is concerned with consistently delivering faster cycle-times under varying levels of product mix complexity demanded by the market.

Figure 5.21: Average Cycle-Time (Minutes) by MAS



Net operating income is the only financial measure of manufacturing success included in this study, and an argument could certainly be made that it is the bottom line and the most important measure. Figures 5.22 through 5.24 present the average net operating income measures for the various management accounting system alternatives under differing levels of product mix complexity demand and differing levels of manufacturing overhead. Activities-based costing clearly outperformed the two other management accounting system alternatives along this measure. Traditional costing systems and time-based accounting performed nearly equally well under low and medium demand settings for product mix complexity. As the product mix complexity increases; however, traditional costing systems begin to fall behind time-based accounting.

Figure 5.22: Average Net Operating Income by MAS
(Low Manufacturing Overhead Level)

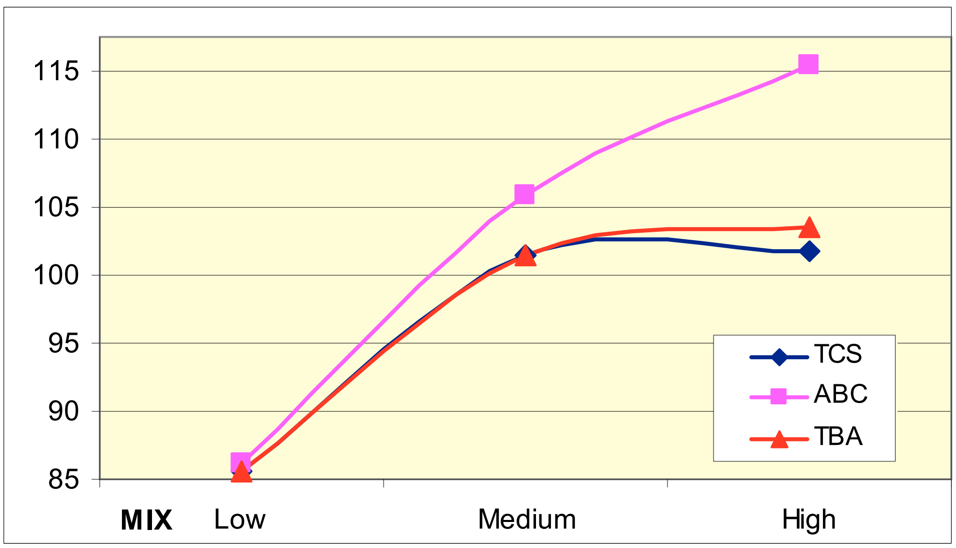


Figure 5.23 below shows essentially the same results, with activities-based costing clearly outperforming the other two management accounting system alternatives. The difference between traditional costing systems and time-based accounting again is not as great under medium levels of product mix complexity but increases with high levels of product mix complexity.

Figure 5.23: Average Net Operating Income by MAS
(Medium Manufacturing Overhead Level)

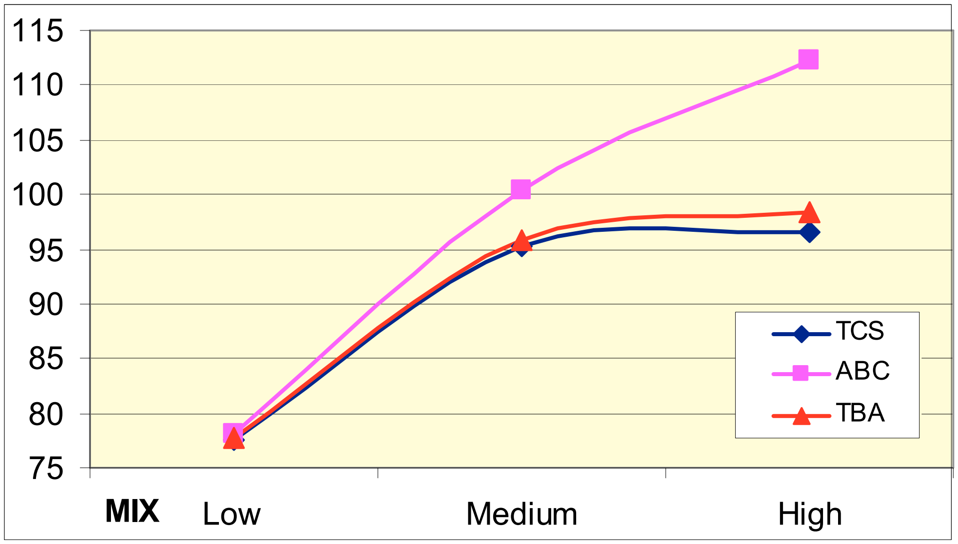
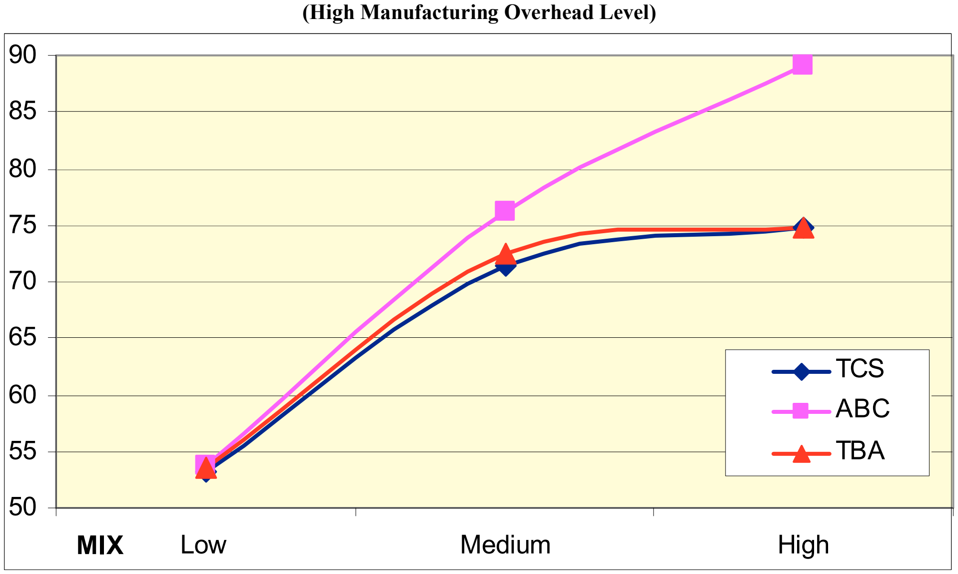


Figure 5.24 again shows very similar results, with activities-based costing clearly outperforming the other two management accounting system alternatives. Overall, average net operating income is at its lowest given the higher levels of manufacturing overhead. The difference between traditional costing systems and time-based accounting again is not as great under medium levels of product mix complexity but increases with high levels of product mix complexity.

Figure 5.24: Average Net Operating Income by MAS
(High Manufacturing Overhead Level)



The results in the figures above present particularly interesting implications for management accounting practice. The increase of demand for more complex and higher priced products presents an opportunity for increased revenues. However, as discussed in Chapter 2, it often presents the paradox as these products may also drive higher overall manufacturing costs. Higher levels of manufacturing overhead had no significant effect on the product mix decision; however, total costs and differences between the various management accounting system alternatives are amplified. As the manufacturing overhead level setting increases, the slope of the cumulative net operating income curve decreases. The implication for both management accounting researchers and practitioners is that the choice of management accounting system alternative becomes increasingly important as product mix complexity increases and may be amplified as manufacturing overhead levels increase.

As can be seen in the following figures (D.1-D.9) in Appendix D, higher levels of product mix complexity drive increasing long-term variances in cumulative net operating income. Review of management accounting system performance under the nine experimental conditions (three levels of manufacturing overhead by three levels of product mix complexity) shows no significant difference in cumulative net operating income when product mix complexity is low. Activities-based costing begins to significantly outperform the other two management accounting system alternatives at a medium demand setting for product mix complexity. This difference becomes more pronounced as product mix complexity is set at a high level. At this high setting, time-based accounting begins to slowly outperform traditional costing systems.

Chapter Six

Conclusions

The primary focus of this study was to evaluate the direct impact of different managerial accounting system alternatives on product mix decisions and ultimately on different manufacturing performance measures under differing levels of manufacturing overhead with differing levels of product mix complexity. The first chapter had posed the research questions and presented an experimental research framework in which to answer these questions. In the second chapter, the relevant literature on managerial accounting and operations management was reviewed as well as a select group of simulation studies that had included managerial accounting as a variable of interest. The third chapter provided the justification for utilizing a simulation research methodology and further developed the variables to be used in the research model. The fourth chapter outlined the specific details of the simulation model itself, while the fifth chapter provided the statistical analyses (MANOVA) of the simulation data as well as a summary of the research findings. This is followed by a discussion of implications for both managerial accounting research and practice. This chapter will conclude by illuminating some of the limitations of this particular study and how these can be addressed in future studies. The final section presents several opportunities to both to advance and extend the findings of this study in future research.

Limitations of Current Study

It is important to remember that every research methodology has its own unique set of strengths and corresponding limitations, and simulation modeling is no exception to this rule. Probably the greatest strength of simulation modeling is the model itself is virtually endlessly reconfigurable and therefore may be relatively easily extended and improved to incorporate more detail. The principal limitation is that no simulation model can possibly capture the infinite number of extraneous variables that exist within any real system.

This study represents an initial step towards better understanding the impact and interactions of different managerial accounting system alternatives, manufacturing overhead levels, and product mix complexity on manufacturing performance. Although it provides a number of interesting results for managerial accounting researchers to consider, it is important to remember that this study presents only a single operating environment. Therefore, the results of the study may not necessarily be generalizable across all manufacturing environments. As has been stated before in the Chapter 3 discussion of methodologies, the results of any simulation study are greatly impacted by the assumptions built into the model and must be interpreted with caution. However, the benefit of being able to observe the behavior of the performance measures under the same environmental settings is the major benefit of simulation modeling, and may provide insight and guidance for future research.

As mentioned above, one specific limitation of this study was that it considered only one particular simulated manufacturing environment, albeit under differing manufacturing overhead levels and with differing demand levels of product mix complexity. Traditional costing systems were used initially in the experiment. Given the three product structures used in this study, the average percentage of each product's cost content varied by product and experimental condition group. Product A had direct material of between 20% and 60%, direct labor from 16% to 26%, and manufacturing overhead from 15% to 63% of total product cost. Product B had direct material of between 60% and 78%, direct labor from 16% to 24%, and manufacturing overhead from 6% to 15% of total product cost. Product C had direct material of between 28% and 71%, direct labor from 16% to 24%, and manufacturing overhead from 6% to 56% of total product cost. Different industries will have differing cost structures that may have a significant impact on performance measures and the selection of managerial accounting system alternative. Future experiments should be conducted in a variety of operating environments to enhance the generalizability of the findings.

Any form of analytical modeling, be it mathematical or simulation, must make assumptions in order to arrive at a solution. This particular study assumed that there were no changes in products demand over the entire five year period. Another assumption, with great implications for competitive markets, is that lost demand had no effect on future demand distributions. Future studies may address this issue by building in feedback loops and dynamic learning of the market, i.e. the inability to fulfill a given market demand for a particular product will affect the future market demand for that same product. This is a particularly important point for the time-based manufacturer and the proposed time-based accounting system as the literature suggests that delivering products with greater speed presents opportunities for premium pricing and with increased demands (Blackburn 1991).

This study had only one external measure of manufacturing performance in terms of customer service levels defined as demand fulfillment rate. In reality this is certainly not the only measure of customer service typically used, and future studies may consider using measures of on-time delivery as well as other quantifiable factors such as contract commitments. It is possible that a particular manufacturing firm may have vastly different performance results for the various managerial accounting system alternatives when different measures of customer service are used. Future studies may want to incorporate multiple measures for customer service as well as differing levels of customer sensitivity to these various measures.

One particularly important limitation for practice is the lack of a measure of return-on-investment. While this study utilized net operating income (NOI) as the primary financial measure of performance, an established practice in the managerial accounting literature, this measure only makes sense under the assumption that all three managerial accounting alternatives require the same initial and ongoing cost of investment. This is particularly an important point when comparing existing traditional costing systems (TCS) to time-based accounting (TBA) and particularly to activities-based-costing (ABC). Many of the failures of ABC in the literature are linked to the high cost of implementation and ongoing costs of maintaining such a detailed accounting system. While ABC was shown to outperform TCS and TBA in many cases and along several of the performance measures, any rational manager would need to weigh the potential benefits against the potentially higher cost of implementation and maintenance.

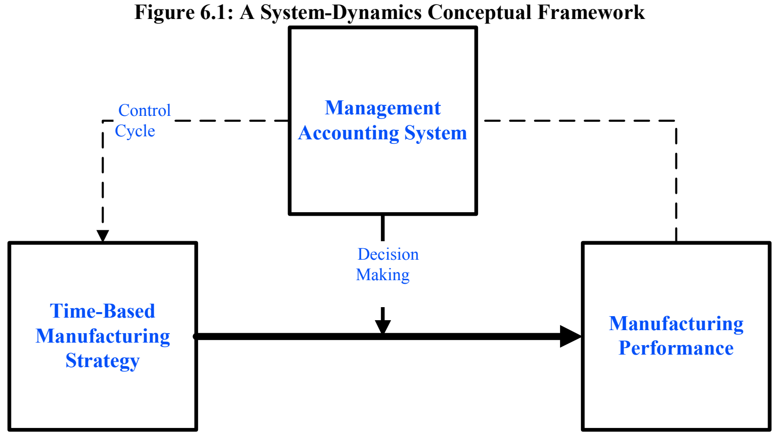
Suggestions for Future Research

This research represents a first step towards integrating managerial accounting and operations management research. Because the scope of this study is somewhat limited, as outlined in the preceding discussion, further research will be needed to develop a complete understanding of the impact of managerial accounting systems on manufacturing performance. The following discussion proposes some possibilities for both advancing and extending this research.

As was mentioned above, one of the greatest strengths of simulation modeling is the malleability of the model itself, especially with newer software packages such as ARENA. The simulation model can be endlessly reconfigured to increase complexity and to incorporate additional realism. One suggestion is to take a systems dynamic approach building learning into the simulation model itself over the length of the simulation run. System dynamics is an approach to understanding the behavior of complex systems over time, and is increasingly finding application in management disciplines. System dynamics deals with internal feedback loops and time delays that affect the behavior of the entire system, and computer software is often used to simulate system dynamics models. System dynamics is very similar to systems thinking and constructs the same causal loop diagrams of systems with feedback. However, system dynamics typically goes further and utilizes simulation to study the behavior of systems and the impact of alternative policies. This type of systems dynamic model learning could be incorporated both on the supply process and demand sides.

Based on this literary evidence, a conceptual framework is presented in figure 6.1 to better illustrate the problem (Hutchinson 2007). In this framework, the MAS has a moderating effect, via the decision making process, on the relationship between time-based strategy and manufacturing performance. Manufacturing managers, knowing the accounting measures by which their performance is evaluated, quite rationally game the system in order to maximize their personal utility, i.e. maximize their personal performance reward or to consolidate their power through obtaining greater allocations of corporate capital. Legacy cost systems have the tendency to encourage behavior that is incongruent with TBM strategy, e.g. manufacturing managers frequently attempt to lower average costs through longer production runs and producing to stock. A strategically congruent MAS, with a clear linkage between throughput time and product cost, will create incentive for manufacturing managers to focus on time compression in production, e.g. produce to market demands only.

Figure 6.1: A System-Dynamics Conceptual Framework



This is a system-dynamics framework, with a feedback loop from manufacturing performance to TBM strategy. System dynamics is an approach to studying complex systems, through the use of feedback loops (Forrester 1961). Stocks and flows are the basic building blocks, connected by feedback loops which create the nonlinearity found so frequently in modern day problems. In this example, manufacturing performance impacts time-based manufacturing strategy through the MAS, i.e. the control cycle. The use of an appropriate MAS, which best reflects the time-based competitive reality, will reinforce the practices of TBM strategy over time. Conversely, the choice of inappropriate MAS, which does not reflect the importance of throughput-time, will undermine TBM strategy and may prove a fetter to its advancement.

On the supply side, it would be interesting to develop a product mix determination using dynamic integer goal programming as opposed to simply integer linear programming in a static environment. Manufacturing performance measures as driven by the various managerial accounting system alternatives can be fed into the goal program through a feedback look, thereby continually driving change in product cost and product mix decision. The choice of managerial accounting system affects the product cost, which in turn affects the product mix decision, which affect manufacturing performance measures, which is fed back into the managerial accounting system itself.

From a demand perspective, incorporating learning into the different product demand distributions would add an additional level of realism. Given a competitive market, it is quite likely that any demand lost to the market may be permanently lost, i.e. a particular customer may never order again from a particular supplier. Breaking down product demands into individual customer demands, with differing levels of customer service requirements and differing sensitivities to stock outs and price increases would add a great deal of complexity and realism to the simulation model.

Future studies may also look at additional measures of financial and operational performance, such as return-on-investment capacity utilization rate. As mentioned above in the limitations, the decision to implement an alternative managerial accounting system will certainly be weighed against the cost of implementation and maintenance. Therefore measures of return-on-investment become increasingly important as the fixed costs of implementing such control systems increases.

In terms of operational performance measures, capacity utilization has become increasingly important in industries with a heavy overhead burden. As is often said in industries with high fixed investments, such as automotive or aircraft, “capacity utilization is king”. This performance metric is easily calculated within ARENA and other simulation software programs as well.

For each resource, ARENA reports two utilization statistics, called scheduled utilization and simply utilization. To understand what these are and how they differ requires some mathematical notation. Let B(t) be the number of units of a particular resource that are available at time t, and let M(t) be the number of units of that resource that are available (busy or not) at time t. If the resource has a fixed capacity, then M(t) is a fixed constant for all t, but if the resource capacity follows a variable schedule, then M (t) will vary with t. Of course, $0 \leq B(t) \leq M(t)$ at all times t. If the resource is not available at time t, e.g. it has failed, then M(t) = 0, which then forces B(t) = 0. Let U(t) = B(t)/M(t) whenever M(t) > 0; thus $0 \leq U(t) \leq 1$, and U(t) represents what might be called instantaneous utilization of the resource.

What ARENA calls simply utilization of the resource is jut the (time) average of this instantaneous utilization over the simulation where T is the length of the simulation:

$$\text{Utilization } U(t) = \frac{\int_0^T U(t)\,dt}{T} = \frac{1}{T}\int_0^T \frac{B(t)}{M(t)}\,dt$$

In words, utilization is the time average of the ratio of the number busy to the number available. ARENA also reports scheduled utilization, which is a ratio of the average number busy to the average number available:

$$\text{Scheduled Utilization} = \frac{\int_0^T B(t)\ dt/T}{\int_0^T M(t)\ dt/T} = \frac{\int_0^T B(t)\,dt}{\int_0^T M(t)\,dt}$$

While the preceding suggestions could rather easily be built into any simulation modeling study, another interesting extension of this research would be to model an actual manufacturing facility and apply the findings *post hoc* to the actual manufacturing system. This would provide a unique opportunity to combine positivist and normative research techniques within a single study, something that is rarely, if ever, seen within managerial accounting research. This would give the opportunity not only to collect real data for developing demand and process distributions, but would also add a new dimension to the kind of case study methodology often employed in managerial accounting research. The ability to suggest normal solutions to real accounting issues through simulation modeling would also help to increase the standing of managerial accounting research and further the development and dissemination of innovative managerial accounting practices. Of course crossing roles between managerial accounting research and consultant has the potential to bring up a unique host of issues to be addressed, but would still present an excellent opportunity if an actual company were willing to participate in such a project.

In the interest of furthering normative accounting research, there are many possibilities for incorporating other managerial accounting alternatives into future studies. With increasing recognition of the deficiencies of traditional costing systems, and newly emerging competitive pressures from the market, new managerial accounting system alternatives are being proposed on many fronts. The focus of some industries on capacity utilization has driven many companies to adopt Resource Consumption Accounting, which has proven popular in Germany. Environmental pressures may drive the need to develop environmentally focused systems such as life-cycle costing. The growth and proliferation of enterprise information systems has brought the practice of back-flush costing into discussion as well. Regardless of what is driving changes in the market, this research has shown that managerial accounting systems can play a significant role in manufacturing success. However, this research has only partially addressed the knowledge gap at the interface of managerial accounting and manufacturing management; continued research is needed.

###

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Appendix A

Direct and Variable Costing Example

Example 1

Assume the following (per unit)

Direct Materials	2.5 lbs @ $4.00	$10.00
Direct Labor	.5 hr @ $16.00	$ 8.00
VOH	.5 hr @ $4.00	$ 2.00
FOH	$40,000	$ 2.50
Actual Output	16,000 units	
Variable S&A	$6.00 per unit	
Fixed S&A	$60,000	
Selling price	$40	

What do the income statements look like if actual sales equal 16,000 units?

Absorption Costing		Direct Costing	
Revenue (40)(16000)	640,000	Revenue (40)(16000)	640,000
Cogs (22.50)(16000)	360,000	Vbl Mfg (20)(16000)	320,000
GM (17.50)(16000)	280,000	Vbl S+A (6)(16000)	96,000
Vbl S+A (6)(16000)	96,000	CM	224,000
Fx S+A	60,000	Fx Mfg	40,000
Profit	124,000	Fx S+A	60,000
		Profit	124,000

- Note: When sales equals production, profit under absorption costing and direct costing are equal.

Example 2
Assume sales of 12,000 units. What is the profit under each costing method?

Absorption Costing		Direct Costing	
Revenue (40)(12000)	480,000	Revenue (40)(12000)	480,000
Cogs (22.50)(12000)	270,000	Vbl Mfg (20)(12000)	240,000
GM (17.50)(12000)	210,000	Vbl S+A (6)(12000)	72,000
Vbl S+A (6)(12000)	72,000	CM (14)(12000)	168,000
Fx S+A	60,000	Fx Mfg	40,000
Profit	78,000	Fx S+A	60,000
		Profit	68,000

- Note: When production exceeds sales, absorption profit exceeds direct profit.

Example 3
Assume sales of 18,000 units. What is the profit under each costing method?

Absorption Costing		Direct Costing	
Revenue (40)(18000)	720,000	Revenue (40)(18000)	720,000
Cogs (22.50)(18000)	405,000	Vbl Mfg (20)(18000)	360,000
GM (17.50)(18000)	315,000	Vbl S+A (6)(18000)	108,000
Vbl S+A (6)(18000)	108,000	CM (14)(18000)	252,000
Fx S+A	60,000	Fx Mfg	40,000
Profit	147,000	Fx S+A	60,000
		Profit	152,000

- Note: When sales exceed production, direct profit exceeds absorption profit.

Appendix B

Time-Based Accounting Overhead Allocation Example

This appendix presents a simple deterministic example of the application of a time-based accounting system for allocating manufacturing overheads (MOH). Based on the actual production data, total cycle time units are calculated for all products.

Product	A	B	C	All Products
Standard Production	1,400	300	100	1,800
Average Cycle Time (minutes)	300	500	800	361
Total Cycle Time Units	420,000	150,000	80,000	650,000

The total cycle time units will then be used to calculate the manufacturing overhead burden per cycle time unit. The total budgeted manufacturing overhead burden used in this study, along with the MOH/Cycle-Time Unit calculation, is as follows:

Depreciation	$ 24,000	
Data Entry	8,800	
Cost Analysis	9,600	
Production Engineering	6,400	
Scheduling	4,400	
Quality Control	1,653	
Production Supervision	8,400	
General Utilities	9,000	
Miscellaneous	1,000	
Total MOH		$ 73,253
MOH/Cycle-Time Unit		$ 0.113

With the cost of direct material and direct labor given, the allocation of manufacturing overhead burden is calculated by simply multiplying the average cycle times of the individual products by the MOH/Cycle Time Unit ($0.113). The following is a breakdown of total product cost by product under the time-based accounting system:

Product	**A**	**B**	**C**
Direct Material	$ 20	$ 40	$ 120
Direct Labor	15	20	60
Manufacturing Overhead Allocation	34	56	90
Manufacturing Cost/Unit	$ 69	$ 116	$ 270
Sales Price/Unit	$ 100	$ 160	$ 360
Gross Margin	31	44	90
Gross Margin Percentage	31%	27%	25%

As shown below, the time-based accounting system, in keeping with US Generally Accepted Accounting Principles (US GAAP), fully absorbs all manufacturing overheads into finished goods inventory. The total manufacturing overhead burden allocated to all three products is $73,253.

Product	**A**	**B**	**C**	**All Products**
Standard Production	1,400	300	100	1,800
Total MOH Allocated	47,333	16,905	9,016	73,253

Appendix C

SIMAN Code

This appendix presents the actual SIMAN language code for the simulation model used in this experiment.

```
;
;
;     Model statements for module:  Create 1
;

94$          CREATE,       1,HoursToBaseTime(0.0),Part
A:HoursToBaseTime(EXPO(.5)):NEXT(95$);

95$          ASSIGN:       Part A Order Arrival.NumberOut=Part A Order
Arrival.NumberOut + 1:NEXT(88$);


;
;
;     Model statements for module:  Record 29
;
88$          COUNT:        Record Total Part A Demand,1:NEXT(0$);


;
;
;     Model statements for module:  Assign 1
;
0$          ASSIGN:       Rework Time=TRIA(20,60,80):
                          Unload Time=TRIA(0.5,1.5,1.75):
                          Load Time=TRIA(1.5,2,2.5):
                          Transport Velocity=UNIF(25,35):
                          Picture=Picture.Blue Ball:
                          Sealer Time=TRIA(16, 18, 20):
                          Prep Time=TRIA(14,18,22):NEXT(Part A);
```

```
Part A       QUEUE,        Part A Order.Queue,16,21$:MARK(Arrive
Time):DETACH;

;
;
;    Model statements for module:  Record 7
;
21$          COUNT:        Record Part A Demand Unfilled,1:NEXT(91$);


;
;
;    Model statements for module:  Record 32
;
91$          TALLY:        Record DFR Part A,1 -  ( NC(Record Part A Demand
Unfilled) / NC(Record Total Part A Demand) ),1
                        :NEXT(22$);


;
;
;    Model statements for module:  Dispose 6
;
22$          ASSIGN:       Part A Demand Unfilled.NumberOut=Part A Demand
Unfilled.NumberOut + 1;
98$          DISPOSE:      Yes;


;
;
;    Model statements for module:  Create 2
;

99$          CREATE,       1,HoursToBaseTime(0.0),Part
B:HoursToBaseTime(EXPO(2)):NEXT(100$);

100$         ASSIGN:       Part B Order Arrival.NumberOut=Part B Order
Arrival.NumberOut + 1:NEXT(89$);


;
;
;    Model statements for module:  Record 30
;
89$          COUNT:        Record Total Part B Demand,1:NEXT(1$);
```

```
;
;
;    Model statements for module:  Assign 2
;
1$          ASSIGN:       Rework Time=TRIA(40,80,100):
                          Unload Time=TRIA(0.5,1.5,2):
                          Load Time=TRIA(1.5,2,3):
                          Transport Velocity=UNIF(20,30):
                          Picture=Picture.Yellow Ball:
                          Prep Time=TRIA(12,18,24):
                          Sealer Time=TRIA(18,20,22):NEXT(Part B);

Part B       QUEUE,        Part B Order.Queue,5,23$:DETACH;

;
;
;    Model statements for module:  Record 8
;
23$          COUNT:        Record Part B Demand Unfilled,1:NEXT(92$);


;
;
;    Model statements for module:  Record 33
;
92$          TALLY:        Record DFR Part B,1 -  ( NC(Record Part B Demand
Unfilled) / NC(Record Total Part B Demand) ),1
                          :NEXT(24$);


;
;
;    Model statements for module:  Dispose 7
;
24$          ASSIGN:       Part B Demand Unfilled.NumberOut=Part B Demand
Unfilled.NumberOut + 1;
103$         DISPOSE:      Yes;


;
;
;    Model statements for module:  Create 4
;
```

```
104$        CREATE,       1,HoursToBaseTime(0.0),Part
C:HoursToBaseTime(EXPO(8)):NEXT(105$);

105$        ASSIGN:       Part C Order Arrival.NumberOut=Part C Order
Arrival.NumberOut + 1:NEXT(90$);



;
;
;    Model statements for module:  Record 31
;
90$         COUNT:        Record Total Part C Demand,1:NEXT(10$);



;
;
;    Model statements for module:  Assign 4
;
10$         ASSIGN:       Rework Time=TRIA(120,180,300):
                          Unload Time=TRIA(1,2.5,5):
                          Load Time=TRIA(2,3,5):
                          Transport Velocity=UNIF(10,30):
                          Picture=Picture.Green Ball:
                          Sealer Time=TRIA(68,72,78):
                          Prep Time=TRIA(64,90,124):NEXT(Part C);

Part C      QUEUE,        Part C Order.Queue,1,25$:DETACH;

;
;
;    Model statements for module:  Record 9
;
25$         COUNT:        Record Part C Demand Unfilled,1:NEXT(93$);



;
;
;    Model statements for module:  Record 34
;
93$         TALLY:        Record DFR Part C,1 -  ( NC(Record Part C Demand
Unfilled) / NC(Record Total Part C Demand) ),1
                          :NEXT(26$);



;
;
```

```
;     Model statements for module:  Dispose 8
;
26$          ASSIGN:       Part C Demand Unfilled.NumberOut=Part C Demand
Unfilled.NumberOut + 1;
108$         DISPOSE:      Yes;



;
;
;     Model statements for module:  Enter 1
;

11$          STATION,      Prep Arrival.Station;
109$         DELAY:        Unload Time,,Transfer:NEXT(111$);

111$         FREE:         Prep Cart:NEXT(2$);



;
;
;     Model statements for module:  Process 2
;
2$           ASSIGN:       Prep Process.NumberIn=Prep Process.NumberIn + 1:
                     Prep Process.WIP=Prep Process.WIP+1;
149$         STACK,        1:Save:NEXT(123$);

123$         QUEUE,        Prep Process.Queue;
122$         SEIZE,        1,VA:
                     Part Prep,1:NEXT(121$);

121$         DELAY:        Prep Time,,VA:NEXT(164$);

164$         ASSIGN:       Prep Process.WaitTime=Prep Process.WaitTime +
Diff.WaitTime;
128$         TALLY:        Prep Process.WaitTimePerEntity,Diff.WaitTime,1;
130$         TALLY:        Prep Process.TotalTimePerEntity,Diff.StartTime,1;
154$         ASSIGN:       Prep Process.VATime=Prep Process.VATime +
Diff.VATime;
155$         TALLY:        Prep Process.VATimePerEntity,Diff.VATime,1;
120$         RELEASE:      Part Prep,1;
169$         STACK,        1:Destroy:NEXT(168$);

168$         ASSIGN:       Prep Process.NumberOut=Prep Process.NumberOut + 1:
                     Prep Process.WIP=Prep Process.WIP-1:NEXT(27$);
```

```
;
;
;     Model statements for module:  Station 12
;

27$          STATION,       Prep Station;
173$         DELAY:         0.0,,VA:NEXT(41$);


;
;
;     Model statements for module:  Request 1
;
41$          QUEUE,         Request Cart 1 to Prep Station.Queue;
           REQUEST,       1:Sealer Cart(SDS),50:NEXT(44$);


;
;
;     Model statements for module:  Delay 2
;
44$          DELAY:         Load Time,,Transfer:NEXT(43$);


;
;
;     Model statements for module:  Transport 2
;
43$          TRANSPORT:     Sealer Cart,Sealer Arrival.Station,Transport Velocity;


;
;
;     Model statements for module:  Enter 2
;

12$          STATION,       Sealer Arrival.Station;
175$         DELAY:         Unload Time,,Transfer:NEXT(177$);

177$         FREE:          Sealer Cart:NEXT(3$);


;
;
;     Model statements for module:  Process 3
;
```

```
3$          ASSIGN:       Sealer Process.NumberIn=Sealer Process.NumberIn + 1:
                    Sealer Process.WIP=Sealer Process.WIP+1;
215$         STACK,        1:Save:NEXT(189$);

189$         QUEUE,        Sealer Process.Queue;
188$         SEIZE,        1,VA:
                    Sealer,1:NEXT(187$);

187$         DELAY:        Sealer Time,,VA:NEXT(230$);

230$         ASSIGN:       Sealer Process.WaitTime=Sealer Process.WaitTime +
Diff.WaitTime;
194$         TALLY:        Sealer Process.WaitTimePerEntity,Diff.WaitTime,1;
196$         TALLY:        Sealer Process.TotalTimePerEntity,Diff.StartTime,1;
220$         ASSIGN:       Sealer Process.VATime=Sealer Process.VATime +
Diff.VATime;
221$         TALLY:        Sealer Process.VATimePerEntity,Diff.VATime,1;
186$         RELEASE:      Sealer,1;
235$         STACK,        1:Destroy:NEXT(234$);

234$         ASSIGN:       Sealer Process.NumberOut=Sealer Process.NumberOut + 1:
                    Sealer Process.WIP=Sealer Process.WIP-1:NEXT(4$);


;
;
;    Model statements for module:  Decide 1
;
4$          BRANCH,       1:
                    If,Entity.Type==Part A,13$,Yes:
                    If,Entity.Type==Part B,14$,Yes:
                    If,Entity.Type==Part C,15$,Yes:
                    Else,20$,Yes;


;
;
;    Model statements for module:  Dispose 5
;
20$          ASSIGN:       Dispose of Sealer Exceptions.NumberOut=Dispose of
Sealer Exceptions.NumberOut + 1;
239$         DISPOSE:      Yes;



;
;
;    Model statements for module:  Decide 3
```

```
;
13$          BRANCH,        1:
                     With,4/100,240$,Yes:
                     Else,241$,Yes;
240$         ASSIGN:       Failed Sealer Inspection Part A.NumberOut True=Failed
Sealer Inspection Part A.NumberOut True + 1
                     :NEXT(28$);

241$         ASSIGN:       Failed Sealer Inspection Part A.NumberOut False=Failed
Sealer Inspection Part A.NumberOut False + 1
                     :NEXT(29$);


;
;
;    Model statements for module:  Station 13
;

28$          STATION,      Failed Parts Station;
244$         DELAY:        0.0,,VA:NEXT(47$);


;
;
;    Model statements for module:  Request 2
;
47$          QUEUE,        Request Cart to Failed Parts.Queue;
           REQUEST,       1:Cart 2(SDS),50:NEXT(45$);


;
;
;    Model statements for module:  Delay 3
;
45$          DELAY:        Load Time,,Transfer:NEXT(46$);


;
;
;    Model statements for module:  Transport 3
;
46$          TRANSPORT:     Cart 2,Rework Arrival.Station,Transport Velocity;


;
;
```

```
;     Model statements for module:  Station 14
;

29$          STATION,       Good Parts Station;
248$          DELAY:         0.0,,VA:NEXT(50$);



;
;
;     Model statements for module:  Request 3
;
50$          QUEUE,         Request Cart to Good Parts.Queue;
           REQUEST,       1:Cart 2(SDS),50:NEXT(52$);



;
;
;     Model statements for module:  Delay 4
;
52$          DELAY:         Load Time,,Transfer:NEXT(49$);



;
;
;     Model statements for module:  Transport 4
;
49$          TRANSPORT:     Cart 2,Shipped Parts Arrival.Station,Transport Velocity;



;
;
;     Model statements for module:  Decide 4
;
14$          BRANCH,        1:
                    With,6/100,250$,Yes:
                    Else,251$,Yes;
250$          ASSIGN:        Failed Sealer Inspection Part B.NumberOut True=Failed
Sealer Inspection Part B.NumberOut True + 1
                    :NEXT(28$);

251$          ASSIGN:        Failed Sealer Inspection Part B.NumberOut False=Failed
Sealer Inspection Part B.NumberOut False + 1
                    :NEXT(29$);


;
```

```
;
;     Model statements for module:  Decide 5
;
15$          BRANCH,       1:
                        With,10/100,252$,Yes:
                        Else,253$,Yes;
252$         ASSIGN:       Failed Sealer Inspection Part C.NumberOut True=Failed
Sealer Inspection Part C.NumberOut True + 1
                        :NEXT(28$);

253$         ASSIGN:       Failed Sealer Inspection Part C.NumberOut False=Failed
Sealer Inspection Part C.NumberOut False + 1
                        :NEXT(29$);

             QPICK,        POR:

$TCS$
                        Part C:
                        Part B:
                        Part A;
;
;

$ABC$

                        Part B:
                        Part A:
                        Part C;

;
;


$TBA$

                        Part A:
                        Part B:
                        Part C;


36$          ALLOCATE,     1:Prep Cart,Order Release Station:MARK(Arrive
Time):NEXT(37$);


;
;
```

```
;     Model statements for module:  Station 17
;

37$          STATION,      Order Release Station;
256$         DELAY:        0.0,,VA:NEXT(65$);


;
;
;     Model statements for module:  Assign 5
;
65$          ASSIGN:       Arrival Time=TNOW:NEXT(38$);


;
;
;     Model statements for module:  Move 1
;
38$          MOVE:         Prep Cart,Prep Arrival.Station,50:NEXT(40$);


;
;
;     Model statements for module:  Delay 1
;
40$          DELAY:        Load Time,,Transfer:NEXT(64$);


;
;
;     Model statements for module:  Decide 9
;
64$          BRANCH,       1:
                           If,NQ(Prep Process.Queue) <= 16 && NQ(Sealer Process.Queue)
<= 16,257$,Yes:
                           Else,258$,Yes;
257$         ASSIGN:       Check Prep and Sealer Queue Availability.NumberOut
True=
                           Check Prep and Sealer Queue Availability.NumberOut True +
1:NEXT(39$);

258$         ASSIGN:       Check Prep and Sealer Queue Availability.NumberOut
False=
                           Check Prep and Sealer Queue Availability.NumberOut False +
1:NEXT(63$);
```

```
;
;
;    Model statements for module:  Transport 1
;
39$          TRANSPORT:     Prep Cart,Prep Arrival.Station,Transport Velocity;


;
;
;    Model statements for module:  Delay 7
;
63$          DELAY:         EXPO( .5 ),,Wait:NEXT(64$);


;
;
;    Model statements for module:  Enter 4
;

30$          STATION,       Rework Arrival.Station;
259$         DELAY:         Unload Time,,Transfer:NEXT(261$);

261$         FREE:          Cart 2:NEXT(5$);


;
;
;    Model statements for module:  Process 4
;
5$           ASSIGN:        Rework Process.NumberIn=Rework Process.NumberIn + 1:
                        Rework Process.WIP=Rework Process.WIP+1;
299$         STACK,         1:Save:NEXT(273$);

273$         QUEUE,         Rework Process.Queue;
272$         SEIZE,         1,Other:
                        Rework,1:NEXT(271$);

271$         DELAY:         Rework Time,,Other:NEXT(314$);

314$         ASSIGN:        Rework Process.WaitTime=Rework Process.WaitTime +
Diff.WaitTime;
278$         TALLY:         Rework Process.WaitTimePerEntity,Diff.WaitTime,1;
280$         TALLY:         Rework Process.TotalTimePerEntity,Diff.StartTime,1;
304$         ASSIGN:        Rework Process.OtherTime=Rework Process.OtherTime +
Diff.OtherTime;
```

```
305$        TALLY:        Rework Process.OtherTimePerEntity,Diff.OtherTime,1;
270$        RELEASE:        Rework,1;
319$        STACK,        1:Destroy:NEXT(318$);

318$        ASSIGN:        Rework Process.NumberOut=Rework Process.NumberOut
+ 1:
                    Rework Process.WIP=Rework Process.WIP-1:NEXT(16$);


;
;
;     Model statements for module:  Decide 6
;
16$        BRANCH,        1:
                    If,Entity.Type==Part A,6$,Yes:
                    If,Entity.Type==Part B,17$,Yes:
                    If,Entity.Type==Part C,18$,Yes:
                    Else,19$,Yes;


;
;
;     Model statements for module:  Dispose 4
;
19$        ASSIGN:        Dispose of Rework Exceptions.NumberOut=Dispose of
Rework Exceptions.NumberOut + 1;
323$        DISPOSE:        Yes;



;
;
;     Model statements for module:  Decide 2
;
6$        BRANCH,        1:
                    With,19/100,324$,Yes:
                    Else,325$,Yes;
324$        ASSIGN:        Failed Rework Inspection Part A.NumberOut True=Failed
Rework Inspection Part A.NumberOut True + 1
                    :NEXT(32$);

325$        ASSIGN:        Failed Rework Inspection Part A.NumberOut False=Failed
Rework Inspection Part A.NumberOut False + 1
                    :NEXT(34$);


;
;
```

```
;     Model statements for module:  Station 15
;

32$          STATION,       Failed Rework Parts Station;
328$          DELAY:         0.0,,VA:NEXT(53$);


;
;
;     Model statements for module:  Allocate 1
;
53$          QUEUE,         Request Cart to Scrapped Parts.Queue;
           ALLOCATE,      2:Cart 2(SDS):NEXT(55$);


;
;
;     Model statements for module:  Move 2
;
55$          MOVE:          Cart 2,Failed Rework Parts Station,50:NEXT(56$);


;
;
;     Model statements for module:  Delay 5
;
56$          DELAY:         Load Time,,Transfer:NEXT(57$);


;
;
;     Model statements for module:  Transport 5
;
57$          TRANSPORT:     Cart 2,Scrapped Parts Arrival.Station,Transport
Velocity;


;
;
;     Model statements for module:  Station 16
;

34$          STATION,       Salvaged Parts Station;
332$          DELAY:         0.0,,VA:NEXT(58$);
```

```
;
;
;     Model statements for module:  Request 4
;
58$          QUEUE,         Request Cart to Salvaged Parts.Queue;
           REQUEST,       1:Cart 2(SDS),50:NEXT(60$);


;
;
;     Model statements for module:  Move 3
;
60$          MOVE:          Cart 2,Salvaged Parts Station,50:NEXT(62$);


;
;
;     Model statements for module:  Delay 6
;
62$          DELAY:         Load Time,,Transfer:NEXT(61$);


;
;
;     Model statements for module:  Transport 6
;
61$          TRANSPORT:     Cart 2,Salvaged Parts Arrival.Station,Transport
Velocity;


;
;
;     Model statements for module:  Decide 7
;
17$          BRANCH,        1:
                    With,27/100,334$,Yes:
                    Else,335$,Yes;
334$         ASSIGN:        Failed Rework Inspection Part B.NumberOut True=Failed
Rework Inspection Part B.NumberOut True + 1
                    :NEXT(32$);

335$         ASSIGN:        Failed Rework Inspection Part B.NumberOut False=Failed
Rework Inspection Part B.NumberOut False + 1
                    :NEXT(34$);
```

```
;
;
;    Model statements for module:  Decide 8
;
18$          BRANCH,       1:
                      With,40/100,336$,Yes:
                      Else,337$,Yes;
336$         ASSIGN:       Failed Rework Inspection Part C.NumberOut True=Failed
Rework Inspection Part C.NumberOut True + 1
                      :NEXT(32$);

337$         ASSIGN:       Failed Rework Inspection Part C.NumberOut False=Failed
Rework Inspection Part C.NumberOut False + 1
                      :NEXT(34$);



;
;
;    Model statements for module:  Enter 5
;

31$          STATION,      Shipped Parts Arrival.Station;
338$         DELAY:        Unload Time,,Transfer:NEXT(340$);

340$         FREE:         Cart 2:NEXT(70$);



;
;
;    Model statements for module:  Decide 11
;
70$          BRANCH,       1:
                      If,Entity.Type==Part A,72$,Yes:
                      If,Entity.Type==Part B,71$,Yes:
                      If,Entity.Type==Part C,73$,Yes:
                      Else,74$,Yes;


;
;
;    Model statements for module:  Dispose 10
;
74$          ASSIGN:       Dispose 10.NumberOut=Dispose 10.NumberOut + 1;
351$         DISPOSE:      Yes;


;
```

```
;
;    Model statements for module:  Record 16
;
72$          TALLY:        Record Part A Shipped Time,INT(Arrival
Time),1:NEXT(75$);


;
;
;    Model statements for module:  Record 18
;
75$          COUNT:        Record Part A Shipped,1:NEXT(78$);


;
;
;    Model statements for module:  Record 21
;
78$          COUNT:        Record Total Shipped,1:NEXT(9$);


;
;
;    Model statements for module:  Dispose 3
;
9$           ASSIGN:       Shipped.NumberOut=Shipped.NumberOut + 1;
352$         DISPOSE:      Yes;


;
;
;    Model statements for module:  Record 15
;
71$          TALLY:        Record Part B Shipped Time,INT(Arrive
Time),1:NEXT(76$);


;
;
;    Model statements for module:  Record 19
;
76$          COUNT:        Record Part B Shipped,1:NEXT(78$);


;
;
```

```
;    Model statements for module:  Record 17
;
73$         TALLY:        Record Part C Shipped Time,INT(Arrival
Time),1:NEXT(77$);


;
;
;    Model statements for module:  Record 20
;
77$         COUNT:        Record Part C Shipped,1:NEXT(78$);


;
;
;    Model statements for module:  Enter 6
;

33$         STATION,      Scrapped Parts Arrival.Station;
353$         DELAY:        Unload Time,,Transfer:NEXT(355$);

355$         FREE:         Cart 2:NEXT(79$);


;
;
;    Model statements for module:  Decide 12
;
79$         BRANCH,       1:
                    If,Entity.Type==Part A,81$,Yes:
                    If,Entity.Type==Part B,80$,Yes:
                    If,Entity.Type==Part C,82$,Yes:
                    Else,83$,Yes;


;
;
;    Model statements for module:  Dispose 11
;
83$         ASSIGN:       Dispose 11.NumberOut=Dispose 11.NumberOut + 1;
366$         DISPOSE:      Yes;


;
;
;    Model statements for module:  Record 23
;
```

```
81$          TALLY:        Record Part A Scrapped Time,INT(Arrival
Time),1:NEXT(84$);


;
;
;    Model statements for module:  Record 25
;
84$          COUNT:        Record Part A Scrapped,1:NEXT(87$);


;
;
;    Model statements for module:  Record 28
;
87$          COUNT:        Record Total Scrapped,1:NEXT(8$);


;
;
;    Model statements for module:  Dispose 1
;
8$           ASSIGN:       Scrapped.NumberOut=Scrapped.NumberOut + 1;
367$         DISPOSE:      Yes;


;
;
;    Model statements for module:  Record 22
;
80$          TALLY:        Record Part B Scrapped Time,INT(Arrive
Time),1:NEXT(85$);


;
;
;    Model statements for module:  Record 26
;
85$          COUNT:        Record Part B Scrapped,1:NEXT(87$);


;
;
;    Model statements for module:  Record 24
;
```

```
82$         TALLY:        Record Part C Scrapped Time,INT(Arrival
Time),1:NEXT(86$);


;
;
;    Model statements for module:  Record 27
;
86$         COUNT:        Record Part C Scrapped,1:NEXT(87$);


;
;
;    Model statements for module:  Enter 7
;

35$         STATION,      Salvaged Parts Arrival.Station;
368$        DELAY:        Unload Time,,Transfer:NEXT(370$);

370$        FREE:         Cart 2:NEXT(66$);


;
;
;    Model statements for module:  Decide 10
;
66$         BRANCH,       1:
                      If,Entity.Type==Part A,68$,Yes:
                      If,Entity.Type==Part B,7$,Yes:
                      If,Entity.Type==Part C,69$,Yes:
                      Else,67$,Yes;

;
;
;    Model statements for module:  Dispose 9
;
67$         ASSIGN:       Dispose 9.NumberOut=Dispose 9.NumberOut + 1;
381$        DISPOSE:      Yes;


;
;
;    Model statements for module:  Record 12
;
68$         TALLY:        Record Part A Salvaged Time,INT(Arrival
Time),1:NEXT(75$);
```

```
;
;
;    Model statements for module:  Record 2
;
7$          TALLY:        Record Part B Salvaged Time,INT(Arrive
Time),1:NEXT(76$);


;
;
;    Model statements for module:  Record 14
;
69$          TALLY:        Record Part C Salvaged Time,INT(Arrival
Time),1:NEXT(77$);
```

Appendix D

Cumulative NOI

This appendix presents the cumulative NOI under the various experimental conditions. Review of management accounting system performance under the nine experimental conditions (three levels of manufacturing overhead by three levels of product mix complexity) shows no significant difference in cumulative net operating income when product mix complexity is low. Activities-based costing begins to significantly outperform the other two management accounting system alternatives at a medium demand setting for product mix complexity. This difference becomes more pronounced as product mix complexity is set at a high level. At this high setting, time-based accounting begins to slowly outperform traditional costing systems.

Figure D.1: Cumulative Net Operating Income by MAS
(Experimental Condition Group 1)

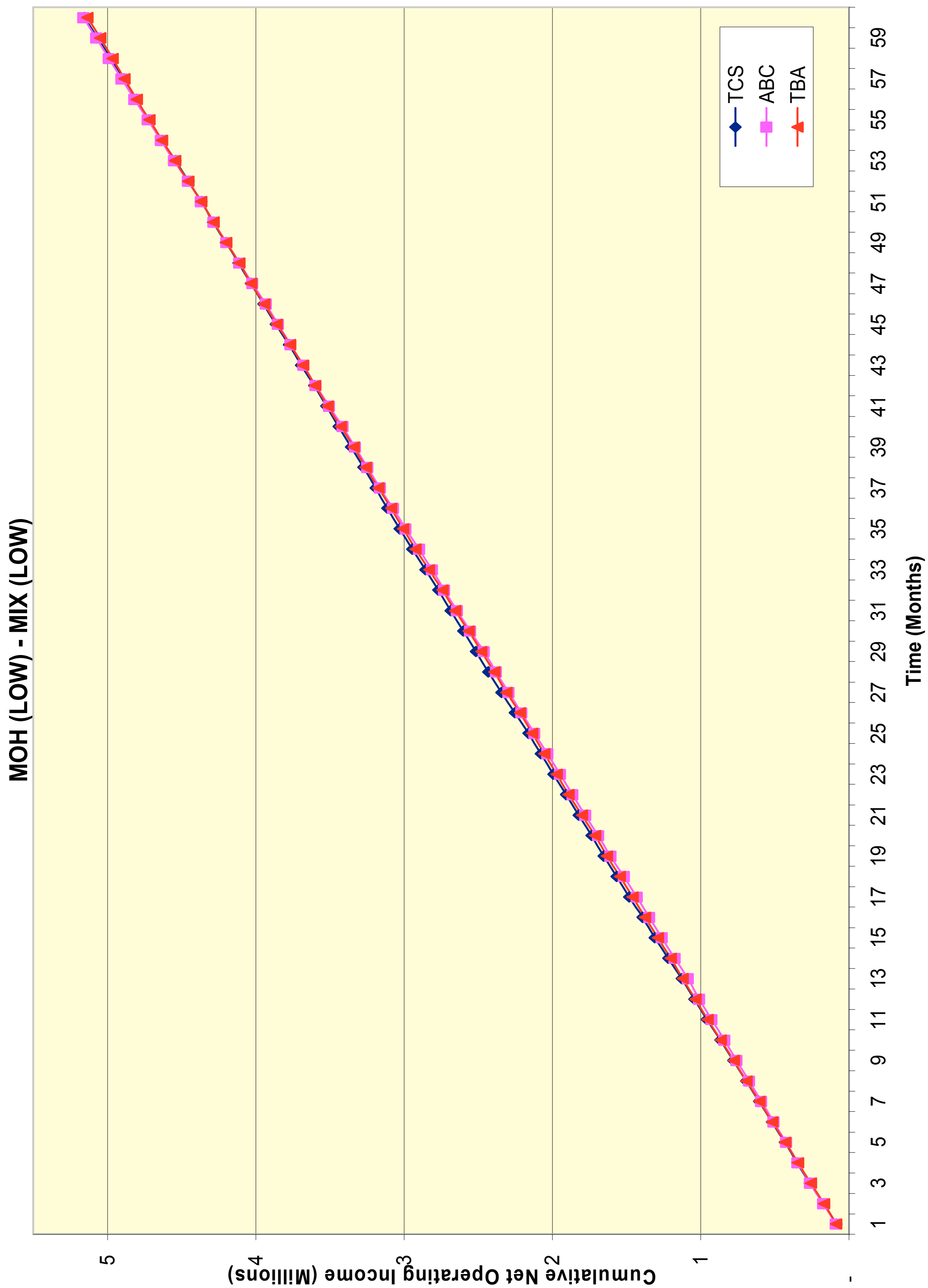


Figure D.2: Cumulative Net Operating Income by MAS
(Experimental Condition Group 2)

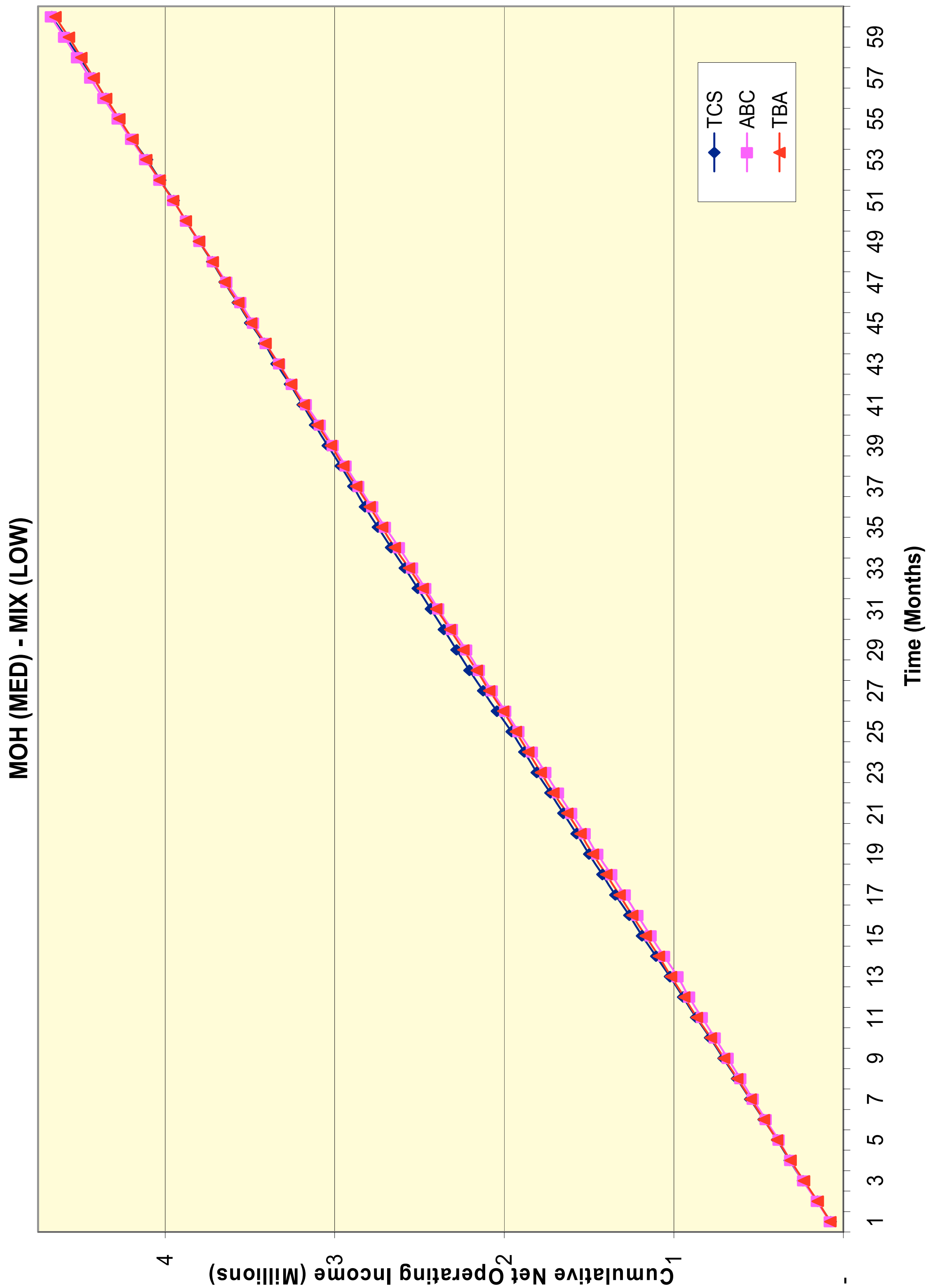


Figure D.3: Cumulative Net Operating Income by MAS
(Experimental Condition Group 3)

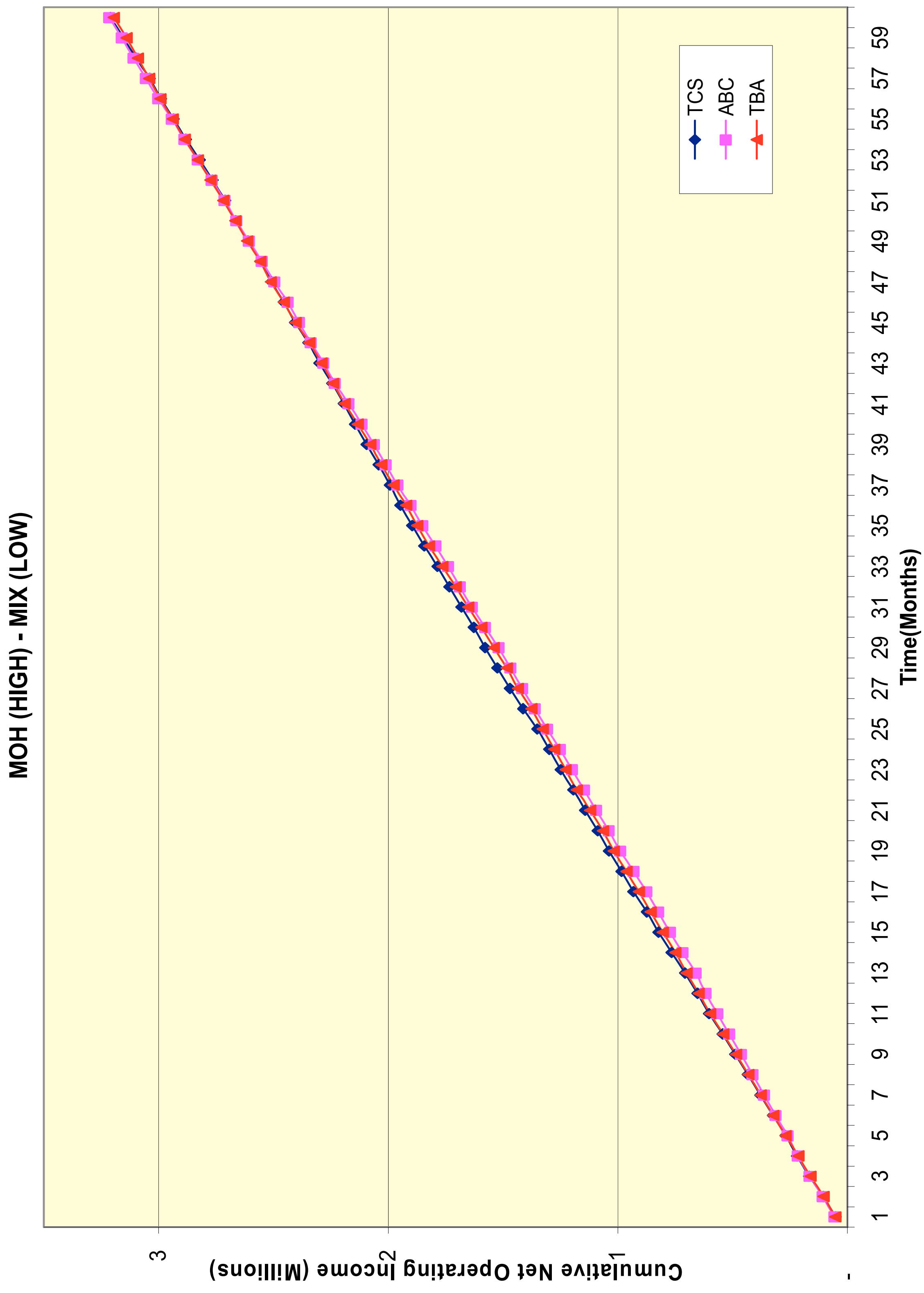


Figure D.4: Cumulative Net Operating Income by MAS
(Experimental Condition Group 4)

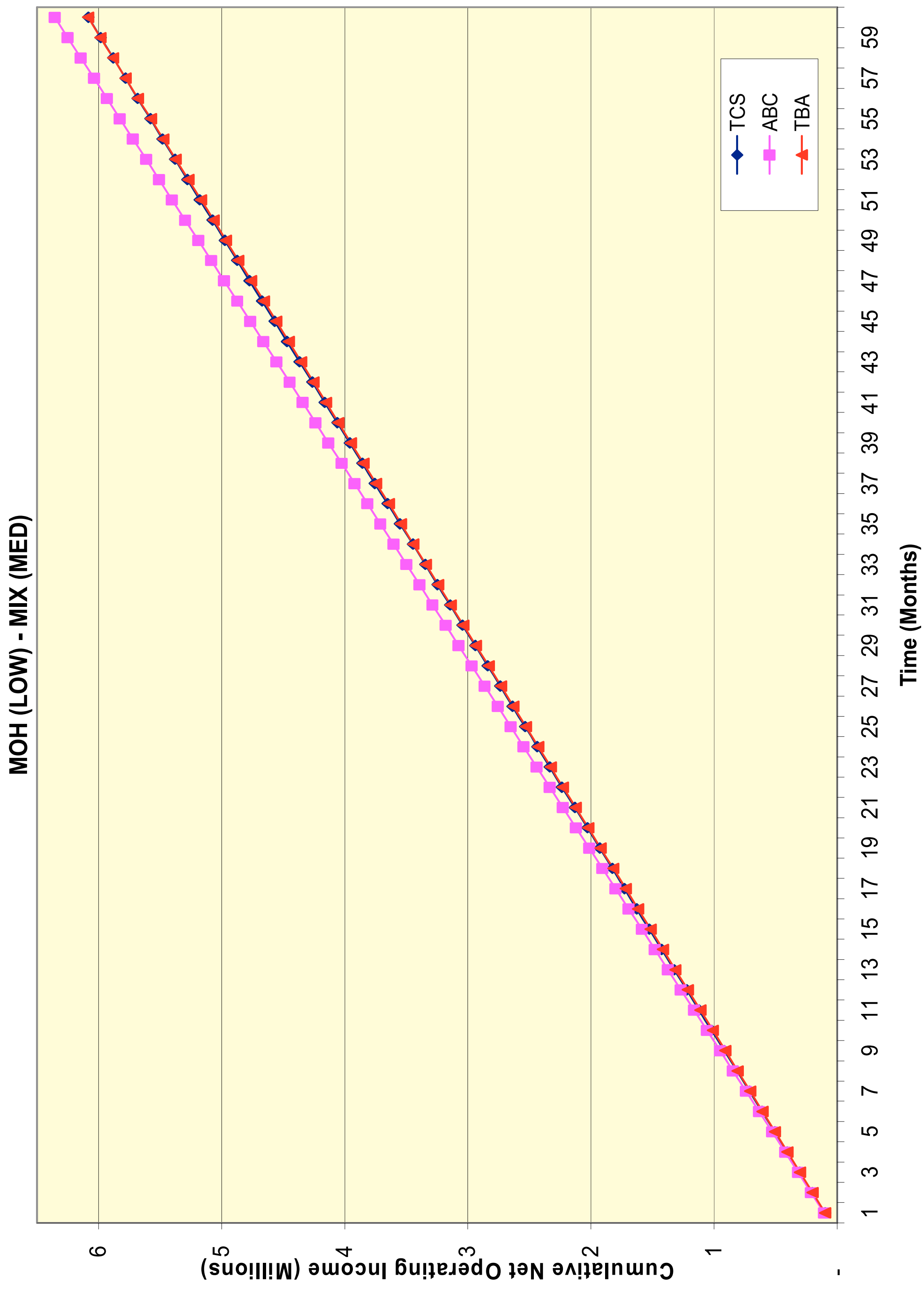


Figure D.5: Cumulative Net Operating Income by MAS
(Experimental Condition Group 5)

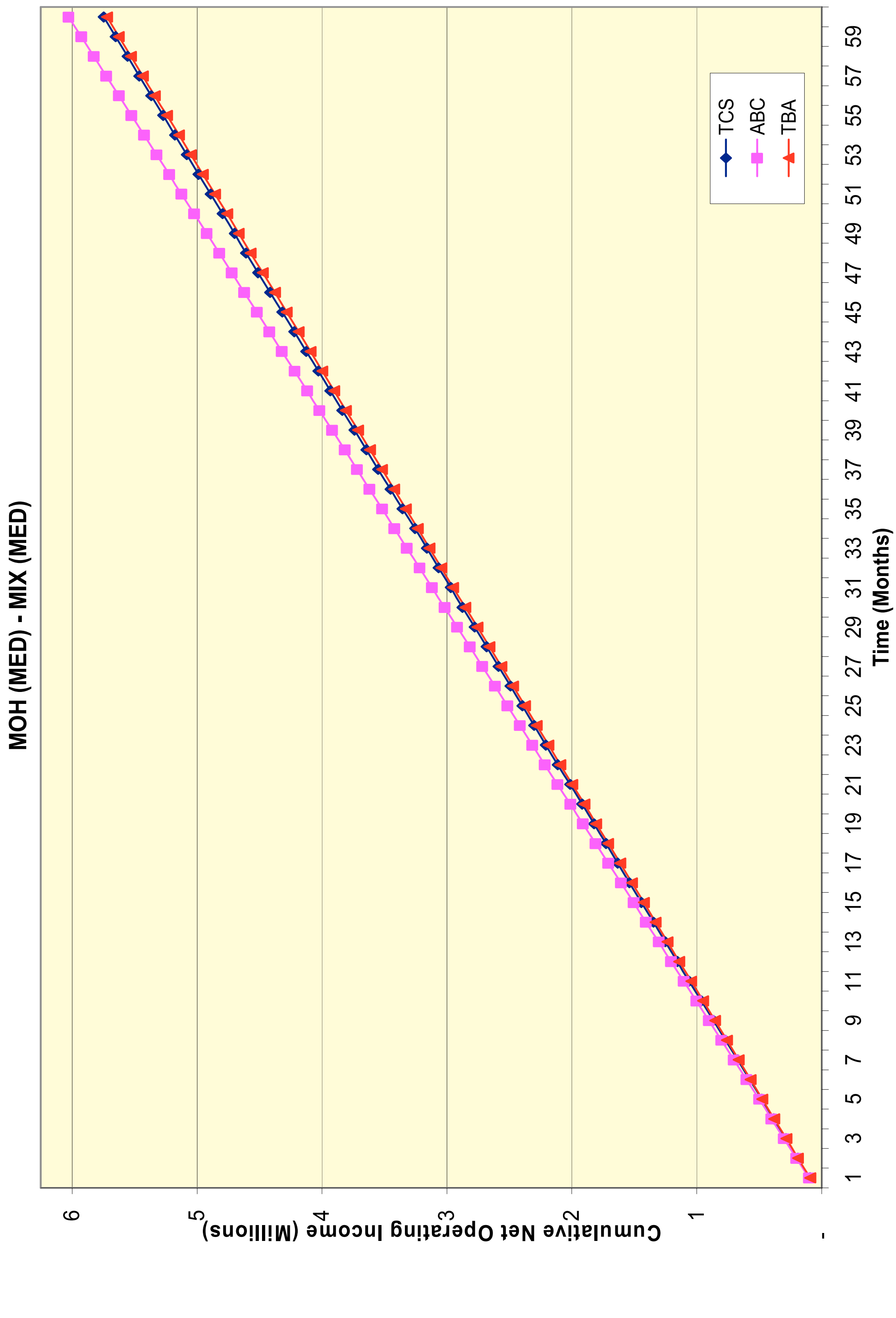


Figure D.6: Cumulative Net Operating Income by MAS
(Experimental Condition Group 6)

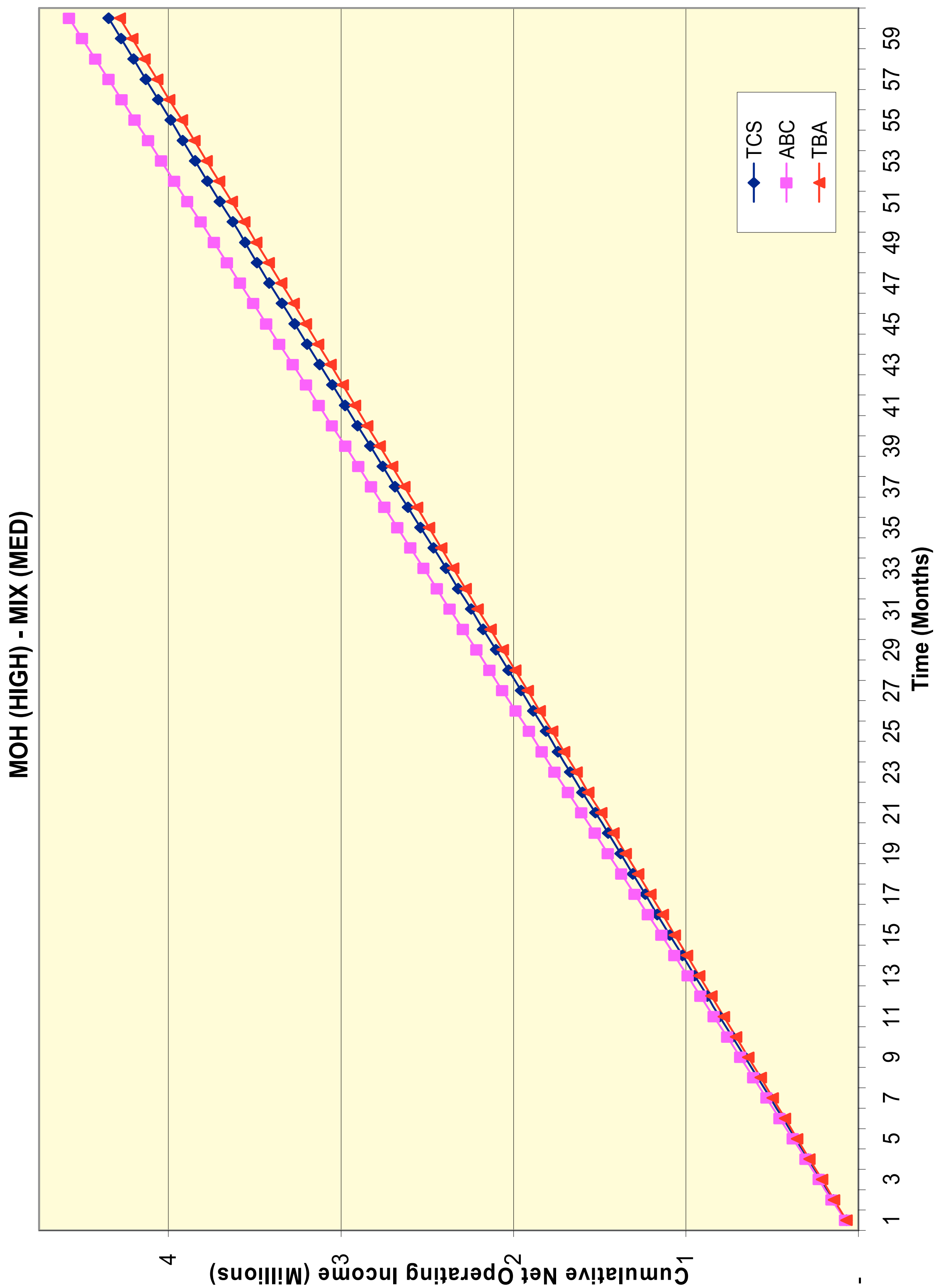


Figure D.7: Cumulative Net Operating Income by MAS
(Experimental Condition Group 7)

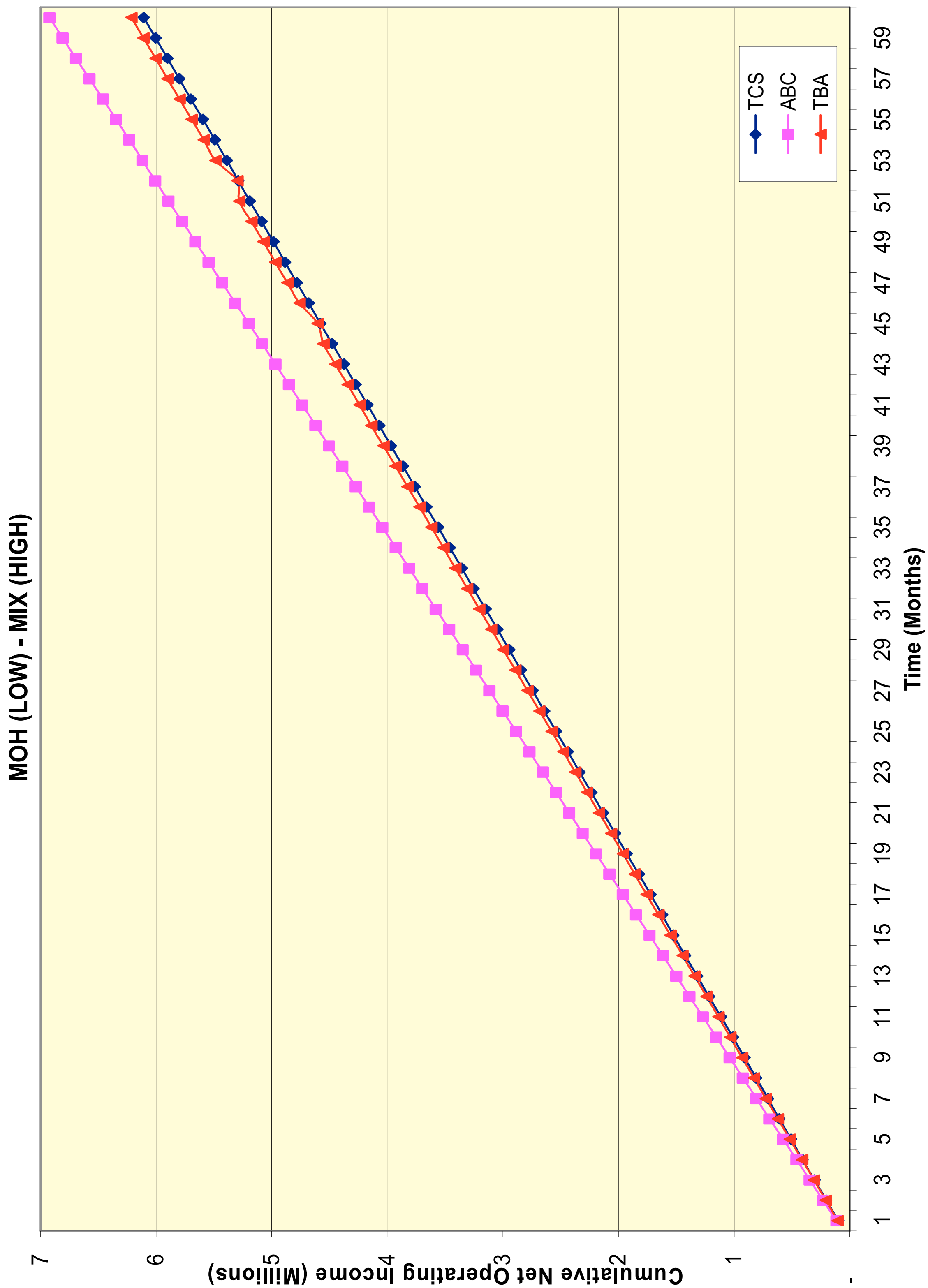


Figure D.8: Cumulative Net Operating Income by MAS
(Experimental Condition Group 8)

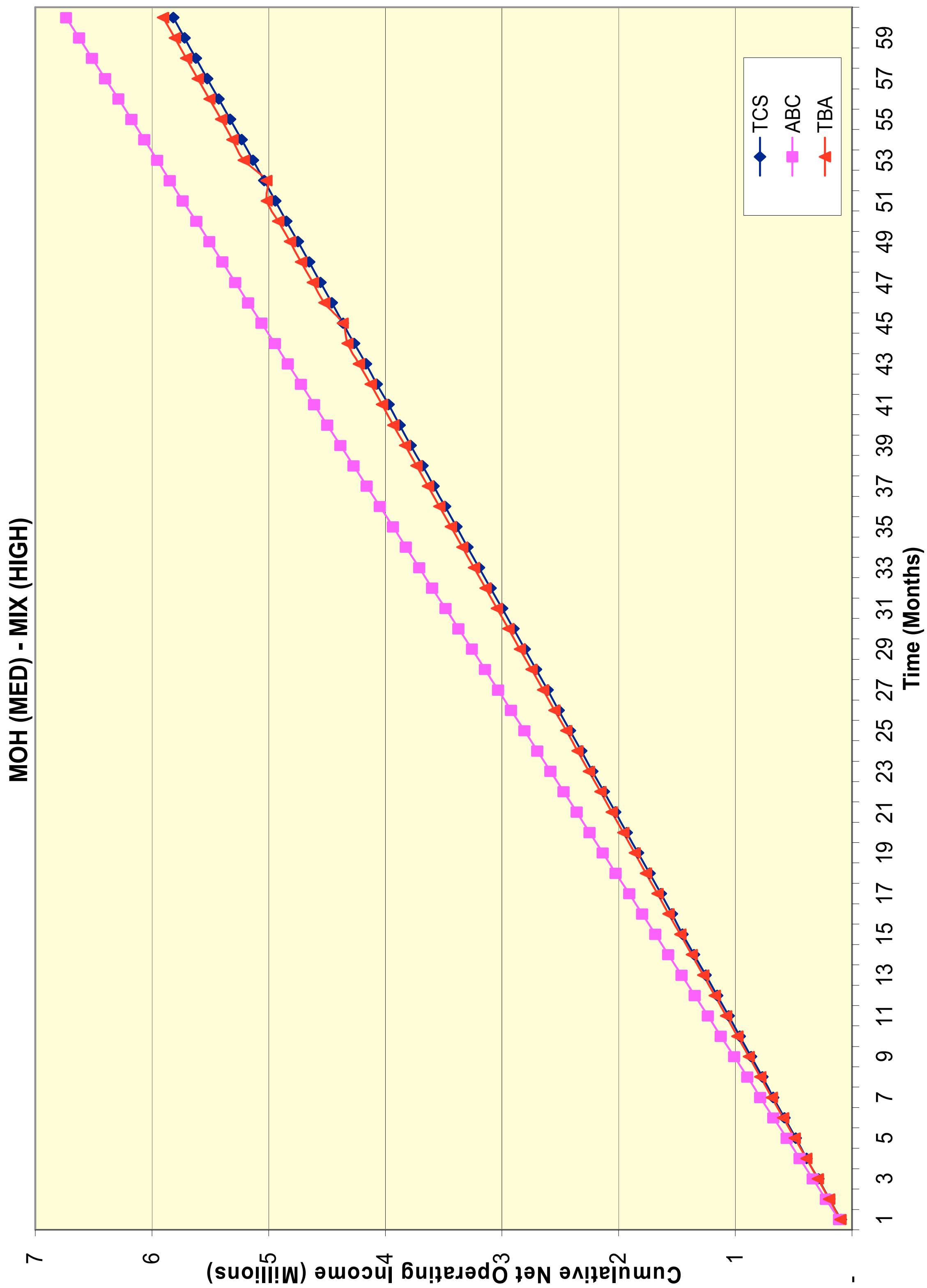
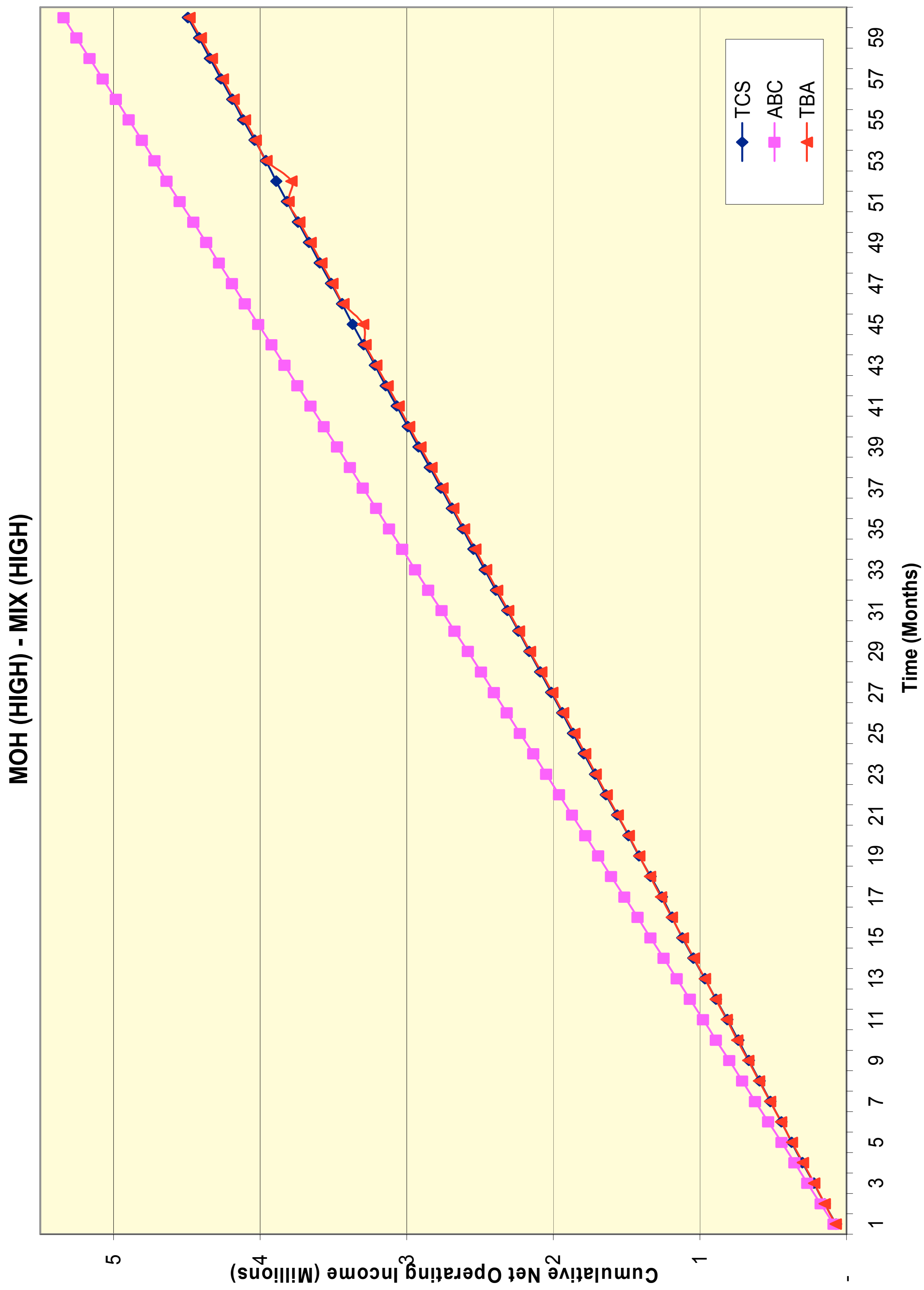


Figure D.9: Cumulative Net Operating Income by MAS
(Experimental Condition Group 9)



Appendix E

Raw Data

This appendix presents the raw data generated from the ARENA simulation model. These data were then loaded into an Excel spreadsheet and sorted for uploading into SPSS for further statistical analyses. What is shown in the following 18 pages are the data in the Excel spreadsheet format.

TBA LOW LOW

	Independent Variables			Dependent Variables: Product A								Product B								Product C							
Replication Number	MAS	MOH	MIX	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time
1	3	1	1	1422	1422	1419	1419	1.00	1.00	266.95	266.95	359	359	352	352	1.00	1.00	264.83	264.83	86	86	82	82	0.96	0.96	353.25	353.25
2	3	1	1	1421	2843	1404	2823	1.00	1.00	283.06	274.96	342	701	331	683	1.00	1.00	303.33	283.49	95	181	82	164	0.98	0.97	385.57	369.41
3	3	1	1	1504	4347	1488	4311	1.00	1.00	320.94	290.83	403	1104	392	1075	1.00	1.00	335.43	302.43	87	268	72	236	0.91	0.95	404.84	380.22
4	3	1	1	1431	5778	1421	5732	1.00	1.00	289.50	290.50	359	1463	350	1425	1.00	1.00	312.98	305.02	84	352	81	317	0.95	0.95	395.64	384.16
5	3	1	1	1491	7269	1456	7188	1.00	1.00	321.50	296.78	342	1805	327	1752	0.95	0.99	343.38	312.18	98	450	91	408	0.95	0.95	385.68	384.50
6	3	1	1	1508	8777	1513	8701	1.00	1.00	323.18	301.37	338	2143	327	2079	0.99	0.99	328.01	314.67	86	536	76	484	0.95	0.95	421.44	390.30
7	3	1	1	1447	10224	1436	10137	1.00	1.00	333.21	305.88	356	2499	349	2428	0.99	0.99	351.15	319.91	91	627	83	567	0.95	0.95	399.86	391.70
8	3	1	1	1447	11671	1436	11573	1.00	1.00	295.76	304.63	356	2855	349	2777	0.99	0.99	304.70	318.00	91	719	83	650	0.95	0.95	381.25	390.37
9	3	1	1	1447	13118	1436	13008	1.00	1.00	298.94	304.00	356	3210	349	3125	0.99	0.99	309.44	317.05	91	810	83	733	0.95	0.95	384.47	389.70
10	3	1	1	1447	14565	1436	14444	1.00	1.00	297.68	303.37	356	3566	349	3474	0.99	0.99	307.53	316.09	91	901	83	816	0.95	0.95	383.14	389.03
11	3	1	1	1488	16053	1483	15927	1.00	1.00	361.58	308.79	351	3917	337	3811	0.99	0.99	391.41	322.75	110	1011	88	904	0.95	0.95	449.33	394.90
12	3	1	1	1417	17470	1406	17333	1.00	1.00	274.89	306.04	346	4263	330	4141	0.99	0.99	277.07	319.11	85	1096	81	985	0.95	0.95	405.97	395.81
13	3	1	1	1463	18933	1451	18784	1.00	1.00	312.51	306.54	337	4600	337	4478	0.99	0.99	349.27	321.38	86	1182	81	1066	0.95	0.95	437.13	398.95
14	3	1	1	1461	20394	1449	20233	1.00	1.00	244.12	302.07	346	4946	334	4812	0.99	0.99	245.31	316.10	75	1257	67	1133	0.95	0.95	369.69	397.22
15	3	1	1	1397	21791	1385	21618	1.00	1.00	305.66	302.30	358	5304	356	5168	0.99	0.99	314.36	315.98	98	1355	93	1226	0.95	0.95	404.60	397.78
16	3	1	1	1465	23256	1454	23072	1.00	1.00	277.23	300.72	353	5657	349	5517	0.99	0.99	275.99	313.45	81	1436	77	1303	0.95	0.95	360.89	395.60
17	3	1	1	1414	24670	1393	24465	1.00	1.00	291.94	300.22	366	6023	350	5867	0.99	0.99	303.90	312.88	88	1524	82	1385	0.95	0.95	401.17	395.93
18	3	1	1	1379	26049	1382	25847	1.00	1.00	270.11	298.61	357	6380	352	6219	0.99	0.99	293.27	311.77	92	1616	92	1477	0.95	0.95	374.58	394.60
19	3	1	1	1449	27498	1438	27285	1.00	1.00	323.28	299.91	349	6729	334	6553	0.99	0.99	360.03	314.23	97	1713	89	1566	0.95	0.95	419.94	396.04
20	3	1	1	1395	28893	1382	28667	1.00	1.00	213.00	295.72	354	7083	349	6902	0.99	0.99	217.52	309.34	78	1791	72	1638	0.95	0.95	331.20	393.19
21	3	1	1	1417	30310	1411	30078	1.00	1.00	247.33	293.45	346	7429	342	7244	0.99	0.99	254.90	306.77	94	1885	92	1730	0.95	0.95	337.91	390.25
22	3	1	1	1410	31720	1400	31478	1.00	1.00	342.24	295.62	390	7819	380	7624	0.99	0.99	380.20	310.43	111	1996	93	1823	0.95	0.95	425.14	392.03
23	3	1	1	1439	33159	1429	32907	1.00	1.00	204.89	291.68	384	8203	376	8000	0.99	0.99	211.92	305.80	63	2059	61	1884	0.95	0.95	315.43	389.55
24	3	1	1	1404	34563	1385	34292	1.00	1.00	290.19	291.62	339	8542	331	8331	0.99	0.99	296.24	305.42	88	2147	84	1968	0.95	0.95	402.90	390.12
25	3	1	1	1432	35995	1413	35705	1.00	1.00	286.06	291.40	341	8883	330	8661	0.99	0.99	305.42	305.42	87	2234	80	2048	0.95	0.95	394.98	390.31
26	3	1	1	1424	37419	1424	37129	1.00	1.00	242.64	289.53	348	9231	346	9007	0.99	0.99	254.14	303.45	75	2309	71	2119	0.95	0.95	335.99	388.49
27	3	1	1	1443	38862	1427	38556	1.00	1.00	343.57	291.53	367	9598	355	9362	0.99	0.99	375.71	306.19	105	2414	96	2215	0.95	0.95	401.64	389.06
28	3	1	1	1430	40292	1421	39977	1.00	1.00	247.36	289.96	333	9931	327	9689	0.99	0.99	249.30	304.27	82	2496	77	2292	0.95	0.95	350.66	387.77
29	3	1	1	1438	41730	1424	41401	1.00	1.00	312.35	290.73	378	10309	368	10057	0.99	0.99	343.35	305.70	97	2593	85	2377	0.95	0.95	390.57	387.87
30	3	1	1	1408	43138	1402	42803	1.00	1.00	303.86	291.16	379	10688	358	10415	0.99	0.99	298.43	305.45	95	2688	86	2463	0.95	0.95	379.56	387.58
31	3	1	1	1459	44597	1448	44251	1.00	1.00	377.34	293.98	363	11051	346	10761	0.99	0.99	401.24	308.53	109	2797	91	2554	0.95	0.95	441.47	389.50
32	3	1	1	1429	46026	1414	45665	1.00	1.00	321.75	294.84	362	11413	358	11119	0.99	0.99	321.57	308.95	91	2888	86	2640	0.95	0.95	415.90	390.36
33	3	1	1	1480	47506	1472	47137	1.00	1.00	364.01	297.00	356	11769	353	11472	0.99	0.99	386.62	311.34	94	2982	86	2726	0.95	0.95	450.27	392.25
34	3	1	1	1509	49015	1507	48644	1.00	1.00	339.61	298.32	346	12115	339	11811	0.99	0.99	374.05	313.14	92	3074	88	2814	0.95	0.95	433.82	393.55
35	3	1	1	1436	50451	1430	50074	1.00	1.00	295.17	298.23	364	12479	354	12165	0.99	0.99	320.01	313.34	80	3154	76	2890	0.95	0.95	400.39	393.73
36	3	1	1	1399	51850	1386	51460	1.00	1.00	242.17	296.72	352	12831	349	12514	0.99	0.99	259.20	311.83	77	3231	72	2962	0.95	0.95	331.61	392.22
37	3	1	1	1474	53324	1454	52914	1.00	1.00	295.99	296.70	397	13228	369	12883	0.99	0.99	298.21	311.44	79	3310	75	3037	0.95	0.95	397.89	392.36
38	3	1	1	1396	54720	1389	54303	1.00	1.00	337.75	297.75	359	13587	358	13241	0.99	0.99	361.37	312.79	89	3399	85	3122	0.95	0.95	427.25	393.31
39	3	1	1	1437	56157	1426	55729	1.00	1.00	234.05	296.12	361	13948	353	13594	0.99	0.99	250.79	311.18	70	3469	66	3188	0.95	0.95	325.69	391.91
40	3	1	1	1429	57586	1421	57150	1.00	1.00	348.00	297.41	359	14307	337	13931	0.99	0.99	375.25	312.73	100	3569	91	3279	0.95	0.95	449.92	393.52
41	3	1	1	1409	58995	1403	58553	1.00	1.00	334.14	298.29	386	14693	370	14301	0.99	0.99	335.53	313.32	108	3677	93	3372	0.95	0.95	396.42	393.60
42	3	1	1	1395	60390	1370	59923	1.00	1.00	284.29	297.97	342	15035	331	14632	0.99	0.99	290.33	312.80	96	3773	88	3460	0.95	0.95	370.80	393.02
43	3	1	1	1400	61790	1398	61321	1.00	1.00	272.53	297.39	369	15404	361	14993	0.99	0.99	292.03	312.30	79	3852	76	3536	0.95	0.95	391.62	392.99
44	3	1	1	1398	63188	1381	62702	1.00	1.00	239.73	296.12	368	15772	359	15352	0.99	0.99	246.02	310.75	88	3940	85	3621	0.95	0.95	325.26	391.40
45	3	1	1	1459	64647	1443	64145	1.00	1.00	361.02	297.58	379	16151	373	15725	0.99	0.99	373.57	312.24	100	4040	92	3713	0.95	0.95	416.42	392.02
46	3	1	1	1458	66105	1445	65590	1.00	1.00	321.18	298.10	353	16504	352	16077	0.99	0.99	352.89	313.13	86	4126	73	3786	0.95	0.95	394.09	392.06
47	3	1	1	1464	67569	1459	67049	1.00	1.00	362.90	299.51	367	16871	345	16422	0.99	0.99	385.96	314.66	103	4229	86	3872	0.95	0.95	466.35	393.71
48	3	1	1	1381	68950	1375	68424	1.00	1.00	261.69	298.75	369	17240	346	16768	0.99	0.99	256.51	313.46	78	4307	72	3944	0.95	0.95	367.42	393.23
49	3	1	1	1434	70384	1434	69858	1.00	1.00	304.11	298.86	382	17622	366	17134	0.99	0.99	300.82	313.19	90	4397	84	4028	0.95	0.95	390.83	393.18
50	3	1	1	1388	71772	1378	71236	1.00	1.00	285.42	298.60	386	18008	377	17511	0.99	0.99	289.50	312.68	84	4481	80	4108	0.95	0.95	412.18	393.55
51	3	1	1	1457	73229	1447	72683	1.00	1.00	315.18	298.93	346	18354	330	17841	0.99	0.99	349.98	313.37	86	4567	80	4188	0.95	0.95	432.81	394.30
52	3	1	1	1483	74712	1467	74150	1.00	1.00	313.59	299.22	370	18724	359	18200	0.99	0.99	325.03	313.60	91	4658	79	4267	0.95	0.95	407.26	394.54
53	3	1	1	1368	76080	1358	75508	1.00	1.00	293.66	299.12	381	19105	359	18559	0.99	0.99	311.53	313.56	108	4766	98	4365	0.95	0.95	374.50	394.09
54	3	1	1	1439	77519	1432	76940	1.00	1.00	349.63	300.06	376	19481	362	18921	0.99	0.99	371.05	314.66	96	4862	86	4451	0.95	0.95	451.54	395.20
55	3	1	1	1392	78911	1385	78325	1.00	1.00	285.92	299.81	349	19830	340	19261	0.99	0.99	314.09	314.65	95	4957	91	4542	0.95	0.95	364.25	394.58
56	3	1	1	1446	80357	1437	79762	1.00	1.00	305.36	299.91	353	20183	349	19610	0.99	0.99	320.27	314.75	85	5042	82	4624	0.95	0.95	412.06	394.89
57	3	1	1	1436	81793	1417	81179	1.00	1.00	230.02	298.69	339	20522	323	19933	0.99	0.99	245.02	313.62	80	5122	78	4702	0.95	0.95	333.40	393.87
58	3	1	1	1399	83192	1389	82568	1.00	1.00	252.32	297.91	348	20870	348	20281	0.99	0.99	275.16	312.96	80	5202	75	4777	0.95	0.95	377.95	393.62
59	3	1	1	1399	84591	1388	83956	1.00	1.00	265.25	297.37	356	21226	351	20632	0.99	0.99	280.63	312.41	80	5282	78	4855	0.95	0.95	368.72	393.22
60	3	1	1	1449	86040	1440	85396	1.00	1.00	352.52	298.30	380	21606	378	21010	0.99	0.99	368.55	313.42	83	5365	78	4933	0.95	0.95	448.24	394.09

TBA LOW MED

	Independent Variables			Dependent Variables																							
				Product A								Product B								Product C							
Replication Number	MAS	MOH	MIX	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time
1	3	1	2	1444	1444	1433	1433	1.00	1.00	549.61	549.61	674	674	524	524	0.81	0.81	556.76	556.76	205	205	76	76	0.38	0.38	363.62	363.62
2	3	1	2	1445	2889	1428	2861	1.00	1.00	555.36	552.48	665	1339	561	1085	0.81	0.81	581.77	569.69	186	391	76	152	0.40	0.39	400.52	382.07
3	3	1	2	1445	4334	1435	4296	1.00	1.00	540.42	548.45	703	2042	509	1594	0.81	0.81	504.46	548.86	168	559	82	234	0.42	0.40	427.99	398.16
4	3	1	2	1477	5811	1470	5766	1.00	1.00	558.49	551.01	721	2763	562	2156	0.77	0.80	549.70	549.08	190	749	69	303	0.40	0.40	362.11	389.95
5	3	1	2	1450	7261	1441	7207	1.00	1.00	556.36	552.08	708	3471	554	2710	0.80	0.80	550.65	549.40	165	914	72	375	0.46	0.41	424.90	396.66
6	3	1	2	1501	8762	1478	8685	1.00	1.00	562.42	553.84	745	4216	555	3265	0.80	0.80	554.17	550.21	178	1092	59	434	0.41	0.41	389.52	395.69
7	3	1	2	1467	10229	1459	10144	1.00	1.00	568.67	555.97	740	4956	557	3822	0.80	0.80	546.28	549.64	180	1272	67	501	0.41	0.41	389.89	394.92
8	3	1	2	1467	11697	1459	11602	1.00	1.00	572.94	558.11	740	5695	557	4378	0.80	0.80	545.13	549.07	180	1451	67	567	0.41	0.41	388.35	394.15
9	3	1	2	1467	13164	1459	13061	1.00	1.00	577.20	560.24	740	6435	557	4935	0.71	0.79	543.99	548.49	180	1631	67	634	0.41	0.41	386.81	393.38
10	3	1	2	1467	14631	1459	14519	1.00	1.00	581.47	562.37	740	7174	557	5491	0.79	0.79	542.84	547.92	180	1810	67	700	0.41	0.41	385.27	392.61
11	3	1	2	1412	16043	1397	15916	1.00	1.00	536.39	560.09	662	7836	542	6033	0.79	0.79	548.70	547.99	189	1999	80	780	0.41	0.41	388.32	392.17
12	3	1	2	1443	17486	1428	17344	1.00	1.00	567.62	560.71	715	8551	574	6607	0.79	0.79	562.61	549.26	158	2157	72	852	0.41	0.41	435.13	395.80
13	3	1	2	1459	18945	1456	18800	1.00	1.00	576.08	561.90	716	9267	551	7158	0.79	0.79	569.53	550.82	193	2350	69	921	0.41	0.41	359.63	393.09
14	3	1	2	1441	20386	1422	20222	1.00	1.00	550.52	561.10	682	9949	535	7693	0.79	0.79	547.23	550.57	202	2552	80	1001	0.41	0.41	382.70	392.26
15	3	1	2	1393	21779	1394	21616	1.00	1.00	541.72	559.85	726	10675	554	8247	0.79	0.79	533.00	549.39	180	2732	76	1077	0.41	0.41	411.53	393.62
16	3	1	2	1467	23246	1452	23068	1.00	1.00	544.44	558.88	694	11369	544	8791	0.79	0.79	538.89	548.74	168	2900	70	1147	0.41	0.41	409.84	394.61
17	3	1	2	1401	24647	1388	24456	1.00	1.00	542.49	557.95	698	12067	545	9336	0.79	0.79	542.74	548.39	196	3096	81	1228	0.41	0.41	394.31	394.59
18	3	1	2	1425	26072	1424	25880	1.00	1.00	553.59	557.71	725	12792	565	9901	0.79	0.79	545.24	548.21	183	3279	75	1303	0.41	0.41	395.81	394.66
19	3	1	2	1412	27484	1397	27277	1.00	1.00	544.24	557.02	731	13523	573	10474	0.79	0.79	530.11	547.22	191	3470	78	1381	0.41	0.41	385.45	394.14
20	3	1	2	1392	28876	1369	28646	1.00	1.00	540.91	556.25	691	14214	549	11023	0.79	0.79	532.36	546.48	185	3655	80	1461	0.41	0.41	418.98	395.50
21	3	1	2	1441	30317	1438	30084	1.00	1.00	552.69	556.08	691	14905	548	11571	0.79	0.79	561.68	547.20	177	3832	77	1538	0.41	0.41	397.90	395.62
22	3	1	2	1355	31672	1348	31432	1.00	1.00	555.61	556.06	723	15628	598	12169	0.79	0.79	541.30	546.91	177	4009	83	1621	0.41	0.41	420.42	396.89
23	3	1	2	1468	33140	1460	32892	1.00	1.00	539.39	555.32	714	16342	482	12651	0.79	0.79	483.39	544.49	192	4201	82	1703	0.41	0.41	396.89	396.89
24	3	1	2	1441	34581	1436	34328	1.00	1.00	542.65	554.79	702	17044	537	13188	0.79	0.79	529.75	543.89	195	4396	76	1779	0.41	0.41	386.12	396.43
25	3	1	2	1470	36051	1453	35781	1.00	1.00	541.98	554.27	709	17753	540	13728	0.79	0.79	530.42	543.36	176	4572	71	1850	0.41	0.41	388.61	396.13
26	3	1	2	1486	37537	1466	37247	1.00	1.00	662.50	558.53	742	18495	562	14290	0.79	0.79	607.69	545.89	199	4771	64	1914	0.41	0.41	367.12	395.16
27	3	1	2	1353	38890	1444	38691	1.00	1.00	543.79	557.98	713	19208	529	14819	0.79	0.79	525.44	545.16	175	4946	76	1990	0.41	0.41	408.51	395.67
28	3	1	2	1580	40470	1480	40171	1.00	1.00	560.69	558.08	692	19900	525	15344	0.79	0.79	560.36	545.68	186	5132	72	2062	0.41	0.41	390.52	395.49
29	3	1	2	1474	41944	1459	41630	1.00	1.00	584.90	559.02	778	20678	582	15926	0.79	0.79	557.17	546.10	172	5304	64	2126	0.41	0.41	419.41	396.21
30	3	1	2	1489	43433	1475	43105	1.00	1.00	561.36	559.10	743	21421	553	16479	0.79	0.79	530.60	545.58	181	5485	69	2195	0.41	0.41	372.35	395.46
31	3	1	2	1352	44785	1338	44443	1.00	1.00	568.40	559.38	704	22125	593	17072	0.79	0.79	573.22	546.54	167	5652	85	2280	0.41	0.41	445.08	397.31
32	3	1	2	1472	46257	1475	45918	1.00	1.00	580.24	560.05	666	22791	526	17598	0.79	0.79	584.01	547.66	187	5839	72	2352	0.41	0.41	397.64	397.32
33	3	1	2	1396	47653	1379	47297	1.00	1.00	539.13	559.44	701	23492	573	18171	0.79	0.79	545.44	547.59	173	6012	76	2428	0.41	0.41	411.06	397.75
34	3	1	2	1473	49126	1468	48765	1.00	1.00	540.17	558.86	679	24171	541	18712	0.79	0.79	540.67	547.39	175	6187	69	2497	0.41	0.41	390.15	397.54
35	3	1	2	1487	50613	1463	50228	1.00	1.00	554.40	558.73	691	24862	503	19215	0.79	0.79	528.29	546.89	201	6388	77	2574	0.41	0.41	379.82	397.01
36	3	1	2	1418	52031	1419	51647	1.00	1.00	535.44	558.09	686	25548	528	19743	0.79	0.79	518.85	546.14	179	6567	80	2654	0.41	0.41	405.97	397.28
37	3	1	2	1442	53473	1429	53076	1.00	1.00	546.95	557.79	733	26281	590	20333	0.79	0.79	564.75	546.68	186	6753	68	2722	0.41	0.41	360.05	396.35
38	3	1	2	1448	54921	1441	54517	1.00	1.00	579.73	558.37	760	27041	563	20896	0.79	0.79	550.02	546.77	168	6921	71	2793	0.41	0.41	438.84	397.43
39	3	1	2	1445	56366	1428	55945	1.00	1.00	565.81	558.56	736	27777	600	21496	0.79	0.79	572.21	547.48	177	7098	65	2858	0.41	0.41	372.37	396.86
40	3	1	2	1419	57785	1414	57359	1.00	1.00	600.75	559.60	738	28515	578	22074	0.79	0.79	583.76	548.43	191	7289	70	2928	0.79	0.42	419.87	397.41
41	3	1	2	1443	59228	1436	58795	1.00	1.00	596.86	560.51	792	29307	597	22671	0.79	0.79	560.96	548.76	179	7468	58	2986	0.42	0.42	421.09	397.87
42	3	1	2	1378	60606	1368	60163	1.00	1.00	555.67	560.40	698	30005	565	23236	0.79	0.79	551.23	548.82	190	7658	80	3066	0.42	0.42	417.42	398.38
43	3	1	2	1361	61967	1357	61520	1.00	1.00	544.08	560.04	731	30736	603	23839	0.79	0.79	547.63	548.79	141	7799	72	3138	0.42	0.42	487.29	400.42
44	3	1	2	1391	63358	1375	62895	1.00	1.00	530.31	559.39	685	31421	565	24404	0.79	0.79	532.81	548.42	180	7979	79	3217	0.42	0.42	396.35	400.32
45	3	1	2	1411	64769	1395	64290	1.00	1.00	540.96	558.99	675	32096	528	24932	0.79	0.79	519.62	547.81	192	8171	87	3304	0.42	0.42	394.62	400.17
46	3	1	2	1458	66227	1462	65752	1.00	1.00	563.49	559.09	715	32811	555	25487	0.79	0.79	554.70	547.96	169	8340	65	3369	0.42	0.42	417.27	400.50
47	3	1	2	1462	67689	1451	67203	1.00	1.00	591.51	559.79	742	33553	585	26072	0.79	0.79	586.29	548.82	170	8510	66	3435	0.42	0.42	427.56	401.02
48	3	1	2	1373	69062	1349	68552	1.00	1.00	524.73	559.10	745	34298	627	26699	0.79	0.79	525.40	548.27	160	8670	74	3509	0.42	0.42	405.76	401.12
49	3	1	2	1442	70504	1435	69987	1.00	1.00	570.32	559.33	718	35016	550	27249	0.79	0.79	556.20	548.43	158	8828	73	3582	0.42	0.42	448.23	402.08
50	3	1	2	1490	71994	1488	71475	1.00	1.00	555.01	559.24	762	35778	518	27767	0.79	0.79	495.90	547.45	190	9018	67	3649	0.42	0.42	386.29	401.79
51	3	1	2	1435	73429	1413	72888	1.00	1.00	600.51	560.04	785	36563	581	28348	0.79	0.79	552.33	547.55	176	9194	73	3722	0.42	0.42	426.77	402.28
52	3	1	2	1428	74857	1421	74309	1.00	1.00	576.77	560.36	746	37309	582	28930	0.79	0.79	566.44	547.93	180	9374	74	3796	0.42	0.42	402.28	402.28
53	3	1	2	1478	76335	1466	75775	1.00	1.00	652.37	562.14	732	38041	558	29488	0.79	0.79	618.22	549.26	199	9573	69	3865	0.42	0.42	383.80	401.95
54	3	1	2	1521	77856	1512	77287	1.00	1.00	563.67	562.17	705	38746	534	30022	0.79	0.79	548.14	549.24	170	9743	61	3926	0.42	0.42	398.09	401.89
55	3	1	2	1386	79242	1373	78660	1.00	1.00	554.15	562.03	749	39495	579	30601	0.79	0.79	535.50	548.98	195	9938	81	4007	0.42	0.42	382.10	401.49
56	3	1	2	1403	80645	1391	80051	1.00	1.00	552.25	561.86	745	40240	585	31186	0.79	0.79	532.99	548.68	198	10136	77	4084	0.42	0.42	379.21	401.07
57	3	1	2	1392	82037	1386	81437	1.00	1.00	537.18	561.44	722	40962	545	31731	0.79	0.79	497.44	547.80	174	10310	84	4168	0.42	0.42	393.13	400.91
58	3	1	2	1407	83444	1396	82833	1.00	1.00	541.86	561.11	699	41661	576	32307	0.79	0.79	553.97	547.91	170	10480	76	4244	0.42	0.42	436.65	401.55
59	3	1	2	1395	84839	1383	84216	1.00	1.00	542.84	560.81	714	42375	584	32891	0.79	0.79	549.04	547.93	177	10657	75	4319	0.42	0.42	406.73	401.64
60	3	1	2	1455	86294	1440	85656	1.00	1.00	537.61	560.42	692	43067	530	33421	0.79	0.79	523.97	547.55	175	10832	76	4395	0.42	0.42	396.44	401.55

	Independent Variables			Dependent Variables																							
				Product A								Product B								Product C							
Replication Number	MAS	MOH	MIX	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time
TBA LOW HIGH																											
1	3	1	3	1453	1453	1466	1466	1.00	1.00	704.02	704.02	1444	1444	692	692	0.46	0.46	444.11	444.11	318	318	33	33	0.10	0.10	211.38	211.38
2	3	1	3	1452	2905	1431	2897	1.00	1.00	717.38	710.62	1436	2880	688	1380	0.50	0.48	448.38	446.24	408	726	45	78	0.12	0.11	181.05	193.88
3	3	1	3	1503	4408	1488	4385	1.00	1.00	705.05	708.73	1370	4250	648	2028	0.48	0.48	454.00	448.72	368	1094	36	114	0.11	0.11	183.11	190.48
4	3	1	3	1438	5846	1409	5794	1.00	1.00	721.89	711.93	1405	5655	719	2747	0.48	0.48	471.53	454.69	372	1466	41	155	0.11	0.11	203.14	193.83
5	3	1	3	1456	7302	1445	7239	1.00	1.00	678.42	705.24	1464	7119	681	3428	0.53	0.49	413.56	446.52	363	1829	46	201	0.11	0.11	199.86	195.21
6	3	1	3	1470	8772	1454	8693	1.00	1.00	702.49	704.78	1437	8556	707	4135	0.49	0.49	448.27	446.82	353	2182	34	235	0.11	0.11	176.06	192.44
7	3	1	3	1473	10245	1449	10142	1.00	1.00	707.11	705.11	1433	9989	704	4839	0.49	0.49	453.61	447.81	360	2542	35	270	0.11	0.11	189.30	192.04
8	3	1	3	1473	11717	1449	11591	1.00	1.00	707.77	705.45	1433	11423	704	5543	0.49	0.49	455.58	448.80	360	2902	35	304	0.11	0.11	188.49	191.64
9	3	1	3	1473	13190	1449	13040	1.00	1.00	708.44	705.78	1433	12856	704	6247	0.49	0.49	457.56	449.78	360	3262	35	339	0.11	0.11	187.69	191.23
10	3	1	3	1473	14662	1449	14489	1.00	1.00	709.10	706.11	1433	14289	704	6951	0.49	0.49	459.53	450.77	360	3622	35	373	0.11	0.11	186.88	190.83
11	3	1	3	1530	16192	1536	16025	1.00	1.00	710.80	706.56	1443	15732	643	7594	0.49	0.49	424.91	448.58	323	3945	29	402	0.11	0.11	191.38	190.87
12	3	1	3	1492	17684	1488	17513	1.00	1.00	723.39	707.99	1502	17234	693	8287	0.49	0.49	441.05	447.95	353	4298	29	431	0.11	0.11	170.81	189.52
13	3	1	3	2220	19904	1395	18908	1.00	1.00	707.85	707.98	1459	18693	737	9024	0.49	0.49	464.36	449.29	382	4680	36	467	0.11	0.11	179.01	188.71
14	3	1	3	651	20555	1454	20362	1.00	1.00	710.92	708.19	1498	20191	711	9735	0.49	0.49	442.72	448.81	333	5013	34	501	0.11	0.11	194.60	189.11
15	3	1	3	1493	22048	1476	21838	1.00	1.00	713.96	708.58	1441	21632	684	10419	0.49	0.49	449.11	448.83	321	5334	35	536	0.11	0.11	203.35	190.04
16	3	1	3	1414	23462	1385	23223	1.00	1.00	717.80	709.13	1514	23146	734	11153	0.49	0.49	442.60	448.42	379	5713	43	579	0.11	0.11	193.14	190.27
17	3	1	3	1506	24968	1485	24708	1.00	1.00	705.64	708.92	1457	24603	666	11819	0.49	0.49	429.43	447.35	346	6059	34	613	0.11	0.11	195.50	190.56
18	3	1	3	1442	26410	1437	26145	1.00	1.00	715.11	709.26	1382	25985	715	12534	0.49	0.49	479.61	449.19	350	6409	35	648	0.11	0.11	187.41	190.39
19	3	1	3	1552	27962	1509	27654	1.00	1.00	705.05	709.03	1465	27450	665	13199	0.49	0.49	430.73	448.26	374	6783	29	677	0.11	0.11	176.15	189.78
20	3	1	3	1469	29431	1449	29103	1.00	1.00	701.20	708.64	1475	28925	711	13910	0.49	0.49	450.80	448.39	337	7120	29	706	0.11	0.11	184.42	189.56
21	3	1	3	1443	30874	1426	30529	1.00	1.00	714.85	708.93	1467	30392	715	14625	0.49	0.49	453.50	448.64	385	7505	37	743	0.11	0.11	184.94	189.33
22	3	1	3	1436	32310	1431	31960	1.00	1.00	717.64	709.32	1448	31840	715	15340	0.49	0.49	454.22	448.90	389	7894	36	779	0.11	0.11	174.18	188.63
23	3	1	3	1483	33793	1433	33393	1.00	1.00	708.62	709.29	1471	33311	699	16039	0.49	0.49	445.92	448.77	348	8242	38	817	0.11	0.11	198.09	189.07
24	3	1	3	1509	35302	1503	34896	1.00	1.00	707.20	709.20	1415	34726	682	16721	0.49	0.49	457.60	449.13	356	8598	31	848	0.11	0.11	92.78	185.55
25	3	1	3	1472	36774	1458	36354	1.00	1.00	712.19	709.32	1367	36093	675	17396	0.49	0.49	463.30	449.68	374	8972	35	883	0.11	0.11	270.07	188.90
26	3	1	3	1423	38197	1413	37767	1.00	1.00	707.72	709.26	1439	37532	703	18099	0.49	0.49	447.36	449.59	344	9316	47	930	0.11	0.11	208.49	189.89
27	3	1	3	1450	39647	1443	39210	1.00	1.00	712.79	709.39	1476	39008	676	18775	0.49	0.49	432.37	448.97	371	9687	43	973	0.11	0.11	195.09	190.12
28	3	1	3	1455	41102	1441	40651	1.00	1.00	707.98	709.34	1447	40455	706	19481	0.49	0.49	449.80	449.00	329	10016	36	1009	0.11	0.11	203.85	190.61
29	3	1	3	1352	42454	1327	41978	1.00	1.00	719.46	709.66	1448	41903	780	20261	0.49	0.49	482.51	450.29	344	10360	40	1049	0.11	0.11	204.77	191.15
30	3	1	3	1438	43892	1434	43412	1.00	1.00	715.71	709.86	1432	43335	701	20962	0.49	0.49	457.17	450.52	394	10754	40	1089	0.11	0.11	182.98	190.85
31	3	1	3	1438	45330	1416	44828	1.00	1.00	711.76	709.92	1407	44742	721	21683	0.49	0.49	473.68	451.29	371	11125	37	1126	0.11	0.11	169.55	190.15
32	3	1	3	1464	46794	1445	46273	1.00	1.00	707.68	709.85	1478	46220	708	22391	0.49	0.49	446.55	451.14	405	11530	33	1159	0.11	0.11	167.67	189.51
33	3	1	3	1435	48229	1419	47692	1.00	1.00	705.14	709.71	1400	47620	697	23088	0.49	0.49	458.76	451.37	333	11863	44	1203	0.11	0.11	210.29	190.27
34	3	1	3	1453	49682	1440	49132	1.00	1.00	716.88	709.92	1559	49179	714	23802	0.49	0.49	428.37	450.68	364	12227	35	1238	0.11	0.11	187.79	190.20
35	3	1	3	1411	51093	1407	50539	1.00	1.00	706.69	709.83	1431	50610	725	24527	0.49	0.49	463.54	451.06	402	12629	40	1278	0.11	0.11	177.74	189.81
36	3	1	3	1453	52546	1431	51970	1.00	1.00	716.73	710.02	1424	52034	697	25224	0.49	0.49	460.11	451.31	367	12996	40	1318	0.11	0.11	190.80	189.84
37	3	1	3	1517	54063	1495	53465	1.00	1.00	713.24	710.11	1432	53466	665	25889	0.49	0.49	436.13	450.92	352	13348	36	1354	0.11	0.11	203.38	190.20
38	3	1	3	1376	55439	1368	54833	1.00	1.00	713.32	710.19	1377	54843	705	26594	0.49	0.49	466.39	451.33	368	13716	52	1406	0.11	0.11	211.29	190.98
39	3	1	3	1478	56917	1445	56278	1.00	1.00	705.52	710.07	1480	56323	702	27296	0.49	0.49	428.78	450.75	355	14071	37	1443	0.11	0.11	189.03	190.93
40	3	1	3	1417	58334	1417	57695	1.00	1.00	709.26	710.05	1405	57728	718	28014	0.49	0.49	475.72	451.39	360	14431	38	1481	0.11	0.11	187.03	190.83
41	3	1	3	1435	59769	1419	59114	1.00	1.00	721.30	710.32	1446	59174	695	28709	0.49	0.49	451.80	451.40	395	14826	40	1521	0.11	0.11	189.31	190.79
42	3	1	3	1422	61191	1412	60526	1.00	1.00	732.18	710.83	1404	60578	697	29406	0.49	0.49	466.59	451.76	339	15165	43	1564	0.11	0.11	213.70	191.42
43	3	1	3	1362	62553	1345	61871	1.00	1.00	714.51	710.91	1379	61957	768	30174	0.49	0.49	492.23	452.79	390	15555	43	1607	0.11	0.11	191.79	191.43
44	3	1	3	1435	63988	1434	63305	1.00	1.00	718.41	711.08	1441	63398	702	30876	0.49	0.49	456.31	452.87	325	15880	38	1645	0.11	0.11	208.31	191.82
45	3	1	3	1449	65437	438	63743	1.00	1.00	695.07	710.97	1398	64796	687	31563	0.49	0.49	457.46	452.97	385	16265	42	1687	0.11	0.11	182.18	191.58
46	3	1	3	1383	66820	2369	66112	1.00	1.00	710.13	710.94	1474	66270	737	32300	0.49	0.49	456.04	453.04	344	16609	41	1728	0.11	0.11	210.12	192.02
47	3	1	3	1357	68177	1346	67458	1.00	1.00	710.94	710.94	1456	67726	722	33022	0.49	0.49	454.41	453.07	360	16969	51	1779	0.11	0.11	220.97	192.85
48	3	1	3	1397	69574	1373	68831	1.00	1.00	709.94	710.92	1412	69138	760	33782	0.49	0.49	477.52	453.62	349	17318	34	1813	0.11	0.11	198.18	192.95
49	3	1	3	1490	71064	1482	70313	1.00	1.00	718.99	711.09	1435	70573	672	34454	0.49	0.49	445.42	453.46	386	17704	36	1849	0.11	0.11	172.41	192.55
50	3	1	3	1433	72497	1402	71715	1.00	1.00	711.09	711.09	1442	72015	754	35208	0.49	0.49	476.34	453.95	336	18040	34	1883	0.11	0.11	194.21	192.58
51	3	1	3	1414	73911	1416	73131	1.00	1.00	711.61	711.10	1421	73436	703	35911	0.49	0.49	460.08	454.07	366	18406	40	1923	0.11	0.11	205.56	192.85
52	3	1	3	1483	75394	1461	74592	1.00	1.00	718.76	711.25	1434	74870	(318)	35593	0.49	0.49	476.46	453.87	332	18738	40	1963	0.11	0.11	194.81	192.89
53	3	1	3	1404	76798	1389	75981	1.00	1.00	715.08	711.32	1440	76310	1737	37330	0.49	0.49	461.61	454.23	357	19095	37	2000	0.11	0.11	206.94	193.15
54	3	1	3	1537	78335	1522	77503	1.00	1.00	711.32	711.32	1478	77788	655	37985	0.49	0.49	414.80	453.55	365	19460	33	2033	0.11	0.11	166.04	192.71
55	3	1	3	1508	79843	1479	78982	1.00	1.00	712.39	711.34	1439	79227	659	38644	0.49	0.49	433.61	453.21	355	19815	38	2071	0.11	0.11	198.70	192.82
56	3	1	3	1369	81212	1382	80364	1.00	1.00	713.67	711.38	1413	80640	728	39372	0.49	0.49	473.22	453.58	381	20196	46	2117	0.11	0.11	201.10	193.00
57	3	1	3	1425	82637	1395	81759	1.00	1.00	710.79	711.37	1459	82099	739	40111	0.49	0.49	461.72	453.73	367	20563	38	2155	0.11	0.11	192.43	192.99
58	3	1	3	1430	84067	1415	83174	1.00	1.00	711.96	711.38	1479	83578	689	40800	0.49	0.49	434.19	453.40	391	20954	47	2202	0.11	0.11	198.14	193.10
59	3	1	3	1466	85533	1451	84625	1.00	1.00	716.63	711.47	1499	85077	722	41522	0.49	0.49	447.65	453.30	359	21313	30	2232	0.11	0.11	173.01	192.83
60	3	1	3	4373	89906	1362	85987	1.00	1.00	712.73	711.49	1483	86560	777	42299	0.49	0.49	478.89	453.77	322	21635	36	2268	0.11	0.11	211.73	193.13

ABC LOW LOW

	Independent Variables			Dependent Variables: Product A								Product B								Product C							
Replication Number	MAS	MOH	MIX	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time
1	2	1	1	1464	1464	1450	1450	1.00	1.00	311.75	311.75	391	391	386	386	1.00	1.00	303.18	303.18	81	81	77	77	0.97	0.97	360.87	360.87
2	2	1	1	1437	2901	1435	2885	1.00	1.00	299.22	305.52	338	729	338	724	1.00	1.00	304.27	303.69	89	170	80	157	0.95	0.96	430.13	396.16
3	2	1	1	1446	4347	1441	4326	1.00	1.00	325.06	312.03	354	1083	343	1067	1.00	1.00	323.94	310.20	101	271	93	250	0.93	0.95	393.01	394.99
4	2	1	1	1366	5713	1329	5655	1.00	1.00	248.16	297.02	369	1452	360	1427	1.00	1.00	256.65	296.69	97	368	95	345	0.95	0.95	350.83	382.83
5	2	1	1	1374	7087	1378	7033	1.00	1.00	233.22	284.52	345	1797	343	1770	1.00	1.00	220.83	281.99	68	436	66	411	0.95	0.95	349.64	377.50
6	2	1	1	1420	8507	1398	8431	1.00	1.00	319.80	290.37	350	2147	338	2108	1.00	1.00	322.03	288.41	97	533	86	497	0.95	0.95	424.77	385.68
7	2	1	1	1424	9931	1417	9848	1.00	1.00	226.91	281.24	343	2490	338	2444	1.00	1.00	248.58	282.91	85	618	80	577	0.95	0.95	379.28	384.79
8	2	1	1	1424	11356	1417	11265	1.00	1.00	256.12	278.08	343	2833	337	2780	1.00	1.00	264.89	280.73	85	704	80	658	1.00	0.96	376.60	383.79
9	2	1	1	1424	12780	1417	12681	1.00	1.00	249.80	274.92	343	3175	337	3116	1.00	1.00	260.49	278.54	85	789	80	738	0.96	0.96	374.60	382.79
10	2	1	1	1424	14204	1417	14098	1.00	1.00	302.88	277.73	343	3518	336	3452	1.00	1.00	290.15	279.67	85	874	80	818	0.96	0.96	371.48	381.68
11	2	1	1	1432	15636	1415	15513	1.00	1.00	251.97	275.38	353	3871	348	3800	1.00	1.00	270.93	278.87	87	961	82	900	0.96	0.96	345.46	378.38
12	2	1	1	1439	17075	1432	16945	1.00	1.00	237.51	272.18	337	4208	329	4129	1.00	1.00	246.11	276.26	84	1045	81	981	0.96	0.96	333.81	374.70
13	2	1	1	1387	18462	1370	18315	1.00	1.00	209.75	267.51	358	4566	352	4481	1.00	1.00	222.67	272.05	68	1113	63	1044	0.96	0.96	334.60	372.28
14	2	1	1	1502	19964	1484	19799	1.00	1.00	332.22	272.36	351	4917	346	4827	1.00	1.00	332.18	276.36	96	1209	84	1128	0.96	0.96	372.55	372.30
15	2	1	1	1478	21442	1478	21277	1.00	1.00	290.50	273.62	364	5281	355	5182	1.00	1.00	299.57	277.95	79	1288	79	1207	0.96	0.96	377.49	372.64
16	2	1	1	1450	22892	1429	22706	1.00	1.00	297.77	275.14	329	5610	321	5503	1.00	1.00	308.12	279.71	93	1381	85	1292	0.96	0.96	393.77	374.03
17	2	1	1	1407	24299	1394	24100	1.00	1.00	257.33	274.11	368	5978	367	5870	1.00	1.00	255.24	278.18	84	1465	77	1369	1.00	0.97	358.56	373.16
18	2	1	1	1421	25720	1418	25518	1.00	1.00	306.14	275.89	367	6345	362	6232	1.00	1.00	293.67	279.08	93	1558	89	1458	0.97	0.97	385.12	373.89
19	2	1	1	1483	27203	1480	26998	1.00	1.00	340.28	279.42	379	6724	376	6608	1.00	1.00	358.69	283.61	90	1648	81	1539	0.97	0.97	395.55	375.03
20	2	1	1	1391	28594	1386	28384	1.00	1.00	224.33	276.73	350	7074	343	6951	1.00	1.00	229.30	280.93	84	1732	82	1621	0.97	0.97	309.60	371.72
21	2	1	1	1448	30042	1436	29820	1.00	1.00	293.34	277.53	381	7455	375	7326	1.00	1.00	295.00	281.65	81	1813	79	1700	0.97	0.97	401.42	373.10
22	2	1	1	1452	31494	1430	31250	1.00	1.00	323.42	279.63	372	7827	357	7683	1.00	1.00	320.17	283.44	100	1913	82	1782	0.97	0.97	415.91	375.07
23	2	1	1	1410	32904	1398	32648	1.00	1.00	303.68	280.66	343	8170	346	8029	1.00	1.00	289.47	283.70	91	2004	84	1866	0.97	0.97	385.73	375.55
24	2	1	1	1495	34399	1429	34077	1.00	1.00	253.00	279.50	375	8545	368	8397	1.00	1.00	267.04	282.97	86	2090	78	1944	0.97	0.97	325.45	373.54
25	2	1	1	1369	35768	1425	35502	1.00	1.00	366.20	282.98	352	8897	344	8741	1.00	1.00	355.13	285.81	101	2191	89	2033	0.97	0.97	479.30	378.17
26	2	1	1	1375	37143	1369	36871	1.00	1.00	308.57	283.93	389	9286	379	9120	1.00	1.00	312.28	286.91	96	2287	89	2122	0.97	0.97	403.44	379.23
27	2	1	1	1491	38634	1475	38346	1.00	1.00	400.66	288.42	362	9648	354	9474	1.00	1.00	405.20	291.33	97	2384	78	2200	0.97	0.97	499.95	383.51
28	2	1	1	1407	40041	1407	39753	1.00	1.00	281.07	288.16	393	10041	384	9858	1.00	1.00	282.09	290.97	76	2460	70	2270	0.97	0.97	413.02	384.42
29	2	1	1	1481	41522	1459	41212	1.00	1.00	290.98	288.26	351	10392	347	10205	1.00	1.00	306.85	291.51	84	2544	72	2342	0.97	0.97	375.31	384.14
30	2	1	1	1441	42963	1441	42653	1.00	1.00	367.88	290.95	361	10753	363	10568	1.00	1.00	357.31	293.77	110	2654	95	2437	0.97	0.97	436.21	386.17
31	2	1	1	1447	44410	1430	44083	1.00	1.00	269.68	290.26	385	11138	379	10947	1.00	1.00	278.75	293.25	87	2741	85	2522	0.97	0.97	372.52	385.71
32	2	1	1	1407	45817	1393	45476	1.00	1.00	313.11	290.96	387	11525	376	11323	1.00	1.00	318.55	294.09	89	2830	82	2604	0.97	0.97	414.29	386.61
33	2	1	1	1485	47302	1472	46948	1.00	1.00	295.11	291.09	342	11867	336	11659	1.00	1.00	293.40	294.07	82	2912	72	2676	0.97	0.97	380.66	386.45
34	2	1	1	1490	48792	1480	48428	1.00	1.00	329.70	292.27	352	12219	350	12009	1.00	1.00	317.06	294.74	88	3000	78	2754	0.97	0.97	413.64	387.22
35	2	1	1	1455	50247	1436	49864	1.00	1.00	298.17	292.44	353	12572	345	12354	1.00	1.00	315.87	295.33	102	3102	96	2850	0.97	0.97	364.06	386.44
36	2	1	1	1440	51687	1425	51289	1.00	1.00	315.48	293.08	309	12881	306	12660	1.00	1.00	335.46	296.30	99	3201	89	2939	0.97	0.97	415.83	387.33
37	2	1	1	1481	53168	1470	52759	1.00	1.00	318.56	293.79	353	13234	342	13002	1.00	1.00	317.59	296.86	96	3297	90	3029	0.97	0.97	378.92	387.08
38	2	1	1	1428	54596	1416	54175	1.00	1.00	278.10	293.38	345	13579	336	13338	1.00	1.00	261.53	295.97	85	3382	82	3111	0.97	0.97	378.35	386.85
39	2	1	1	1406	56002	1407	55582	1.00	1.00	298.91	293.52	386	13965	385	13723	1.00	1.00	295.97	295.97	76	3458	72	3183	0.51	0.96	389.50	386.91
40	2	1	1	1470	57472	1454	57036	1.00	1.00	270.38	292.93	330	14295	326	14049	1.00	1.00	272.70	295.43	85	3543	83	3266	0.96	0.96	379.04	386.71
41	2	1	1	1448	58920	1432	58468	1.00	1.00	329.68	293.83	336	14631	329	14378	1.00	1.00	315.10	295.88	104	3647	100	3366	0.96	0.96	431.81	388.05
42	2	1	1	1430	60350	1414	59882	1.00	1.00	357.35	295.33	376	15007	370	14748	1.00	1.00	360.85	297.51	74447	78094	98	3464	0.96	0.96	421.63	389.00
43	2	1	1	1415	61765	1400	61282	1.00	1.00	252.43	294.35	368	15375	363	15111	1.00	1.00	244.23	296.23	(74259)	3835	75	3539	0.96	0.96	366.35	388.52
44	2	1	1	1447	63212	1456	62738	1.00	1.00	365.45	296.00	368	15743	361	15472	1.00	1.00	363.95	297.81	92	3927	81	3620	0.96	0.96	449.75	389.89
45	2	1	1	1405	64617	1384	64122	1.00	1.00	249.21	294.99	368	16111	362	15834	1.00	1.00	248.82	296.69	87	4014	79	3699	0.96	0.96	375.37	389.58
46	2	1	1	1387	66004	1383	65505	1.00	1.00	266.10	294.38	344	16455	340	16174	1.00	1.00	260.54	295.93	90	4104	83	3782	0.96	0.96	344.01	388.58
47	2	1	1	1420	67424	1417	66922	1.00	1.00	427.56	297.20	401	16856	401	16575	1.00	1.00	396.79	298.37	107	4211	85	3867	0.96	0.96	465.92	390.28
48	2	1	1	1447	68871	1429	68351	1.00	1.00	300.55	297.27	377	17233	372	16947	1.00	1.00	294.27	298.28	87	4298	81	3948	0.96	0.96	414.65	390.78
49	2	1	1	1475	70346	1461	69812	1.00	1.00	377.07	298.94	354	17587	347	17294	1.00	1.00	361.58	299.55	98	4396	86	4034	0.96	0.96	437.22	391.77
50	2	1	1	1434	71780	1420	71232	1.00	1.00	275.36	298.47	366	17953	363	17657	1.00	1.00	290.31	299.36	91	4487	87	4121	0.96	0.96	373.77	391.39
51	2	1	1	1428	73208	1427	72659	1.00	1.00	276.58	298.04	354	18307	349	18006	1.00	1.00	277.17	298.93	84	4571	76	4197	0.96	0.96	379.24	391.17
52	2	1	1	1400	74608	1389	74048	1.00	1.00	288.98	297.87	364	18671	359	18365	1.00	1.00	293.81	298.83	101	4672	95	4292	0.96	0.96	364.06	390.57
53	2	1	1	1487	76095	1456	75504	1.00	1.00	391.21	299.67	383	19054	379	18744	1.00	1.00	375.49	300.38	101	4773	93	4385	0.96	0.96	464.12	392.13
54	2	1	1	1525	77620	1503	77007	1.00	1.00	357.05	300.79	356	19410	350	19094	1.00	1.00	347.84	301.25	100	4873	83	4468	0.96	0.96	383.52	391.97
55	2	1	1	1427	79047	1432	78439	1.00	1.00	329.82	301.32	345	19755	338	19432	1.00	1.00	319.07	301.56	105	4978	90	4558	0.96	0.96	399.57	392.12
56	2	1	1	1455	80502	1446	79885	1.00	1.00	319.00	301.64	384	20139	381	19813	1.00	1.00	314.04	301.80	91	5069	90	4648	0.96	0.96	408.13	392.43
57	2	1	1	1456	81958	1449	81334	1.00	1.00	345.42	302.42	364	20503	357	20170	1.00	1.00	335.13	302.39	89	5158	79	4727	0.96	0.96	428.33	393.03
58	2	1	1	1420	83378	1399	82733	1.00	1.00	277.58	302.00	373	20876	367	20537	1.00	1.00	270.49	301.82	92	5250	83	4810	0.96	0.96	397.09	393.10
59	2	1	1	1341	84719	1344	84077	1.00	1.00	309.51	302.12	347	21223	346	20883	1.00	1.00	312.08	301.99	101	5351	95	4905	0.96	0.96	403.94	393.31
60	2	1	1	1409	86128	1393	85470	1.00	1.00	319.91	302.41	381	21604	372	21255	1.00	1.00	309.99	302.13	96	5447	85	4990	0.96	0.96	393.31	393.31

ABC LOW MED

	Independent Variables			Dependent Variables																							
				Product A								Product B								Product C							
Replication Number	MAS	MOH	MIX	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time
1	2	1	2	1411	1411	1333	1333	0.97	0.97	803.14	803.14	786	786	744	744	0.97	0.97	673.38	673.38	192	192	51	51	0.37	0.37	332.45	332.45
2	2	1	2	1442	2853	1334	2667	0.95	0.96	788.69	795.91	756	1542	731	1475	0.97	0.97	667.67	670.55	214	406	57	108	0.29	0.33	349.82	341.62
3	2	1	2	1443	4296	1395	4062	0.96	0.96	784.41	791.96	716	2258	689	2164	0.97	0.97	671.27	670.78	146	552	49	157	0.29	0.32	408.81	362.59
4	2	1	2	1396	5692	1373	5435	0.96	0.96	788.24	791.02	707	2965	676	2840	0.97	0.97	657.76	667.68	182	734	56	213	0.32	0.32	404.01	373.48
5	2	1	2	1492	7184	1433	6868	0.96	0.96	808.03	794.57	680	3645	669	3509	0.97	0.97	657.87	665.81	167	901	47	260	0.27	0.31	417.68	381.47
6	2	1	2	1430	8614	1356	8224	0.96	0.96	800.63	795.57	727	4372	700	4209	1.00	0.98	674.89	667.32	173	1074	59	319	0.31	0.31	425.54	389.62
7	2	1	2	1449	10063	1382	9606	0.96	0.96	801.88	796.48	727	5099	703	4912	0.98	0.98	674.31	668.32	172	1246	49	368	0.31	0.31	403.70	391.50
8	2	1	2	1449	11511	1382	10988	0.96	0.96	803.69	797.39	727	5826	703	5614	0.98	0.98	676.31	669.32	172	1418	49	418	0.31	0.31	407.46	393.39
9	2	1	2	1449	12960	1382	12369	0.96	0.96	805.51	798.29	727	6553	703	6317	0.98	0.98	678.31	670.32	172	1589	49	467	0.31	0.31	411.23	395.27
10	2	1	2	1449	14408	1382	13751	0.96	0.96	807.32	799.20	727	7280	703	7019	0.98	0.98	680.31	671.32	172	1761	49	516	0.31	0.31	414.99	397.15
11	2	1	2	1489	15897	1419	15170	0.96	0.96	817.37	800.90	711	7991	700	7719	0.98	0.98	696.46	673.60	187	1948	46	562	0.31	0.31	350.97	393.37
12	2	1	2	1424	17321	1334	16504	0.96	0.96	823.42	802.72	740	8731	710	8429	0.98	0.98	698.29	675.68	174	2122	62	624	0.31	0.31	465.94	400.58
13	2	1	2	1530	18851	1446	17950	0.96	0.96	810.42	803.34	689	9420	662	9091	0.98	0.98	692.43	676.90	175	2297	43	667	0.31	0.31	384.91	399.57
14	2	1	2	1423	20274	1366	19316	0.96	0.96	779.02	801.62	723	10143	707	9798	0.98	0.98	669.55	676.37	181	2478	56	723	0.31	0.31	372.20	397.45
15	2	1	2	1427	21701	1361	20677	0.96	0.96	802.23	801.66	731	10874	697	10495	0.98	0.98	693.08	677.48	168	2646	52	775	0.31	0.31	440.97	400.37
16	2	1	2	1342	23043	1280	21957	0.96	0.96	806.29	801.93	718	11592	701	11196	0.98	0.98	683.87	677.88	194	2840	75	850	0.31	0.31	446.84	404.47
17	2	1	2	1433	24476	1352	23309	0.96	0.96	801.93	801.93	729	12321	714	11910	0.98	0.98	680.05	678.01	174	3014	57	907	0.31	0.31	414.97	405.13
18	2	1	2	1423	25899	1356	24665	0.96	0.96	760.64	799.66	696	13017	672	12582	0.98	0.98	668.46	677.50	157	3171	66	973	0.31	0.31	457.76	408.70
19	2	1	2	1470	27369	1401	26066	0.96	0.96	832.41	801.42	763	13780	731	13313	0.98	0.98	678.59	677.56	181	3352	41	1014	0.31	0.31	326.34	405.37
20	2	1	2	1477	28846	1412	27478	0.96	0.96	818.55	802.30	690	14470	667	13980	0.98	0.98	672.53	677.32	190	3542	56	1070	0.31	0.31	402.70	405.23
21	2	1	2	1384	30230	1302	28780	0.96	0.96	794.78	801.96	759	15229	747	14727	0.98	0.98	681.26	677.52	149	3691	60	1130	0.31	0.31	470.96	408.72
22	2	1	2	1394	31624	1350	30130	0.96	0.96	789.46	801.40	736	15965	703	15430	0.98	0.98	648.33	676.19	182	3873	58	1188	0.31	0.31	397.66	408.18
23	2	1	2	1377	33001	1348	31478	0.96	0.96	760.30	799.64	714	16679	695	16125	0.98	0.98	633.27	674.34	187	4060	60	1248	0.31	0.31	415.67	408.54
24	2	1	2	1501	34502	1422	32900	0.96	0.96	768.17	798.28	701	17380	675	16800	0.98	0.98	634.77	672.75	146	4206	48	1296	0.31	0.31	427.44	409.24
25	2	1	2	1463	35965	1416	34316	0.96	0.96	801.92	798.43	672	18052	651	17451	0.98	0.98	686.15	673.25	165	4371	54	1350	0.31	0.31	427.49	409.97
26	2	1	2	1413	37378	1353	35669	0.96	0.96	795.00	798.30	759	18811	721	18172	0.98	0.98	655.36	672.54	198	4569	51	1401	0.31	0.31	350.63	407.81
27	2	1	2	1416	38794	1354	37023	0.96	0.96	818.53	799.04	752	19563	732	18904	0.98	0.98	701.21	673.65	182	4751	51	1452	0.31	0.31	380.76	406.86
28	2	1	2	1442	40236	1381	38404	0.96	0.96	811.83	799.50	769	20332	724	19628	0.98	0.98	673.92	673.66	186	4937	41	1493	0.31	0.31	359.52	405.56
29	2	1	2	1414	41650	1376	39780	0.96	0.96	748.33	797.73	684	21016	670	20298	0.98	0.98	613.67	671.68	182	5119	60	1553	0.31	0.31	380.19	404.58
30	2	1	2	1481	43131	1390	41170	0.96	0.96	832.98	798.92	733	21749	697	20995	0.98	0.98	685.23	672.13	187	5306	51	1604	0.31	0.31	435.40	405.56
31	2	1	2	1393	44524	1335	42505	0.96	0.96	789.05	798.61	731	22480	715	21710	0.98	0.98	658.16	671.67	183	5489	59	1663	0.31	0.31	401.05	405.40
32	2	1	2	1471	45995	1414	43919	0.96	0.96	788.67	798.29	702	23182	664	22374	0.98	0.98	676.05	671.80	185	5674	51	1714	0.31	0.31	389.60	404.93
33	2	1	2	1405	47400	1359	45278	0.96	0.96	792.29	798.11	701	23883	690	23064	0.98	0.98	681.16	672.08	177	5851	62	1776	0.31	0.31	415.53	405.30
34	2	1	2	1417	48817	1359	46637	0.96	0.96	775.12	797.44	724	24607	694	23758	0.98	0.98	631.68	670.90	180	6031	56	1832	0.31	0.31	374.55	404.36
35	2	1	2	1426	50243	1321	47958	0.96	0.96	730.64	795.60	718	25325	698	24456	0.98	0.98	637.61	669.95	182	6213	60	1892	0.31	0.31	394.90	404.06
36	2	1	2	1358	51601	1337	49295	0.96	0.96	680.20	792.47	700	26025	688	25144	0.98	0.98	566.16	667.11	166	6379	60	1952	0.31	0.31	401.78	403.99
37	2	1	2	1454	53055	1409	50704	0.96	0.96	809.74	792.95	707	26732	688	25832	0.98	0.98	669.36	667.17	188	6567	49	2001	0.31	0.31	365.60	403.05
38	2	1	2	1447	54502	1380	52084	0.96	0.96	828.43	793.89	742	27474	694	26526	0.98	0.98	687.43	667.70	180	6747	49	2050	0.31	0.31	396.36	402.89
39	2	1	2	1424	55926	1394	53478	0.96	0.96	767.80	793.21	680	28154	661	27187	0.98	0.98	645.08	667.15	179	6926	61	2111	0.31	0.31	402.89	402.89
40	2	1	2	1412	57338	1361	54839	0.96	0.96	809.33	793.61	715	28869	704	27891	0.98	0.98	690.92	667.75	177	7103	55	2166	0.31	0.31	418.25	403.28
41	2	1	2	1477	58815	1428	56267	0.96	0.96	795.97	793.67	700	29569	679	28570	0.98	0.98	680.79	668.06	160	7263	46	2212	0.31	0.31	400.39	403.22
42	2	1	2	1387	60202	1345	57612	0.96	0.96	821.94	794.33	742	30311	714	29284	0.98	0.98	685.29	668.48	179	7442	50	2262	0.31	0.31	400.05	403.15
43	2	1	2	1396	61598	1347	58959	0.96	0.96	771.57	793.81	664	30975	647	29931	0.98	0.98	665.24	668.41	178	7620	77	2339	0.31	0.31	442.03	404.43
44	2	1	2	1399	62997	1377	60336	0.96	0.96	799.51	793.94	714	31689	697	30628	0.98	0.98	660.94	668.24	202	7822	53	2392	0.31	0.31	367.87	403.62
45	2	1	2	1394	64391	1369	61705	0.96	0.96	805.21	794.19	698	32387	685	31313	0.98	0.98	663.21	668.13	176	7998	59	2451	0.31	0.31	422.31	404.07
46	2	1	2	1452	65843	1401	63106	0.96	0.96	830.68	795.00	691	33078	669	31982	0.98	0.98	693.47	668.66	178	8176	55	2506	0.31	0.31	425.03	404.53
47	2	1	2	1422	67265	1377	64483	0.96	0.96	754.26	794.13	667	33745	666	32648	0.98	0.98	627.48	667.82	187	8363	64	2570	0.31	0.31	399.71	404.41
48	2	1	2	1421	68686	1383	65866	0.96	0.96	784.60	793.93	730	34475	706	33354	0.98	0.98	665.46	667.77	186	8549	47	2617	0.31	0.31	370.44	403.80
49	2	1	2	1430	70116	1361	67227	0.96	0.96	796.40	793.98	730	35205	711	34065	0.98	0.98	667.29	667.76	186	8735	50	2667	0.31	0.31	391.53	403.57
50	2	1	2	1436	71552	1385	68612	0.96	0.96	818.25	794.47	696	35901	674	34739	0.98	0.98	687.86	668.15	198	8933	58	2725	0.31	0.31	390.88	403.30
51	2	1	2	1465	73017	1346	69958	0.96	0.96	810.58	794.78	726	36627	708	35447	0.98	0.98	696.19	668.71	175	9108	59	2784	0.31	0.31	430.67	403.88
52	2	1	2	1458	74475	1402	71360	0.96	0.96	770.35	794.30	691	37318	688	36135	0.98	0.98	652.43	668.40	169	9277	49	2833	0.31	0.31	402.72	403.86
53	2	1	2	1502	75977	1411	72771	0.96	0.96	777.80	793.98	738	38056	712	36847	0.98	0.98	623.89	667.54	162	9439	42	2875	0.31	0.31	392.91	403.70
54	2	1	2	1454	77431	1389	74160	0.96	0.96	827.62	794.61	714	38770	693	37540	0.98	0.98	688.12	667.92	208	9647	52	2927	0.31	0.31	345.72	402.67
55	2	1	2	1440	78871	1386	75546	0.96	0.96	815.32	794.99	733	39503	714	38254	0.98	0.98	684.53	668.23	185	9832	48	2975	0.31	0.31	372.30	402.18
56	2	1	2	1469	80340	1359	76905	0.96	0.96	811.97	795.29	749	40252	714	38968	0.98	0.98	695.52	668.73	185	10017	53	3028	0.31	0.31	404.47	402.22
57	2	1	2	1471	81811	1413	78318	0.96	0.96	831.87	795.95	702	40954	670	39638	0.98	0.98	693.58	669.15	175	10192	52	3080	0.31	0.31	427.10	402.64
58	2	1	2	1412	83223	1345	79663	0.96	0.96	781.74	795.71	713	41667	707	40345	0.98	0.98	677.14	669.29	174	10366	57	3137	0.31	0.31	425.20	403.05
59	2	1	2	1446	84669	1388	81051	0.96	0.96	786.95	795.56	686	42353	670	41015	0.98	0.98	666.84	669.25	176	10542	59	3196	0.31	0.31	407.38	403.13
60	2	1	2	1394	86063	1363	82414	0.96	0.96	816.72	795.91	711	43064	697	41712	0.98	0.98	663.86	669.16	166	10708	56	3252	0.31	0.31	455.39	404.03

ABC LOW HIGH

	Independent Variables			Dependent Variables																							
				Product A								Product B								Product C							
Replication Number	MAS	MOH	MIX	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time
1	2	1	3	1389	1389	1038	1038	0.75	0.75	801.26	801.26	1454	1454	1116	1116	0.78	0.78	570.92	570.92	356	356	19	19	0.05	0.05	166.42	166.42
2	2	1	3	1536	2925	1072	2110	0.73	0.74	750.20	775.32	1510	2964	1148	2264	0.78	0.78	558.95	564.85	385	741	5	24	0.05	0.05	38.50	139.77
3	2	1	3	1498	4423	1055	3165	0.74	0.74	753.42	768.02	1414	4378	1128	3392	0.78	0.78	580.58	570.08	386	1127	14	38	0.02	0.04	150.87	143.86
4	2	1	3	1425	5848	1068	4233	0.74	0.74	775.91	770.01	1368	5746	1098	4490	0.78	0.78	597.03	576.67	370	1497	20	58	0.04	0.04	148.56	145.48
5	2	1	3	1422	7270	1082	5315	0.74	0.74	779.05	771.85	1467	7213	1080	5570	0.78	0.78	545.98	570.72	351	1848	22	80	0.04	0.04	160.50	149.61
6	2	1	3	1395	8665	994	6309	0.74	0.74	783.21	773.64	1465	8678	1160	6730	0.78	0.78	579.13	572.17	343	2191	21	101	0.04	0.04	158.46	151.45
7	2	1	3	1416	10081	1052	7361	0.74	0.74	777.19	774.15	1433	10111	1125	7855	0.78	0.78	573.95	572.43	374	2565	16	117	0.04	0.04	146.67	150.81
8	2	1	3	1416	11497	1052	8414	0.74	0.74	778.21	774.66	1433	11545	1125	8979	0.86	0.79	574.46	572.68	374	2940	16	133	0.12	0.05	145.38	150.16
9	2	1	3	1416	12912	1052	9466	0.74	0.74	779.22	775.16	1433	12978	1125	10104	0.79	0.79	574.97	572.94	374	3314	16	148	0.05	0.05	144.09	149.52
10	2	1	3	1416	14328	1052	10518	0.74	0.74	780.24	775.67	1433	14411	1125	11228	0.79	0.79	575.48	573.19	374	3688	16	164	0.05	0.05	142.80	148.87
11	2	1	3	1449	15777	1065	11583	0.74	0.74	775.56	775.66	1407	15818	1122	12350	0.79	0.79	579.68	573.78	351	4039	16	180	0.05	0.05	161.47	149.99
12	2	1	3	1429	17206	1061	12644	0.74	0.74	787.22	776.63	1456	17274	1119	13469	0.79	0.79	569.57	573.43	351	4390	18	198	0.05	0.05	157.25	150.65
13	2	1	3	1393	18599	1038	13682	0.74	0.74	800.36	778.43	1473	18747	1147	14616	0.79	0.79	567.06	572.93	357	4747	13	211	0.05	0.05	149.84	150.60
14	2	1	3	1443	20042	1056	14738	0.74	0.74	782.34	778.71	1417	20164	1123	15739	0.79	0.79	575.59	573.12	370	5117	17	228	0.05	0.05	147.25	150.35
15	2	1	3	1477	21519	1065	15803	0.74	0.74	766.84	777.91	1521	21685	1137	16876	0.79	0.79	549.67	571.54	363	5480	9	237	0.05	0.05	124.02	149.35
16	2	1	3	1516	23035	1101	16904	0.74	0.74	766.24	777.15	1427	23112	1115	17991	0.79	0.79	566.38	571.22	388	5868	10	247	0.05	0.05	113.29	147.89
17	2	1	3	1399	24434	1032	17936	0.74	0.74	801.31	778.54	1415	24527	1120	19111	0.79	0.79	588.62	572.24	373	6241	22	269	0.05	0.05	167.09	149.46
18	2	1	3	1413	25847	1030	18966	0.74	0.74	774.12	778.30	1441	25968	1146	20257	0.79	0.79	575.24	572.41	360	6601	17	286	0.05	0.05	150.30	149.51
19	2	1	3	1419	27266	1040	20006	0.74	0.74	791.00	778.96	1440	27408	1124	21381	0.79	0.79	582.68	572.95	355	6956	20	306	0.05	0.05	155.02	149.87
20	2	1	3	1423	28689	1070	21076	0.74	0.74	791.37	779.59	1474	28882	1101	22482	0.79	0.79	552.94	571.97	339	7295	17	323	0.05	0.05	149.68	149.86
21	2	1	3	1405	30094	1083	22159	0.74	0.74	799.44	780.56	1381	30263	1094	23576	0.79	0.79	581.67	572.42	391	7686	19	342	0.05	0.05	152.92	150.03
22	2	1	3	1425	31519	1074	23233	0.74	0.74	803.92	781.64	1444	31707	1123	24699	0.79	0.79	564.50	572.06	362	8048	11	353	0.05	0.05	119.86	149.09
23	2	1	3	1385	32904	1061	24294	0.74	0.74	791.26	782.06	1427	33134	1091	25790	0.79	0.79	563.55	571.70	358	8406	22	375	0.05	0.05	171.76	150.42
24	2	1	3	1459	34363	1004	25298	0.74	0.74	747.29	780.68	1477	34611	1148	26938	0.79	0.79	578.50	571.99	376	8782	20	395	0.05	0.05	156.54	150.73
25	2	1	3	1440	35803	1055	26353	0.74	0.74	799.16	781.42	1541	36152	1152	28090	0.79	0.79	550.04	571.09	358	9140	7	402	0.05	0.05	46.78	148.92
26	2	1	3	1420	37223	1045	27398	0.74	0.74	784.04	781.52	1425	37577	1129	29219	0.79	0.79	577.04	571.32	368	9508	18	420	0.05	0.05	177.62	150.15
27	2	1	3	1476	38699	1087	28485	0.74	0.74	770.51	781.10	1391	38968	1098	30317	0.79	0.79	574.08	571.42	339	9847	16	436	0.05	0.05	157.51	150.42
28	2	1	3	1432	40131	1023	29508	0.74	0.74	769.85	780.71	1414	40382	1123	31440	0.79	0.79	596.90	572.33	344	10191	22	458	0.05	0.05	155.83	150.68
29	2	1	3	1412	41543	1052	30560	0.74	0.74	791.75	781.09	1413	41795	1076	32516	0.79	0.79	572.33	572.33	330	10521	30	488	0.05	0.05	182.56	152.64
30	2	1	3	1401	42944	996	31556	0.74	0.74	798.20	781.63	1492	43287	1160	33676	0.79	0.79	576.68	572.48	365	10886	20	508	0.05	0.05	156.70	152.80
31	2	1	3	1474	44418	1063	32619	0.74	0.74	764.75	781.08	1404	44691	1110	34786	0.79	0.79	573.11	572.50	370	11256	20	528	0.05	0.05	152.27	152.78
32	2	1	3	1401	45819	1038	33657	0.74	0.74	779.78	781.04	1362	46053	1127	35913	0.79	0.79	606.28	573.56	419	11675	22	550	0.05	0.05	141.53	152.33
33	2	1	3	1493	47312	1098	34755	0.74	0.74	767.43	780.61	1396	47449	1104	37017	0.79	0.79	579.26	573.73	341	12016	12	562	0.05	0.05	139.22	152.05
34	2	1	3	1483	48795	1055	35810	0.74	0.74	774.84	780.44	1479	48928	1140	38157	0.79	0.79	570.72	573.64	340	12356	11	573	0.05	0.05	151.53	152.04
35	2	1	3	1401	50196	1032	36842	0.74	0.74	787.22	780.63	1458	50386	1140	39297	0.79	0.79	576.40	573.72	380	12736	17	590	0.05	0.05	139.55	151.68
36	2	1	3	1371	51567	1055	37897	0.74	0.74	794.64	781.02	1458	51844	1119	40416	0.79	0.79	572.28	573.68	361	13097	18	608	0.05	0.05	151.68	151.68
37	2	1	3	1468	53035	1066	38963	0.74	0.74	763.11	780.53	1477	53321	1112	41528	0.79	0.79	550.15	573.05	350	13447	16	624	0.05	0.05	150.90	151.66
38	2	1	3	1481	54516	1045	40008	0.74	0.74	756.79	779.91	1434	54755	1111	42639	0.79	0.79	574.59	573.09	362	13809	22	646	0.05	0.05	163.11	152.05
39	2	1	3	1487	56003	1074	41082	0.74	0.74	770.35	779.66	1454	56209	1122	43761	0.79	0.79	567.63	572.95	360	14169	12	658	0.05	0.05	129.57	151.64
40	2	1	3	1423	57426	1070	42152	0.74	0.74	800.15	780.18	1335	57544	1111	44872	0.79	0.79	602.43	573.68	353	14522	18	676	0.05	0.05	159.90	151.86
41	2	1	3	1388	58814	1038	43190	0.74	0.74	777.68	780.12	1500	59044	1148	46020	0.79	0.79	561.25	573.37	327	14849	16	692	0.05	0.05	160.08	152.05
42	2	1	3	1426	60240	1048	44238	0.74	0.74	788.56	780.32	1395	60439	1115	47135	0.79	0.79	589.01	573.74	362	15211	19	711	0.05	0.05	144.57	151.85
43	2	1	3	1377	61617	1060	45298	0.74	0.74	797.84	780.73	1418	61857	1101	48236	0.79	0.79	573.74	573.74	347	15558	21	732	0.05	0.05	171.02	152.40
44	2	1	3	1440	63057	1084	46382	0.74	0.74	792.71	781.01	1404	63261	1104	49340	0.79	0.79	579.10	573.86	363	15921	14	746	0.05	0.05	134.28	152.06
45	2	1	3	1460	64517	980	47362	0.74	0.74	752.50	780.42	1507	64768	1170	50510	0.79	0.79	570.41	573.78	349	16270	22	768	0.05	0.05	174.40	152.70
46	2	1	3	1447	65964	1055	48417	0.74	0.74	772.16	780.24	1432	66200	1130	51640	0.79	0.79	576.52	573.84	361	16631	18	786	0.05	0.05	161.00	152.89
47	2	1	3	1391	67355	1083	49500	0.74	0.74	804.46	780.77	1427	67627	1105	52745	0.79	0.79	569.54	573.75	350	16981	14	800	0.05	0.05	139.75	152.66
48	2	1	3	1443	68798	1070	50570	0.74	0.74	785.50	780.87	1384	69011	1107	53852	0.79	0.79	589.32	574.07	346	17327	16	816	0.05	0.05	160.31	152.81
49	2	1	3	1477	70275	1098	51668	0.74	0.74	769.11	780.62	1388	70399	1076	54928	0.79	0.79	564.88	573.89	330	17657	18	834	0.05	0.05	169.49	153.17
50	2	1	3	1450	71725	1089	52757	0.74	0.74	777.23	780.55	1462	71861	1110	56038	0.79	0.79	552.69	573.47	340	17997	11	845	0.05	0.05	140.88	153.01
51	2	1	3	1460	73185	1126	53883	0.74	0.74	769.07	780.31	1475	73336	1122	57160	0.79	0.79	556.15	573.13	365	18362	14	859	0.05	0.05	148.10	152.93
52	2	1	3	1439	74624	1109	54992	0.74	0.74	791.72	780.54	1384	74720	1067	58227	0.79	0.79	565.49	572.99	382	18744	24	883	0.05	0.05	149.62	152.84
53	2	1	3	1455	76079	1022	56014	0.74	0.74	777.80	780.49	1458	76178	1075	59302	0.79	0.79	548.72	572.55	372	19116	18	901	0.05	0.05	158.85	152.96
54	2	1	3	1452	77531	1092	57106	0.74	0.74	773.17	780.35	1391	77569	1063	60365	0.79	0.79	565.74	572.43	318	19434	19	920	0.05	0.05	174.27	153.40
55	2	1	3	2453	79984	1064	58170	0.74	0.74	784.18	780.42	1382	78951	1111	61476	0.79	0.79	585.71	572.67	331	19765	17	937	0.05	0.05	163.32	153.58
56	2	1	3	446	80430	1096	59266	0.74	0.74	763.12	780.10	1425	80376	1075	62551	0.79	0.79	559.29	572.44	369	20134	19	956	0.05	0.05	157.10	153.65
57	2	1	3	1416	81846	1061	60327	0.74	0.74	798.86	780.43	1345	81721	1102	63653	0.79	0.79	594.39	572.82	388	20522	21	977	0.05	0.05	152.25	153.62
58	2	1	3	1406	83252	1041	61368	0.74	0.74	785.74	780.52	1462	83183	1141	64794	0.79	0.79	578.50	572.92	344	20866	16	993	0.05	0.05	156.10	153.66
59	2	1	3	1378	84630	1065	62433	0.74	0.74	794.59	780.76	1453	84636	1111	65905	0.79	0.79	557.50	572.66	381	21247	18	1011	0.05	0.05	149.17	153.58
60	2	1	3	1401	86031	1032	63465	0.74	0.74	802.28	781.11	1370	86006	1101	67006	0.79	0.79	590.92	572.96	355	21602	23	1034	0.05	0.05	164.82	153.83

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Replication Number	MAS	MOH	MIX	Product A Period Demand	Product A Total Demand	Product A Period Shipped	Product A Total Shipped	Product A Period DFR	Product A Total DFR	Product A Period Cycle Time	Product A Total Cycle Time
1	1	1	1	1415	1415	1401	1401	0.99	0.99	295.04	295.04
2	1	1	1	1455	2870	1419	2820	0.99	0.99	295.83	295.44
3	1	1	1	1431	4301	1421	4241	0.99	0.99	524.50	372.19
4	1	1	1	1374	5675	1362	5603	0.99	0.99	290.49	352.33
5	1	1	1	1435	7110	1371	6974	0.99	0.99	307.16	343.45
6	1	1	1	1432	8542	1451	8425	0.99	0.99	290.96	334.41
7	1	1	1	1440	9982	1419	9844	0.99	0.99	357.83	337.79
8	1	1	1	1440	11423	1419	11262	0.99	0.99	364.58	341.16
9	1	1	1	1440	12863	1419	12681	0.99	0.99	371.33	344.54
10	1	1	1	1440	14303	1419	14099	0.99	0.99	378.08	347.91
11	1	1	1	1441	15744	1409	15508	0.99	0.99	437.17	356.02
12	1	1	1	1416	17160	1407	16915	0.99	0.99	295.67	351.00
13	1	1	1	1430	18590	1431	18346	0.99	0.99	295.87	346.70
14	1	1	1	1486	20076	1431	19777	0.99	0.99	385.95	349.54
15	1	1	1	1402	21478	1407	21184	0.99	0.99	407.36	353.38
16	1	1	1	1467	22945	1456	22640	0.99	0.99	333.32	352.09
17	1	1	1	1446	24391	1387	24027	0.99	0.99	545.59	363.26
18	1	1	1	1364	25755	1362	25389	0.99	0.99	274.34	358.49
19	1	1	1	1391	27146	1383	26772	0.99	0.99	230.34	351.87
20	1	1	1	1412	28558	1399	28171	0.99	0.99	233.67	346.00
21	1	1	1	1429	29987	1412	29583	0.99	0.99	309.55	344.26
22	1	1	1	1425	31412	1405	30988	0.99	0.99	331.91	343.70
23	1	1	1	1443	32855	1428	32416	0.99	0.99	397.27	346.06
24	1	1	1	1435	34290	1429	33845	0.99	0.99	249.19	341.97
25	1	1	1	1379	35669	1363	35208	0.99	0.99	292.89	340.07
26	1	1	1	1438	37107	1357	36565	0.99	0.99	461.32	344.57
27	1	1	1	1495	38602	1507	38072	0.99	0.99	352.15	344.87
28	1	1	1	1432	40034	1428	39500	0.99	0.99	364.23	345.57
29	1	1	1	1448	41482	1446	40946	0.99	0.99	268.83	342.86
30	1	1	1	1356	42838	1342	42288	0.99	0.99	304.73	341.65
31	1	1	1	1437	44275	1421	43709	0.99	0.99	347.19	341.83
32	1	1	1	1421	45696	1404	45113	0.99	0.99	277.57	339.83
33	1	1	1	1475	47171	1455	46568	0.99	0.99	320.95	339.24
34	1	1	1	1421	48592	1405	47973	0.99	0.99	322.17	338.74
35	1	1	1	1413	50005	1374	49347	0.99	0.99	378.25	339.84
36	1	1	1	1411	51416	1399	50746	0.99	0.99	257.14	337.56
37	1	1	1	1359	52775	1356	52102	0.99	0.99	218.06	334.45
38	1	1	1	1385	54160	1369	53471	0.99	0.99	303.59	333.66
39	1	1	1	1404	55564	1380	54851	0.99	0.99	264.90	331.93
40	1	1	1	1407	56971	1415	56266	0.99	0.99	354.99	332.51
41	1	1	1	1424	58395	1393	57659	0.99	0.99	310.99	331.99
42	1	1	1	1388	59783	1355	59014	0.99	0.99	326.33	331.86
43	1	1	1	1433	61216	1421	60435	0.99	0.99	258.28	330.13
44	1	1	1	1431	62647	1432	61867	0.99	0.99	251.07	328.30
45	1	1	1	1499	64146	1457	63324	0.99	0.99	476.94	331.72
46	1	1	1	1371	65517	1364	64688	0.99	0.99	308.01	331.22
47	1	1	1	1486	67003	1452	66140	0.99	0.99	297.97	330.49
48	1	1	1	1368	68371	1354	67494	0.99	0.99	279.65	329.47
49	1	1	1	1453	69824	1434	68928	0.99	0.99	266.50	328.16
50	1	1	1	1416	71240	1391	70319	0.99	0.99	253.85	326.69
51	1	1	1	1394	72634	1388	71707	0.99	0.99	225.95	324.74
52	1	1	1	1451	74085	1440	73147	0.99	0.99	279.53	323.85
53	1	1	1	1472	75557	1443	74590	0.99	0.99	257.17	322.56
54	1	1	1	1426	76983	1403	75993	0.99	0.99	497.51	325.79
55	1	1	1	1427	78410	1411	77404	0.99	0.99	351.57	326.26
56	1	1	1	1447	79857	1451	78855	0.99	0.99	302.89	325.83
57	1	1	1	1438	81295	1375	80230	0.99	0.99	245.89	324.46
58	1	1	1	1529	82824	1514	81744	0.99	0.99	443.78	326.67
59	1	1	1	1473	84297	1470	83214	0.99	0.99	383.84	327.68
60	1	1	1	1446	85743	1395	84609	0.99	0.99	325.25	327.64

Replication Number	Product B Period Demand	Product B Total Demand	Product B Period Shipped	Product B Total Shipped	Product B Period DFR	Product B Total DFR	Product B Period Cycle Time	Product B Total Cycle Time
1	343	343	339	339	1.00	1.00	289.71	289.71
2	366	709	358	697	1.00	1.00	297.01	293.46
3	373	1082	369	1066	1.00	1.00	447.99	346.95
4	354	1436	348	1414	1.00	1.00	304.25	336.44
5	344	1780	336	1750	1.00	1.00	309.46	331.26
6	389	2169	382	2132	1.00	1.00	282.31	322.49
7	373	2542	365	2497	1.00	1.00	331.16	323.76
8	373	2914	365	2862	1.00	1.00	333.70	325.03
9	373	3287	365	3227	1.00	1.00	336.23	326.29
10	373	3659	365	3592	1.00	1.00	338.77	327.56
11	347	4006	342	3934	1.00	1.00	396.35	333.54
12	378	4384	372	4306	1.00	1.00	291.06	329.87
13	373	4757	366	4672	1.00	1.00	307.79	328.14
14	377	5134	362	5034	1.00	1.00	384.88	332.22
15	334	5468	335	5369	1.00	1.00	377.26	335.03
16	291	5759	283	5652	1.00	1.00	321.05	334.33
17	368	6127	361	6013	1.00	1.00	466.75	342.28
18	374	6501	375	6388	1.00	1.00	270.39	338.06
19	387	6888	380	6768	1.00	1.00	229.24	331.95
20	338	7226	336	7104	1.00	1.00	249.92	328.07
21	387	7613	383	7487	1.00	1.00	305.20	326.90
22	345	7958	341	7828	1.00	1.00	302.34	325.83
23	353	8311	348	8176	1.00	1.00	373.05	327.84
24	352	8663	350	8526	1.00	1.00	252.81	324.76
25	375	9038	371	8897	1.00	1.00	287.11	323.19
26	407	9445	393	9290	1.00	1.00	413.25	327.00
27	355	9800	350	9640	1.00	1.00	325.07	326.93
28	379	10179	374	10014	1.00	1.00	348.62	327.74
29	343	10522	342	10356	1.00	1.00	269.90	325.83
30	371	10893	367	10723	1.00	1.00	281.42	324.31
31	308	11201	303	11026	1.00	1.00	340.32	324.75
32	348	11549	339	11365	1.00	1.00	274.13	323.24
33	362	11911	355	11720	1.00	1.00	293.86	322.35
34	328	12239	322	12042	1.00	1.00	321.98	322.34
35	392	12631	383	12425	1.00	1.00	342.45	322.96
36	341	12972	332	12757	1.00	1.00	265.32	321.46
37	360	13332	361	13118	1.00	1.00	213.54	318.49
38	331	13663	326	13444	1.00	1.00	291.68	317.84
39	352	14015	347	13791	1.00	1.00	272.53	316.70
40	343	14358	334	14125	1.00	1.00	344.19	317.35
41	342	14700	339	14464	1.00	1.00	287.06	316.64
42	362	15062	360	14824	1.00	1.00	278.34	315.71
43	368	15430	364	15188	1.00	1.00	265.22	314.50
44	347	15777	340	15528	1.00	1.00	259.70	313.30
45	371	16148	363	15891	1.00	1.00	421.43	315.77
46	350	16498	339	16230	1.00	1.00	300.93	315.46
47	371	16869	368	16598	1.00	1.00	280.28	314.68
48	378	17247	367	16965	1.00	1.00	250.89	313.30
49	408	17655	402	17367	1.00	1.00	264.48	312.17
50	370	18025	355	17722	1.00	1.00	257.26	311.07
51	354	18379	350	18072	1.00	1.00	228.97	309.48
52	345	18724	344	18416	1.00	1.00	281.64	308.96
53	365	19089	356	18772	1.00	1.00	264.67	308.12
54	395	19484	386	19158	1.00	1.00	409.87	310.17
55	354	19838	351	19509	1.00	1.00	337.40	310.66
56	352	20190	344	19853	1.00	1.00	290.46	310.31
57	407	20597	400	20253	1.00	1.00	258.16	309.28
58	342	20939	339	20592	1.00	1.00	393.11	310.66
59	360	21299	358	20950	1.00	1.00	380.30	311.85
60	383	21682	378	21328	1.00	1.00	310.72	311.83

Replication Number	Product C Period Demand	Product C Total Demand	Product C Period Shipped	Product C Total Shipped	Product C Period DFR	Product C Total DFR	Product C Period Cycle Time	Product C Total Cycle Time
1	91	91	85	85	1.00	1.00	430.02	430.02
2	88	179	82	167	1.00	1.00	385.03	407.93
3	103	282	103	270	1.00	1.00	515.90	449.12
4	96	378	94	364	1.00	1.00	382.40	431.89
5	87	465	86	450	1.00	1.00	422.94	430.18
6	76	541	75	525	1.00	1.00	352.76	419.12
7	89	630	84	609	1.00	1.00	424.79	419.90
8	89	719	84	693	1.00	1.00	426.36	420.69
9	89	808	84	777	1.00	1.00	427.92	421.47
10	89	897	84	861	1.00	1.00	429.49	422.25
11	110	1007	104	965	0.91	0.99	488.41	429.38
12	76	1083	74	1039	0.99	0.99	406.35	427.74
13	83	1166	79	1118	0.99	0.99	376.51	424.12
14	100	1266	92	1210	0.99	0.99	439.38	425.28
15	109	1375	105	1315	0.99	0.99	459.47	428.01
16	93	1468	88	1403	0.99	0.99	458.94	429.95
17	103	1571	101	1504	0.99	0.99	536.12	437.08
18	89	1660	85	1589	0.99	0.99	349.59	432.40
19	86	1746	84	1673	0.99	0.99	318.08	426.66
20	86	1832	79	1752	0.99	0.99	335.51	422.55
21	79	1911	78	1830	0.99	0.99	383.84	420.90
22	92	2003	86	1916	0.99	0.99	393.94	419.69
23	92	2095	87	2003	0.99	0.99	455.61	421.25
24	75	2170	73	2076	0.99	0.99	351.01	418.78
25	87	2257	82	2158	0.99	0.99	354.57	416.34
26	111	2368	108	2266	0.99	0.99	467.12	418.76
27	84	2452	80	2346	0.99	0.99	392.66	417.87
28	88	2540	82	2428	0.99	0.99	421.13	417.98
29	83	2623	80	2508	0.99	0.99	347.76	415.74
30	84	2707	83	2591	0.99	0.99	390.14	414.92
31	99	2806	97	2688	0.99	0.99	395.24	414.21
32	92	2898	87	2775	0.99	0.99	364.45	412.65
33	76	2974	72	2847	0.99	0.99	381.41	411.86
34	110	3084	106	2953	0.99	0.99	424.12	412.30
35	88	3172	83	3036	0.99	0.99	468.26	413.83
36	90	3262	84	3120	0.99	0.99	363.32	412.47
37	70	3332	69	3189	0.99	0.99	337.60	410.85
38	91	3423	87	3276	0.99	0.99	395.03	410.43
39	91	3514	87	3363	0.99	0.99	360.95	409.15
40	91	3605	83	3446	0.99	0.99	476.82	410.78
41	83	3688	78	3524	0.99	0.99	385.48	410.22
42	90	3778	83	3607	0.99	0.99	405.01	410.10
43	87	3865	86	3693	0.99	0.99	341.82	408.51
44	75	3940	69	3762	0.99	0.99	360.53	407.63
45	94	4034	87	3849	0.99	0.99	497.00	409.65
46	88	4122	86	3935	0.99	0.99	408.28	409.62
47	84	4206	73	4008	0.99	0.99	364.60	408.80
48	78	4284	76	4084	0.99	0.99	358.82	407.87
49	72	4356	69	4153	0.99	0.99	372.96	407.29
50	97	4453	90	4243	0.99	0.99	347.42	406.02
51	64	4517	65	4308	0.99	0.99	351.01	405.19
52	89	4606	88	4396	0.99	0.99	368.22	404.45
53	88	4694	81	4477	0.99	0.99	359.13	403.63
54	104	4798	101	4578	0.99	0.99	481.14	405.34
55	98	4896	87	4665	0.99	0.99	425.18	405.71
56	87	4983	81	4746	0.99	0.99	410.40	405.79
57	73	5056	67	4813	0.99	0.99	387.83	405.54
58	91	5147	86	4899	0.99	0.99	483.01	406.90
59	83	5230	78	4977	0.99	0.99	473.26	407.94
60	97	5327	93	5070	0.99	0.99	406.85	407.92

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	Independent Variables			Dependent Variables: Product A								Product B								Product C							
Replication Number	MAS	MOH	MIX	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time
1	1	1	2	1477	1477	826	826	0.60	0.60	754.99	754.99	695	695	671	671	0.98	0.98	651.90	651.90	185	185	162	162	0.84	0.84	669.35	669.35
2	1	1	2	1465	2942	811	1637	0.56	0.58	736.14	745.65	768	1463	737	1408	0.98	0.98	639.31	645.31	175	360	161	323	0.96	0.90	666.58	667.97
3	1	1	2	1367	4309	808	2445	0.58	0.58	788.10	759.68	730	2193	718	2126	0.98	0.98	653.63	648.12	175	535	155	478	0.93	0.91	664.08	666.71
4	1	1	2	1459	5768	773	3218	0.54	0.57	734.54	753.64	757	2950	741	2867	0.98	0.98	650.21	648.66	194	729	161	639	0.95	0.92	618.53	654.57
5	1	1	2	1387	7155	770	3988	0.57	0.57	764.93	755.82	720	3670	696	3563	1.00	0.99	656.85	650.26	186	915	170	809	0.92	0.92	676.56	659.19
6	1	1	2	1422	8577	842	4830	0.57	0.57	780.77	760.17	715	4385	704	4267	0.99	0.99	638.87	648.38	174	1089	161	970	0.92	0.92	647.14	657.19
7	1	1	2	1496	10073	843	5673	0.57	0.57	748.25	758.40	732	5117	711	4978	0.99	0.99	643.71	647.71	178	1267	156	1126	0.92	0.92	635.58	654.20
8	1	1	2	1496	11568	843	6515	0.57	0.57	744.71	756.63	732	5848	711	5689	0.99	0.99	642.37	647.05	178	1445	156	1282	0.92	0.92	629.60	651.21
9	1	1	2	1496	13064	843	7358	0.57	0.57	741.17	754.86	732	6580	711	6400	0.99	0.99	641.04	646.38	178	1623	156	1437	0.92	0.92	623.62	648.22
10	1	1	2	1496	14559	843	8200	0.57	0.57	737.63	753.09	732	7311	711	7111	0.99	0.99	639.70	645.71	178	1801	156	1593	0.92	0.92	617.64	645.23
11	1	1	2	1366	15925	749	8949	0.57	0.57	745.56	752.46	764	8075	737	7848	0.99	0.99	659.55	647.01	193	1994	168	1761	0.92	0.92	645.54	645.26
12	1	1	2	1529	17454	869	9818	0.57	0.57	746.13	751.90	702	8777	690	8538	0.99	0.99	642.18	646.62	166	2160	149	1910	0.92	0.92	677.31	647.76
13	1	1	2	1432	18886	770	10588	0.57	0.57	744.75	751.38	758	9535	729	9267	0.99	0.99	656.79	647.42	181	2341	163	2073	0.92	0.92	661.50	648.84
14	1	1	2	1470	20356	752	11340	0.57	0.57	724.69	749.61	716	10251	696	9963	0.99	0.99	657.44	648.12	194	2535	172	2245	0.92	0.92	661.50	649.81
15	1	1	2	1454	21810	963	12303	0.57	0.57	763.02	750.66	705	10956	689	10652	0.99	0.99	623.23	646.51	155	2690	139	2384	0.92	0.92	641.23	649.31
16	1	1	2	1400	23210	783	13086	0.57	0.57	763.36	751.42	764	11720	745	11397	0.99	0.99	647.12	646.55	178	2868	157	2541	0.92	0.92	650.28	649.37
17	1	1	2	1465	24675	940	14026	0.57	0.57	749.78	751.31	718	12438	690	12087	0.99	0.99	622.20	645.16	158	3026	135	2676	0.92	0.92	628.75	648.33
18	1	1	2	1396	26071	852	14878	0.57	0.57	734.72	750.36	729	13167	705	12792	0.99	0.99	631.37	644.40	164	3190	149	2825	0.92	0.92	666.34	649.28
19	1	1	2	1418	27489	859	15737	0.57	0.57	768.86	751.37	746	13913	716	13508	0.99	0.99	629.50	643.61	176	3366	148	2973	0.92	0.92	599.86	646.82
20	1	1	2	1426	28915	770	16507	0.57	0.57	742.58	750.96	724	14637	683	14191	0.99	0.99	662.52	644.52	201	3567	171	3144	0.92	0.92	681.02	648.68
21	1	1	2	1453	30368	800	17307	0.57	0.57	756.58	751.22	751	15388	727	14918	0.99	0.99	638.98	644.25	175	3742	160	3304	0.92	0.92	620.18	647.30
22	1	1	2	1456	31824	816	18123	0.57	0.57	745.45	750.96	725	16113	711	15629	0.99	0.99	645.79	644.32	190	3932	168	3472	0.92	0.92	633.45	646.63
23	1	1	2	1407	33231	755	18878	0.57	0.57	765.71	751.55	716	16829	689	16318	0.99	0.99	662.79	645.10	196	4128	170	3642	0.92	0.92	642.56	646.44
24	1	1	2	1431	34662	806	19684	0.57	0.57	755.95	751.73	707	17536	679	16997	0.99	0.99	654.36	645.47	199	4327	163	3805	0.92	0.92	611.89	644.96
25	1	1	2	1448	36110	880	20564	0.57	0.57	755.00	751.87	689	18225	677	17674	0.99	0.99	642.08	645.34	171	4498	147	3952	0.92	0.92	633.67	644.54
26	1	1	2	1472	37582	888	21452	0.57	0.57	769.26	752.59	717	18942	697	18371	0.99	0.99	642.70	645.24	169	4667	153	4105	0.92	0.92	612.88	643.36
27	1	1	2	1421	39003	808	22260	0.57	0.57	739.37	752.11	716	19658	688	19059	0.99	0.99	650.23	645.42	197	4864	162	4267	0.92	0.92	657.85	643.91
28	1	1	2	1413	40416	839	23099	0.57	0.57	772.76	752.86	746	20404	717	19776	0.99	0.99	635.21	645.05	177	5041	153	4420	0.92	0.92	628.02	643.36
29	1	1	2	1412	41828	764	23863	0.57	0.57	736.62	752.34	748	21152	718	20494	0.99	0.99	658.18	645.51	183	5224	166	4586	0.92	0.92	688.94	645.01
30	1	1	2	1515	43343	762	24625	0.57	0.57	724.55	751.48	724	21876	719	21213	0.99	0.99	661.74	646.06	188	5412	169	4755	0.92	0.92	652.89	645.29
31	1	1	2	1441	44784	756	25381	0.57	0.57	749.80	751.43	705	22581	682	21895	0.99	0.99	669.50	646.79	198	5610	172	4927	0.92	0.92	663.62	645.93
32	1	1	2	1419	46203	840	26221	0.57	0.57	770.78	752.05	736	23317	713	22608	0.99	0.99	635.38	646.43	174	5784	158	5085	0.92	0.92	650.44	646.07
33	1	1	2	1375	47578	819	27040	0.57	0.57	757.66	752.22	753	24070	733	23341	0.99	0.99	645.79	646.41	184	5968	148	5233	0.92	0.92	630.16	645.62
34	1	1	2	1442	49020	749	27789	0.57	0.57	727.36	751.55	736	24806	711	24052	0.99	0.99	675.84	647.28	193	6161	165	5398	0.92	0.92	683.57	646.78
35	1	1	2	1510	50530	830	28619	0.57	0.57	743.96	751.33	738	25544	719	24771	0.99	0.99	641.77	647.12	180	6341	164	5562	0.92	0.92	640.00	646.58
36	1	1	2	1379	51909	830	29449	0.57	0.57	784.33	752.26	726	26270	698	25469	0.99	0.99	648.94	647.17	181	6522	162	5724	0.92	0.92	629.97	646.11
37	1	1	2	1483	53392	847	30296	0.57	0.57	744.03	752.03	768	27038	746	26215	0.99	0.99	630.30	646.69	168	6690	149	5873	0.92	0.92	632.31	645.76
38	1	1	2	1536	54928	945	31241	0.57	0.57	739.80	751.66	739	27777	715	26930	0.99	0.99	607.52	645.65	148	6838	132	6005	0.92	0.92	624.38	645.29
39	1	1	2	1429	56357	776	32017	0.57	0.57	754.14	751.72	739	28516	723	27653	0.99	0.99	643.36	645.59	189	7027	164	6169	0.92	0.92	644.91	645.28
40	1	1	2	1439	57796	737	32754	0.57	0.57	745.94	751.59	693	29209	672	28325	0.99	0.99	678.89	646.38	204	7231	183	6352	0.92	0.92	663.33	645.80
41	1	1	2	1410	59206	863	33617	0.57	0.57	780.42	752.33	724	29933	702	29027	0.99	0.99	629.84	645.98	174	7405	152	6504	0.92	0.92	626.97	645.36
42	1	1	2	1500	60706	881	34498	0.57	0.57	729.62	751.75	724	30657	711	29738	0.99	0.99	633.01	645.67	170	7575	148	6652	0.92	0.92	649.41	645.45
43	1	1	2	1398	62104	797	35295	0.57	0.57	780.09	752.39	748	31405	729	30467	0.99	0.99	642.74	645.60	182	7757	162	6814	0.92	0.92	653.44	645.64
44	1	1	2	1483	63587	877	36172	0.57	0.57	739.60	752.08	722	32127	704	31171	0.99	0.99	631.43	645.28	172	7929	152	6966	0.92	0.92	627.77	645.25
45	1	1	2	1453	65040	936	37108	0.57	0.57	758.42	752.24	695	32822	673	31844	0.99	0.99	627.30	644.90	166	8095	146	7112	0.92	0.92	611.64	644.56
46	1	1	2	1395	66435	749	37857	0.57	0.57	754.26	752.28	747	33569	718	32562	0.99	0.99	661.23	645.26	189	8284	172	7284	0.92	0.92	681.40	645.43
47	1	1	2	612221	678656	759	38616	0.57	0.57	748.21	752.20	769	34338	740	33302	0.99	0.99	650.66	645.38	187	8471	162	7446	0.92	0.92	652.32	645.58
48	1	1	2	(609285)	69371	874	39490	0.57	0.57	744.52	752.03	699	35037	690	33992	0.99	0.99	639.47	645.26	174	8645	154	7600	0.92	0.92	635.22	645.37
49	1	1	2	1392	70763	885	40375	0.57	0.57	756.59	752.13	674	35711	636	34628	0.99	0.99	633.83	645.05	174	8819	153	7753	0.92	0.92	667.67	645.81
50	1	1	2	1443	72206	869	41244	0.57	0.57	753.08	752.15	732	36443	705	35333	0.99	0.99	624.50	644.64	169	8988	150	7903	0.92	0.92	627.90	645.47
51	1	1	2	1301	73507	865	42109	0.57	0.57	784.28	752.81	751	37194	748	36081	0.99	0.99	632.58	644.39	168	9156	146	8049	0.92	0.92	628.38	645.16
52	1	1	2	1509	75016	936	43045	0.57	0.57	735.33	752.43	707	37901	685	36766	0.99	0.99	613.80	643.82	156	9312	142	8191	0.92	0.92	663.62	645.48
53	1	1	2	1389	76405	835	43880	0.57	0.57	781.33	752.98	664	38565	653	37419	0.99	0.99	660.44	644.11	188	9500	168	8359	0.92	0.92	673.34	646.04
54	1	1	2	1421	77826	849	44729	0.57	0.57	780.38	753.50	700	39265	695	38114	0.99	0.99	643.01	644.09	177	9677	156	8515	0.92	0.92	636.76	645.87
55	1	1	2	1352	79178	770	45499	0.57	0.57	804.91	754.37	719	39984	706	38820	0.99	0.99	658.39	644.35	193	9870	159	8674	0.92	0.92	634.41	645.66
56	1	1	2	1473	80651	732	46231	0.57	0.57	718.37	753.80	698	40682	681	39501	0.99	0.99	681.47	644.99	208	10078	184	8858	0.92	0.92	660.10	645.96
57	1	1	2	1448	82099	771	47002	0.57	0.57	753.80	753.80	696	41378	684	40185	0.99	0.99	658.50	645.22	188	10266	170	9028	0.92	0.92	677.82	646.56
58	1	1	2	1427	83526	800	47802	0.57	0.57	760.97	753.92	709	42087	688	40873	0.99	0.99	657.70	645.43	187	10453	164	9192	0.92	0.92	664.50	646.88
59	1	1	2	1474	85000	872	48674	0.57	0.57	744.43	753.75	715	42802	688	41561	0.99	0.99	641.81	645.37	175	10628	150	9342	0.92	0.92	653.73	646.99
60	1	1	2	1494	86494	875	49549	0.57	0.57	753.75	753.75	716	43518	704	42265	0.99	0.99	628.56	645.09	175	10803	150	9492	0.92	0.92	598.90	646.23

TCS LOW HIGH

Independent Variables				Dependent Variables																							
				Product A								Product B								Product C							
Replication Number	MAS	MOH	MIX	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Total Cycle Time
1	1	1	3	1423	1423	36	36	0.04	0.04	292.06	292.06	1424	1424	848	848	0.61	0.61	588.00	588.00	350	350	274	274	0.77	0.77	730.25	730.25
2	1	1	3	1474	2897	49	85	0.02	0.03	613.79	477.53	1456	2880	927	1775	0.63	0.62	586.35	587.14	363	713	268	542	0.79	0.78	671.10	701.00
3	1	1	3	1391	4288	38	123	0.03	0.03	467.92	474.56	1390	4270	830	2605	0.62	0.62	596.93	590.26	379	1092	281	823	0.81	0.79	708.41	703.53
4	1	1	3	1439	5727	41	164	0.03	0.03	515.20	484.72	1383	5653	868	3473	0.62	0.62	610.27	595.26	347	1439	284	1107	0.79	0.79	747.15	714.72
5	1	1	3	1446	7173	45	209	0.03	0.03	498.51	487.69	1420	7073	861	4334	0.62	0.62	596.37	595.48	373	1812	272	1379	0.79	0.79	691.75	710.19
6	1	1	3	1468	8641	34	243	0.03	0.03	488.19	487.76	1434	8507	839	5173	0.62	0.62	581.42	593.20	368	2180	279	1658	0.79	0.79	718.27	711.55
7	1	1	3	1457	10098	30	273	0.03	0.03	479.76	486.89	1421	9928	849	6022	0.62	0.62	597.55	593.81	375	2555	279	1937	0.79	0.79	700.05	710
8	1	1	3	1457	11554	30	303	0.03	0.03	478.02	486.02	1421	11348	849	6871	0.62	0.62	598.77	594.43	375	2930	279	2216	0.79	0.79	696.74	708
9	1	1	3	1457	13011	30	332	0.03	0.03	476.27	485.14	1421	12769	849	7719	0.62	0.62	600.00	595.04	375	3304	279	2494	0.79	0.79	693.43	707
10	1	1	3	1457	14467	30	362	0.03	0.03	474.53	484.27	1421	14189	849	8568	0.62	0.62	601.22	595.65	375	3679	279	2773	0.79	0.79	690.12	704.93
11	1	1	3	1422	15889	41	403	0.03	0.03	546.49	490.60	1432	15621	781	9349	0.62	0.62	557.70	592.48	401	4080	296	3069	0.79	0.79	724.42	706.81
12	1	1	3	1499	17388	31	434	0.03	0.03	541.28	494.22	1473	17094	886	10235	0.62	0.62	587.63	592.06	364	4444	281	3350	0.79	0.79	695.96	705.90
13	1	1	3	1468	18856	55	489	0.03	0.03	442.12	488.36	1408	18502	883	11118	0.62	0.62	596.34	592.40	375	4819	273	3623	0.79	0.79	666.75	702.95
14	1	1	3	1454	20310	58	547	0.03	0.03	491.00	488.64	1555	20057	924	12042	0.62	0.62	554.08	589.46	340	5159	273	3896	0.79	0.79	708.52	703.34
15	1	1	3	1418	21728	33	580	0.03	0.03	425.89	485.07	1399	21456	891	12933	0.62	0.62	611.52	590.98	361	5520	271	4167	0.79	0.79	708.57	703.68
16	1	1	3	1494	23222	42	622	0.03	0.03	567.71	490.65	1450	22906	784	13717	0.62	0.62	555.64	588.96	382	5902	283	4450	0.79	0.79	743.78	706.23
17	1	1	3	1468	24690	86	708	0.03	0.03	515.92	493.72	1384	24290	879	14596	0.62	0.62	596.43	589.41	345	6247	255	4705	0.79	0.79	689.07	705.30
18	1	1	3	1410	26100	64	772	0.03	0.03	522.67	496.12	1427	25717	838	15434	0.62	0.62	583.15	589.07	357	6604	282	4987	0.79	0.79	738.02	707.15
19	1	1	3	1397	27497	53	825	0.03	0.03	475.26	494.78	1457	27174	961	16395	0.62	0.62	597.77	589.58	332	6936	262	5249	0.79	0.79	675.50	705.57
20	1	1	3	1441	28938	51	876	0.03	0.03	509.04	495.61	1442	28616	890	17285	0.62	0.62	591.52	589.68	348	7284	265	5514	0.79	0.79	694.75	705.05
21	1	1	3	1466	30404	73	949	0.03	0.03	512.38	496.90	1404	30020	988	18273	0.62	0.62	617.79	591.20	331	7615	245	5759	0.79	0.79	642.76	702.40
22	1	1	3	1459	31863	69	1018	0.03	0.03	505.31	497.47	1481	31501	983	19256	0.62	0.62	592.57	591.27	329	7944	246	6005	0.79	0.79	649.18	700.22
23	1	1	3	1447	33310	48	1066	0.03	0.03	405.08	493.31	1460	32961	838	20094	0.62	0.62	567.05	590.26	363	8307	284	6289	0.79	0.79	722.36	701.22
24	1	1	3	1446	34756	49	1115	0.03	0.03	499.68	493.59	1386	34347	882	20976	0.62	0.62	605.72	590.91	356	8663	272	6561	0.79	0.79	714.25	701.76
25	1	1	3	1414	36170	43	1158	0.03	0.03	509.75	494.19	1368	35715	820	21796	0.62	0.62	602.34	591.34	373	9036	286	6847	0.79	0.79	712.29	702.20
26	1	1	3	1449	37619	20	1178	0.03	0.03	471.81	493.81	1379	37094	813	22609	0.62	0.62	610.25	592.02	373	9409	293	7140	0.79	0.79	732.66	703.46
27	1	1	3	1367	38986	91	1269	0.03	0.03	595.89	501.13	1412	38506	938	23547	0.62	0.62	597.54	592.24	330	9739	248	7388	0.79	0.79	677.53	702.58
28	1	1	3	1467	40453	61	1330	0.03	0.03	464.06	499.43	1460	39966	914	24461	0.62	0.62	588.49	592.10	347	10086	261	7649	0.79	0.79	670.05	701.47
29	1	1	3	1441	41894	68	1398	0.03	0.03	491.62	499.05	1441	41407	957	25418	0.62	0.62	600.33	592.41	343	10429	249	7898	0.79	0.79	638.35	699.48
30	1	1	3	1456	43350	31	1429	0.03	0.03	412.39	497.17	1448	42855	903	26321	0.62	0.62	594.16	592.47	370	10799	271	8169	0.79	0.79	671.75	698.56
31	1	1	3	1458	44808	43	1472	0.03	0.03	557.08	498.92	1451	44306	868	27189	0.62	0.62	586.21	592.27	355	11154	277	8446	0.79	0.79	731.49	699.64
32	1	1	3	1454	46262	84	1556	0.03	0.03	517.63	499.93	1453	45759	930	28119	0.62	0.62	585.32	592.04	339	11493	263	8709	0.79	0.79	677.78	698.98
33	1	1	3	1485	47747	45	1601	0.03	0.03	433.40	498.06	1404	47163	940	29059	0.62	0.62	611.82	592.68	337	11830	259	8968	0.79	0.79	697.25	698.93
34	1	1	3	1447	49194	51	1652	0.03	0.03	470.20	497.20	1486	48649	937	29996	0.62	0.62	587.88	592.53	332	12162	261	9229	0.79	0.79	695.04	698.82
35	1	1	3	1450	50644	35	1687	0.03	0.03	558.41	498.47	1524	50173	858	30854	0.62	0.62	550.46	591.36	388	12550	274	9503	0.79	0.79	675.24	698.14
36	1	1	3	1477	52121	49	1736	0.03	0.03	480.76	497.97	1493	51666	920	31774	0.62	0.62	580.65	591.05	334	12884	265	9768	0.79	0.79	713.62	698.56
37	1	1	3	1349	53470	69	1805	0.03	0.03	530.93	499.23	1429	53095	913	32687	0.62	0.62	589.98	591.02	351	13235	261	10029	0.79	0.79	685.50	698.22
38	1	1	3	1413	54883	54	1859	0.03	0.03	536.75	500.32	1418	54513	877	33564	0.62	0.62	596.76	591.17	368	13603	271	10300	0.79	0.79	712.28	698.59
39	1	1	3	1400	56283	40	1899	0.03	0.03	407.27	498.36	1479	55992	904	34468	0.62	0.62	579.35	590.86	366	13969	275	10575	0.79	0.79	650.91	697.35
40	1	1	3	1408	57691	35	1934	0.03	0.03	408.29	496.73	1425	57417	901	35369	0.62	0.62	608.13	591.30	363	14332	265	10840	0.79	0.79	691.62	697.21
41	1	1	3	1400	59091	34	1968	0.03	0.03	629.28	499.02	1435	58852	864	36233	0.62	0.62	590.88	591.29	373	14705	275	11115	0.79	0.79	689.93	697.03
42	1	1	3	1347	60438	61	2029	0.03	0.03	577.52	501.38	1480	60332	930	37163	0.62	0.62	575.31	590.89	357	15062	265	11380	0.79	0.79	648.50	695.90
43	1	1	3	1450	61888	37	2066	0.03	0.03	398.08	499.53	1436	61768	829	37992	0.62	0.62	574.85	590.54	381	15443	280	11660	0.79	0.79	704.23	696.10
44	1	1	3	1458	63346	74	2140	0.03	0.03	557.37	501.53	1437	63205	952	38944	0.62	0.62	599.54	590.76	333	15776	256	11916	0.79	0.79	652.81	695.17
45	1	1	3	1462	64808	26	2166	0.03	0.03	139.14	497.18	1498	64703	829	39773	0.62	0.62	558.14	590.08	399	16175	285	12201	0.79	0.79	696.88	695.21
46	1	1	3	1404	66212	85	2251	0.03	0.03	652.10	503.03	1441	66144	886	40659	0.62	0.62	578.61	589.83	346	16521	262	12463	0.79	0.79	695.21	695.21
47	1	1	3	1403	67615	68	2319	0.03	0.03	492.46	502.72	1419	67563	850	41509	0.62	0.62	560.53	589.23	354	16875	279	12742	0.79	0.79	733.12	696.04
48	1	1	3	1406	69021	28	2347	0.03	0.03	336.75	500.74	1481	69044	830	42339	0.62	0.62	589.23	589.23	376	17251	291	13033	0.79	0.79	730.53	696.81
49	1	1	3	1404	70425	77	2424	0.03	0.03	529.07	501.64	1393	70437	911	43250	0.62	0.62	589.23	589.23	364	17615	257	13290	0.79	0.79	641.48	695.74
50	1	1	3	1414	71839	26	2450	0.03	0.03	601.52	502.70	1518	71955	900	44150	0.62	0.62	588.74	589.22	363	17978	273	13563	0.79	0.79	693.75	695.70
51	1	1	3	1426	73265	55	2505	0.03	0.03	548.25	503.70	1532	73487	869	45019	0.62	0.62	542.60	588.32	369	18347	272	13835	0.79	0.79	702.31	695.83
52	1	1	3	1396	74661	36	2541	0.03	0.03	288.42	500.65	1478	74965	867	45886	0.62	0.62	576.68	588.10	376	18723	272	14107	0.79	0.79	675.60	695.44
53	1	1	3	1408	76069	17	2558	0.03	0.03	329.11	499.51	1455	76420	855	46741	0.62	0.62	592.47	588.18	366	19089	275	14382	0.79	0.79	731.00	696.12
54	1	1	3	1445	77514	49	2607	0.03	0.03	688.38	503.06	1454	77874	924	47665	0.62	0.62	590.24	588.22	355	19444	265	14647	0.79	0.79	671.80	695.68
55	1	1	3	1506	79020	44	2651	0.03	0.03	451.25	502.20	1436	79310	915	48580	0.62	0.62	598.31	588.41	366	19810	270	14917	0.79	0.79	656.45	694.97
56	1	1	3	1469	80489	61	2712	0.03	0.03	531.99	502.87	1501	80811	965	49545	0.62	0.62	585.84	588.36	349	20159	252	15169	0.79	0.79	655.24	694.31
57	1	1	3	1439	81928	57	2769	0.03	0.03	502.87	502.87	1500	82311	908	50453	0.62	0.62	567.25	587.98	352	20511	264	15433	0.79	0.79	677.94	694.03
58	1	1	3	1453	83381	39	2808	0.03	0.03	433.75	501.91	1434	83745	885	51338	0.62	0.62	597.26	588.14	357	20868	272	15705	0.79	0.79	707.89	694.27
59	1	1	3	1422	84803	58	2866	0.03	0.03	549.84	502.88	1429	85174	936	52274	0.62	0.62	602.66	588.40	341	21209	260	15965	0.79	0.79	680.15	694.04
60	1	1	3	1453	86256	55	2921	0.03	0.03	508.72	502.99	1409	86583	886	53160	0.62	0.62	596.80	588.54	369	21578	270	16235	0.79	0.79	693.44	694.03

TBA LOW LOW

	Independent Variables			All Products								MOH LOW		MOH MED		MOH HIGH	
Replication Number	MAS	MOH	MIX	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Cycle Time	Period NOI	Cumulative NOI	Period NOI	Cumulative NO	Period NOI	Cumulative NO
1	3	1	1	1867	1867	1853	1853	0.998	0.998	270.37	270.37	85,464.41	85,464.41	77,333.49	77,333.49	53,111.63	53,111.63
2	3	1	1	1858	3725	1817	3670	0.999	0.999	291.38	280.77	82,898.22	168,362.63	74,482.29	151,815.77	50,260.44	103,372.07
3	3	1	1	1994	5719	1952	5622	0.996	0.998	326.94	296.80	89,451.21	257,813.83	81,865.28	233,681.05	57,643.43	161,015.49
4	3	1	1	1874	7593	1852	7474	0.998	0.998	298.58	297.24	85,097.21	342,911.05	76,936.29	310,617.34	52,714.43	213,729.93
5	3	1	1	1931	9524	1874	9348	0.988	0.996	328.44	303.49	88,074.61	430,985.66	80,058.68	390,676.02	55,836.83	269,566.76
6	3	1	1	1932	11456	1916	11264	0.996	0.996	327.90	307.65	86,529.01	517,514.67	78,498.08	469,174.11	54,276.23	323,842.98
7	3	1	1	1894	13350	1868	13132	0.996	0.996	339.52	312.18	86,387.06	603,901.73	78,327.38	547,501.49	54,105.53	377,948.52
8	3	1	1	1894	15244	1868	14999	0.996	0.996	301.23	310.82	86,387.06	690,288.79	78,327.38	625,828.88	54,105.53	432,054.05
9	3	1	1	1894	17138	1868	16867	0.996	0.996	304.70	310.14	86,387.06	776,675.85	78,327.38	704,156.26	54,105.53	486,159.58
10	3	1	1	1894	19032	1868	18734	0.996	0.996	303.32	309.46	86,387.06	863,062.91	78,327.38	782,483.65	54,105.53	540,265.11
11	3	1	1	1949	20981	1908	20642	0.995	0.996	370.89	315.14	89,437.41	952,500.32	81,596.48	864,080.13	57,374.63	597,639.74
12	3	1	1	1848	22829	1817	22459	0.996	0.996	281.13	312.39	82,615.22	1,035,115.54	74,179.29	938,259.42	49,957.44	647,597.17
13	3	1	1	1886	24715	1869	24328	0.996	0.996	324.54	313.32	85,598.61	1,120,714.15	77,457.68	1,015,717.10	53,235.83	700,833.01
14	3	1	1	1882	26597	1850	26178	0.996	0.996	248.89	308.77	80,966.81	1,201,680.96	72,505.89	1,088,222.99	48,284.03	749,117.04
15	3	1	1	1853	28450	1834	28012	0.995	0.996	312.37	309.00	87,349.61	1,289,030.58	79,308.69	1,167,531.67	55,086.83	804,203.87
16	3	1	1	1899	30349	1880	29892	0.996	0.996	280.42	307.21	85,547.81	1,374,578.39	77,461.88	1,244,993.56	53,240.03	857,443.90
17	3	1	1	1868	32217	1825	31717	0.996	0.996	299.14	306.74	83,912.81	1,458,491.20	75,631.89	1,320,625.45	51,410.03	908,853.94
18	3	1	1	1828	34045	1826	33543	0.996	0.996	279.84	305.28	86,548.01	1,545,039.22	78,432.09	1,399,057.53	54,210.23	963,064.17
19	3	1	1	1895	35940	1861	35404	0.996	0.996	334.50	306.81	87,096.01	1,632,135.23	79,020.09	1,478,077.62	54,798.23	1,017,862.40
20	3	1	1	1827	37767	1803	37207	0.996	0.996	218.59	302.54	80,191.42	1,712,326.64	71,645.49	1,549,723.11	47,423.64	1,065,286.04
21	3	1	1	1857	39624	1845	39052	0.996	0.996	253.25	300.21	87,248.81	1,799,575.46	79,177.89	1,628,901.00	54,956.03	1,120,242.07
22	3	1	1	1911	41535	1873	40925	0.995	0.996	354.06	302.67	90,168.41	1,889,743.87	82,442.48	1,711,343.48	58,220.63	1,178,462.70
23	3	1	1	1886	43421	1866	42791	0.996	0.996	209.92	298.63	81,608.01	1,971,351.88	73,347.09	1,784,690.57	49,125.23	1,227,587.94
24	3	1	1	1831	45252	1800	44591	0.996	0.996	296.57	298.55	82,497.82	2,053,849.70	74,026.89	1,858,717.46	49,805.04	1,277,392.97
25	3	1	1	1860	47112	1823	46414	0.996	0.996	294.35	298.38	82,682.41	2,136,532.11	74,261.49	1,932,978.94	50,039.63	1,327,432.61
26	3	1	1	1847	48959	1841	48255	0.996	0.996	248.40	296.47	81,868.01	2,218,400.13	73,482.09	2,006,461.03	49,260.23	1,376,692.84
27	3	1	1	1915	50874	1878	50133	0.995	0.996	352.61	298.58	90,415.41	2,308,815.54	82,634.48	2,089,095.52	58,412.63	1,435,105.47
28	3	1	1	1845	52719	1825	51958	0.996	0.996	252.07	296.94	81,939.81	2,390,755.35	73,468.89	2,162,564.40	49,247.03	1,484,352.51
29	3	1	1	1913	54632	1877	53835	0.995	0.996	321.97	297.82	87,993.21	2,478,748.56	80,107.28	2,242,671.69	55,885.43	1,540,237.94
30	3	1	1	1882	56514	1846	55681	0.995	0.996	306.33	298.10	86,286.01	2,565,034.58	78,210.09	2,320,881.77	53,988.23	1,594,226.17
31	3	1	1	1931	58445	1885	57566	0.995	0.996	384.82	300.94	89,248.81	2,654,283.39	81,382.88	2,402,264.66	57,161.03	1,651,387.20
32	3	1	1	1882	60327	1858	59424	0.996	0.996	326.08	301.72	86,924.41	2,741,207.80	78,908.49	2,481,173.14	54,686.63	1,706,073.83
33	3	1	1	1930	62257	1911	61335	0.996	0.996	372.07	303.92	89,589.01	2,830,796.81	81,813.08	2,562,986.23	57,591.23	1,763,665.06
34	3	1	1	1947	64204	1934	63269	0.996	0.996	349.93	305.32	90,882.61	2,921,679.41	83,181.68	2,646,167.91	58,959.83	1,822,624.89
35	3	1	1	1880	66084	1860	65129	0.996	0.996	304.20	305.29	84,386.81	3,006,066.23	76,210.89	2,722,378.79	51,989.03	1,874,613.92
36	3	1	1	1828	67912	1807	66936	0.996	0.996	249.02	303.77	80,404.22	3,086,470.44	71,878.29	2,794,257.08	47,656.44	1,922,270.36
37	3	1	1	1950	69862	1898	68834	0.996	0.996	300.45	303.68	86,621.41	3,173,091.85	78,695.48	2,872,952.56	54,473.63	1,976,743.99
38	3	1	1	1844	71706	1832	70666	0.996	0.996	346.52	304.79	85,289.21	3,258,381.07	77,128.29	2,950,080.85	52,906.43	2,029,650.42
39	3	1	1	1868	73574	1845	72511	0.996	0.996	240.53	303.15	81,037.81	3,339,418.88	72,631.89	3,022,712.74	48,410.03	2,078,060.45
40	3	1	1	1888	75462	1849	74360	0.995	0.996	357.98	304.52	87,054.61	3,426,473.49	78,963.69	3,101,676.42	54,741.83	2,132,802.29
41	3	1	1	1903	77365	1866	76226	0.995	0.996	337.52	305.33	89,486.01	3,515,959.50	81,675.09	3,183,351.51	57,453.23	2,190,255.52
42	3	1	1	1833	79198	1789	78015	0.996	0.996	289.67	304.97	82,920.62	3,598,880.12	74,454.69	3,257,806.20	50,232.84	2,240,488.35
43	3	1	1	1848	81046	1835	79850	0.996	0.996	281.30	304.42	83,273.81	3,682,153.94	75,007.89	3,332,814.09	50,786.03	2,291,274.39
44	3	1	1	1854	82900	1825	81675	0.996	0.996	244.95	303.09	84,947.81	3,767,101.75	76,756.89	3,409,570.97	52,535.03	2,343,809.42
45	3	1	1	1938	84838	1908	83583	0.995	0.996	366.14	304.53	91,561.41	3,858,663.16	83,960.48	3,493,531.46	59,738.63	2,403,548.05
46	3	1	1	1897	86735	1870	85453	0.996	0.996	330.00	305.09	84,100.81	3,942,763.97	75,919.88	3,569,451.34	51,698.03	2,455,246.08
47	3	1	1	1934	88669	1890	87343	0.995	0.996	371.81	306.53	88,223.81	4,030,987.78	80,302.88	3,649,754.22	56,081.03	2,511,327.11
48	3	1	1	1828	90497	1793	89136	0.996	0.996	264.94	305.70	79,566.42	4,110,554.20	70,955.49	3,720,709.71	46,733.64	2,558,060.75
49	3	1	1	1906	92403	1884	91020	0.996	0.996	307.34	305.73	88,051.61	4,198,605.81	80,175.68	3,800,885.40	55,953.83	2,614,014.58
50	3	1	1	1858	94261	1835	92855	0.996	0.996	291.78	305.46	84,777.81	4,283,383.62	76,651.89	3,877,537.29	52,430.03	2,666,444.61
51	3	1	1	1889	96150	1857	94712	0.996	0.996	326.43	305.87	84,491.21	4,367,874.83	76,240.29	3,953,777.57	52,018.43	2,718,463.05
52	3	1	1	1944	98094	1905	96617	0.996	0.996	319.63	306.14	87,691.81	4,455,566.64	79,810.88	4,033,588.45	55,589.03	2,774,052.07
53	3	1	1	1857	99951	1815	98432	0.995	0.996	301.56	306.05	87,691.82	4,543,258.46	79,645.89	4,113,234.34	55,424.04	2,829,476.11
54	3	1	1	1911	101862	1880	100312	0.996	0.996	358.41	307.04	88,218.81	4,631,477.27	80,332.88	4,193,567.23	56,111.03	2,885,587.14
55	3	1	1	1836	103698	1816	102128	0.996	0.996	295.12	306.82	85,392.02	4,716,869.29	77,151.09	4,270,718.32	52,929.24	2,938,516.38
56	3	1	1	1884	105582	1868	103996	0.996	0.996	312.83	306.93	86,169.41	4,803,038.70	78,098.48	4,348,816.80	53,876.63	2,992,393.01
57	3	1	1	1855	107437	1818	105814	0.996	0.996	237.12	305.73	81,695.42	4,884,734.11	73,184.49	4,422,001.29	48,962.64	3,041,355.64
58	3	1	1	1827	109264	1812	107626	0.996	0.996	261.91	304.99	81,395.22	4,966,129.33	72,934.29	4,494,935.58	48,712.44	3,090,068.08
59	3	1	1	1835	111099	1817	109443	0.996	0.996	272.66	304.46	82,510.22	5,048,639.54	74,134.29	4,569,069.87	49,912.44	3,139,980.51
60	3	1	1	1912	113011	1896	111339	0.996	0.996	359.65	305.40	87,550.01	5,136,189.55	79,704.08	4,648,773.95	55,482.23	3,195,462.74

TBA LOW MED

	Independent Variables			All Products							MOH LOW				MOH MED		MOH HIGH	
Replication Number	MAS	MOH	MIX	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Cycle Time	Period NOI	Cumulative NOI	Period NOI	Cumulative NO	Period NOI	Cumulative NO
1	3	1	2	2323	2323	2033	2033	0.890	0.890	544.50	544.50	99,741.45	99,741.45	93,407.93	93,407.93	69,440.90	69,440.90
2	3	1	2	2296	4619	2065	4098	0.896	0.893	556.84	550.72	102,603.46	202,344.91	96,614.94	190,022.87	72,647.91	142,088.81
3	3	1	2	2316	6935	2026	6124	0.900	0.896	526.83	542.81	100,413.29	302,758.19	94,059.77	284,082.65	70,092.74	212,181.56
4	3	1	2	2388	9323	2101	8225	0.883	0.893	549.69	544.57	102,799.85	405,558.04	96,891.33	380,973.98	72,924.30	285,105.86
5	3	1	2	2323	11646	2067	10292	0.900	0.894	550.25	545.71	101,485.65	507,043.69	95,412.13	476,386.11	71,445.10	356,550.96
6	3	1	2	2424	14070	2092	12384	0.895	0.894	555.36	547.34	99,580.50	606,624.19	93,441.99	569,828.10	69,474.95	426,025.91
7	3	1	2	2386	16456	2082	14466	0.894	0.894	556.97	548.73	100,954.26	707,578.45	94,883.25	664,711.34	70,916.22	496,942.13
8	3	1	2	2386	18843	2082	16547	0.894	0.894	559.61	550.10	100,954.26	808,532.71	94,883.25	759,594.59	70,916.22	567,858.35
9	3	1	2	2386	21229	2082	18629	0.867	0.891	562.24	551.45	100,954.26	909,486.98	94,883.25	854,477.84	70,916.22	638,774.56
10	3	1	2	2386	23615	2082	20710	0.891	0.891	564.87	552.80	100,954.26	1,010,441.24	94,883.25	949,361.08	70,916.22	709,690.78
11	3	1	2	2263	25878	2019	22729	0.889	0.891	533.83	551.12	100,557.13	1,110,998.37	94,303.61	1,043,664.70	70,336.58	780,027.36
12	3	1	2	2316	28194	2074	24803	0.895	0.891	561.63	552.00	102,480.81	1,213,479.17	96,542.29	1,140,206.99	72,575.26	852,602.62
13	3	1	2	2368	30562	2076	26879	0.888	0.891	567.14	553.17	101,118.99	1,314,598.17	95,030.48	1,235,237.47	71,063.45	923,666.07
14	3	1	2	2325	32887	2037	28916	0.887	0.891	543.07	552.45	101,304.82	1,415,902.99	95,106.31	1,330,343.78	71,139.28	994,805.35
15	3	1	2	2299	35186	2024	30940	0.887	0.890	534.44	551.28	100,189.10	1,516,092.09	93,960.58	1,424,304.36	69,993.55	1,064,798.90
16	3	1	2	2329	37515	2066	33006	0.895	0.891	538.42	550.47	100,618.05	1,616,710.14	94,459.54	1,518,763.90	70,492.51	1,135,291.41
17	3	1	2	2295	39810	2014	35020	0.886	0.890	536.60	549.67	100,634.16	1,717,344.30	94,385.64	1,613,149.54	70,418.61	1,205,710.02
18	3	1	2	2333	42143	2064	37084	0.888	0.890	545.57	549.44	102,421.86	1,819,766.16	96,433.35	1,709,582.89	72,466.32	1,278,176.34
19	3	1	2	2334	44477	2048	39132	0.886	0.890	534.24	548.65	102,568.36	1,922,334.52	96,584.84	1,806,167.73	72,617.81	1,350,794.15
20	3	1	2	2268	46745	1998	41130	0.888	0.890	533.68	547.92	99,648.65	2,021,983.17	93,325.14	1,899,492.87	69,358.11	1,420,152.26
21	3	1	2	2309	49054	2063	43193	0.892	0.890	549.30	547.99	102,345.27	2,124,328.45	96,296.76	1,995,789.63	72,329.72	1,492,481.98
22	3	1	2	2255	51309	2029	45222	0.886	0.890	545.86	547.89	103,585.07	2,227,913.52	97,706.55	2,093,496.18	73,739.52	1,566,221.51
23	3	1	2	2374	53683	2024	47246	0.889	0.890	520.28	546.71	99,469.10	2,327,382.61	92,970.58	2,186,466.76	69,003.55	1,635,225.06
24	3	1	2	2338	56021	2049	49295	0.888	0.890	533.46	546.16	101,001.95	2,428,384.57	94,813.44	2,281,280.20	70,846.41	1,706,071.47
25	3	1	2	2355	58376	2064	51359	0.893	0.890	533.68	545.66	100,638.86	2,529,023.43	94,465.35	2,375,745.55	70,498.32	1,776,569.79
26	3	1	2	2427	60803	2092	53451	0.887	0.890	638.74	549.30	101,057.50	2,630,080.93	95,028.99	2,470,774.54	71,061.95	1,847,631.74
27	3	1	2	2241	63044	2049	55500	0.887	0.890	534.04	548.74	100,753.95	2,730,834.89	94,525.44	2,565,299.97	70,558.41	1,918,190.15
28	3	1	2	2458	65502	2077	57577	0.896	0.890	554.71	548.95	101,122.59	2,831,957.47	94,954.07	2,660,254.05	70,987.04	1,989,177.19
29	3	1	2	2424	67926	2105	59682	0.891	0.890	572.20	549.77	102,374.22	2,934,331.70	96,510.71	2,756,764.76	72,543.68	2,061,720.87
30	3	1	2	2413	70339	2097	61779	0.891	0.890	547.03	549.68	102,306.47	3,036,638.17	96,332.96	2,853,097.71	72,365.93	2,134,086.80
31	3	1	2	2223	72562	2016	63795	0.889	0.890	564.62	550.15	103,237.35	3,139,875.52	97,298.83	2,950,396.54	73,331.80	2,207,418.60
32	3	1	2	2325	74887	2073	65868	0.892	0.890	574.85	550.93	100,939.21	3,240,814.73	94,755.70	3,045,152.24	70,788.67	2,278,207.26
33	3	1	2	2270	77157	2028	67896	0.890	0.890	536.11	550.49	100,992.48	3,341,807.20	94,878.96	3,140,031.20	70,911.93	2,349,119.19
34	3	1	2	2327	79484	2078	69974	0.894	0.890	535.32	550.04	100,916.18	3,442,723.39	94,787.67	3,234,818.87	70,820.64	2,419,939.83
35	3	1	2	2379	81863	2043	72017	0.889	0.890	541.39	549.79	99,878.39	3,542,601.77	93,504.87	3,328,323.74	69,537.84	2,489,477.67
36	3	1	2	2283	84146	2027	74044	0.891	0.890	526.00	549.14	100,551.88	3,643,153.66	94,268.37	3,422,592.11	70,301.34	2,559,779.01
37	3	1	2	2361	86507	2087	76131	0.888	0.890	545.89	549.05	102,665.53	3,745,819.19	96,812.01	3,519,404.12	72,844.98	2,632,623.99
38	3	1	2	2376	88883	2075	78206	0.891	0.890	566.85	549.52	101,941.40	3,847,760.59	95,937.89	3,615,342.01	71,970.85	2,704,594.85
39	3	1	2	2358	91241	2093	80299	0.890	0.890	561.64	549.84	102,541.09	3,950,301.68	96,722.58	3,712,064.59	72,755.55	2,777,350.40
40	3	1	2	2348	93589	2062	82361	0.917	0.891	589.85	550.84	101,457.68	4,051,759.36	95,449.16	3,807,513.75	71,482.13	2,848,832.53
41	3	1	2	2414	96003	2091	84452	0.888	0.891	581.73	551.61	100,576.91	4,152,336.26	94,628.39	3,902,142.14	70,661.36	2,919,493.89
42	3	1	2	2266	98269	2013	86465	0.887	0.891	548.93	551.54	100,948.56	4,253,284.83	94,780.05	3,996,922.19	70,813.02	2,990,306.91
43	3	1	2	2233	100502	2032	88497	0.895	0.891	543.12	551.35	101,128.85	4,354,413.68	95,125.34	4,092,047.52	71,158.31	3,061,465.21
44	3	1	2	2256	102758	2019	90516	0.890	0.891	525.77	550.78	101,018.13	4,455,431.81	94,864.61	4,186,912.14	70,897.58	3,132,362.79
45	3	1	2	2278	105036	2010	92526	0.889	0.891	529.02	550.31	101,404.78	4,556,836.59	95,141.27	4,282,053.40	71,174.24	3,203,537.03
46	3	1	2	2342	107378	2082	94608	0.894	0.891	556.58	550.44	100,556.56	4,657,393.15	94,458.04	4,376,511.45	70,491.01	3,274,028.04
47	3	1	2	2374	109752	2102	96710	0.893	0.891	584.91	551.19	102,810.44	4,760,203.59	96,976.93	4,473,488.37	73,009.90	3,347,037.94
48	3	1	2	2278	112030	2050	98760	0.891	0.891	520.64	550.56	103,341.55	4,863,545.14	97,578.03	4,571,066.41	73,611.00	3,420,648.94
49	3	1	2	2318	114348	2058	100818	0.895	0.891	562.21	550.80	101,131.30	4,964,676.44	95,007.78	4,666,074.19	71,040.75	3,491,689.70
50	3	1	2	2442	116790	2073	102891	0.889	0.891	534.78	550.47	99,431.21	5,064,107.65	93,132.70	4,759,206.89	69,165.67	3,560,855.36
51	3	1	2	2396	119186	2067	104958	0.889	0.891	580.83	551.07	102,574.65	5,166,682.30	96,651.13	4,855,858.02	72,684.10	3,633,539.46
52	3	1	2	2354	121540	2077	107035	0.889	0.891	567.66	551.39	103,393.59	5,270,075.89	97,540.07	4,953,398.09	73,573.04	3,707,112.51
53	3	1	2	2409	123949	2093	109128	0.888	0.891	634.41	552.99	102,247.09	5,372,322.98	96,278.58	5,049,676.67	72,311.55	3,779,424.05
54	3	1	2	2396	126345	2107	111235	0.897	0.891	554.94	553.02	100,237.41	5,472,560.39	94,098.90	5,143,775.57	70,131.87	3,849,555.92
55	3	1	2	2330	128675	2033	113268	0.884	0.891	541.98	552.83	102,706.45	5,575,266.84	96,722.93	5,240,498.50	72,755.90	3,922,311.82
56	3	1	2	2346	131021	2053	115321	0.884	0.891	540.27	552.60	102,956.33	5,678,223.17	97,042.81	5,337,541.31	73,075.78	3,995,387.61
57	3	1	2	2288	133309	2015	117336	0.890	0.891	520.43	552.05	101,443.75	5,779,666.92	95,245.24	5,432,786.55	71,278.21	4,066,665.81
58	3	1	2	2276	135585	2048	119384	0.892	0.891	541.36	551.87	102,157.36	5,881,824.28	96,158.84	5,528,945.39	72,191.81	4,138,857.62
59	3	1	2	2286	137871	2042	121426	0.890	0.891	539.61	551.66	101,831.79	5,983,656.07	95,828.28	5,624,773.67	71,861.25	4,210,718.87
60	3	1	2	2322	140193	2046	123472	0.894	0.891	528.83	551.28	100,624.17	6,084,280.24	94,385.66	5,719,159.33	70,418.62	4,281,137.50

	Independent Variables				All Products								MOH LOW		MOH MED		MOH HIGH	
	Replication Number	MAS	MOH	MIX	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Cycle Time	Period NOI	Cumulative NOI	Period NOI	Cumulative NO	Period NOI	Cumulative NO
TBA LOW HIGH	1	3	1	3	3215	3215	2191	2191	0.668	0.668	614.51	614.51	102,781.92	102,781.92	97,559.64	97,559.64	73,845.09	73,845.09
	2	3	1	3	3296	6511	2164	4355	0.673	0.671	620.71	617.59	104,217.57	206,999.49	99,020.30	196,579.94	75,305.75	149,150.84
	3	3	1	3	3241	9752	2172	6527	0.679	0.674	621.50	618.89	101,143.45	308,142.94	95,651.18	292,231.12	71,936.63	221,087.47
	4	3	1	3	3215	12967	2169	8696	0.670	0.673	629.09	621.44	104,441.75	412,584.69	99,364.47	391,595.59	75,649.92	296,737.39
	5	3	1	3	3283	16250	2172	10868	0.691	0.676	585.24	614.20	104,686.45	517,271.14	99,509.18	491,104.77	75,794.63	372,532.02
	6	3	1	3	3260	19510	2195	13063	0.679	0.677	612.45	613.91	103,715.86	620,987.00	98,603.58	589,708.35	74,889.03	447,421.05
	7	3	1	3	3266	22776	2188	15251	0.678	0.677	617.36	614.40	103,342.09	724,329.09	98,184.82	687,893.17	74,470.27	521,891.33
	8	3	1	3	3266	26042	2188	17438	0.678	0.677	618.42	614.91	103,342.09	827,671.19	98,184.82	786,077.99	74,470.27	596,361.60
	9	3	1	3	3266	29307	2188	19626	0.678	0.677	619.48	615.42	103,342.09	931,013.28	98,184.82	884,262.81	74,470.27	670,831.87
	10	3	1	3	3266	32573	2188	21813	0.678	0.677	620.55	615.93	103,342.09	1,034,355.38	98,184.82	982,447.63	74,470.27	745,302.14
	11	3	1	3	3296	35869	2208	24021	0.690	0.678	620.72	616.37	101,176.91	1,135,532.29	95,734.64	1,078,182.27	72,020.09	817,322.23
	12	3	1	3	3347	39216	2210	26231	0.677	0.678	627.60	617.32	102,835.38	1,238,367.67	97,653.11	1,175,835.38	73,938.56	891,260.78
	13	3	1	3	4061	43277	2168	28399	0.733	0.683	616.30	617.24	103,685.51	1,342,053.18	98,618.24	1,274,453.61	74,903.69	966,164.47
	14	3	1	3	2482	45759	2199	30598	0.573	0.677	616.22	617.17	104,056.80	1,446,109.98	98,984.52	1,373,438.14	75,269.97	1,041,434.45
	15	3	1	3	3255	49014	2195	32739	0.686	0.678	623.29	618.60	103,254.86	1,549,364.84	98,042.58	1,471,480.72	74,328.03	1,115,762.48
	16	3	1	3	3307	52321	2162	34955	0.665	0.677	613.94	617.35	105,031.10	1,654,395.94	100,023.83	1,571,504.55	76,309.28	1,192,071.76
	17	3	1	3	3309	55630	2185	37140	0.682	0.678	613.51	617.13	101,902.51	1,756,298.45	96,535.23	1,668,039.78	72,820.68	1,264,892.44
	18	3	1	3	3174	58804	2187	39327	0.680	0.678	629.67	617.82	103,781.98	1,860,080.43	98,684.70	1,766,724.48	74,970.15	1,339,862.59
	19	3	1	3	3391	62195	2203	41530	0.682	0.678	615.28	617.69	101,587.74	1,961,668.16	96,230.46	1,862,954.94	72,515.91	1,412,378.51
	20	3	1	3	3281	65476	2189	43719	0.679	0.678	613.02	617.45	102,254.45	2,063,922.61	97,057.17	1,960,012.12	73,342.62	1,485,721.13
	21	3	1	3	3295	68771	2178	45897	0.669	0.677	620.05	617.58	103,797.86	2,167,720.47	98,685.59	2,058,697.70	74,971.04	1,560,692.17
	22	3	1	3	3273	72044	2182	48079	0.669	0.677	622.36	617.79	103,762.80	2,271,483.27	98,655.53	2,157,353.23	74,940.98	1,635,633.15
	23	3	1	3	3302	75346	2170	50249	0.679	0.677	615.06	617.68	103,119.98	2,374,603.26	97,902.71	2,255,255.94	74,188.16	1,709,821.30
	24	3	1	3	3280	78626	2216	52465	0.683	0.677	621.79	617.85	103,323.79	2,477,927.05	98,146.52	2,353,402.46	74,431.97	1,784,253.27
	25	3	1	3	3213	81839	2168	54633	0.679	0.678	627.56	618.24	101,511.51	2,579,438.56	96,119.24	2,449,521.69	72,404.69	1,856,657.96
	26	3	1	3	3206	85045	2163	56796	0.676	0.677	612.25	618.01	105,132.34	2,684,570.90	100,035.06	2,549,556.76	76,320.51	1,932,978.47
	27	3	1	3	3297	88342	2162	58958	0.672	0.677	614.82	617.89	103,233.10	2,787,804.00	97,935.83	2,647,492.58	74,221.28	2,007,199.75
	28	3	1	3	3231	91573	2183	61141	0.681	0.677	616.17	617.83	103,538.04	2,891,342.04	98,390.76	2,745,883.35	74,676.21	2,081,875.97
	29	3	1	3	3144	94717	2147	63288	0.668	0.677	623.79	618.03	104,887.58	2,996,229.61	99,990.30	2,845,873.65	76,275.75	2,158,151.72
	30	3	1	3	3264	97981	2175	65463	0.669	0.677	622.59	618.18	103,957.16	3,100,186.77	98,804.88	2,944,678.53	75,090.33	2,233,242.05
	31	3	1	3	3216	101197	2174	67637	0.674	0.677	623.57	618.36	103,766.92	3,203,953.69	98,664.65	3,043,343.18	74,950.10	2,308,192.15
	32	3	1	3	3347	104544	2186	69823	0.667	0.676	614.95	618.25	103,006.74	3,306,960.44	97,839.47	3,141,182.65	74,124.92	2,382,317.07
	33	3	1	3	3168	107712	2160	71983	0.681	0.677	615.56	618.17	104,027.63	3,410,988.07	98,840.36	3,240,023.00	75,125.81	2,457,442.88
	34	3	1	3	3376	111088	2189	74172	0.669	0.676	614.31	618.05	103,859.45	3,514,847.52	98,767.17	3,338,790.18	75,052.62	2,532,495.50
	35	3	1	3	3244	114332	2172	76344	0.665	0.676	615.78	617.99	104,538.46	3,619,385.97	99,491.18	3,438,281.35	75,776.63	2,608,272.13
	36	3	1	3	3244	117576	2168	78512	0.675	0.676	624.52	618.17	103,453.51	3,722,839.48	98,246.24	3,536,527.59	74,531.69	2,682,803.82
	37	3	1	3	3301	120877	2196	80708	0.684	0.676	620.96	618.25	102,972.09	3,825,811.57	97,684.82	3,634,212.41	73,970.27	2,756,774.08
	38	3	1	3	3121	123998	2125	82833	0.670	0.676	619.11	618.27	104,393.41	3,930,204.98	99,191.13	3,733,403.54	75,476.58	2,832,250.67
	39	3	1	3	3313	127311	2184	85017	0.677	0.676	607.81	618.00	103,720.27	4,033,925.25	98,573.00	3,831,976.54	74,858.45	2,907,109.12
	40	3	1	3	3182	130493	2173	87190	0.674	0.676	622.96	618.12	103,871.69	4,137,796.94	98,764.41	3,930,740.95	75,049.86	2,982,158.98
	41	3	1	3	3276	133769	2154	89344	0.668	0.676	624.46	618.28	102,632.22	4,240,429.16	97,344.95	4,028,085.90	73,630.40	3,055,789.38
	42	3	1	3	3165	136934	2152	91496	0.678	0.676	635.80	618.69	103,341.75	4,343,770.91	98,099.48	4,126,185.38	74,384.93	3,130,174.31
	43	3	1	3	3131	140065	2156	93652	0.665	0.676	624.90	618.83	105,759.69	4,449,530.61	100,892.42	4,227,077.80	77,177.87	3,207,352.17
	44	3	1	3	3201	143266	2174	95826	0.680	0.676	624.86	618.97	103,429.92	4,552,960.53	98,247.65	4,325,325.44	74,533.10	3,281,885.27
	45	3	1	3	3232	146498	1167	97993	0.673	0.676	536.74	611.67	49,358.28	4,602,318.81	39,126.01	4,364,451.45	15,411.46	3,297,296.73
	46	3	1	3	3201	149699	3147	100140	0.670	0.675	644.11	618.80	158,041.57	4,760,360.38	157,944.30	4,522,395.75	134,229.75	3,431,526.48
	47	3	1	3	3173	152872	2119	102259	0.665	0.675	611.74	618.65	104,343.00	4,864,703.38	99,180.72	4,621,576.47	75,466.17	3,506,992.65
	48	3	1	3	3158	156030	2167	104426	0.674	0.675	620.39	618.69	103,840.28	4,968,543.66	98,853.00	4,720,429.47	75,138.45	3,582,131.11
	49	3	1	3	3311	159341	2190	106616	0.675	0.675	626.06	618.84	102,863.68	5,071,407.34	97,581.41	4,818,010.88	73,866.86	3,655,997.96
	50	3	1	3	3211	162552	2190	108806	0.678	0.675	622.24	618.91	104,901.68	5,176,309.02	99,999.41	4,918,010.29	76,284.86	3,732,282.82
	51	3	1	3	3201	165753	2159	110965	0.672	0.675	620.33	618.94	103,151.40	5,279,460.42	97,929.12	5,015,939.41	74,214.57	3,806,497.40
	52	3	1	3	3249	169002	1183	113148	0.684	0.675	766.18	615.01	18,567.04	5,298,027.46	3,359.77	5,019,299.18	(20,354.78)	3,786,142.61
	53	3	1	3	3201	172203	3163	115311	0.671	0.675	569.94	619.10	188,901.33	5,486,928.79	193,824.06	5,213,123.24	170,109.51	3,956,252.12
	54	3	1	3	3380	175583	2210	117521	0.681	0.675	615.29	619.03	102,665.38	5,589,594.18	97,353.11	5,310,476.34	73,638.56	4,029,890.68
	55	3	1	3	3302	178885	2176	119697	0.682	0.676	618.99	619.03	102,205.39	5,691,799.57	96,818.12	5,407,294.46	73,103.57	4,102,994.25
	56	3	1	3	3163	182048	2156	121853	0.665	0.675	621.54	619.08	105,275.69	5,797,075.26	100,253.42	5,507,547.88	76,538.87	4,179,533.12
	57	3	1	3	3251	185299	2172	124025	0.671	0.675	616.98	619.04	104,468.45	5,901,543.71	99,461.18	5,607,009.06	75,746.63	4,255,279.75
	58	3	1	3	3300	188599	2151	126176	0.666	0.675	611.76	618.92	104,047.52	6,005,591.23	98,820.24	5,705,829.30	75,105.69	4,330,385.44
	59	3	1	3	3324	191923	2203	128379	0.674	0.675	621.07	618.95	103,606.74	6,109,197.97	98,549.46	5,804,378.76	74,834.91	4,405,220.35
	60	3	1	3	6178	198101	2175	130554	0.831	0.680	620.90	618.98	105,305.16	6,214,503.13	100,472.88	5,904,851.65	76,758.33	4,481,978.69

ABC LOW LOW

Replication Number	Independent Variables: MAS	MOH	MIX	All Products: Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Cycle Time	MOH LOW: Period NOI	Cumulative NOI	MOH MED: Period NOI	Cumulative NO	MOH HIGH: Period NOI	Cumulative NO
1	2	1	1	1936	1936	1913	1913	0.999	0.999	312.00	312.00	88,165.29	88,165.29	80,375.30	80,375.30	56,045.33	56,045.33
2	2	1	1	1864	3800	1853	3766	0.998	0.998	305.80	308.95	84,243.28	172,408.57	75,958.29	156,333.59	51,628.32	107,673.65
3	2	1	1	1901	5701	1877	5643	0.996	0.998	328.23	315.36	88,950.28	261,358.85	81,005.30	237,338.89	56,675.33	164,348.98
4	2	1	1	1832	7533	1784	7427	0.997	0.998	255.34	300.94	85,036.77	346,395.62	76,741.79	314,080.68	52,411.82	216,760.80
5	2	1	1	1787	9320	1787	9214	0.998	0.998	235.14	288.18	77,361.27	423,756.89	68,561.29	382,641.97	44,231.32	260,992.11
6	2	1	1	1867	11187	1822	11036	0.997	0.998	325.17	294.29	84,107.11	507,864.00	75,757.12	458,399.09	51,427.15	312,419.27
7	2	1	1	1852	13039	1835	12869	0.998	0.998	237.56	286.20	83,307.19	591,171.20	74,930.96	533,330.05	50,600.99	363,020.26
8	2	1	1	1852	14892	1834	14702	1.000	0.998	263.00	283.31	83,265.11	674,436.31	74,883.88	608,213.93	50,553.91	413,574.16
9	2	1	1	1852	16744	1834	16535	0.998	0.998	257.22	280.42	83,223.03	757,659.34	74,836.79	683,050.72	50,506.82	464,080.98
10	2	1	1	1852	18596	1833	18368	0.998	0.998	303.55	282.72	83,180.94	840,840.28	74,789.71	757,840.43	50,459.74	514,540.72
11	2	1	1	1872	20468	1845	20213	0.998	0.998	259.70	280.62	84,631.95	925,472.23	76,386.96	834,227.39	52,056.99	566,597.71
12	2	1	1	1860	22328	1842	22055	0.998	0.998	243.28	277.50	83,631.45	1,009,103.67	75,261.46	909,488.85	50,931.49	617,529.20
13	2	1	1	1813	24141	1785	23840	0.998	0.998	216.70	272.95	76,777.94	1,085,881.61	67,967.95	977,456.80	43,637.98	661,167.18
14	2	1	1	1949	26090	1914	25754	0.998	0.998	333.98	277.49	88,742.45	1,174,624.06	80,862.47	1,058,319.27	56,532.50	717,699.68
15	2	1	1	1921	28011	1912	27666	0.998	0.998	295.78	278.75	87,655.12	1,262,279.18	79,735.13	1,138,054.40	55,405.16	773,104.84
16	2	1	1	1872	29883	1835	29501	0.998	0.998	304.03	280.32	84,019.28	1,346,298.46	75,634.29	1,213,688.69	51,304.32	824,409.17
17	2	1	1	1859	31742	1838	31399	1.000	0.999	261.16	278.67	83,588.78	1,429,887.24	75,328.79	1,289,017.49	50,998.82	875,407.99
18	2	1	1	1881	33623	1869	33208	0.999	0.999	307.49	280.79	88,105.95	1,517,993.18	80,155.96	1,369,173.45	55,825.99	931,233.98
19	2	1	1	1952	35575	1937	35145	0.999	0.999	346.17	284.39	90,139.29	1,608,132.47	82,479.30	1,451,652.75	58,149.33	989,383.31
20	2	1	1	1825	37400	1811	36956	0.999	0.999	229.13	281.69	82,669.28	1,690,801.75	74,229.29	1,525,882.04	49,899.32	1,039,282.63
21	2	1	1	1910	39310	1890	38846	0.999	0.999	298.19	282.49	87,105.45	1,777,907.20	79,175.46	1,605,057.51	54,845.49	1,094,128.13
22	2	1	1	1924	41234	1869	40715	0.998	0.999	326.86	284.53	86,186.95	1,864,094.15	78,106.96	1,683,164.47	53,776.99	1,147,905.12
23	2	1	1	1844	43078	1828	42543	0.999	0.999	304.76	285.40	84,170.11	1,948,264.26	75,860.13	1,759,024.59	51,530.15	1,199,435.27
24	2	1	1	1956	45034	1875	44418	0.999	0.999	258.77	284.27	85,838.95	2,034,103.20	77,783.96	1,836,808.56	53,453.99	1,252,889.27
25	2	1	1	1822	46856	1858	46276	0.998	0.999	369.57	287.70	86,963.11	2,121,066.32	78,868.13	1,915,676.69	54,538.16	1,307,427.42
26	2	1	1	1860	48716	1837	48113	0.998	0.999	313.93	288.70	86,931.61	2,207,997.93	78,906.63	1,994,583.31	54,576.66	1,362,004.08
27	2	1	1	1950	50666	1907	50020	0.999	0.999	405.56	293.15	87,106.28	2,295,104.21	79,141.30	2,073,724.61	54,811.33	1,416,815.41
28	2	1	1	1876	52542	1861	51881	0.999	0.999	286.25	292.91	83,574.61	2,378,678.83	75,409.63	2,149,134.24	51,079.66	1,467,895.07
29	2	1	1	1916	54458	1878	53759	0.999	0.999	297.15	293.05	83,835.45	2,462,514.28	75,600.46	2,224,734.70	51,270.49	1,519,165.56
30	2	1	1	1912	56370	1899	55658	0.998	0.999	369.28	295.65	91,243.95	2,553,758.23	83,538.97	2,308,273.67	59,208.99	1,578,374.55
31	2	1	1	1919	58289	1894	57552	0.999	0.999	276.11	295.01	88,954.12	2,642,712.34	81,154.13	2,389,427.80	56,824.16	1,635,198.71
32	2	1	1	1883	60172	1851	59403	0.999	0.999	318.70	295.75	85,818.95	2,728,531.29	77,743.96	2,467,171.76	53,413.99	1,688,612.70
33	2	1	1	1909	62081	1880	61283	0.999	0.999	298.08	295.82	83,600.78	2,812,132.07	75,320.80	2,542,492.56	50,990.83	1,739,603.53
34	2	1	1	1930	64011	1908	63191	0.999	0.999	330.81	296.88	87,035.45	2,899,167.52	79,055.47	2,621,548.02	54,725.50	1,794,329.03
35	2	1	1	1910	65921	1877	65068	0.998	0.999	304.80	297.11	89,768.28	2,988,935.81	81,878.30	2,703,426.32	57,548.33	1,851,877.35
36	2	1	1	1848	67769	1820	66888	0.998	0.999	323.74	297.83	83,764.78	3,072,700.58	75,289.79	2,778,716.11	50,959.82	1,902,837.17
37	2	1	1	1930	69699	1902	68790	0.999	0.999	321.24	298.48	89,492.45	3,162,193.03	81,622.47	2,860,338.58	57,292.50	1,960,129.67
38	2	1	1	1858	71557	1834	70624	0.999	0.999	279.55	297.99	83,675.11	3,245,868.14	75,315.13	2,935,653.70	50,985.16	2,011,114.82
39	2	1	1	1868	73425	1864	72488	0.980	0.998	301.80	298.08	84,269.11	3,330,137.26	76,154.13	3,011,807.83	51,824.16	2,062,938.98
40	2	1	1	1885	75310	1863	74351	0.998	0.998	275.62	297.52	85,158.95	3,415,296.21	76,908.96	3,088,716.79	52,578.99	2,115,517.97
41	2	1	1	1888	77198	1861	76212	0.998	0.998	332.59	298.38	89,429.61	3,504,725.82	81,439.63	3,170,156.42	57,109.66	2,172,627.63
42	2	1	1	76253	153451	1882	78094	0.961	0.980	361.39	299.90	91,313.12	3,596,038.93	83,603.13	3,253,759.55	59,273.16	2,231,900.79
43	2	1	1	(72476)	80975	1838	79932	0.959	0.998	255.46	298.87	82,960.78	3,678,999.71	74,650.79	3,328,410.35	50,320.82	2,282,221.61
44	2	1	1	1907	82882	1898	81830	0.998	0.998	368.76	300.50	87,600.78	3,766,600.50	79,670.80	3,408,081.15	55,340.83	2,337,562.44
45	2	1	1	1860	84742	1825	83655	0.998	0.998	254.59	299.49	83,246.61	3,849,847.11	74,926.62	3,483,007.77	50,596.65	2,388,159.10
46	2	1	1	1821	86563	1806	85461	0.998	0.998	268.63	298.84	82,562.44	3,932,409.55	74,097.46	3,557,105.23	49,767.49	2,437,926.58
47	2	1	1	1928	88491	1903	87364	0.998	0.998	422.79	301.54	90,114.62	4,022,524.17	82,469.63	3,639,574.86	58,139.66	2,496,066.24
48	2	1	1	1911	90402	1882	89246	0.998	0.998	304.22	301.60	87,091.12	4,109,615.28	79,136.13	3,718,710.99	54,806.16	2,550,872.40
49	2	1	1	1927	92329	1894	91140	0.998	0.998	376.96	303.16	88,214.12	4,197,829.40	80,269.13	3,798,980.12	55,939.16	2,606,811.57
50	2	1	1	1891	94220	1870	93010	0.998	0.998	282.84	302.76	87,686.11	4,285,515.51	79,716.13	3,878,696.25	55,386.16	2,662,197.72
51	2	1	1	1866	96086	1852	94862	0.998	0.998	280.90	302.33	83,523.11	4,369,038.63	75,228.13	3,953,924.38	50,898.16	2,713,095.88
52	2	1	1	1865	97951	1843	96705	0.998	0.998	293.79	302.17	88,142.61	4,457,181.24	80,137.63	4,034,062.00	55,807.66	2,768,903.54
53	2	1	1	1971	99922	1928	98633	0.998	0.998	391.64	303.92	92,777.79	4,549,959.02	85,267.80	4,119,329.81	60,937.83	2,829,841.37
54	2	1	1	1981	101903	1936	100569	0.998	0.998	356.52	304.93	89,784.12	4,639,743.15	82,019.14	4,201,348.94	57,689.17	2,887,530.53
55	2	1	1	1877	103780	1860	102429	0.998	0.998	331.24	305.41	87,135.45	4,726,878.59	79,035.46	4,280,384.40	54,705.49	2,942,236.03
56	2	1	1	1930	105710	1917	104346	0.998	0.998	322.20	305.71	91,498.95	4,818,377.55	83,898.97	4,364,283.37	59,569.00	3,001,805.02
57	2	1	1	1909	107619	1885	106231	0.998	0.998	346.95	306.45	86,281.62	4,904,659.16	78,236.63	4,442,520.00	53,906.66	3,055,711.68
58	2	1	1	1885	109504	1849	108080	0.998	0.998	281.54	306.02	85,685.61	4,990,344.77	77,570.63	4,520,090.63	53,240.66	3,108,952.34
59	2	1	1	1789	111293	1785	109865	0.998	0.998	315.03	306.17	84,655.94	5,075,000.71	76,295.95	4,596,386.58	51,965.98	3,160,918.32
60	2	1	1	1886	113179	1850	111715	0.998	0.998	321.29	306.42	86,397.78	5,161,398.49	78,342.79	4,674,729.38	54,012.82	3,214,931.15

ABC LOW MED

Independent Variables				All Products								MOH LOW		MOH MED		MOH HIGH	
Replication Number	MAS	MOH	MIX	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Cycle Time	Period NOI	Cumulative NOI	Period NOI	Cumulative NO	Period NOI	Cumulative NO
1	2	1	2	2389	2389	2128	2128	0.922	0.922	746.49	746.49	106,901.02	106,901.02	101,661.54	101,661.54	77,482.58	77,482.58
2	2	1	2	2412	4801	2122	4250	0.898	0.910	735.21	740.86	107,685.40	214,586.42	102,440.92	204,102.47	78,261.96	155,744.55
3	2	1	2	2305	7106	2133	6383	0.921	0.913	739.23	740.32	104,962.54	319,548.96	99,443.06	303,545.53	75,264.10	231,008.65
4	2	1	2	2285	9391	2105	8488	0.912	0.913	736.11	739.27	104,808.64	424,357.61	99,189.16	402,734.69	75,010.20	306,018.85
5	2	1	2	2339	11730	2149	10637	0.913	0.913	752.75	742.00	104,704.20	529,061.80	99,134.72	501,869.40	74,955.76	380,974.61
6	2	1	2	2330	14060	2115	12752	0.924	0.917	748.55	743.08	106,849.68	635,911.48	101,445.20	603,314.60	77,266.24	458,240.85
7	2	1	2	2347	16407	2134	14886	0.919	0.917	750.68	744.17	105,471.09	741,382.57	100,025.36	703,339.96	75,846.40	534,087.25
8	2	1	2	2347	18755	2134	17019	0.919	0.917	752.60	745.23	105,471.09	846,853.66	100,025.36	803,365.33	75,846.40	609,933.65
9	2	1	2	2347	21102	2134	19153	0.919	0.917	754.52	746.27	105,471.09	952,324.76	100,025.36	903,390.69	75,846.40	685,780.05
10	2	1	2	2347	23449	2134	21286	0.919	0.917	756.45	747.29	105,471.09	1,057,795.85	100,025.36	1,003,416.05	75,846.40	761,626.46
11	2	1	2	2387	25836	2165	23451	0.915	0.917	768.37	749.23	106,278.85	1,164,074.70	100,929.37	1,104,345.42	76,750.41	838,376.87
12	2	1	2	2338	28174	2106	25557	0.918	0.917	770.71	751.00	107,428.75	1,271,503.44	102,074.27	1,206,419.69	77,895.31	916,272.18
13	2	1	2	2394	30568	2151	27708	0.918	0.917	765.60	752.14	103,587.40	1,375,090.85	97,932.92	1,304,352.61	73,753.96	990,026.14
14	2	1	2	2327	32895	2129	29837	0.916	0.917	731.97	750.70	107,068.13	1,482,158.97	101,723.65	1,406,076.26	77,544.69	1,067,570.83
15	2	1	2	2326	35221	2110	31947	0.919	0.917	757.27	751.13	104,722.16	1,586,881.13	99,172.68	1,505,248.94	74,993.72	1,142,564.55
16	2	1	2	2254	37475	2056	34003	0.910	0.917	751.44	751.15	107,720.57	1,694,601.71	102,266.09	1,607,515.03	78,087.13	1,220,651.68
17	2	1	2	2336	39811	2123	36126	0.918	0.917	750.55	751.11	107,212.51	1,801,814.21	101,888.03	1,709,403.06	77,709.07	1,298,360.75
18	2	1	2	2276	42087	2094	38220	0.921	0.917	721.51	749.49	106,609.51	1,908,423.72	101,065.03	1,810,468.08	76,886.07	1,375,246.81
19	2	1	2	2414	44501	2173	40393	0.918	0.917	771.11	750.66	106,412.68	2,014,836.40	101,183.20	1,911,651.28	77,004.24	1,452,251.05
20	2	1	2	2357	46858	2135	42528	0.913	0.917	762.02	751.23	106,152.75	2,120,989.14	100,638.27	2,012,289.55	76,459.31	1,528,710.36
21	2	1	2	2292	49150	2109	44637	0.924	0.917	745.36	750.95	108,234.06	2,229,223.20	103,049.58	2,115,339.13	78,870.62	1,607,580.98
22	2	1	2	2312	51462	2111	46748	0.915	0.917	731.70	750.08	106,474.26	2,335,697.46	101,049.78	2,216,388.91	76,870.82	1,684,451.80
23	2	1	2	2278	53740	2103	48851	0.913	0.917	708.49	748.29	106,297.44	2,441,994.90	100,822.96	2,317,211.87	76,644.00	1,761,095.80
24	2	1	2	2348	56088	2145	50996	0.926	0.917	718.57	747.04	104,925.78	2,546,920.68	99,381.30	2,416,593.17	75,202.34	1,836,298.14
25	2	1	2	2300	58388	2121	53117	0.919	0.918	756.85	747.43	104,395.30	2,651,315.98	98,700.82	2,515,293.99	74,521.86	1,910,820.00
26	2	1	2	2370	60758	2125	55242	0.912	0.917	736.96	747.03	106,025.71	2,757,341.69	100,656.23	2,615,950.22	76,477.27	1,987,297.28
27	2	1	2	2350	63108	2137	57379	0.916	0.917	767.90	747.80	107,015.95	2,864,357.64	101,761.47	2,717,711.69	77,582.51	2,064,879.79
28	2	1	2	2397	65505	2146	59525	0.916	0.917	756.66	748.12	104,734.88	2,969,092.53	99,335.41	2,817,047.10	75,156.45	2,140,036.24
29	2	1	2	2280	67785	2106	61631	0.914	0.917	695.00	746.31	105,684.75	3,074,777.28	100,100.27	2,917,147.37	75,921.31	2,215,957.54
30	2	1	2	2401	70186	2138	63769	0.915	0.917	775.33	747.28	105,985.06	3,180,762.33	100,560.58	3,017,707.94	76,381.62	2,292,339.16
31	2	1	2	2307	72493	2109	65878	0.915	0.917	733.82	746.85	106,990.06	3,287,752.39	101,630.58	3,119,338.52	77,451.62	2,369,790.78
32	2	1	2	2358	74851	2129	68007	0.915	0.917	743.99	746.76	104,475.13	3,392,227.52	98,840.65	3,218,179.17	74,661.69	2,444,452.47
33	2	1	2	2283	77134	2111	70118	0.916	0.917	744.90	746.71	107,079.26	3,499,306.78	101,649.78	3,319,828.95	77,470.82	2,521,923.29
34	2	1	2	2321	79455	2109	72227	0.916	0.917	717.28	745.85	105,583.06	3,604,889.84	100,073.58	3,419,902.53	75,894.62	2,597,817.91
35	2	1	2	2326	81781	2079	74306	0.915	0.917	689.72	744.28	105,091.95	3,709,981.79	99,512.47	3,519,415.00	75,333.51	2,673,151.42
36	2	1	2	2224	84005	2085	76391	0.918	0.917	634.56	741.28	105,106.57	3,815,088.36	99,507.09	3,618,922.10	75,328.14	2,748,479.56
37	2	1	2	2349	86354	2146	78537	0.914	0.917	754.60	741.65	105,634.88	3,920,723.25	100,175.41	3,719,097.50	75,996.45	2,824,476.01
38	2	1	2	2369	88723	2123	80660	0.917	0.917	772.36	742.45	104,576.51	4,025,299.76	99,032.03	3,818,129.53	74,853.07	2,899,329.07
39	2	1	2	2283	91006	2116	82776	0.915	0.917	718.95	741.85	106,198.78	4,131,498.54	100,634.30	3,918,763.83	76,455.34	2,975,784.41
40	2	1	2	2304	93310	2120	84896	0.916	0.917	759.86	742.30	106,236.19	4,237,734.73	100,816.72	4,019,580.54	76,637.76	3,052,422.17
41	2	1	2	2337	95647	2153	87049	0.921	0.917	751.20	742.52	104,978.61	4,342,713.34	99,464.13	4,119,044.67	75,285.17	3,127,707.34
42	2	1	2	2308	97955	2109	89158	0.916	0.917	765.67	743.07	104,691.06	4,447,404.40	99,191.58	4,218,236.25	75,012.62	3,202,719.96
43	2	1	2	2238	100193	2071	91229	0.914	0.917	726.10	742.68	107,362.13	4,554,766.52	101,742.65	4,319,978.90	77,563.69	3,280,283.64
44	2	1	2	2315	102508	2127	93356	0.909	0.917	743.34	742.70	105,893.92	4,660,660.44	100,444.44	4,420,423.34	76,265.48	3,356,549.12
45	2	1	2	2268	104776	2113	95469	0.916	0.917	748.48	742.83	106,276.47	4,766,936.91	100,786.99	4,521,210.33	76,608.03	3,433,157.16
46	2	1	2	2321	107097	2125	97594	0.916	0.917	776.98	743.57	105,421.71	4,872,358.63	99,852.23	4,621,062.56	75,673.27	3,508,830.43
47	2	1	2	2276	109373	2107	99701	0.912	0.916	703.42	742.72	106,622.85	4,978,981.48	101,083.37	4,722,145.93	76,904.41	3,585,734.84
48	2	1	2	2337	111710	2136	101837	0.915	0.916	736.11	742.58	105,147.85	5,084,129.33	99,698.37	4,821,844.30	75,519.41	3,661,254.25
49	2	1	2	2346	114056	2122	103959	0.915	0.916	743.60	742.60	105,301.40	5,189,430.73	99,851.92	4,921,696.22	75,672.96	3,736,927.21
50	2	1	2	2330	116386	2117	106076	0.911	0.916	765.03	743.05	105,899.88	5,295,330.61	100,360.40	5,022,056.63	76,181.45	3,813,108.66
51	2	1	2	2366	118752	2113	108189	0.918	0.916	761.64	743.42	106,989.47	5,402,320.08	101,614.99	5,123,671.62	77,436.03	3,890,544.69
52	2	1	2	2318	121070	2139	110328	0.919	0.916	724.00	743.04	105,256.16	5,507,576.24	99,761.68	5,223,433.30	75,582.72	3,966,127.41
53	2	1	2	2402	123472	2165	112493	0.922	0.916	719.72	742.59	105,642.85	5,613,219.09	100,293.37	5,323,726.67	76,114.41	4,042,241.82
54	2	1	2	2376	125848	2134	114627	0.909	0.916	770.57	743.11	105,896.64	5,719,115.74	100,447.16	5,424,173.83	76,268.20	4,118,510.03
55	2	1	2	2358	128206	2148	116775	0.915	0.916	761.95	743.46	106,297.09	5,825,412.83	100,962.61	5,525,136.45	76,783.65	4,195,293.68
56	2	1	2	2403	130609	2126	118901	0.916	0.916	762.70	743.80	106,366.82	5,931,779.64	100,997.34	5,626,133.78	76,818.38	4,272,112.06
57	2	1	2	2348	132957	2135	121036	0.918	0.916	778.61	744.42	105,237.75	6,037,017.39	99,678.27	5,725,812.05	75,499.31	4,347,611.37
58	2	1	2	2299	135256	2109	123145	0.917	0.916	737.04	744.29	106,238.06	6,143,255.45	100,808.58	5,826,620.63	76,629.62	4,424,240.98
59	2	1	2	2308	137564	2117	125262	0.916	0.916	738.36	744.19	106,027.88	6,249,283.33	100,483.40	5,927,104.03	76,304.45	4,500,545.43
60	2	1	2	2271	139835	2116	127378	0.919	0.916	756.81	744.40	106,054.78	6,355,338.11	100,595.30	6,027,699.33	76,416.34	4,576,961.77

ABC LOW HIGH

Replication Number	MAS	MOH	MIX	All Products Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Cycle Time	MOH LOW Period NOI	LOW Cumulative NOI	MED Period NOI	MED Cumulative NO	HIGH Period NOI	HIGH Cumulative NO
1	2	1	3	3199	3199	2173	2173	0.686	0.686	677.41	677.41	114,769.74	114,769.74	111,589.12	111,589.12	88,317.89	88,317.89
2	2	1	3	3431	6630	2225	4398	0.676	0.681	649.93	663.51	115,090.65	229,860.39	112,120.03	223,709.16	88,848.80	177,166.68
3	2	1	3	3298	9928	2197	6595	0.673	0.678	660.84	662.62	115,200.31	345,060.71	112,124.70	335,833.85	88,853.46	266,020.14
4	2	1	3	3163	13091	2186	8781	0.675	0.678	680.32	667.02	115,177.97	460,238.67	111,987.35	447,821.20	88,716.11	354,736.26
5	2	1	3	3240	16331	2184	10965	0.682	0.678	657.57	665.14	115,014.09	575,252.76	111,753.47	559,574.67	88,482.23	443,218.49
6	2	1	3	3203	19534	2175	13140	0.683	0.679	668.34	665.67	116,747.62	692,000.38	113,827.00	673,401.67	90,555.77	533,774.26
7	2	1	3	3223	22757	2193	15333	0.677	0.679	668.42	666.06	115,285.58	807,285.96	112,196.21	785,597.89	88,924.98	622,699.23
8	2	1	3	3223	25981	2193	17525	0.721	0.684	669.16	666.45	115,285.58	922,571.55	112,196.21	897,794.10	88,924.98	711,624.21
9	2	1	3	3223	29204	2193	19718	0.682	0.684	669.90	666.83	115,285.58	1,037,857.13	112,196.21	1,009,990.32	88,924.98	800,549.19
10	2	1	3	3223	32427	2193	21910	0.682	0.684	670.64	667.22	115,285.58	1,153,142.71	112,196.21	1,122,186.53	88,924.98	889,474.17
11	2	1	3	3207	35634	2203	24113	0.686	0.684	671.34	667.59	115,847.96	1,268,990.67	112,802.34	1,234,988.87	89,531.10	979,005.27
12	2	1	3	3236	38870	2198	26311	0.688	0.684	671.25	667.90	115,984.26	1,384,974.92	112,928.64	1,347,917.51	89,657.40	1,068,662.67
13	2	1	3	3223	42093	2198	28509	0.686	0.684	674.77	668.43	115,592.26	1,500,567.18	112,601.64	1,460,519.14	89,330.40	1,157,993.07
14	2	1	3	3230	45323	2196	30705	0.683	0.684	671.70	668.66	115,746.37	1,616,313.55	112,685.76	1,573,204.90	89,414.52	1,247,407.59
15	2	1	3	3361	48684	2211	32916	0.688	0.685	652.54	667.58	114,988.48	1,731,302.04	111,952.86	1,685,157.76	88,681.63	1,336,089.22
16	2	1	3	3331	52015	2226	35142	0.681	0.684	663.20	667.30	115,382.59	1,846,684.63	112,326.97	1,797,484.74	89,055.74	1,425,144.96
17	2	1	3	3187	55202	2174	37316	0.681	0.684	685.32	668.35	115,704.68	1,962,389.31	112,594.06	1,910,078.80	89,322.83	1,514,467.78
18	2	1	3	3214	58416	2193	39509	0.685	0.684	665.36	668.18	116,294.55	2,078,683.86	113,333.93	2,023,412.73	90,062.70	1,604,530.48
19	2	1	3	3214	61630	2184	41693	0.686	0.684	677.96	668.70	115,874.09	2,194,557.95	112,803.47	2,136,216.20	89,532.23	1,694,062.71
20	2	1	3	3236	64866	2188	43881	0.690	0.685	666.41	668.58	114,624.85	2,309,182.80	111,414.23	2,247,630.43	88,142.99	1,782,205.71
21	2	1	3	3177	68043	2196	46077	0.677	0.684	685.36	669.38	115,351.37	2,424,534.17	112,175.76	2,359,806.19	88,904.52	1,871,110.23
22	2	1	3	3231	71274	2208	48285	0.685	0.684	678.74	669.81	114,893.66	2,539,427.83	111,803.04	2,471,609.23	88,531.81	1,959,642.03
23	2	1	3	3170	74444	2174	50459	0.685	0.684	670.72	669.85	114,805.68	2,654,233.51	111,550.06	2,583,159.30	88,278.83	2,047,920.86
24	2	1	3	3312	77756	2172	52631	0.684	0.684	652.64	669.14	115,958.80	2,770,192.31	112,948.18	2,696,107.48	89,676.95	2,137,597.81
25	2	1	3	3339	81095	2214	54845	0.689	0.685	667.16	669.06	115,114.30	2,885,306.62	112,138.69	2,808,246.16	88,867.45	2,226,465.26
26	2	1	3	3213	84308	2192	57037	0.683	0.684	672.45	669.19	115,964.61	3,001,271.23	112,928.99	2,921,175.16	89,657.76	2,316,123.01
27	2	1	3	3206	87514	2201	59238	0.689	0.685	668.06	669.15	114,994.08	3,116,265.31	111,818.46	3,032,993.62	88,547.22	2,404,670.24
28	2	1	3	3190	90704	2168	61406	0.688	0.685	674.03	669.32	115,468.04	3,231,733.34	112,342.42	3,145,336.04	89,071.18	2,493,741.42
29	2	1	3	3155	93859	2158	63564	0.690	0.685	673.88	669.47	115,477.63	3,347,210.98	112,187.01	3,257,523.05	88,915.78	2,582,657.20
30	2	1	3	3258	97117	2176	65740	0.686	0.685	674.22	669.63	116,550.56	3,463,761.54	113,619.94	3,371,142.99	90,348.71	2,673,005.90
31	2	1	3	3248	100365	2193	67933	0.683	0.685	662.16	669.39	115,934.55	3,579,696.09	112,838.93	3,483,981.93	89,567.70	2,762,573.60
32	2	1	3	3182	103547	2187	70120	0.671	0.684	683.95	669.84	116,635.91	3,696,332.00	113,625.29	3,597,607.22	90,354.05	2,852,927.66
33	2	1	3	3230	106777	2214	72334	0.689	0.685	670.19	669.86	114,886.30	3,811,218.30	111,745.69	3,709,352.90	88,474.45	2,941,402.11
34	2	1	3	3302	110079	2206	74540	0.691	0.685	666.25	669.75	115,310.78	3,926,529.08	112,295.16	3,821,648.07	89,023.93	3,030,426.03
35	2	1	3	3239	113318	2189	76729	0.682	0.685	672.40	669.82	115,888.79	4,042,417.87	112,878.17	3,934,526.24	89,606.94	3,120,032.97
36	2	1	3	3190	116508	2192	78921	0.685	0.685	675.84	669.99	115,654.61	4,158,072.48	112,568.99	4,047,095.23	89,297.76	3,209,330.72
37	2	1	3	3295	119803	2194	81115	0.689	0.685	650.71	669.47	115,043.49	4,273,115.98	111,902.87	4,158,998.11	88,631.64	3,297,962.36
38	2	1	3	3277	123080	2178	83293	0.686	0.685	657.85	669.17	115,645.44	4,388,761.42	112,509.83	4,271,507.93	89,238.59	3,387,200.95
39	2	1	3	3301	126381	2208	85501	0.687	0.685	663.85	669.03	115,114.66	4,503,876.08	112,034.04	4,383,541.97	88,762.81	3,475,963.76
40	2	1	3	3111	129492	2199	87700	0.683	0.685	695.01	669.68	115,791.20	4,619,667.28	112,700.58	4,496,242.55	89,429.34	3,565,393.10
41	2	1	3	3215	132707	2202	89902	0.693	0.685	660.36	669.45	116,599.02	4,736,266.30	113,678.40	4,609,920.95	90,407.16	3,655,800.26
42	2	1	3	3183	135890	2182	92084	0.683	0.685	680.98	669.73	115,233.21	4,851,499.50	112,092.59	4,722,013.54	88,821.35	3,744,621.61
43	2	1	3	3142	139032	2182	94266	0.686	0.685	678.73	669.93	115,303.21	4,966,802.71	112,122.59	4,834,136.13	88,851.35	3,833,472.97
44	2	1	3	3207	142239	2202	96468	0.684	0.685	681.43	670.20	114,731.02	5,081,533.72	111,560.40	4,945,696.53	88,289.16	3,921,762.13
45	2	1	3	3316	145555	2172	98640	0.690	0.685	648.55	669.72	117,144.80	5,198,678.52	114,274.18	5,059,970.71	91,002.95	4,012,765.07
46	2	1	3	3240	148795	2203	100843	0.685	0.685	666.82	669.66	116,599.96	5,315,278.48	113,624.34	5,173,595.05	90,353.10	4,103,118.18
47	2	1	3	3168	151963	2202	103045	0.686	0.685	682.35	669.93	114,762.02	5,430,040.50	111,596.40	5,285,191.45	88,325.16	4,191,443.34
48	2	1	3	3173	155136	2193	105238	0.687	0.685	681.91	670.18	114,833.55	5,544,874.05	111,662.93	5,396,854.38	88,391.70	4,279,835.04
49	2	1	3	3195	158331	2192	107430	0.690	0.685	663.93	670.05	114,321.61	5,659,195.66	111,020.99	5,507,875.37	87,749.76	4,367,584.80
50	2	1	3	3252	161583	2210	109640	0.690	0.685	661.28	669.87	114,600.54	5,773,796.21	111,454.92	5,619,330.30	88,183.69	4,455,768.48
51	2	1	3	3300	164883	2262	111852	0.686	0.685	659.61	669.96	118,585.45	5,892,381.66	115,804.83	5,735,135.13	92,533.60	4,548,302.08
52	2	1	3	3205	168088	2200	114032	0.679	0.685	674.99	670.18	115,994.14	6,008,375.80	112,778.52	5,847,913.65	89,507.28	4,637,809.36
53	2	1	3	3285	171373	2115	116217	0.684	0.685	656.10	669.52	110,060.19	6,118,435.98	106,369.57	5,954,283.22	83,098.33	4,720,907.70
54	2	1	3	3161	174534	2174	118391	0.693	0.685	666.51	669.46	113,181.68	6,231,617.66	109,741.06	6,064,024.28	86,469.83	4,807,377.52
55	2	1	3	4166	178700	2192	120583	0.702	0.686	678.77	669.63	115,154.61	6,346,772.27	112,013.99	6,176,038.28	88,742.76	4,896,120.28
56	2	1	3	2240	180940	2190	122773	0.658	0.685	657.81	669.42	114,432.73	6,461,205.01	111,132.11	6,287,170.39	87,860.88	4,983,981.16
57	2	1	3	3149	184089	2184	124957	0.676	0.685	689.47	669.77	115,444.09	6,576,649.09	112,278.47	6,399,448.86	89,007.23	5,072,988.39
58	2	1	3	3212	187301	2198	127155	0.689	0.685	673.57	669.84	116,162.26	6,692,811.35	113,186.64	6,512,635.49	89,915.40	5,162,903.79
59	2	1	3	3212	190513	2194	129349	0.681	0.685	669.23	669.83	115,516.49	6,808,327.84	112,400.87	6,625,036.37	89,129.64	5,252,033.43
60	2	1	3	3126	193639	2156	131505	0.684	0.685	687.55	670.12	114,378.75	6,922,706.59	111,098.13	6,736,134.50	87,826.90	5,339,860.32

		Independent Variables			All Products								MOH LOW		MOH MED		MOH HIGH	
	Replication Number	MAS	MOH	MIX	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Cycle Time	Period NOI	Cumulative NOI	Period NOI	Cumulative NO	Period NOI	Cumulative NO
TCS LOW LOW	1	1	1	1	1849	1849	1825	1825	0.992	0.992	300.34	300.34	84,212.16	84,212.16	75,884.38	75,884.38	51,588.82	51,588.82
	2	1	1	1	1909	3758	1859	3684	0.992	0.992	300.00	300.16	85,850.53	170,062.69	77,742.75	153,627.13	53,447.19	105,036.01
	3	1	1	1	1907	5665	1893	5577	0.992	0.992	509.12	371.09	93,288.91	263,351.60	85,721.13	239,348.26	61,425.56	166,461.57
	4	1	1	1	1824	7489	1804	7381	0.992	0.992	297.93	353.21	85,644.07	348,995.67	77,391.29	316,739.55	53,095.73	219,557.31
	5	1	1	1	1866	9355	1793	9174	0.992	0.992	313.14	345.38	82,671.98	431,667.66	74,184.20	390,923.75	49,888.64	269,445.95
	6	1	1	1	1897	11252	1908	11082	0.992	0.992	291.66	336.13	87,432.39	519,100.05	79,584.61	470,508.37	55,289.05	324,735.00
	7	1	1	1	1902	13154	1868	12950	0.992	0.992	355.63	338.94	87,022.88	606,122.93	79,022.60	549,530.96	54,727.03	379,462.04
	8	1	1	1	1902	15056	1868	14817	0.992	0.992	361.32	341.76	87,022.88	693,145.80	79,022.60	628,553.56	54,727.03	434,189.07
	9	1	1	1	1902	16957	1868	16685	0.992	0.992	367.02	344.59	87,022.88	780,168.68	79,022.60	707,576.15	54,727.03	488,916.10
	10	1	1	1	1902	18859	1868	18552	0.992	0.992	372.71	347.42	87,022.88	867,191.55	79,022.60	786,598.75	54,727.03	543,643.14
	11	1	1	1	1898	20757	1855	20407	0.987	0.992	432.52	355.16	90,686.14	957,877.69	82,808.36	869,407.10	58,512.79	602,155.93
	12	1	1	1	1870	22627	1853	22260	0.992	0.992	299.16	350.49	83,949.94	1,041,827.63	75,762.16	945,169.26	51,466.60	653,622.53
	13	1	1	1	1886	24513	1876	24136	0.992	0.992	301.59	346.69	86,245.22	1,128,072.85	78,217.44	1,023,386.70	53,921.88	707,544.41
	14	1	1	1	1963	26476	1885	26021	0.992	0.992	388.35	349.71	89,875.11	1,217,947.96	82,067.33	1,105,454.03	57,771.77	765,316.18
	15	1	1	1	1845	28321	1847	27868	0.992	0.992	404.86	353.37	90,296.34	1,308,244.30	82,358.56	1,187,812.59	58,063.00	823,379.18
	16	1	1	1	1851	30172	1827	29695	0.992	0.992	337.47	352.39	83,338.36	1,391,582.66	74,785.58	1,262,598.17	50,490.02	873,869.19
	17	1	1	1	1917	32089	1849	31544	0.992	0.992	529.68	362.78	90,200.54	1,481,783.20	82,342.76	1,344,940.93	58,047.20	931,916.39
	18	1	1	1	1827	33916	1822	33366	0.992	0.992	277.04	358.10	85,168.86	1,566,952.06	77,006.08	1,421,947.01	52,710.52	984,626.91
	19	1	1	1	1864	35780	1847	35213	0.992	0.992	234.10	351.59	86,399.34	1,653,351.40	78,371.56	1,500,318.57	54,076.00	1,038,702.91
	20	1	1	1	1836	37616	1814	37027	0.992	0.992	241.11	346.18	82,023.07	1,735,374.47	73,535.29	1,573,853.86	49,239.73	1,087,942.64
	21	1	1	1	1895	39511	1873	38900	0.992	0.992	311.75	344.52	86,360.92	1,821,735.39	78,388.14	1,652,242.00	54,092.58	1,142,035.22
	22	1	1	1	1862	41373	1832	40732	0.992	0.992	329.32	343.84	84,897.85	1,906,633.24	76,630.07	1,728,872.07	52,334.51	1,194,369.73
	23	1	1	1	1888	43261	1863	42595	0.992	0.992	395.47	346.10	87,012.93	1,993,646.17	78,950.15	1,807,822.22	54,654.59	1,249,024.32
	24	1	1	1	1862	45123	1852	44447	0.992	0.992	253.89	342.26	82,962.84	2,076,609.01	74,645.06	1,882,467.28	50,349.50	1,299,373.81
	25	1	1	1	1841	46964	1816	46263	0.992	0.992	294.49	340.38	83,970.27	2,160,579.27	75,712.49	1,958,179.76	51,416.92	1,350,790.74
	26	1	1	1	1956	48920	1858	48121	0.992	0.992	451.49	344.67	93,434.43	2,254,013.71	85,886.65	2,044,066.41	61,591.09	1,412,381.83
	27	1	1	1	1934	50854	1937	50058	0.992	0.992	348.93	344.84	89,240.27	2,343,253.98	81,452.49	2,125,518.91	57,156.93	1,469,538.76
	28	1	1	1	1899	52753	1884	51942	0.992	0.992	363.61	345.52	87,674.01	2,430,927.99	79,771.23	2,205,290.14	55,475.67	1,525,014.43
	29	1	1	1	1874	54627	1868	53810	0.992	0.992	272.41	342.98	85,328.43	2,516,256.42	77,155.65	2,282,445.78	52,860.08	1,577,874.52
	30	1	1	1	1811	56438	1792	55602	0.992	0.992	303.91	341.72	82,823.88	2,599,080.30	74,441.10	2,356,886.89	50,145.54	1,628,020.06
	31	1	1	1	1844	58282	1821	57423	0.992	0.992	348.60	341.94	85,907.76	2,684,988.06	77,559.98	2,434,446.87	53,264.42	1,681,284.48
	32	1	1	1	1861	60143	1830	59253	0.992	0.992	281.06	340.06	84,981.65	2,769,969.72	76,708.87	2,511,155.74	52,413.31	1,733,697.79
	33	1	1	1	1913	62056	1882	61135	0.992	0.992	318.15	339.38	84,458.81	2,854,428.53	76,301.03	2,587,456.78	52,005.47	1,785,703.26
	34	1	1	1	1859	63915	1833	62968	0.992	0.992	328.03	339.05	89,401.95	2,943,830.49	81,344.17	2,668,800.95	57,048.61	1,842,751.88
	35	1	1	1	1893	65808	1840	64808	0.992	0.992	374.86	340.07	85,868.65	3,029,699.13	77,805.87	2,746,606.82	53,510.31	1,896,262.18
	36	1	1	1	1842	67650	1815	66623	0.992	0.992	263.55	337.99	83,212.17	3,112,911.30	74,784.39	2,821,391.20	50,488.82	1,946,751.01
	37	1	1	1	1789	69439	1786	68409	0.992	0.992	221.77	334.95	78,791.29	3,191,702.59	70,138.51	2,891,529.71	45,842.95	1,992,593.95
	38	1	1	1	1807	71246	1782	70191	0.992	0.992	305.88	334.21	82,029.89	3,273,732.48	73,452.11	2,964,981.82	49,156.55	2,041,750.50
	39	1	1	1	1847	73093	1814	72005	0.992	0.992	270.96	332.62	84,380.07	3,358,112.55	76,067.29	3,041,049.11	51,771.73	2,093,522.23
	40	1	1	1	1841	74934	1832	73837	0.992	0.992	358.54	333.26	83,924.85	3,442,037.40	75,577.07	3,116,626.18	51,281.51	2,144,803.74
	41	1	1	1	1849	76783	1810	75647	0.992	0.992	309.71	332.70	81,651.67	3,523,689.07	73,143.89	3,189,770.07	48,848.33	2,193,652.07
	42	1	1	1	1840	78623	1798	77445	0.992	0.992	320.35	332.41	82,925.48	3,606,614.55	74,537.70	3,264,307.77	50,242.14	2,243,894.21
	43	1	1	1	1888	80511	1871	79316	0.992	0.992	263.47	330.79	87,681.72	3,694,296.27	79,723.94	3,344,031.71	55,428.38	2,299,322.59
	44	1	1	1	1853	82364	1841	81157	0.992	0.992	256.76	329.11	81,060.75	3,775,357.02	72,577.97	3,416,609.68	48,282.40	2,347,604.99
	45	1	1	1	1964	84328	1907	83064	0.992	0.992	467.29	332.28	89,814.30	3,865,171.32	82,046.51	3,498,656.19	57,750.95	2,405,355.95
	46	1	1	1	1809	86137	1789	84853	0.992	0.992	311.49	331.84	82,552.59	3,947,723.90	74,059.81	3,572,716.00	49,764.24	2,455,120.19
	47	1	1	1	1941	88078	1893	86746	0.992	0.992	297.10	331.08	85,697.91	4,033,421.81	77,675.13	3,650,391.13	53,379.56	2,508,499.76
	48	1	1	1	1824	89902	1797	88543	0.992	0.992	277.12	329.99	81,325.38	4,114,747.19	72,862.60	3,723,253.72	48,567.04	2,557,066.80
	49	1	1	1	1933	91835	1905	90448	0.992	0.992	269.93	328.72	86,381.10	4,201,128.29	78,528.32	3,801,782.04	54,232.76	2,611,299.55
	50	1	1	1	1883	93718	1836	92284	0.992	0.992	259.09	327.34	86,552.25	4,287,680.54	78,434.47	3,880,216.51	54,138.91	2,665,438.46
	51	1	1	1	1812	95530	1803	94087	0.992	0.992	231.04	325.49	78,344.98	4,366,025.51	69,662.20	3,949,878.71	45,366.63	2,710,805.09
	52	1	1	1	1885	97415	1872	95959	0.992	0.992	284.09	324.68	87,618.82	4,453,644.33	79,596.04	4,029,474.75	55,300.48	2,766,105.58
	53	1	1	1	1925	99340	1880	97839	0.992	0.992	262.98	323.50	86,651.62	4,540,295.95	78,623.84	4,108,098.58	54,328.27	2,820,433.85
	54	1	1	1	1925	101265	1890	99729	0.992	0.992	478.74	326.44	93,152.61	4,633,448.56	85,624.83	4,193,723.41	61,329.27	2,881,763.12
	55	1	1	1	1879	103144	1849	101578	0.992	0.992	352.35	326.91	86,362.54	4,719,811.10	78,244.76	4,271,968.17	53,949.20	2,935,712.32
	56	1	1	1	1886	105030	1876	103454	0.992	0.992	305.25	326.52	86,067.22	4,805,878.32	77,959.44	4,349,927.61	53,663.88	2,989,376.19
	57	1	1	1	1918	106948	1842	105296	0.992	0.992	253.72	325.25	82,469.85	4,888,348.16	74,262.07	4,424,189.68	49,966.50	3,039,342.70
	58	1	1	1	1962	108910	1939	107235	0.992	0.992	436.66	327.26	90,517.47	4,978,865.63	82,774.69	4,506,964.37	58,479.13	3,097,821.83
	59	1	1	1	1916	110826	1906	109141	0.992	0.992	386.84	328.30	87,338.20	5,066,203.83	79,405.42	4,586,369.78	55,109.85	3,152,931.68
	60	1	1	1	1926	112752	1866	111007	0.992	0.992	326.38	328.27	89,614.23	5,155,818.06	81,806.45	4,668,176.23	57,510.89	3,210,442.57

TCS LOW MED

Replication Number	Independent Variables: MAS	Independent Variables: MOH	Independent Variables: MIX	All Products: Period Demand	All Products: Total Demand	All Products: Period Shipped	All Products: Total Shipped	All Products: Period DFR	Total DFR	Period Cycle Time	Cycle Time	MOH LOW: Period NOI	MOH LOW: Cumulative NOI	MOH MED: Period NOI	MOH MED: Cumulative NO	HIGH: Period NOI	HIGH: Cumulative NO
1	1	1	2	2357	2357	1659	1659	0.731	0.731	704.93	704.93	99,824.01	99,824.01	93,964.60	93,964.60	70,635.80	70,635.80
2	1	1	2	2408	4765	1709	3368	0.723	0.727	687.83	696.25	104,125.32	203,949.33	98,830.92	192,795.52	75,502.11	146,137.91
3	1	1	2	2272	7037	1681	5049	0.736	0.730	719.23	703.90	100,620.23	304,569.56	95,000.82	287,796.35	71,672.01	217,809.92
4	1	1	2	2410	9447	1675	6724	0.711	0.725	686.08	699.46	102,544.35	407,113.91	97,099.95	384,896.29	73,771.14	291,581.06
5	1	1	2	2293	11740	1636	8360	0.733	0.729	709.77	701.48	101,461.64	508,575.55	95,732.24	480,628.53	72,403.43	363,984.49
6	1	1	2	2311	14051	1707	10067	0.726	0.728	709.64	702.86	103,002.03	611,577.59	97,532.63	578,161.16	74,203.82	438,188.31
7	1	1	2	2405	16456	1709	11776	0.724	0.728	694.50	701.65	102,008.86	713,586.45	96,506.96	674,668.12	73,178.15	511,366.46
8	1	1	2	2405	18861	1709	13486	0.724	0.727	691.65	700.38	102,008.86	815,595.31	96,506.96	771,175.07	73,178.15	584,544.60
9	1	1	2	2405	21266	1709	15195	0.724	0.727	688.81	699.08	102,008.86	917,604.17	96,506.96	867,682.03	73,178.15	657,722.75
10	1	1	2	2405	23671	1709	16904	0.724	0.726	685.96	697.75	102,008.86	1,019,613.03	96,506.96	964,188.99	73,178.15	730,900.90
11	1	1	2	2323	25994	1654	18558	0.737	0.727	697.08	697.69	103,131.28	1,122,744.31	97,666.87	1,061,855.86	74,338.06	805,238.96
12	1	1	2	2397	28391	1708	20266	0.717	0.726	698.14	697.73	99,594.18	1,222,338.49	93,879.77	1,155,735.63	70,550.97	875,789.93
13	1	1	2	2371	30762	1662	21928	0.731	0.727	698.00	697.75	102,024.45	1,324,362.93	96,485.04	1,252,220.68	73,156.23	948,946.16
14	1	1	2	2380	33142	1620	23548	0.725	0.727	689.09	697.16	101,163.30	1,425,526.24	95,383.90	1,347,604.57	72,055.09	1,021,001.25
15	1	1	2	2314	35456	1791	25339	0.721	0.726	699.79	697.34	101,205.32	1,526,731.56	95,750.92	1,443,355.49	72,422.11	1,093,423.36
16	1	1	2	2342	37798	1685	27024	0.734	0.727	701.43	697.60	102,161.81	1,628,893.37	96,727.41	1,540,082.90	73,398.60	1,166,821.96
17	1	1	2	2341	40139	1765	28789	0.722	0.727	690.65	697.17	98,924.52	1,727,817.89	93,285.11	1,633,368.01	69,956.31	1,236,778.27
18	1	1	2	2289	42428	1706	30495	0.729	0.727	686.04	696.55	99,958.89	1,827,776.77	94,309.48	1,727,677.50	70,980.67	1,307,758.94
19	1	1	2	2340	44768	1723	32218	0.730	0.727	696.43	696.54	100,900.37	1,928,677.15	95,375.97	1,823,053.46	72,047.16	1,379,806.10
20	1	1	2	2351	47119	1624	33842	0.729	0.727	702.43	696.82	100,708.89	2,029,386.03	94,869.48	1,917,922.95	71,540.67	1,451,346.77
21	1	1	2	2379	49498	1687	35529	0.728	0.727	692.97	696.64	102,460.11	2,131,846.14	96,990.70	2,014,913.65	73,661.89	1,525,008.67
22	1	1	2	2371	51869	1695	37224	0.726	0.727	692.54	696.45	104,381.28	2,236,227.42	98,991.87	2,113,905.52	75,663.06	1,600,671.73
23	1	1	2	2319	54188	1614	38838	0.729	0.727	708.81	696.97	100,141.42	2,336,368.84	94,267.02	2,208,172.54	70,938.21	1,671,609.94
24	1	1	2	2337	56525	1648	40486	0.727	0.727	699.84	697.08	99,772.40	2,436,141.24	93,912.99	2,302,085.54	70,584.19	1,742,194.13
25	1	1	2	2308	58833	1704	42190	0.721	0.727	699.67	697.19	98,486.59	2,534,627.83	92,657.19	2,394,742.72	69,328.38	1,811,522.51
26	1	1	2	2358	61191	1738	43928	0.723	0.727	704.74	697.49	102,323.57	2,636,951.40	96,854.16	2,491,596.89	73,525.35	1,885,047.86
27	1	1	2	2334	63525	1658	45586	0.728	0.727	694.41	697.38	100,300.86	2,737,252.26	94,521.46	2,586,118.35	71,192.65	1,956,240.51
28	1	1	2	2336	65861	1709	47295	0.731	0.727	702.10	697.55	101,489.32	2,838,741.59	95,974.92	2,682,093.27	72,646.11	2,028,886.62
29	1	1	2	2343	68204	1648	48943	0.731	0.727	697.64	697.55	101,737.40	2,940,478.99	96,117.99	2,778,211.26	72,789.19	2,101,675.81
30	1	1	2	2427	70631	1650	50593	0.722	0.727	689.84	697.30	102,624.69	3,043,103.68	97,065.29	2,875,276.55	73,736.48	2,175,412.29
31	1	1	2	2344	72975	1610	52203	0.726	0.727	706.58	697.58	100,227.84	3,143,331.52	94,328.44	2,969,604.98	70,999.63	2,246,411.91
32	1	1	2	2329	75304	1711	53914	0.729	0.727	703.24	697.76	102,725.62	3,246,057.14	97,276.21	3,066,881.20	73,947.40	2,320,359.32
33	1	1	2	2312	77616	1700	55614	0.735	0.727	698.33	697.78	100,274.01	3,346,331.14	94,719.60	3,161,600.80	71,390.79	2,391,750.11
34	1	1	2	2371	79987	1625	57239	0.729	0.727	700.37	697.85	100,115.03	3,446,446.18	94,330.63	3,255,931.43	71,001.82	2,462,751.93
35	1	1	2	2428	82415	1713	58952	0.724	0.727	691.12	697.66	104,523.91	3,550,970.09	99,204.51	3,355,135.93	75,875.70	2,538,627.63
36	1	1	2	2286	84701	1690	60642	0.731	0.727	713.62	698.10	102,215.54	3,653,185.63	96,646.14	3,451,782.07	73,317.33	2,611,944.96
37	1	1	2	2419	87120	1742	62384	0.728	0.727	685.77	697.76	103,035.15	3,756,220.78	97,770.75	3,549,552.82	74,441.94	2,686,386.90
38	1	1	2	2423	89543	1792	64176	0.719	0.727	678.52	697.22	100,297.47	3,856,518.25	94,873.06	3,644,425.89	71,544.26	2,757,931.16
39	1	1	2	2357	91900	1663	65839	0.730	0.727	695.20	697.17	102,140.59	3,958,658.85	96,591.19	3,741,017.08	73,262.38	2,831,193.54
40	1	1	2	2336	94236	1592	67431	0.725	0.727	708.14	697.43	101,787.21	4,060,446.05	95,912.80	3,836,929.88	72,583.99	2,903,777.53
41	1	1	2	2308	96544	1717	69148	0.728	0.727	705.27	697.62	101,173.49	4,161,619.55	95,609.09	3,932,538.97	72,280.28	2,976,057.81
42	1	1	2	2394	98938	1740	70888	0.722	0.727	683.32	697.27	101,597.86	4,263,217.41	96,133.46	4,028,672.43	72,804.65	3,048,862.46
43	1	1	2	2328	101266	1688	72576	0.732	0.727	708.62	697.54	103,076.25	4,366,293.66	97,651.85	4,126,324.27	74,323.04	3,123,185.50
44	1	1	2	2377	103643	1733	74309	0.723	0.727	685.85	697.27	102,037.84	4,468,331.50	96,563.43	4,222,887.70	73,234.62	3,196,420.12
45	1	1	2	2314	105957	1755	76064	0.721	0.727	695.93	697.23	100,668.05	4,568,999.55	95,058.65	4,317,946.35	71,729.84	3,268,149.96
46	1	1	2	2331	108288	1639	77703	0.733	0.727	705.86	697.42	102,798.08	4,671,797.63	97,223.68	4,415,170.03	73,894.87	3,342,044.83
47	1	1	2	613177	721465	1661	79364	0.571	0.594	695.40	697.37	102,063.30	4,773,860.93	96,558.90	4,511,728.93	73,230.09	3,415,274.92
48	1	1	2	(608412)	113053	1718	81082	0.569	0.727	692.53	697.27	101,355.64	4,875,216.58	95,766.24	4,607,495.17	72,437.43	3,487,712.35
49	1	1	2	2240	115293	1674	82756	0.724	0.727	701.82	697.36	97,223.20	4,972,439.78	91,128.80	4,698,623.97	67,799.99	3,555,512.34
50	1	1	2	2344	117637	1724	84480	0.726	0.727	689.61	697.21	101,113.52	5,073,553.30	95,569.11	4,794,193.08	72,240.31	3,627,752.65
51	1	1	2	2220	119857	1759	86239	0.739	0.727	706.83	697.40	103,193.64	5,176,746.94	97,979.24	4,892,172.32	74,650.43	3,702,403.07
52	1	1	2	2372	122229	1763	88002	0.718	0.727	682.34	697.10	100,433.23	5,277,180.16	94,863.82	4,987,036.14	71,535.01	3,773,938.09
53	1	1	2	2241	124470	1656	89658	0.724	0.727	722.71	697.57	100,627.57	5,377,807.73	94,753.17	5,081,789.30	71,424.36	3,845,362.44
54	1	1	2	2298	126768	1700	91358	0.725	0.727	711.04	697.82	101,112.01	5,478,919.74	95,487.60	5,177,276.91	72,158.79	3,917,521.24
55	1	1	2	2264	129032	1635	92993	0.733	0.727	725.06	698.30	98,949.50	5,577,869.24	93,100.09	5,270,377.00	69,771.28	3,987,292.52
56	1	1	2	2379	131411	1597	94590	0.724	0.727	695.92	698.26	102,568.94	5,680,438.18	96,779.53	5,367,156.53	73,450.72	4,060,743.25
57	1	1	2	2332	133743	1625	96215	0.724	0.727	705.74	698.39	100,538.03	5,780,976.21	94,693.63	5,461,850.16	71,364.82	4,132,108.07
58	1	1	2	2323	136066	1652	97867	0.726	0.727	708.38	698.56	100,503.98	5,881,480.19	94,724.58	5,556,574.74	71,395.77	4,203,503.84
59	1	1	2	2364	138430	1710	99577	0.723	0.727	695.18	698.50	99,884.47	5,981,364.67	94,185.07	5,650,759.81	70,856.26	4,274,360.10
60	1	1	2	2385	140815	1729	101306	0.722	0.727	689.34	698.34	101,333.25	6,082,697.92	95,808.85	5,746,568.66	72,480.04	4,346,840.13

TCS LOW HIGH

	Independent Variables			All Products						MOH LOW				MOH MED		MOH HIGH	
Replication Number	MAS	MOH	MIX	Period Demand	Total Demand	Period Shipped	Total Shipped	Period DFR	Total DFR	Period Cycle Time	Cycle Time	Period NOI	Cumulative NOI	Period NOI	Cumulative NO	Period NOI	Cumulative NO
1	1	1	3	3197	3197	1158	1158	0.374	0.374	612.46	612.46	99,446.39	99,446.39	94,263.11	94,263.11	72,166.56	72,166.56
2	1	1	3	3293	6490	1244	2402	0.375	0.374	605.69	608.95	104,035.50	203,481.89	99,587.22	193,850.33	77,490.67	149,657.23
3	1	1	3	3160	9650	1149	3551	0.383	0.377	619.93	612.50	100,270.19	303,752.08	95,056.92	288,907.25	72,960.36	222,617.59
4	1	1	3	3169	12819	1193	4744	0.371	0.375	639.58	619.31	104,072.71	407,824.79	99,314.44	388,221.69	77,217.88	299,835.47
5	1	1	3	3239	16058	1178	5922	0.376	0.376	614.65	618.39	100,194.72	508,019.51	95,146.44	483,368.13	73,049.89	372,885.36
6	1	1	3	3270	19328	1152	7074	0.374	0.375	611.81	617.32	100,172.59	608,192.10	94,989.31	578,357.44	72,892.76	445,778.12
7	1	1	3	3252	22580	1157	8231	0.375	0.375	619.21	617.58	100,634.79	708,826.89	95,522.76	673,880.20	73,426.21	519,204.33
8	1	1	3	3252	25832	1157	9389	0.375	0.375	619.26	617.79	100,634.79	809,461.68	95,522.76	769,402.97	73,426.21	592,630.54
9	1	1	3	3252	29083	1157	10546	0.375	0.375	619.32	617.96	100,634.79	910,096.47	95,522.76	864,925.73	73,426.21	666,056.75
10	1	1	3	3252	32335	1157	11703	0.375	0.375	619.38	618.10	100,634.79	1,010,731.26	95,522.76	960,448.49	73,426.21	739,482.96
11	1	1	3	3255	35590	1118	12821	0.383	0.376	601.43	616.65	101,214.73	1,111,945.99	95,826.46	1,056,274.95	73,729.90	813,212.86
12	1	1	3	3336	38926	1198	14019	0.373	0.376	611.84	616.23	104,087.04	1,216,033.04	99,398.77	1,155,673.72	77,302.21	890,515.08
13	1	1	3	3251	42177	1211	15203	0.373	0.376	605.21	616.45	102,530.11	1,318,563.15	97,771.83	1,253,445.55	75,675.28	966,190.35
14	1	1	3	3349	45526	1255	16485	0.381	0.376	584.76	613.03	105,669.63	1,424,232.77	101,336.35	1,354,781.90	79,239.80	1,045,430.15
15	1	1	3	3178	48704	1195	17680	0.376	0.376	628.40	614.07	101,594.65	1,525,827.42	96,766.37	1,451,548.27	74,669.82	1,120,099.97
16	1	1	3	3326	52030	1109	18789	0.375	0.376	604.11	613.48	97,649.54	1,623,476.96	92,036.26	1,543,584.53	69,939.71	1,190,039.68
17	1	1	3	3197	55227	1220	20009	0.367	0.375	610.12	613.27	98,252.30	1,721,729.26	93,249.03	1,636,833.56	71,152.47	1,261,192.15
18	1	1	3	3194	58421	1184	21193	0.379	0.376	616.76	613.47	102,256.52	1,823,985.78	97,273.24	1,734,106.80	75,176.69	1,336,368.84
19	1	1	3	3186	61607	1276	22469	0.379	0.376	608.64	613.20	104,936.42	1,928,922.20	100,728.15	1,834,834.94	78,631.59	1,415,000.43
20	1	1	3	3231	64838	1206	23675	0.375	0.376	610.72	613.07	100,518.78	2,029,440.97	95,650.50	1,930,485.44	73,553.95	1,488,554.37
21	1	1	3	3201	68039	1306	24981	0.367	0.375	616.58	613.25	102,763.41	2,132,204.39	98,585.14	2,029,070.58	76,488.58	1,565,042.96
22	1	1	3	3269	71308	1298	26279	0.374	0.375	598.66	612.53	102,520.68	2,234,725.07	98,292.41	2,127,362.98	76,195.85	1,641,238.81
23	1	1	3	3270	74578	1170	27449	0.378	0.375	598.11	611.92	102,165.99	2,336,891.06	97,142.71	2,224,505.69	75,046.16	1,716,284.96
24	1	1	3	3188	77766	1203	28652	0.371	0.375	625.94	612.51	101,907.38	2,438,798.43	97,089.10	2,321,594.79	74,992.55	1,791,277.51
25	1	1	3	3155	80921	1149	29801	0.376	0.375	626.24	613.04	101,220.19	2,540,018.63	96,031.92	2,417,626.71	73,935.36	1,865,212.87
26	1	1	3	3201	84122	1126	30927	0.373	0.375	639.64	614.00	101,790.47	2,641,809.09	96,557.19	2,514,183.90	74,460.64	1,939,673.51
27	1	1	3	3109	87231	1277	32204	0.379	0.375	612.96	613.96	100,737.89	2,742,546.98	96,209.61	2,610,393.51	74,113.06	2,013,786.57
28	1	1	3	3274	90505	1236	33440	0.374	0.375	599.57	613.43	101,528.77	2,844,075.75	96,870.49	2,707,264.00	74,773.94	2,088,560.50
29	1	1	3	3225	93730	1274	34714	0.374	0.375	601.96	613.01	101,451.49	2,945,527.24	97,018.21	2,804,282.21	74,921.66	2,163,482.16
30	1	1	3	3274	97004	1205	35919	0.377	0.375	606.93	612.81	102,391.31	3,047,918.54	97,673.03	2,901,955.24	75,576.48	2,239,058.64
31	1	1	3	3264	100268	1188	37107	0.375	0.375	619.03	613.01	102,096.38	3,150,014.93	97,208.10	2,999,163.35	75,111.55	2,314,170.19
32	1	1	3	3246	103514	1277	38384	0.373	0.375	599.91	612.57	104,269.89	3,254,284.81	99,926.61	3,099,089.96	77,830.06	2,392,000.25
33	1	1	3	3226	106740	1244	39628	0.366	0.375	623.16	612.90	102,170.50	3,356,455.31	97,652.22	3,196,742.18	75,555.67	2,467,555.92
34	1	1	3	3265	110005	1249	40877	0.376	0.375	605.47	612.67	102,793.83	3,459,249.14	98,315.55	3,295,057.73	76,219.00	2,543,774.92
35	1	1	3	3362	113367	1167	42044	0.385	0.375	579.99	611.77	100,138.59	3,559,387.73	95,050.31	3,390,108.04	72,953.76	2,616,728.68
36	1	1	3	3304	116671	1234	43278	0.373	0.375	605.24	611.58	102,637.83	3,662,025.56	98,059.56	3,488,167.60	75,963.00	2,692,691.68
37	1	1	3	3129	119800	1243	44521	0.385	0.375	606.76	611.45	101,795.03	3,763,820.59	97,166.75	3,585,334.36	75,070.20	2,767,761.88
38	1	1	3	3199	122999	1202	45723	0.379	0.376	620.11	611.67	101,457.91	3,865,278.50	96,594.63	3,681,928.99	74,498.08	2,842,259.96
39	1	1	3	3245	126244	1219	46942	0.385	0.376	589.85	611.11	104,024.84	3,969,303.34	99,441.56	3,781,370.55	77,345.01	2,919,604.97
40	1	1	3	3196	129440	1201	48143	0.379	0.376	620.73	611.35	100,647.44	4,069,950.79	95,809.17	3,877,179.72	73,712.61	2,993,317.58
41	1	1	3	3208	132648	1173	49316	0.382	0.376	615.22	611.44	100,831.39	4,170,782.17	95,818.11	3,972,997.83	73,721.56	3,067,039.14
42	1	1	3	3184	135832	1256	50572	0.389	0.376	590.86	610.93	103,882.09	4,274,664.27	99,463.82	4,072,461.65	77,367.26	3,144,406.40
43	1	1	3	3267	139099	1146	51718	0.378	0.376	600.75	610.70	99,859.79	4,374,524.06	94,611.52	4,167,073.16	72,514.96	3,216,921.37
44	1	1	3	3228	142327	1282	53000	0.371	0.376	607.74	610.63	103,400.22	4,477,924.28	99,086.94	4,266,160.11	76,990.39	3,293,911.76
45	1	1	3	3359	145686	1140	54140	0.383	0.376	583.27	610.06	100,864.99	4,578,789.27	95,661.72	4,361,821.82	73,565.16	3,367,476.92
46	1	1	3	3191	148877	1233	55373	0.379	0.376	608.45	610.02	100,785.37	4,679,574.64	95,987.09	4,457,808.91	73,890.54	3,441,367.46
47	1	1	3	3176	152053	1197	56570	0.378	0.377	596.89	609.74	102,424.58	4,781,999.22	97,521.30	4,555,330.22	75,424.75	3,516,792.21
48	1	1	3	3263	155316	1149	57719	0.385	0.377	618.86	609.92	102,790.19	4,884,789.41	97,726.92	4,653,057.13	75,630.36	3,592,422.57
49	1	1	3	3161	158477	1245	58964	0.378	0.377	596.29	609.64	100,809.96	4,985,599.38	96,121.69	4,749,178.82	74,025.13	3,666,447.70
50	1	1	3	3295	161772	1199	60163	0.386	0.377	612.93	609.70	102,547.51	5,088,146.89	97,814.23	4,846,993.05	75,717.68	3,742,165.38
51	1	1	3	3327	165099	1196	61359	0.386	0.377	579.18	609.11	101,207.11	5,189,354.00	96,288.84	4,943,281.89	74,192.28	3,816,357.66
52	1	1	3	3250	168349	1175	62534	0.386	0.377	590.75	608.76	100,253.32	5,289,607.32	95,220.04	5,038,501.93	73,123.49	3,889,481.15
53	1	1	3	3229	171578	1147	63681	0.382	0.377	621.78	609.00	99,448.26	5,389,055.58	94,259.98	5,132,761.91	72,163.43	3,961,644.58
54	1	1	3	3254	174832	1238	64919	0.377	0.377	611.59	609.05	102,931.70	5,491,987.28	98,393.42	5,231,155.34	76,296.87	4,037,941.45
55	1	1	3	3308	178140	1229	66148	0.370	0.377	605.82	608.99	103,530.50	5,595,517.78	98,977.23	5,330,132.56	76,880.67	4,114,822.12
56	1	1	3	3319	181459	1278	67426	0.377	0.377	596.96	608.76	102,625.35	5,698,143.13	98,297.08	5,428,429.64	76,200.52	4,191,022.65
57	1	1	3	3291	184750	1229	68655	0.380	0.377	588.04	608.39	101,801.50	5,799,944.64	97,123.23	5,525,552.86	75,026.67	4,266,049.32
58	1	1	3	3244	187994	1196	69851	0.374	0.377	617.09	608.54	101,703.11	5,901,647.75	96,864.84	5,622,417.70	74,768.28	4,340,817.60
59	1	1	3	3192	191186	1254	71105	0.375	0.377	616.28	608.67	102,723.16	6,004,370.91	98,249.89	5,720,667.58	76,153.33	4,416,970.93
60	1	1	3	3231	194417	1211	72316	0.374	0.377	614.35	608.77	101,867.11	6,106,238.02	97,078.83	5,817,746.42	74,982.28	4,491,953.21