2010-11-22

Lean Manufacturing as a Source of Competitive Advantage

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LEAN MANUFACTURING AS A SOURCE OF COMPETITIVE ADVANTAGE

by

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A thesis submitted to the faculty of

Brigham Young University

in partial fulfillment of the requirements for the degree of

Master of Science

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December 2010

BRIGHAM YOUNG UNIVERSITY

GRADUATE COMMITTEE APPROVAL

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ABSTRACT

LEAN MANUFACTURING AS A SOURCE

OF COMPETITIVE ADVANTAGE

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The productivity advances generated from lean manufacturing are self-evident. Plants that adopt lean are more capable of achieving high levels of quality, shorter lead times, and less waste in the system. While it seems logical that higher levels of productivity and quality, as is common in lean companies, should result in positive financial performance, the research community has failed to establish the financial profitability of lean. Those researchers who have studied the financial returns issue report varying results. The goal of this research was to determine if a connection exists between lean and financial success and to discover why so many researchers are finding mixed results.

Information Velocity (IV) was theorized to provide the solidifying link between lean and financial performance. Measured by combining the environmental volatility with a company's leanness, IV measures how fast a company can transmit information from the market into a customer-satisfying product in the hands of the consumer. This study analyzed over 530 publicly-traded manufacturing companies to validate the following hypotheses: 1) there is a positive relationship between leanness and financial returns, 2) there is a negative relationship between environmental volatility and financial returns, and 3) there is a positive relationship between IV and financial returns. Regression models were run in various combinations to determine the effect of lean, environmental instability, environmental unpredictability, and IV on financial performance indicators such as return on sales (ROS), return on assets (ROA), and quarter-closing stock price. The outcome of this study showed that financial rewards do result from lean, which positively affected financial performance in almost all scenarios. Environmental instability always negatively correlated with financial returns, and IV mostly shows a positive effect, but with mixed results. Lastly, IV does not explain why researchers find mixed results on the profitability measures of lean.

The results of this thesis highlight the significance of implementing lean manufacturing, especially in a dynamic environment. As the instability in the environment increases, profitability decreases. Therefore, an increase in leanness by boosting inventory turns can compensate for the volatility and create enhanced productivity measures and financial results.

Keywords: Ryan Scott Williams, lean, manufacturing, production, inventory, inventory turns, Toyota Production System, TPS, TQM, just-in-time, SPC, information velocity, IV, entropy, financial performance indicators, ROA, ROS, Lean Six Sigma, pull system, push system, six sigma, takt time, Theory of Constraints, competitive advantage, waste

ACKNOWLEDGMENTS

I would like to express my gratitude and appreciation to all those who supported me in this endeavor. Several individuals were particularly influential in providing intellectual, emotional, and spiritual assistance throughout the last three years of personal research and data analysis. Most importantly, I am grateful for my wife, Michelle, who has been a constant foundation of support throughout my education and the completion of this thesis. She has always encouraged me to attain higher levels of education, and without her, none of this would have been accomplished.

Several others were particularly influential in my learning about lean, information velocity, and the research methods and skills required in composing this study. My graduate committee chair, Dr. Mike Miles, spent numerous hours in mentoring, editing, and critiquing the research and played a vital role as a subject matter expert on lean production. Dr. Nile Hatch equally provided statistical counsel and was significant in painting the picture of information velocity. Finally, Alex Cavallini previously explored lean and information velocity and provided the foundation whereupon I was able to begin. His prior knowledge and research greatly influenced the speed of the work, as well as the results obtained.

Unfortunately, I cannot acknowledge all of the individuals who graciously provided assistance. But lastly, I would like to thank all the professors in the School of Technology and the Marriott School of Business for their expertise and helping hand in providing me with an education and experience that will help me develop a successful career.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

"Lean production" is a socio-technical system designed to eliminate waste by reducing variability in the internal and external processes (Shah and Ward 2007). Academics and practitioners have flooded the literature with evidence of increased operational performance and competitive advantage, leading to widespread adoption of the lean strategy (Mackelprang and Nair 2010). Literature shows plants that adopt this system are more capable of achieving high levels of productivity and quality (Krafcik 1988, Shah and Ward 2003, Wood, et al. 2004). These promised benefits have led to organizations worldwide implementing these lean principles in their manufacturing plants and seeing tremendous productivity savings from reduced lead-time, lower inventory levels, and a continuous eye on process improvement (George 2002).

This research is primarily concerned with the financial performance of lean firms. It would seem logical that higher levels of productivity and quality, as is common in lean companies, should result in positive financial performance (Lewis 2000). Unfortunately, the research community has failed to establish the financial profitability of lean. Some report a correlation between the amount of leanness and positive financial returns (Husan and Nanda 1995), whereas others demonstrate negative returns (Cannon 2008). Other researchers report no statistical significance (Oliver and Hunter 1998, Balakrishnan, Linsmeier and Venkatachalam 1996, Demeter 2003, Vastag and Whybark 2005)or mixed impact (Chen, Frank and Wu 2005, Narasimhan, Swink and Kim 2006). This discrepancy in the financial performance of lean organizations is an important issue that requires further exploration.

Why do financial benefits continue to elude academics, especially when the operational benefits are so apparent? We are measuring the benefits of lean in the wrong way. The components of lean are excellent tools that can increase productivity in many organizations, but if a firm cannot understand market demand and quickly satisfy that demand, then a competitive advantage is difficult to maintain or even achieve. Financial returns do exist when lean is understood within the lens of Information Velocity (IV).Information velocity measures the ability of an organization to respond correctly to uncertain market demands (George 2006) and this research shows that IV, along with lean, positively correlate with financial returns.

The purpose of this thesis is to determine if lean manufacturing companies are financially rewarded for responding faster and more effectively to the demands of a dynamic market. When sales are volatile and difficult to predict, companies that implement lean principles should better accommodate customers' needs because of flexible and agile processes. The ability to scale production volumes according to demand should provide a competitive advantage, especially in a dynamic environment. That competitive advantage should emerge in the form of increased reduced lead times, better cost structure, and increased customer satisfaction. Therefore, lean companies competing in a dynamic environment should financially outperform non-lean companies. Determining the accuracy of this hypothesis was the purpose of the current research study.

1.1 **Toyota Production System (TPS)**

Prior to the late 19th and early 20th centuries, specialized craftsmen tailored products to each individual customer to provide manufactured goods. Highly skilled workers in areas such as design, machine operation, and fitting were required to fabricate an unlimited variety of items.

Inconsistencies in dimensions, functionality, and quality and the ineffective use of economies of scale created incentives to improve the low volume, manual system (Womack, Jones and Roos 1990, 20-22).

Technology escalated during the era known as the Industrial Revolution leading to major changes in the manufacturing industry. Innovative leaders in this period stand out in history as those who presented the mass production system to the world. Frederick Winslow Taylor laid the foundation for mass production with innovations including: standardized work, cycle time reduction, and time/motion studies. Henry Ford's implementation of interchangeable parts, specialized workers, and sequential production operations by way of an automatic conveyor drastically reduced the cost per part/car on the Ford Model T. There were also many others responsible for the creative development of mass production (Hopp and Spearman 2004, Womack, Jones and Roos 1990, 22-28).

While inexpensive labor, high volume, and economies of scale had some benefits, mass production came with many drawbacks. Standard work and specialized employees assigned to simple tasks led to a limited product variety forcing customers to accept limited variety and sometimes poor quality. Lead times were prolonged due to large batch sizes and lengthy product changeover operations. Inventory carrying and material handling costs skyrocketed as parts were produced in mass quantities to save money on economies of scale (Womack, Jones and Roos 1990, 24-36).

Shortly after World War II, the damage to the Japanese economy required a large variety of cars and trucks to begin reconstruction. Toyota did not have excess capital to spend on additional equipment, inventory, or resources as common in Western mass production facilities, so Toyota focused its efforts on reducing waste and improving the system to make products in

high variety and low volume (Ohno 1988). Through fifty years of simple trial-and-error (Lewis 2000), Toyota slowly developed an unbeatable management philosophy and successful tools/techniques that led to its becoming one of the world's greatest manufacturers (Holweg 2007). This socio-technical system is the Toyota Production System (TPS), and is commonly known as the original lean production system (Schonberger 2007).

The heart of TPS is the complete elimination of waste. The two "pillars" supporting the system are just-in-time, and autonomation, or automation with a human touch (Ohno 1988). The introduction of Just-in-Time (JIT) to a large audience in the United States is attributed to Monden (1983, 1989) and Schonberger (1982, 1986)is considered an early JIT research pioneer in the United States (Sakakibara, et al. 1997). The primary objective of the JIT philosophy requires production and delivery of the right product, in the right quantity, to the right location, while meeting all quality specifications and reducing total supply chain costs (Gomes and Mentzer 1988, Claycomb, Germain and Droge 1999, Davy, et al. 1992). Autonomation is the practice of "mistake proofing" processes to quickly check specifications and other quality attributes, to empower workers with ownership for their own quality (Hopp and Spearman 2004),and to prevent defects from infesting the system (Ohno 1988).

1.2 **Lean Production**

Although the lean philosophies and tools were largely developed by Toyota, John F. Krafcik, in his research titled *Triumph of the Lean Production System*, coined the term "lean production" to describe a system containing little or no excess. The selected term (lean) differentiated buffered systems with extra inventory and resources, from systems that minimize them and other forms of waste (Krafcik 1988). Widespread popularity of lean came from the

publication of “The Machine that Changed the World” (Womack, Jones and Roos 1990), which is now “one of the most cited books in operations management” (Holweg 2007, Lewis 2000).

The International Motor Vehicle Program (IMVP) was a five-year (1985-1990) study into the performance of the automobile industry (Womack, Jones and Roos 1990). The study focused on car assembly plants in Japan and in the West, finding a 2:1 productivity discrepancy in favor of Japan. The performance disparity was attributed to lean production practices, improving productivity through faster lead times, increased quality, demand production, etc. These spectacular findings led to further benchmarking studies, confirming the IMVP results (Boston Consulting Group 1993, IBM Consulting 1993, Andersen Consulting 1993). Enhanced productivity has “universal appeal”, and it is expected that lean production practices produced such a welcoming reception. Since the original IMVP report, publications have continued rendering lean as a “universal set of management principles” for production of both goods and services (Lewis 2000).

> *“We've become convinced that the principles of lean production can be applied equally in every industry across the globe and that the conversion to lean production will have a profound effect on human society—it will truly change the world"* (Womack, Jones and Roos 1990, 6).

Originating from the Toyota Production System, or alternatively just-in-time (Schonberger 2007), lean production lacks common definitions partly because of the extended time over which it evolved (Shah and Ward 2007, Hopp and Spearman 2004, Womack, Jones and Roos 1990, Spear and Bowen 1999)and many lean buzz words are synonymous with others (Hopp and Spearman 2004). Thus, any study on TPS or JIT generates “valuable theoretical and managerial implications for lean manufacturing” (Mackelprang and Nair 2010). Despite the adoption of worldwide lean, TPS, or JIT practices, skepticism surrounds mixed results related to

performance. "For example, Dean and Snell (1996) found a lack of significant relationships between JIT practices and performance, while Shah and Ward (2003) identified significant positive relationships between them" (Mackelprang and Nair 2010). However, even critics of the methodology acknowledge that "lean production will be the standard manufacturing mode of the 21st century" (Rinehart, Huxley and Robertson 1997, 2, Shah and Ward 2007).

Despite the contradictions, lean maintains its popularity and remains "widely utilized in firms around the world" (Mackelprang and Nair 2010). The basic components of the lean system include work cells with cross-trained operators, quick set-up and changeovers, single-piece flow pulled by customer demand, and a continuous improvement philosophy to combat waste. Other common components include total preventive maintenance (TPM), quality circles, andon cords, and target costing. "Primary measures of success included minimization of throughput times, setup times, flow distances, defects, rework, equipment down times, inventories, administrative transactions, obstacles to visibility and clutter" (Schonberger 2007).

Womack and Jones, in their book, *Lean Thinking*, summarize these and other lean components in five principles: "1) precisely specify value by specific product, 2) identify the value steam for each product, 3) make value flow without interruptions, 4) let the customer pull value from the producer, and 5) pursue perfection" (Womack and Jones 1996, 10). Each of these principles are a major part of the lean concept, but will not be discussed at this point in the paper. It is sufficient to say that lean principles can lead an organization to a company-wide focus on the customer's needs and satisfying those needs through short lead times, little waste, and added value.

All five principles contain concepts that are mandatory for any business establishment to remain competitive in the volatile world. Any ideology (including lean) that can reduce lead

times and costs or increase quality, throughput, and efficiency is highly sought after. Lean production is just that: a popular technique to improve lead times, quality, and customer satisfaction (Shah and Ward 2003). The productivity and financial gains promised by implementing this methodology are tremendous, and any company who accomplishes these tasks should have higher financial returns than those who do not (Womack, Jones and Roos 1990, Womack and Jones 1996, George 2002, Krafcik 1988, Shah and Ward 2003). Therefore, a correlation should exist between the level of leanness of a company and its financial returns.

1.3 **Information Velocity (IV)**

Although there are many benefits to a lean organization, implementation is simplest and benefits are most visible when demand is predictable in low variety and high volume. But market conditions are not that way. Market volatility is now expected to increase "as life cycles shorten and as global economic and competitive forces create additional uncertainty" (Christopher 2000). As companies find themselves surrounded by erratic demand, the ability to respond rapidly to market changes can provide a competitive advantage (Christopher 2000).

IV provides the link between lean and financial performance. Defined as information entropy divided by lead-time, IV concludes that in a competitive industry, the company that can translate information from the market into a customer-satisfying product faster than any other organization will achieve significant profits and growth (George 2006). This entropy of information measures the level of market volatility, and when combined with the operational excellence of lean, financial performance is properly measured.

It is important to mention that maximum IV is not the ultimate objective. In a stagnant environment, excessive expenses on lean tools are a waste of resources and will reduce financial

returns. On the other hand, insufficient upgrades to lean production in an unreliable industry can prevent a company from quickly satisfying the customer and competitors will eventually erode profitability. Rather, companies should seek the optimal implementation of lean for the present environmental volatility. Neither a shorter (too lean) or longer (insufficiently lean) lead time is desired by any company to meet customer demand. Thus, IV is depicted by an upward parabola with an optimal financial performance at the apex and descending levels of performance as a company moves away from an optimum level of lean implementation.

1.4 **Contribution**

Success stories are common when companies apply lean principles to the company strategy. The tools and techniques can initiate strong productivity gains and higher customer satisfaction with excellent products and services. The contribution of this study will not only corroborate these success stories with significant data correlating lean production with financial success, but also will connect the amount of environmental instability to lean. A defined optimum value of leanness for each manufacturing company can provide a framework for researchers and companies to discover the most profitable level lean implementation necessary for their specific industry.

In addition, diminishing financial results justify investment in the right level of manufacturing flexibility, or lean, and a potential improvement in profitability can serve as the catalyst for implementation. The results will serve as solid evidence for all businesses to apply lean tools and strategies, not in a "cookie-cutter" fashion, but in a way that makes sense for the customers they are serving.

2 LITERATURE REVIEW

2.1 Introduction

A review of published literature on lean production and dynamic environments is necessary to develop an appropriate level of understanding regarding background and historical information on the research topic. The review begins with a basic explanation of lean production and the measurement of the leanness of a company. Information Velocity is discussed and the volatility of an environment is defined.

2.2 Lean Production

The last 15 years have produced a number of scholarly articles on lean philosophies, tools, and techniques (Shah and Ward 2003). Extensive research is available on the genealogical advancements of lean (Holweg 2007, Ohno 1988, Womack, Jones and Roos 1990). The evolution of lean has led to ambiguous terms and descriptions regarding lean production (Shah and Ward 2007) because there was no "single-point invention", but a slow, adaptive response to a dynamic environment (Holweg 2007). Shah & Ward proposed a definition encompassing many components of lean: "lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability" (2007).

Essential to lean philosophy is the idea that waste and any excess must be minimized or be eliminated (Claycomb, Germain and Droge 1999). Ohno (1988) describes identifying seven types of waste as the preliminary step in implementing the lean:

- Overproduction
- Time on hand (waiting)
- Transportation
- Over-processing
- Stock on hand (inventory)
- Movement
- Making defective products

The cost of carrying inventory is seen, in many contemporary views, as a "necessary evil" (Cannon 2008). When inventory is held, systems are buffered against unexpected quality problems, assembly line issues, absenteeism, and other possible failures (Krafcik 1988). But lowering inventory levels, in spite of possible failures, can be beneficial. Alles et al. (Alles, Datar and Lambert 1995, 188) wrote:

> *"Eliminating buffer inventories makes the production setting 'transparent,' exposing flaws and thus helping management and workers to eliminate problems. The incentive to eliminate these problems is greater when inventories are low, because small buffer stocks provide less insurance against problems."*

In addition to the seven wastes, lean can be "summarized in five principles: precisely specify value by specific product, identify the value steam for each product, make value flow without interruptions, let the customer pull value from the producer, and pursue perfection" (Womack and Jones 1996, 10). Essentially, implementing each of these principles allows an order to reach a customer faster "by removing the non-value-added wastes" (Ohno 1988). The

five principles are a major part of the lean concept, but will not be discussed in this study. It suffices to say that lean principles can lead an organization to a company-wide focus on the customer's needs and on continuous improvement.

2.3 **Measurement of a Lean System**

Womack and Jones' five principles succinctly explain the main concepts of lean, and the above mentioned components list the tools commonly used in a lean system. But "beyond these general [principles and components], the definition of lean production is actually rather vague and confused" (Lewis 2000, Bartezzaghi 1999). There have been many attempts to define lean (Karlsson and Åhlström 1996), and a variety of popular metrics, tools, and techniques have become the standard definition of a lean company (Lewis 2000). Each attempt by academics and practitioners brings more understanding to a truly lean system.

The "TPS house" diagram (Figure 1) depicts the fundamental goals, characteristics, and foundational elements of a lean system defined by the Toyota Motor Company. The foundation, pillars, center, and roof all provide components necessary in a successful lean enterprise. Each element of the house is individually critical, but the reinforcement of each element in a structural system provides a unique insight into lean as a total system improvement methodology (Liker 2004).

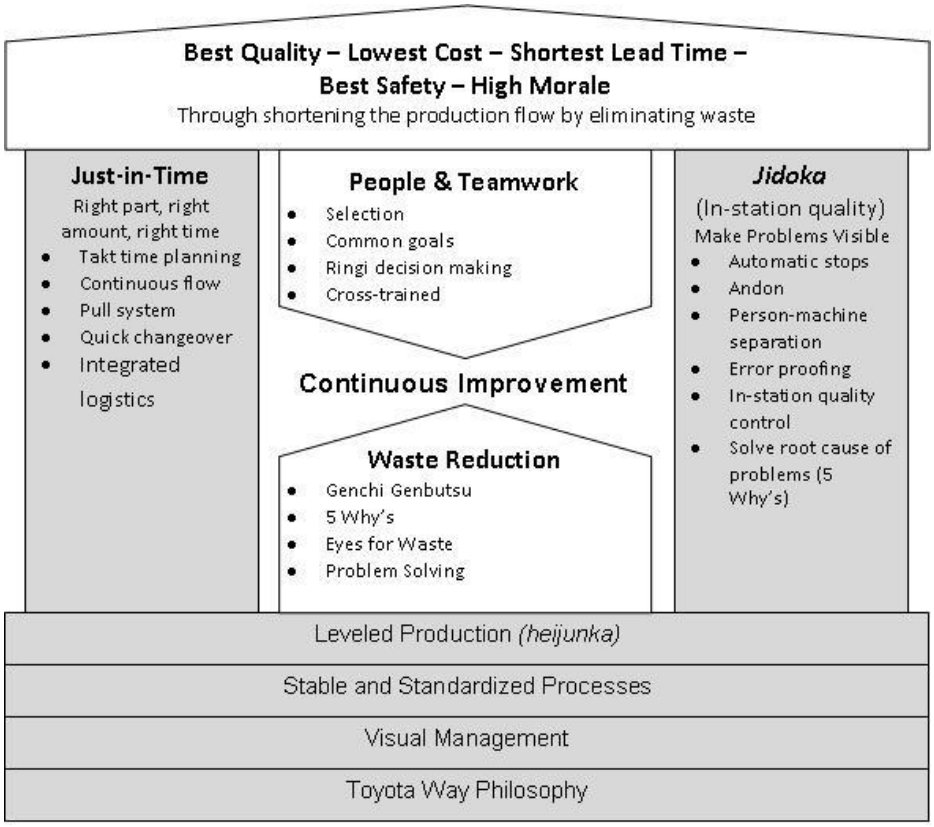

Figure 1: The Toyota Production System "House" After (Liker 2004)

The "TPS House" is not the only attempt to fuse lean principles and components into one philosophy. Over the last 30 years, a number of articles have been published that unite the characteristics of lean production using knowledge gained through surveys or through individual firm experiences. A review of this literature reveals many of the manufacturing practices that are commonly associated with lean production (Shah and Ward 2003).

Table 1: Lean Practices and Their Appearance in Key References*

Lean Practice	Sources																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Pull system/kanban	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Quick changeover techniques	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
JIT/continuous flow production	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•
Lot size reductions	•	•		•	•	•	•	•	•	•	•	•	•		•	•		
Continuous improvement programs		•				•	•	•	•		•	•	•	•	•	•		•
Total quality management		•				•	•	•	•		•	•	•	•	•	•		
Preventive maintenance			•			•		•	•	•	•	•	•	•	•	•		
Cross-functional work force	•		•		•	•			•		•	•	•	•	•	•		•
Self-directed work teams		•					•	•	•	•	•	•	•	•	•			•
Cellular manufacturing									•			•	•	•	•	•	•	
Focused factory production									•		•	•	•	•	•	•		
Process capability measurements									•			•	•	•	•		•	•
Cycle time reductions									•			•	•		•	•		•
New process equipment/technologies									•			•			•			
Safety improvement programs									•			•			•			
Quality management programs		•															•	•
Planning and scheduling strategies																		•
Bottleneck removal (production smoothing)																		

*adapted from **(Shah and Ward 2003)**

Table 1 represents a list of the most popular components of lean in published literature. Information from Table 1 was retrieved from the following sources: (1) (Sugimori, et al. 1977, Monden 1981a, Pegels 1984); (2) (Wantuck 1983); (3) (Lee and Ebrahimpour 1984); (4) (Suzaki 1985); (5) (Finch and Cox 1986); (6) (Voss and Robinson 1987); (7) (Hay 1988); (8) (Bicheno 1989); (9) (Chan, Samson and Sohal 1990); (10) (Piper and McLachlin 1990); (11) (White 1993); (12) (Richey 1996); (13) (Sakakibara, et al. 1997); (14) (Koufteros, Vonderembse and Doll 1998); (15) (Flynn, Schroeder and Flynn 1999); (16) (White, Pearson and Wilson 1999); (17) (Lewis 2000); (18) (Liker 2004).

In addition to the many practices consistently used in lean research studies, the number of times a company completely replaces its inventory in a year is an objective measurement of the leanness of an organization. This replacement measurement, or inventory turns, is found to correlate with the best long-term lean trends. Thus, in his ongoing research, Schonberger grades companies on their leanness by comparing inventory turns (Schonberger 2007).

2.4 **Operational Benefits of Lean**

The purpose of implementing lean is to improve productivity. Some refer to it as doing more with less (Christopher 2000). Implementation of the many practices mentioned in table 1 will likely result in reduced quality problems and less money tied up in inventory. However, a number of operational benefits are available. A few benefits are listed below (George 2002):

- Shorter lead times
- Less handling
- Less cost for storage
- Less parts shortages
- Fewer employees
- Fewer defects shipped to customers

Lantech is a Kentucky-based company that manufactures stretch wrapping equipment for the shipment of large pallet loads. Started in the early 1970s, Lantech began mass producing the stretch wrapping machines in a "batch and queue" mode, where ten or fifteen machines of a specific model were fabricated and assembled collectively. However, customers usually only purchased one machine, requiring Lantech to store many machine models in finished goods inventory to await a customer order. Defects per machine were high (eight) from constant

movement of each machine to various departments and storage areas. Long lead times and expedited orders often caused late deliveries and dissatisfied customers. Inventory costs went through the roof to compensate for long lead times, a new MRP system was a complete disaster, and in 1991, orders fell and Lantech began losing money for the first time (Womack and Jones 1996, 109-110).

In early 1992, a new vice president of operations was brought on and introduced lean to Lantech. Teams were immediately formed to rethink the value stream and product flow. Batch and queue was transformed into single-piece flow, production cells were created for each type of machine, and movement was reduced. Standard work was documented and publicized throughout the facility, ensuring all employees were informed on best practices. Buffers were eliminated leaving all operations directly linked. In the end, lead time fell from sixteen weeks to fourteen hours, employee hours per machine dropped in half, delivered defects per machine plummeted from eight to 0.8, and finished goods inventory was reduced by $700,000. These improvements cost Lantech almost nothing, led the company back to profitability in 1993, and industry leading financial performance by 1994 (Womack and Jones 1996, 109-121).

Lantech is not the only example of lean performance. Other success stories are widely available through peer-reviewed literature, books, websites, and magazines. The benefit of a lean operation comes not from just reducing waste, but from using less of everything compared with a company that is not lean: less human effort, less manufacturing space, less investment in tools, less engineering hours to develop new products, less on-site inventory, and less defects. Ultimately, lean implementation improves productivity, reduces costs, and makes profitability much more viable (Womack, Jones and Roos 1990, 11).

2.5 **Information Velocity**

Michael L. George defines Information Velocity (IV) as the ability to respond correctly to highly uncertain market demands (George 2006). A manufacturing company with high levels of information velocity can quickly transform information from market demand into a product that satisfies customer expectations. The concept of Information Velocity (IV) is defined as:

$$IV = \frac{Variety\ and\ Profit\ Information\ Transmitted\ by\ Market\ Demand}{Lead\ Time\ to\ Create\ or\ Destroy\ Offerings, or\ Satisfy\ Demand} \quad \textbf{(2-1)}$$

The numerator and denominator in this case are broadly defined. "Variety and Profit information Transmitted by Market Demand" could include customer orders, market surveys, product development techniques, or other ways to retrieve information from the market. The certainty of this information is vital to any company to effectively challenge its competitors. The ability to respond fast enough to market demand requires that certainty of information transmitted by market demand. The denominator "lead time to create or destroy offerings, or satisfy demand" is also general. The time to provide a customer with a product, to develop a new product, or to realize that a product is not selling, remove it from the shelves and replace it with a more promising product, could all be included in this definition (George 2006).

Information velocity provides guidance to attaining competitive advantage in all economic processes, but most importantly, IV is concerned with speed. Accelerating the velocity at which a company can translate information from the market into a product demanded by a customer potentially can allow a company to outperform competitors who focus on revolutionary innovation. For example, Compaq, before it was acquired by Hewlett Packard (HP), was a pioneer in the PC market with innovative products such as the Compaq Portable, the Deskpro series, and the Presario. However, Compaq did not focus its efforts in manufacturing processes,

but rather attempted to satisfy demand by maintaining large stocks of inventory, causing the company to suffer from stock outs, lost sales, devaluation, dealer and customer dissatisfaction, and overall increased costs. Rather than compete on innovation, Dell focused on reducing lead time. By quickly reverse engineering competitor's products, Dell achieved equivalence with Compaq's and other competitors' variety and product offerings allowing it to compete on price, which it did very well. In addition, Dell shortened the lead time of its entire supply chain (equating to increased inventory turns) to approximately 1/17th to that of Compaq (George 2006).

Since the products Dell produced were comparable, but the lead time of Dell was 17 times faster than Compaq, Dell created a competitive advantage and diminished Compaq's returns. The creation of value by the pursuit of product and service innovation attempts only to increase the numerator of information velocity. Failure to quickly deliver innovation will eventually result in increased competition by a competitor who can quickly produce the innovation and bring it to market (George 2006). Information Velocity is deeply rooted in speed, but the ability to translate information correctly from the market is determined by the volatility of the environment.

2.6 **Measurement of Environmental Volatility**

Researchers have used many variations of objective and subjective environmental volatility measurements (Figure 2). In 1967, Lawrence and Lorsch aimed their research at discovering what types of organizations will be successful under diverse economic and technical conditions by measuring the internal uncertainty in a system (Tosi, Aldag and Storey 1973). Although their research was criticized because "their concept of volatility was tied closely to top

manager's perceptions of environmental uncertainty" (Snyder and Glueck 1982), the results suggest "effectiveness derives from structuring an administrative arrangement appropriate to the nature of an organization's external environment" (Bourgeois III 1985).

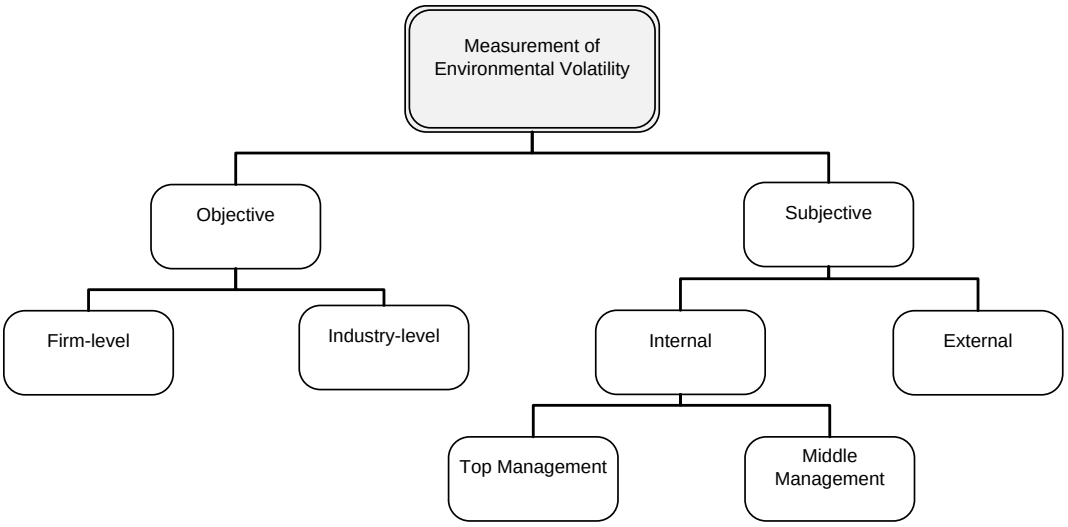

Figure 2: Diagram of Objective and Subjective Environmental Volatility Measures

Tosi et al. (1973) sought to assess the model used by Lawrence and Lorsch, making specific changes to increase validity such as using a larger sample and including middle managers rather than only top level executives. Three volatility measures were calculated for each industry and firm represented in the study: market volatility, technological volatility, and income volatility (equations 2.2, 2.3, and 2.4).

$$\boldsymbol{Market\ Volatility} = \frac{\sqrt{\frac{\sum_{i=1}^{X}(Y_i-\bar{Y})^2}{X}}}{\bar{Y}} \quad \textbf{(2-2)}$$

Where:

X is the number of years

Y_i is sales revenues for year i

$\bar{Y}$ is average sales revenues over X years

$$\boldsymbol{Technological\ Volatility} = \frac{\sum_{i=1}^{X}(\frac{A_i+B_i}{C_i})}{X} \quad \textbf{(2-3)}$$

Where:

X is the number of years

A_i is research and development (R&D) expenditures for year i

B_i is capital expenditures for year i

C_i is total assets for year i

$$\boldsymbol{Income\ Volatility} = \frac{\sqrt{\frac{\sum_{i=1}^{X}(Y_i-\bar{Y})^2}{X}}}{\bar{Z}} \quad \textbf{(2-4)}$$

Where:

X is the number of years

Y_i is earnings before interest and taxes (EBIT) for year i

$\bar{Y}$ is average earnings before interest and taxes (EBIT) over X years

$\bar{Z}$ is corporate sales for X years

In Tosi et al.'s (1973) research, the correlation coefficients between the Lawrence and Lorsch subscale totals and the industry and firm volatility measures were analyzed and the

findings were less than favorable. "When subscale scores are correlated with alternative measures of uncertainty, the results are disappointing. Internal reliability assessments and factor analysis of the scales suggest that the instrument is methodologically inadequate" (Tosi, Aldag and Storey 1973).

Snyder and Glueck sought to find an objective volatility measurement of an environment and to validate Tosi et al's paper (1973) measures of industrial environmental volatility. The market and technology volatility calculations in question were compared using an analysis performed by four major stockbrokerage firms. The results show "that there appear[s] to be indices that can be used to calculate industry volatility" (Snyder and Glueck 1982).

In 1984, Dess and Beard used industry-level data to reduce five of the six environmental dimensions developed by Aldrich (1979): capacity, homogeneity-heterogeneity, stability-instability, concentration-dispersion, and turbulence, to three dimensions and found statistically significant data using factor analysis to support their hypothesis that the three could be identified as separate factors: munificence, dynamism, and complexity. Munificence is the environmental capacity to supply sufficient resources to sustain economic growth (Dess and Beard 1984). Dynamism is the "amount of turbulence and instability in an environment" (Ketchen, Thomas and Snow 1993). Complexity is the "number and diversity of competitors, suppliers, buyers, and other environmental actors that firm decision makers need to consider in formulating strategy" (Ketchen, Thomas and Snow 1993). Following the Dess and Beard (1984) study, the three environmental dimensions have become widely accepted as environmental descriptors (Lawless and Finch 1989).The three dimensions were operationalized into twenty-three continuous scale measures/variables which are found in Table 2 with corresponding dimensions from Aldrich

(1979) and Dess and Beard (1984). A more detailed table including formulas for each variable is available in the appendix.

Table 2: Variable Dimension Comparison

Aldrich (1979) Dimension	Dess and Beard (1984) Dimension	Industry Variables	
Capacity	Munificence	V1	Growth in total sales
Capacity	Munificence	V2	Growth in price-cost margin
Capacity	Munificence	V3	Growth in total employment
Capacity	Munificence	V4	Growth in value added by manufacture
Capacity	Munificence	V5	Growth in the number of manufacturing establishments
Capacity	Munificence	V6	Sales concentration
Homogeneity-Heterogeneity	Complexity	V7	Concentration of inputs
Homogeneity-Heterogeneity	Complexity	V8	Diversity of products
Homogeneity-Heterogeneity	Complexity	V9	Specialization ratio
Homogeneity-Heterogeneity	Complexity	V10	Concentration of outputs
Stability-Instability	Dynamism	V11	Instability in total sales
Stability-Instability	Dynamism	V12	Instability in price-cost margin
Stability-Instability	Dynamism	V13	Instability in total employment
Stability-Instability	Dynamism	V14	Technological instability
Stability-Instability	Dynamism	V15	Instability in value added by manufacture
Concentration-Dispersion	Complexity	V16	Geographical concentration of total sales
Concentration-Dispersion	Complexity	V17	Geographical concentration of value added by manufacture
Concentration-Dispersion	Complexity	V18	Geographical concentration of total employment
Concentration-Dispersion	Complexity	V19	Geographical concentration of industry establishments
Turbulence	Dynamism	V20	Impact of all other industries on output of given industry
Turbulence	Dynamism	V21	Relative power of indirectly linked factors on output
Turbulence	Dynamism	V22	Proportion of industry shipments sold to intermediate markets
Turbulence	Dynamism	V23	Proportion of industry shipments sold for investment

It is important to mention that the dynamism/stability-instability dimension will be the primary measurement of environmental volatility in the current research. The approach of using objective information to obtain an environmental dynamism index has been "adopted by a number of studies and is viewed as the appropriate level of analysis" (Simerly and Li 2000, Boyd

1995, Dess and Beard 1984, Keats and Hitt 1988, Rasheed and Prescott 1992, Wholey and Brittain 1989).

Five stability variables (V11-V15) were "measured by the dispersion about the regression line obtained when each dependent variable was regressed on time over the [time] period" (Dess and Beard 1984, Rasheed and Prescott 1992). Equation 2.5 is considered a superior volatility measurement to adaptations of the coefficient of variation formula used in equations 2.2, 2.3, and 2.4 (Dess and Beard 1984), and was used by a number of researchers to measure environmental volatility (Dess and Beard 1984, Wholey and Brittain 1989, Simerly and Li 2000). Each of the stability variables (V11-V15) use equation 2.5 to analyze dynamism with variables such as: value of shipments, value added by manufacture minus total wages, total employment, percentage of scientists and engineers in total number of employees, and value added by manufacture (Dess and Beard 1984, Rasheed and Prescott 1992).

$$\boldsymbol{Instability} = \frac{\boldsymbol{Standard\ Error\ of\ the\ Regression\ Slope\ Coefficient}}{\boldsymbol{Mean\ Value}} \qquad \textbf{(2-5)}$$

3 METHODOLOGY

3.1 Introduction

This segment of the thesis explains the qualifiers implemented into the analysis sample, the performance indicators used to measure lean production, IV, and financial performance, and the data collection process.

3.2 Qualifiers

This research study narrowed its scope to analyzing only publicly traded manufacturing companies with sales revenues above $100 million a year. There are three reasons for these constraints. First, publicly held companies are required by the government to provide specific financial information to the shareholders and the public. This type of information is published in annual reports such as 10-K, and can be found online at the Security Exchange Commission website or specialized databases such as WRDS. Second, inventory in manufacturing companies is more easily quantified than in service companies, even though it is not impossible to do so for the service industry. It is hypothesized the leanness can be objectively determined by comparing the number of inventory turns, which can be calculated from information available in published annual reports (Schonberger 2007). Third, companies having a high volume of sales are more likely to have in place mature lean systems, thus facilitating the measurement of lean companies in dynamic environments.

The United States Department of Labor defines a manufacturer as "engaged in the chemical or mechanical transformation of raw materials or processed substances into new products." The current study filters out all companies not classified as manufacturers and includes only companies with Standard Industrial Classification (SIC) codes between 2000 and 3999, inclusive. The SIC manual is published by the U.S. Office of Management and Budget, and a complete listing of the codes and descriptions is available in the appendix.

3.3 Financial Performance Indicators (Independent Variables)

While different combinations of lean tools and techniques help describe a system, George suggests the emphasis should be on financial metrics because "the voice of the customer is represented within the value creation that leads to increased revenue retention and growth rates of the company". George mentions areas of financial improvement tier-one auto suppliers have made by implementing lean with the addition of Six Sigma (200210):

Table 3: Financial Metrics of Lean Production

Financial Metric:	Financial Metric:
• Operating Margin	• Economic Profit (ROIC% - WACC%)
• Gross Profit	• Enterprise Value
• Operating Profit	• EBITDA
• Capital Turnover	• Manufacturing Lead Time
• Work-in-Process (WIP) Inventory Turns	• On-Time Delivery
• Return on Invested Capital (ROIC)	• Quality Performance (External CTQ)
• Weighted Average Cost of Capital (WACC)	• Cost of Goods Sold

A series of variables will be used to quantify the financial benefit to companies. The following financial indicators were used in prior mentioned research studies to compare elements of lean systems: Return on Assets (ROA), Return on Sales (ROS), and profits (Kinney and

Wempe 2002, Claycomb, Germain and Droge 1999). Chapter 2 discussed the number of indicators that can be used to measure the leanness of companies. Financial indicators are determined superior measures of leanness compared to the tools and techniques implemented in a system (George 2002). ROA, ROS, and stock price were all used in previous studies of lean concepts and will be used as dependent variables in the current study. The formulas for ROA, and ROS are found below.

3.3.1 Return on Assets (ROA)

The ROA is an indicator of a company's profitability relative to its total assets. In other words, ROA informs a knowledge seeker how efficiently management using its assets to generate earnings. Performance on generic manufacturing capabilities (e.g. quality, cost, dependability, flexibility, etc.) is also linked to ROA (Corbett and Claridge 2002). Calculated by dividing a company net income by its total assets (equation 3.1), ROA is calculated quarterly or annually and is displayed as a percentage.

$$\boldsymbol{Return\ on\ Assets\ (ROA) = \frac{Net\ Income}{Average\ Total\ Assets}} \qquad \textbf{(3-1)}$$

3.3.2 Return on Sales (ROS)

ROS is a ratio commonly used to assess a company's operational efficiency and is known as the "operating profit margin". This metric provides insight to management and potential investors into how much profit is produced per dollar of sales. Measured by dividing net income before interest and taxes by sales (equation 3.2), lean companies should succeed in ROS by

increasing net income through reduced costs, and by increasing sales through faster lead times, higher quality, etc.

$$\textbf{\textit{Return on Sales}}\ (\textbf{\textit{ROS}}) = \frac{\textbf{\textit{Net Income (Before Interest and Tax)}}}{\textbf{\textit{Sales}}} \qquad \textbf{(3-2)}$$

3.3.3 Stock Price

The stock valuation at the close of each quarter is included as the third financial returns variable. While the stock price is affected my many other factors out of the company's control, the influence that information velocity and lean have on the share price could possibly enlighten the reading. There are many theories that attempt to explain the movement of stock prices. However, there is no one theory that can explain everything. Information velocity is hypothesized to be one of those theories.

3.4 Lean Variables

It is difficult to determine if a company is lean because there are many companies who claim to be lean where an expert would disagree (Liker 2004). Ideally, many variables would be included in this study. However, not all metrics are easily available to researchers. Without an inside knowledge of a company's operational data, the only information publicly available is the annual financial report (Cavallini 2008).

Production indicators are assumed to drive financial results in manufacturing companies (Cavallini 2008). Therefore, the average number of quarterly inventory turns was assigned as an independent variable to the FPIs previously mentioned. Inventory turns (equation 3.3) represent a ratio of the number of times a company's inventory is sold and replaced, and stands as one of the

few lean indicators available in public records. As previously stated, inventory reduction is an essential aspect of lean systems (Claycomb, Germain and Droge 1999) and as inventory is reduced, the inventory turns ratio increases. Thus, companies with a larger number of inventory turns can be considered more lean than companies with a lesser number of turns (Schonberger, Japanese Production Management: An Evolution—With Mixed Success 2007).

$$\boldsymbol{Inventory\ Turns} = \frac{\boldsymbol{Cost\ of\ Goods\ Sold\ (COGS)}}{\boldsymbol{Average\ Inventory}} \quad \textbf{(3-3)}$$

3.5 Information Velocity Variable

The initial concept of IV is too broad with which to perform experiments, as discussed in chapter 2. For the purposes of this study, IV will be simplified to a combination of three variables: instability, unpredictability, and inventory turns.

Entropy of information is a measure of the uncertainty associated with some variable (Shannon 1948). In the case of IV, the information transmitted by market demand, no matter the certainty, is defined as entropy because the amount of information transmitted from the market is explained with a level of certainty. IV, therefore, is increased when little information on market demand is known. The denominator of the IV formula in chapter 2 will be simplified to the lead-time from customer order to delivery. When a greater lead-time is required to satisfy customer demand, information velocity is reduced, but increases as the lead time shortens. This designation allows for a simplification of information velocity:

$$\boldsymbol{Information\ Velocity\ (IV)} = \frac{\boldsymbol{Entropy}}{\boldsymbol{Lead\ Time}} \quad \textbf{(3-4)}$$

The instability variable measures the level of certainty or entropy in a market by capturing the weighted variation in sales revenue. The literature review provided in Chapter 2 concluded that the most widely accepted measure of environmental volatility is Dess and Beard's instability equation (2.5). However, firm-level information on the five variables applied to the formula is not widely available to researchers, so sales revenue will be substituted as the variable used in the equation. This method of substitution was feasible because "Keats and Hitt (1988) observed convergence between the instability (dynamism) measure derived from sales and operating income and content analysis of annual reports. This set of empirical evidence became the basis of using variations in industry revenue as the key indicator when assessing environmental dynamism" (Simerly and Li 2000). Equation 2.5 will then be adapted to the following:

$$\boldsymbol{Instability} = \frac{\boldsymbol{Standard\ Error\ of\ the\ Regression\ Slope\ Coefficient}}{\boldsymbol{Mean\ Value}} \qquad \textbf{(3-5)}$$

In equation 3.5, revenue is the independent variable (X), a financial performance indicator is the dependent variable (Y) and the average revenues are found in the denominator.

Although the instability measure captures weighted variation in sales revenue, predictability should discount the instability measure because Dess and Beard (1984) suggest that "turnover, absence of pattern, and unpredictability are the best measures of environmental stability-instability." This research will distinguish unpredictability from environmental instability by measuring the difference between the predicted revenues based on a regression line of same-quarter revenues in past years and the actual revenue data point. Wholey and Brittain (1989) used the correlation coefficient (R^2) for sales regressed on sales lagged one year signifying that a large R^2 value (close to 1.000) will suggest that a previous year's sales will

predict the current of future year's sales. However, this method did not fit the often cyclical nature of manufacturing. Unpredictability is calculated using the following equation:

$$\boldsymbol{Unpredictability} = |\boldsymbol{Predicted}_{rev} - \boldsymbol{actual}_{rev}| \quad \textbf{(3-6)}$$

The need for a measure of unpredictability in information velocity is depicted in the Campbell Soup Company. Sales revenues for Campbell are highly cyclical as illustrated inFigure 3. The instability equation (2.5) will consider the cyclical quarterly revenue fluctuations as volatile (0.0058), when it is actually extremely predictable, proving the instability measure can be misleading.

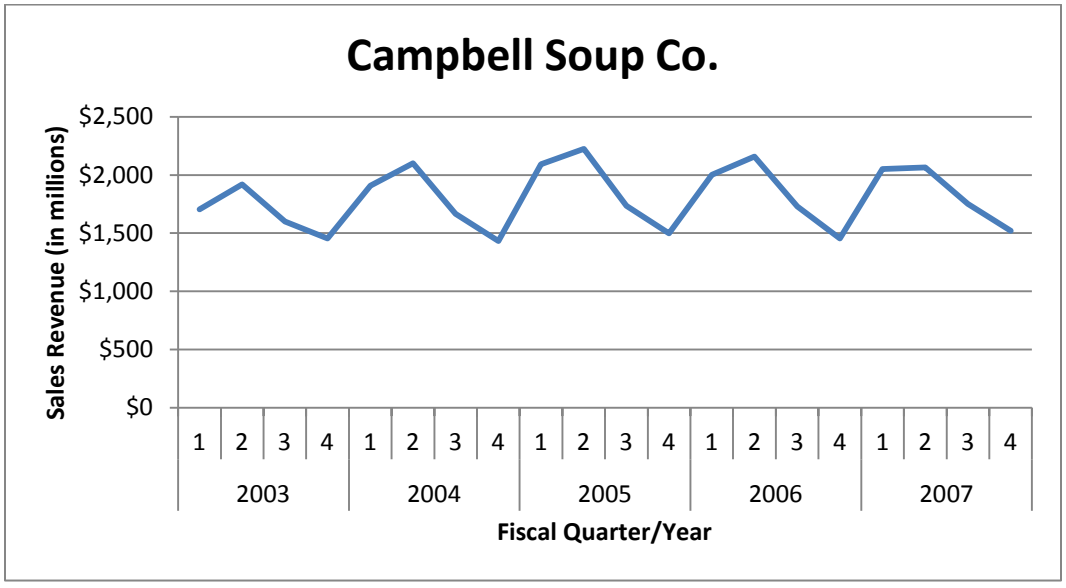

Figure 3: Campbell Soup Company Sales Revenues

Most companies do not publish lead times and they are often kept under strict confidentiality. Schonberger (2007) suggests the inverse of inventory turns (equation 3-3) is a

viable substitute for lead time. This assumption allows for an even greater simplification of information velocity:

$$\boldsymbol{IV = Instability \times Unpredictability \times Inventory\ Turns} \quad \textbf{(3-7)}$$

The simplified equation compensates for the unknown market information through instability and unpredictability and for a company's ability to quickly satisfy demand. The environmental volatility, measured by the product of instability and unpredictability, reflects precariousness by reducing the value by its level of predictability to prevent consistent companies, like Campbell Soup Company, from consideration as truly volatile. Also, a faster response time reduces lead-time, and subsequently, increases inventory turns. Therefore, when market volatility is held constant, a faster response time increases IV.

3.6 Other Independent Variables

Other independent variables included in regression analysis are SIC codes, quarterly revenue, global company key, and interactions between several of the variables. Two, three, and four-digit SIC codes are included in the analysis to account for any industry bias. All SIC codes are four digits, but the positioning of each digit communicates the type of industry for which a particular company is categorized (e.g. food and kindred products: 20XX; meat products: 201X; poultry slaughtering and processing: 2015).

Quarterly revenue is included to weight company size. The global company key is a company specific identifier in the COMPUSTAT database and is included to distinguish firm-level from industry-level data.

3.7 Data Collection

After an initial pilot study, the researcher extracted financial information from all publicly-traded manufacturing (SIC 2000 to 3999) companies. Financial data was extracted from the Wharton Research Data Services (WRDS) using the COMPUSTAT North America database. This WRDS database is supported by the University of Pennsylvania and serves as a "comprehensive economic and financial data management system." The data was collected for five years, beginning in the first fiscal quarter of 2003 and running through the last quarter of 2007. All available data was found either on the Balance Sheets or Income Statements from annual 10-K reports. The following list (Table 4) includes the variables mined for each company itemized by the variable selection options available in the COMPUSTAT database. The list combines the variables' identifying labels with the unique abbreviated variable name in parentheses as found in the extraction process.

Table 4: COMPUSTAT Extracted Variables

Identifying Information:	**Quarterly Data Items:**
Data date	Total Assets (ATQ)
Fiscal year	Cash and short-term investments (CHEQ)
Fiscal quarter	Cost of goods sold (COGSQ)
SIC	Gross profit (loss) (GPQ)
Company name	Total inventories (INVTQ)
Ticker symbol	Total current liabilities (LCTQ)
	Net income (loss) (NIQ)
Yearly Data Items:	Pretax income (PIQ)
Total revenue (REVTY)	Total revenue (REVTQ)
	Sales/turnover (net) (SALEQ)
Supplemental Data Items:	Total shareholders' equity (SEQQ)
Stock price close (quarter) (PRCCQ)	Total interest expense (TIEQ)
	Total income taxes (TXTQ)

The data query was filtered by the qualifiers as described in section 3.2 of this research, and by completeness of data as described in the delimitations section (1.6). Any company that

did not meet the industry requirement (SIC 2000 to 3999), size requirement (yearly sales revenue greater than $100 million), or totality requirement (completeness of data) was removed from the study.

The raw data was extracted into Microsoft® Excel and aggregated using pivot tables. FPIs including ROS, ROA, and stock price were calculated along with other indicators such as instability (equation 2.5), predictability (equation 3.6), and inventory turns (equation 3.4). Each of these dependent variables were selected based on the insight into the level of leanness and the fiscal success to support the hypotheses that lean companies and lean industries have higher financial returns in dynamic industries. The results and conclusions of the data are found in the next two chapters.

4 RESULTS

The primary goal of this thesis involved identifying the relationship between lean production and strong financial performance in a volatile environment. An approach using a series of statistical analyses answered this research question. The initial analysis consisted in running simple and multivariate linear regressions on hundreds of manufacturing companies. The sample size identified the strength of the correlation between lean and financial performance, and information velocity provided clarity to understanding how and when lean benefits financial performance.

4.1 Linear Regression

The linear regression facilitates an analysis of how a single dependent variable is affected by the values of one or more independent variables. The regression analysis used the least squares method to fit a line through a set of observations with an assortment of independent variables to evaluate the effect lean and environmental volatility have on financial returns. A number of regression models were calculated each with a different combination of dependent variables, interactions, and measures of financial performance.

The level of importance an independent variable has on a dependent variable is determined by the p-value. A significant variable has a p-value of less than 0.1 (*p<0.10) or at the 90% confidence level, and increases in significance as the p-value decreases (**p<0.05; ***p<0.01). Each regression model ran uses quarterly data and has a sample size (n) of almost 12,600. The

correlation coefficient (S), coefficient of determination (R-Sq), adjusted R-Squared, F-statistic, and p-value are all listed below the corresponding model. Industry dummy variables were also included in each regression model, but not published in the summaries below. The four-digit SIC codes were labeled with a one or zero in the raw data to reduce any industry bias in the models. The five summaries below show inventory turns and instability generally have a significant effect on ROA, ROS, and stock price in most of the models ran. Information Velocity, which is the product of instability, inventory turns, and sometimes unpredictability, also shows great significance.

4.1.1 Regression Summaries

The regression summaries are grouped by the various combinations of independent variables. Regression Summary #1 (Table 5) illuminates the connection between instability and financial returns: as instability in the environment increases, financial returns decrease. Conversely, inventory turns shows a positive coefficient for ROA and the stock price, while unpredictability shows no signs of significance. IV, the interaction between instability, inventory turns, and unpredictability, and its squared term are divided by one thousand to serve as a scaling factor. IV shows positive, significant coefficients while the sign changes to negative for the squared information velocity term. This indicates that a downward parabola describes the behavior of information velocity.

Table 5: Regression Summary #1

Regression Summary #1	ROS		ROA		Stock Price	
Constant	-22.950	***	-3.902	***	-3541.500	***
Time	0.012	***	0.002	***	1.787	***
Total Revenue (yearly)	-0.00000012		0.00000003		0.00014431	***
Instability	-0.89773000	***	-0.02706000	**	-38.05200000	***
Inventory Turns	0.00289200		0.00114110	***	5.79670000	***
Unpredictability	0.00000074		-0.00000075		-0.00014220	
Information Velocity (x 0.001)	0.01808500	***	0.00246340	***	-1.55640000	**
[Information Velocity]^2 (x 0.001)	-0.00000063	**	-0.00000008	**	0.00000828	
S =	0.2684		0.0393		32.6355	
R-Sq =	4.9%		6.8%		35.8%	
R-Sq (adj) =	3.6%		5.6%		34.9%	
F =	3.82		5.42		39.55	
P =	0.00		0.00		0.00	

Table 6: Regression Summary #2

Regression Summary #2	ROS		ROA		Stock Price	
Constant	-25.065	***	-3.994	***	-3665.000	***
Time	0.013	***	0.002	***	1.852	***
Total Revenue (yearly)	0.00000022		0.00000001		0.00009687	***
Information Velocity (x 0.001)	0.00824400		0.00255220	***	0.88640000	
[Information Velocity]^2 (x 0.001)	-0.00000032		-0.00000008	**	-0.00003940	
S =	0.2699		0.0393		33.4506	
R-Sq =	3.8%		6.6%		32.5%	
R-Sq (adj) =	2.5%		5.4%		31.6%	
F =	2.97		5.35		34.83	
P =	0.00		0.00		0.00	

Regression Summary #2 (Table 6) removes the three individual components of information velocity from the regression, leaving screening variables (time, revenue, and SIC codes), IV, and IV^2 in the model. A significant downward parabola pattern in IV remains present in ROA as previously mentioned in Summary #1, but it is important to note that ROS and stock price do not show significant results, but still continues the pattern.

The third regression summary (Table 7) removes the IV and IV^2 terms from the first summary, but does include the components. Inventory turns shows is has a positive significant effect on all three financial returns. Instability (as with regression #1) shows it has a negative effect on financial returns. Unpredictability still shows no signs of significance.

Table 7: Regression Summary #3

Regression Summary #3	ROS		ROA		Stock Price	
Constant	-22.982	***	-3.904	***	-3545.800	***
Time	0.012	***	0.002	***	1.790	***
Total Revenue (yearly)	0.00000011		0.00000006	**	0.00011758	***
Instability	-0.84644000	***	-0.01984000	*	-43.63300000	***
Inventory Turns	0.00430100	**	0.00134740	***	5.57970000	***
Unpredictability	0.00000504		-0.00000009		-0.00098570	
S =	0.2685		0.0393		32.6523	
R-Sq =	4.8%		6.8%		35.7%	
R-Sq (adj) =	3.5%		5.5%		34.8%	
F =	3.79		5.42		39.90	
P =	0.00		0.00		0.00	

Unpredictability was later removed from the model and additional regressions were run because it showed no signs of significance in regression summaries one through three. Summary

#4 (Table 8) repeats the first summary, but removes unpredictability as an individual independent variable and as a term of IV. When unpredictability is removed from the IV term, the number of significant terms and the level of significance is greatly increased for most variables. Instability continues to have a negative influence on financial returns, except for stock price. Inventory turns either turns negative or decreases its significance in ROS or ROA, but still remains an extreme influence on stock price. IV maintains the significant downward parabola for ROS and ROA, but the inverse occurs for stock price.

Table 8: Regression Summary #4

Regression Summary #4	ROS		ROA		Stock Price	
Constant	-22.394	***	-3.853	***	-3675.500	***
Time	0.011	***	0.002	***	1.853	***
Total Revenue (yearly)	0.00000034	**	0.00000007	***	0.00006827	***
Instability	-1.41130000	***	-0.07480000	***	69.45000000	***
Inventory Turns	-0.00557200	**	0.00039330		7.60440000	***
Instability x Inventory Turns	0.43902000	***	0.04191000	***	-87.78100000	***
(Instability x Inventory Turns)^2	-0.13352000	***	-0.01225000	**	23.76600000	***
S =	0.2680		0.0392		32.4805	
R-Sq =	5.2%		6.9%		36.4%	
R-Sq (adj) =	3.9%		5.7%		35.5%	
F =	4.06		5.52		40.85	
P =	0.00		0.00		0.00	

The fifth regression summary (Table 9) removes IV and its squared term from regression #4 to mimic #3, without unpredictability. Similar results were then found as Summary #4. Significant negative coefficients for instability and positive coefficients for inventory turns were found on all three financial indicators in congruence with the previous three summaries.

Table 9: Regression Summary #5

Regression Summary #5	ROS		ROA		Stock Price	
Constant	-22.926	***	-3.905	***	-3556.800	***
Time	0.011	***	0.002	***	1.795	***
Total Revenue (yearly)	0.00000023		0.00000006	**	0.00009518	***
Instability	-0.84094000	***	-0.01994000	*	-44.72700000	***
Inventory Turns	0.00432400	**	0.00134700	***	5.57590000	***
S =	0.2685		0.0393		32.6541	
R-Sq =	4.8%		6.8%		35.7%	
R-Sq (adj) =	3.5%		5.5%		34.8%	
F =	3.81		5.46		40.13	
P =	0.00		0.00		0.00	

Table 10: Regression Summary #6

Regression Summary #6	ROS		ROA		Stock Price	
Constant	-24.799	***	-4.0871	***	-3680.6	***
Time	0.012416	***	0.0020468	***	1.8593	***
Total Revenue (yearly)	0.00000033	**	0.00000007	***	0.00010949	***
Instability x Inventory	-0.12164	***	0.019592	***	10.377	*
(Instability x Inventory Turns)^2	0.08806	**	-0.003133		-10.930	**
S =	0.269724		0.0391701		33.4455	
R-Sq =	3.8%		6.7%		32.5%	
R-Sq (adj) =	2.6%		5.5%		31.6%	
F =	3.01		5.44		34.87	
P =	0.0		0.0		0.00	

The last regression table (Table 10) reproduces summary #2, while removing unpredictability from the IV terms and no longer using the scaling factor (x0.001). The remaining screening variables (time, revenue, and SIC codes), IV, and IV2 in the model continue

to show great importance in IV's effect on the stock price. There, both the IV and IV2 terms are statistically significant and continue the downward parabola pattern as consistently throughout the regression summaries. ROA portrays the downward parabola in resembling regression summary #2, but the IV2 term is no longer significant. Lastly, ROS reverses the coefficient signs from summary #2, but increases greatly in significance.

4.1.2 Regression Summaries by Financial Performance Indicator

The results from the six regressions revealed in section 4.1.1 are grouped by financial performance indicator to facilitate analysis by dependent variables in the three tables below. The various combinations were placed side by side to provide the reader and researcher with a simple view for comparison.

The results grouped by ROS are seen in Table 11. Each of the screening variables (time and revenue) remains relatively consistent in coefficient and the significance only varies in revenue for summaries four and six. Instability always negatively affects ROS and is highly significant in all cases. The coefficient is mostly positive for inventory turns, but turns negative on the summary (#4) with the largest instability coefficient. Unpredictability seemed to have no effect on summaries one through three, and was removed as an individual term and as a component to IV from summaries four through six. IV and its squared term are significant and follow the downward parabola pattern only when instability and inventory turns are included in the model. Lastly, the correlation coefficient, coefficient of determination, adjusted R^2, and F-statistic are generally higher for summary four, indicating that the model is the best indicator representation of the hypothesis.

Table 11: Regression Summaries Organized by ROS

	#1		#2		#3		#4		#5		#6	
Constant	-22.950	***	-25.065	***	-22.982	***	-22.394	***	-22.926	***	-24.799	***
Time	0.012	***	0.013	***	0.012	***	0.011	***	0.011	***	0.012	***
Total Revenue (yearly)	0.000		0.000		0.000		0.000	**	0.000		0.000	**
Instability	-0.898	***			-0.846	***	-1.411	***	-0.841	***		
Inventory Turns	0.003				0.004	**	-0.006	**	0.004	**		
Unpredictability	0.000				0.000							
IV (x 0.001)	0.018	***	0.008				0.439	***			-0.122	***
IV^2 (x 0.001)	0.000	**	0.000				-0.134	***			0.088	**
S =	0.2684		0.2699		0.2685		0.268		0.2685		0.2697	
R-Sq =	4.90%		3.80%		4.80%		5.20%		4.80%		3.80%	
R-Sq (adj) =	3.60%		2.50%		3.50%		3.90%		3.50%		2.60%	
F =	3.82		2.97		3.79		4.06		3.81		3.01	
P =	0		0		0		0		0		0	

Table 12 groups the six regression summaries by ROA. Similar to Table 11, the screening variables coefficients are consistent and only lack significance in revenue for summaries one and two. Instability remains negative and significant, while inventory turns is always positive, but lacks significance in one model. Significance continues to lack for unpredictability, whereas IV shines. The IV and IV^2 terms follow the downward parabola in each situation, and significance is not found in only one term. Overall, the summary statistics below the grouped summaries are much higher, suggesting that all six models provide an enhanced explanation of ROA than ROS.

Table 12: Regression Summaries Organized by ROA

	#1		#2		#3		#4		#5		#6	
Constant	-3.902	***	-3.994	***	-3.904	***	-3.853	***	-3.905	***	-4.087	***
Time	0.002	***	0.002	***	0.002	***	0.002	***	0.002	***	0.002	***
Total Revenue (yearly)	0.000		0.000		0.000	**	0.000	***	0.000	**	0.000	***
Instability	-0.027	**			-0.020	*	-0.075	***	-0.020	*		
Inventory Turns	0.001	***			0.001	***	0.000		0.001	***		
Unpredictability	0.000				0.000							
IV (x 0.001)	0.002	***	0.003	***			0.042	***			0.020	***
IV^2 (x 0.001)	0.000	**	0.000	**			-0.012	**			-0.003	
S =	0.0393		0.0393		0.0393		0.0392		0.0393		0.0391	
R-Sq =	6.80%		6.60%		6.80%		6.90%		6.80%		6.70%	
R-Sq (adj) =	5.60%		5.40%		5.50%		5.70%		5.50%		5.50%	
F =	5.42		5.35		5.42		5.52		5.46		5.44	
P =	0		0		0		0		0		0	

The last grouped table (Table 13) organizes the regression summaries by stock price as the financial performance indicator. All coefficients are exponentially larger for the stock price regressions than in the prior two. The screening variables are all highly significant, but the consistency of time varies more than the previous tables; revenue remains stable. Instability maintains significantly negative coefficients, with the exception of one instance in summary number four, and inventory turns upholds the positive and significant trend. As has been the case, unpredictability is deficient in significance and is removed from the last three regressions. IV does not follow the downward parabola pattern set by the previous groups. IV and IV^2 still alternate signs, indicating a parabolic description, but instead vary in the direction of the parabola. Also varying among the IV terms is significance, which lacks in almost half of those

terms. Finally, the summary statistics below suggest a large amount of the variation in stock price can be explained by the models.

Table 13: Regression Summaries Organized by Stock Price

	#1		#2		#3		#4		#5		#6	
Constant	-3541.5	***	-3665.0	***	-3545.8	***	-3675.5	***	-3556.8	***	-3680.6	***
Time	1.787	***	1.852	***	1.790	***	1.853	***	1.795	***	1.859	***
Total Revenue (yearly)	0.000	***	0.000	***	0.000	***	0.000	***	0.000	***	0.000	***
Instability	-38.052	***			-43.633	***	69.450	***	-44.727	***		
Inventory Turns	5.797	***			5.580	***	7.604	***	5.576	***		
Unpredictability	0.000				-0.001							
IV (x 0.001)	-1.556	**	0.886				-87.781	***			10.377	*
IV^2 (x 0.001)	0.000		0.000				23.766	***			-10.930	**
S =	32.635		33.450		32.652		32.480		32.654		33.445	
R-Sq =	35.80%		32.50%		35.70%		36.40%		35.70%		32.50%	
R-Sq (adj) =	34.90%		31.60%		34.80%		35.50%		34.80%		31.60%	
F =	39.55		34.83		39.9		40.85		40.13		34.87	
P =	0		0		0		0		0		0	

4.2 **Industry Results**

It is understandable that manufacturing industries fluctuate in profitability. Figure 4 below depicts the variation of ROS and ROA among industries at the two-digit SIC code level. The graph shows that tobacco products (SIC 2100s) are the most profitable in terms of average ROS and average ROA. Only companies labeled as “Miscellaneous Manufacturing Industries” (SIC

3900) come close to tobacco products in both of the utilized profitability indicators. The industry with the lowest returns is textile mill products (SIC 2200).

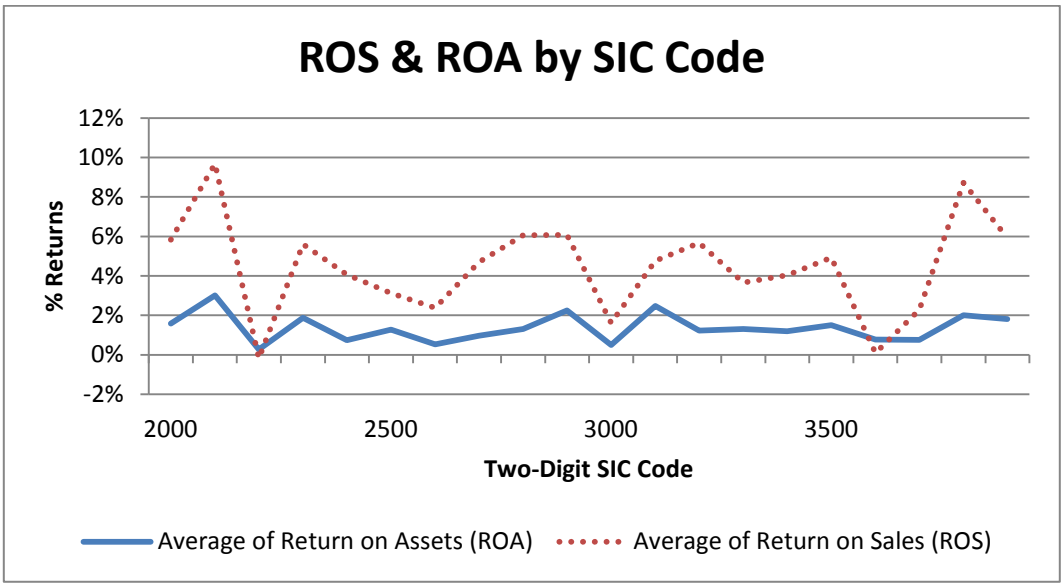

Figure 4: Average ROS and ROA Organized by Two-Digit SIC Code

A similar graph as Figure 4 was created to analyze the third financial performance metric, stock price (Figure 5). The leading manufacturing industries in average stock price include printing, publishing, & allied industries (SIC 2700), petroleum refining and related industries (SIC 2900), and tobacco products (SIC 2100). Many relatively poor-performing industries hover around $30. Several of those include electronic and other electrical equipment and components, except computer equipment (SIC 3600), miscellaneous manufacturing industries (SIC 3900), and lumber and wood products, except furniture (SIC 2400). It is important to highlight that the companies labeled as part of the miscellaneous manufacturing industry not only have relatively considerable profits in average ROS and ROA, but also closes with very low stock prices.

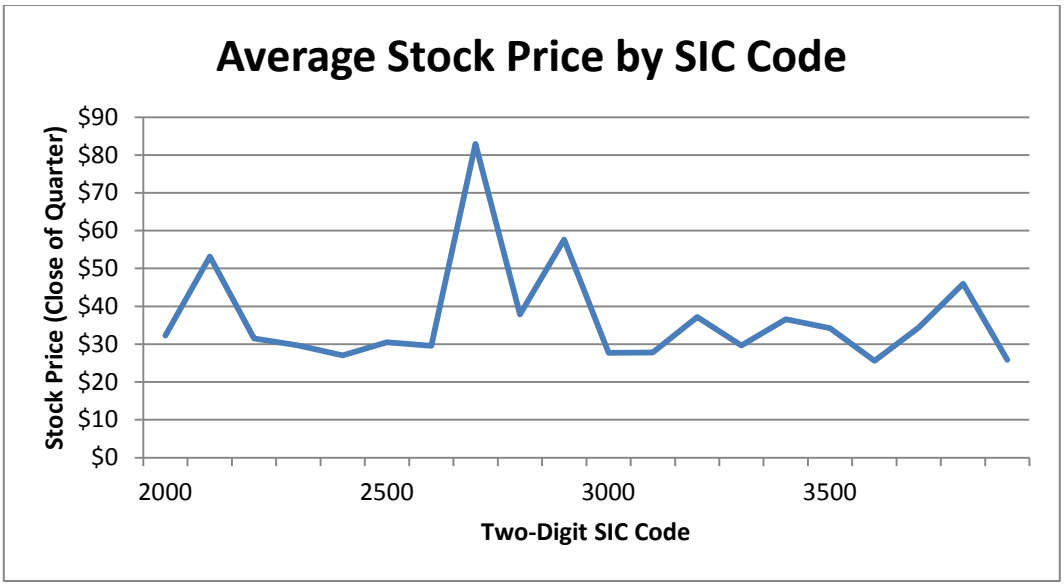

Figure 5: Average Stock Price at Quarter-Close Organized by Two-Digit SIC Code

The levels of instability and inventory turns were graphed below in the same figure with instability highlighted on the left axis, while inventory turns are labeled on the right axis (Figure 6). The axes align numerically, but a scaling factor of 100 is used for an easy comparison on the same graph. No obvious trends between the two measures can be interpreted. However, the graph does highlight the industries that can benefit most from lean by measuring the gap between the two lines. For example, the leather and leather products industry (SIC 3100) is the most instable industry in terms of sales revenues. On the other hand, the industry on average turns its inventory fewer times than most, but not all, other industries. This gap between the instability line and the inventory line could possibly be a quick measure of which industries should be implementing lean principles based on information velocity.

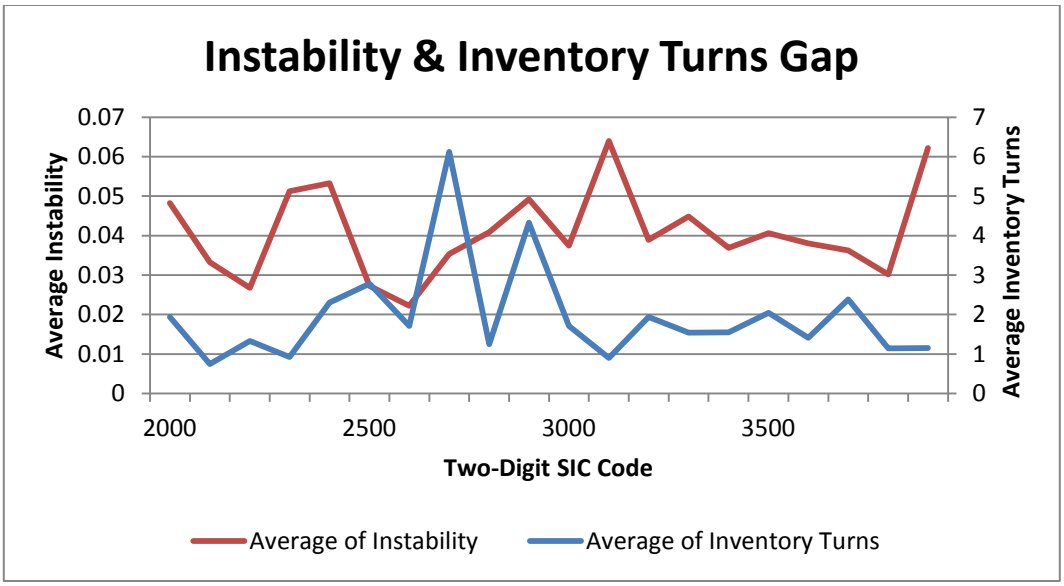

Figure 6: Average Instability and Inventory Turns Organized by Two-Digit SIC Code

5 CONCLUSION

5.1 Summary

The primary objective of this research required a determination if lean manufacturing companies are financially rewarded for their faster and more effective response to the demands of a volatile environment. There is little doubt that the productivity advances obtained from the implementation of lean and its tools provide impressive results, but wide discrepancy exists in research on the overall profitability of companies who put lean into practice. The research community concludes with positive, negative, mixed impact, and insignificant correlations between the amount of leanness and positive financial returns. This thesis study sought to determine the connection between lean and financial success and to discover why so many researchers are finding mixed results.

A lens researchers have failed to look through is Information Velocity (IV). Lean companies can generally better accommodate customers' needs because of flexible, agile, and streamlined processes. The scalability of production volumes according to demand, combined with reduced waste in the system, creates a competitive advantage that is difficult to compete against, especially in a dynamic environment. IV combines the stability of the market with a company's lean performance to measure the ability a company has to translate information from the market into a customer-satisfying product. The use of IV in the question of financial profitability allows researchers to answer "yes" when asked if it is financially sound to implement lean.

Financial information on publicly-traded manufacturing companies was extracted from the WRDS database between the years of 2002 and 2007. The mined data was used to calculate independent variables, such as instability (equation 3-5), unpredictability (equation 3-6), inventory turns (equation 3-3), and IV (equation 3-7), as well as the financial performance indicators, such as ROS (equation 3-1), ROA (equation 3-2), and stock price at the close of each fiscal quarter. Various combinations of the independent variables were regressed using the financial performance indicators as dependent variables. Results from the six combinations are organized by combination and by dependent variable and found in the tables of chapter four.

5.2 **Conclusion**

The correlation coefficients and p-values are strong enough to uphold the hypothesis that manufacturing companies are financially rewarded for lean implementation by responding faster and more effectively to the demands of a dynamic market. The regression models included more than 530 companies with almost 24 data points per company. In most regression models run, inventory turns (the method chosen by this research to determine the leanness of a company or industry) was found to have a positive, significant effect on financial performance. Therefore, as a company becomes more lean, the profitability in terms of ROS, ROA, and stock price should increase.

Environmental instability proved a significant detriment to financial returns. The instability measure consistently negatively affected the financial performance indicators, concluding that it is more difficult for companies to obtain financial performance in a volatile and unpredictable environment. However, as the uncertainty is reduced, the negative effect on financial performance is also reduced.

Finally, IV was hypothesized to explain why so many researchers are finding mixed results on the profitability of lean. After the various combinations of IV and its components were regressed, the inclusion of IV did not affect whether the lean measure (inventory turns) was positive or negative. Therefore, this research validates other publications that find positive correlations between lean and financial performance (Husan and Nanda 1995).

5.3 **Recommendations for Future Study**

Based on the work presented in this thesis, the following areas may be opportunities for additional research on lean manufacturing and information velocity:

- Industry comparisons of lean production and information velocity. The volatility of different industries varies significantly. The discovery of which industries would benefit most from lean would be valuable to the academic and practitioner community.
- The definition of information velocity used in this study might be considered vague by some standards. The broad definition allowed for a large-scale study of publicly-traded companies. A closer look into companies where more information was readily available could allow for a more specific definition of information velocity
- The instability-inventory turns gap opens up research for a range of company- or industry-wide applications. Some researchers may want to experiment with its application to identify areas where lean implementation would be most beneficial. Others can measure the accuracy of the theory to determine if the gap is a sufficient measurement of necessary lean initiatives.

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APPENDIX A. STANDARD INDUSTRIAL CLASSIFICATION (SIC) SYSTEM

	Division/Group	Definition
A.	Division A	Agriculture, Forestry, And Fishing
	Major Group 01	Agricultural Production Crops
	Major Group 02	Agriculture production livestock and animal specialties
	Major Group 07	Agricultural Services
	Major Group 08	Forestry
	Major Group 09	Fishing, hunting, and trapping
B.	Division B	Mining
	Major Group 10	Metal Mining
	Major Group 12	Coal Mining
	Major Group 13	Oil And Gas Extraction
	Major Group 14	Mining And Quarrying Of Nonmetallic Minerals, Except Fuels
C.	Division C	Construction
	Major Group 15	Building Construction General Contractors And Operative Builders
	Major Group 16	Heavy Construction Other Than Building Construction Contractors
	Major Group 17	Construction Special Trade Contractors
D.	Division D	Manufacturing
	Major Group 20	Food And Kindred Products
	Major Group 21	Tobacco Products
	Major Group 22	Textile Mill Products
	Major Group 23	Apparel And Other Finished Products Made From Fabrics And Similar Materials
	Major Group 24	Lumber And Wood Products, Except Furniture
	Major Group 25	Furniture And Fixtures
	Major Group 26	Paper And Allied Products
	Major Group 27	Printing, Publishing, And Allied Industries
	Major Group 28	Chemicals And Allied Products
	Major Group 29	Petroleum Refining And Related Industries
	Major Group 30	Rubber And Miscellaneous Plastics Products
	Major Group 31	Leather And Leather Products
	Major Group 32	Stone, Clay, Glass, And Concrete Products
	Major Group 33	Primary Metal Industries
	Major Group 34	Fabricated Metal Products, Except Machinery And Transportation Equipment
	Major Group 35	Industrial And Commercial Machinery And Computer Equipment
	Major Group 36	Electronic And Other Electrical Equipment And Components, Except Computer

	Division/Group	Definition
		Equipment
	Major Group 37	Transportation Equipment
	Major Group 38	Measuring, Analyzing, And Controlling Instruments; Photographic, Medical And Optical Goods; Watches And Clocks
	Major Group 39	Miscellaneous Manufacturing Industries
E.	Division E	Transportation, Communications, Electric, Gas, And Sanitary Services
	Major Group 40	Railroad Transportation
	Major Group 41	Local And Suburban Transit And Interurban Highway Passenger Transportation
	Major Group 42	Motor Freight Transportation And Warehousing
	Major Group 43	United States Postal Service
	Major Group 44	Water Transportation
	Major Group 45	Transportation By Air
	Major Group 46	Pipelines, Except Natural Gas
	Major Group 47	Transportation Services
	Major Group 48	Communications
	Major Group 49	Electric, Gas, And Sanitary Services
F.	Division F	Wholesale Trade
	Major Group 50	Wholesale Trade-durable Goods
	Major Group 51	Wholesale Trade-non-durable Goods
G.	Division G	Retail Trade
	Major Group 52	Building Materials, Hardware, Garden Supply, And Mobile Home Dealers
	Major Group 53	General Merchandise Stores
	Major Group 54	Food Stores
	Major Group 55	Automotive Dealers And Gasoline Service Stations
	Major Group 56	Apparel And Accessory Stores
	Major Group 57	Home Furniture, Furnishings, And Equipment Stores
	Major Group 58	Eating And Drinking Places
	Major Group 59	Miscellaneous Retail
H.	Division H	Finance, Insurance, And Real Estate
	Major Group 60	Depository Institutions
	Major Group 61	Non-depository Credit Institutions
	Major Group 62	Security And Commodity Brokers, Dealers, Exchanges, And Services
	Major Group 63	Insurance Carriers
	Major Group 64	Insurance Agents, Brokers, And Service
	Major Group 65	Real Estate
	Major Group 67	Holding And Other Investment Offices
I.	Division I	Services
	Major Group 70	Hotels, Rooming Houses, Camps, And Other Lodging Places
	Major Group 72	Personal Services
	Major Group 73	Business Services
	Major Group 75	Automotive Repair, Services, And Parking
	Major Group 76	Miscellaneous Repair Services

	Division/Group	Definition
	Major Group 78	Motion Pictures
	Major Group 79	Amusement And Recreation Services
	Major Group 80	Health Services
	Major Group 81	Legal Services
	Major Group 82	Educational Services
	Major Group 83	Social Services
	Major Group 84	Museums, Art Galleries, And Botanical And Zoological Gardens
	Major Group 86	Membership Organizations
	Major Group 87	Engineering, Accounting, Research, Management, And Related Services
	Major Group 88	Private Households
	Major Group 89	Miscellaneous Services
J.	Division J	Public Administration
	Major Group 91	Executive, Legislative, And General Government, Except Finance
	Major Group 92	Justice, Public Order, And Safety
	Major Group 93	Public Finance, Taxation, And Monetary Policy
	Major Group 94	Administration Of Human Resource Programs
	Major Group 95	Administration Of Environmental Quality And Housing Programs
	Major Group 96	Administration Of Economic Programs
	Major Group 97	National Security And International Affairs
	Major Group 99	Non classifiable Establishments

*United States Department of Labor

*http://www.osha.gov/pls/imis/sic_manual.html

APPENDIX B. MANUFACTURING SIC CODE BREAKDOWN

Industry Description	SIC
Food & kindred products	2000
Meat products	2010
Meat packing plants	2011
Sausages & other prepared meat products	2013
Poultry slaughtering & processing	2015
Dairy products	2020
Creamery butter	2021
Natural, processed, & imitation cheese	2022
Dry, condensed, & evaporated dairy products	2023
Ice cream & frozen desserts	2024
Fluid milk	2026
Canned, frozen, & preserved fruits, vegetables, & food specialties	2030
Canned specialties	2032
Canned fruits, vegetables, preserves, jams, & jellies	2033
Dried & dehydrated fruits, vegetables, & soup mixes	2034
Pickled fruits & vegetables, vegetable sauces & seasonings, & salad dressings	2035
Frozen fruits, fruit juices, & vegetables 203	2037
Frozen specialties, n.e.c .*	2038
Grain mill products	2040
Flour & other grain mill products	2041
Cereal breakfast foods 204	2043
Rice milling	2044
Prepared flour mixes & doughs	2045
Wet corn milling	2046
Dog & cat food	2047
Prepared feeds & feed ingredients for animals & fowls, except dogs & cats	2048
Bakery products	2050
Bread & other bakery products, except cookies & crackers	2051
Cookies & crackers	2052
Frozen bakery products, except bread	2053
Sugar & confectionery products	2060
Cane sugar, except refining	2061
Cane sugar refining	2062

Industry Description	SIC
Beet sugar	2063
Candy & other confectionery products	2064
Chocolate & cocoa products	2066
Chewing gum	2067
Salted & roasted nuts & seeds	2068
Fats & oils	2070
Cottonseed oil mills	2074
Soybean oil mills	2075
Vegetable oil mills, except corn, cottonseed, & soybean	2076
Animal & marine fats & oils	2077
Shortening, table oils, margarine, & other edible fats & oils, n.e.c.*	2079
Beverages	2080
Malt beverages	2082
Malt	2083
Wines, brandy, & brandy spirits	2084
Distilled & blended liquors	2085
Bottled & canned soft drinks & carbonated waters	2086
Flavoring extracts & flavoring syrups, n.e.c .*	2087
Misc. food preparations & kindred products	2090
Canned & cured fish & seafoods	2091
Prepared fresh or frozen fish & seafoods	2092
Roasted coffee	2095
Potato chips, corn chips, & similar snacks	2096
Manufactured ice	2097
Macaroni, spaghetti, vermicelli, & noodles	2098
Food preparation, n.e.c .*	2099
Tobacco products	**2100**
Tobacco products	2110
Cigarettes	2111
Cigars	2121
Chewing & smoking tobacco & snuff	2131
Tobacco stemming & redrying	2141
Textile mill products	**2200**
Broadwoven fabric mills, cotton	2211
Broadwoven fabric mills, manmade fiber & silk	2221
Broadwoven fabric mills, wool (including dyeing & finishing)	2231
Narrow fabric & other smallwares mills: cotton, wool, silk, & manmade fiber	2241
Knitting mills	2250
Women's full-length & knee-length hosiery, except socks	2251
Hosiery, n.e.c .*	2252
Knit outerwear mills	2253
Knit underwear & nightwear mills	2254

Industry Description	SIC
Weft knit fabric mills	2257
Lace & warp knit fabric mills	2258
Knitting mills, n.e.c.*	2259
Dyeing & finishing textiles, except wool fabrics & knit goods	2260
Finishers of broadwoven fabrics of cotton	2261
Finishers of broadwoven fabrics of manmade fiber & silk	2262
Finishers of textiles, n.e.c .*	2269
Carpets & rugs	2273
Yarn & thread mills	2280
Yarn spinning mills	2281
Yarn texturizing, throwing, twisting, & winding mills	2282
Thread mills	2284
Misc. textile goods	2290
Coated fabrics, not rubberized	2295
Tire cord & fabrics	2296
Nonwoven fabrics	2297
Cordage & twine	2298
Textile goods, n.e.c.*	2299
Apparel & other finished products made from fabrics & similar materials	**2300**
Men's & boys' suits, coats, & overcoats	2311
Men's & boys' furnishing, work clothing, & allied garments	2320
Men's & boys' shirts, except work shirts	2321
Men's & boys' underwear & nightwear	2322
Men's & boys' neckwear	2323
Men's & boys' separate trousers & slacks	2325
Men's & boys' work clothing	2326
Men's & boys' clothing, n.e.c.*	2329
Women's, misses', & juniors' outerwear	2330
Women's, misses', & juniors' blouses & shirts	2331
Women's, misses', & juniors' dresses	2335
Women's, misses', & juniors' suits, skirts, & coats	2337
Women's, misses', & juniors' outerwear, n.e.c .*	2339
Women's, misses', children's, & infants' undergarments	2340
Women's, misses', children's, & infants' underwear & nightwear	2341
Bras, girdles, & allied garments	2342
Hats, caps, & millinery	2353
Girls', children's, & infants' outerwear	2360
Girls', children's, & infants' dresses, blouses, & shirts	2361
Girls', children's, & infants' outerwear, n.e.c.*	2369
Fur goods	2371
Misc. apparel & accessories	2380
Dress & work gloves, except knit & all-leather	2381

Industry Description	SIC
Robes & dressing gowns	2384
Waterproof outerwear	2385
Leather & sheep-lined clothing	2386
Apparel belts	2387
Apparel & accessories, n.e.c .*	2389
Misc. fabricated textile products	2390
Curtains & draperies	2391
House furnishings, except curtains & draperies	2392
Textile bags	2393
Canvas & related products	2394
Pleating, decorative & novelty stitching, & tucking for the trade	2395
Automotive trimmings, apparel findings, & related products	2396
Schiffli machine embroideries	2397
Fabricated textile products, n.e.c .*	2399
Lumber & wood products, except furniture	**2400**
Logging	2411
Sawmills & planning mills	2420
Sawmills & planning mills, general	2421
Hardwood dimension & flooring mills	2426
Special product sawmills, n.e.c.*	2429
Millwork, veneer, plywood, & structural wood members	2430
Millwork	2431
Wood kitchen cabinets	2434
Hardwood veneer & plywood	2435
Softwood veneer & plywood	2436
Structural wood members, n.e.c.*	2439
Wood containers	2440
Nailed & lock corner wood boxes & shook	2441
Wood pallets & skids	2448
Wood containers, n.e.c .*	2449
Wood buildings & mobile homes	2450
Mobile homes	2451
Prefabricated wood bldgs. & components	2452
Misc. wood products	2490
Wood preserving	2491
Reconstituted wood products	2493
Wood products, n.e.c .*	2499
Furniture & fixtures	**2500**
Household furniture	2510
Wood household furniture, except upholstered	2511
Wood household furniture, upholstered	2512
Metal household furniture	2514

Industry Description	SIC
Mattresses, foundations, & convertible beds	2515
Wood television, radio, phonograph, & sewing machine cabinets	2517
Household furniture, n.e.c .*	2519
Office furniture	2520
Wood office furniture	2521
Office furniture, except wood	2522
Public bldg. & related furniture	2531
Partitions, shelving, lockers, & office & store fixtures	2540
Wood office & store fixtures, partitions, shelving, & lockers	2541
Office & store fixtures, partitions, shelving, & lockers, except wood	2542
Misc. furniture & fixtures	2590
Drapery hardware & window blinds & shades	2591
Furniture & fixtures, n.e.c .*	2599
Paper & allied products	**2600**
Pulp mills	2611
Paper mills	2621
Paperboard mills	2631
Paperboard containers & boxes	2650
Setup paperboard boxes	2652
Corrugated & solid fiber boxes	2653
Fiber cans, tubes, drums, & similar products	2655
Sanitary food containers, except folding	2656
Folding paperboard boxes, including sanitary	2657
Converted paper & paperboard products, except containers & boxes	2670
Packaging paper & plastics film, coated & laminated	2671
Coated & laminated paper, n.e.c.*	2672
Plastics, foil, & coated paper bags	2673
Uncoated paper & multiwall bags	2674
Die-cut paper & paperboard & cardboard	2675
Sanitary paper products	2676
Envelopes	2677
Stationery, tablets, & related products	2678
Converted paper & paperboard products, n.e.c .*	2679
Printing, publishing, & allied industries	**2700**
Newspapers: publishing, or publishing & printing	2711
Periodicals: publishing, or publishing & printing	2721
Books	2730
Books: publishing, or publishing & printing	2731
Book printing	2732
Misc. printing	2741
Commercial printing	2750
Commercial printing, lithographi	2752

Industry Description	SIC
Commercial printing, gravure	2754
Commercial printing, n.e.c.*	2759
Manifold business forms	2761
Greeting cards	2771
Blankbooks, loose-leaf binders, & bookbinding & related work	2780
Blankbooks, loose-leaf binders & devices	2782
Bookbinding & related work	2789
Service industries for the printing trade	2790
Typesetting	2791
Plate making & related services	2796
Chemicals & allied products	**2800**
Industrial inorganic chemicals	2810
Alkalies & chlorine	2812
Industrial gases	2813
Inorganic pigments	2816
Industrial inorganic chemicals, n.e.c .*	2819
Plastics materials & synthetic resins, synthetic rubber, cellulosic & other manmade fibers, except glass	2820
Plastics, materials, synthetic resins, & nonvulcanizable elastomers	2821
Synthetic rubber (vulcanizable elastomers)	2822
Cellulosic manmade fibers	2823
Manmade organic fibers, except cellulosic	2824
Drugs	2830
Medicinal chemicals & botanical products	2833
Pharmaceutical preparations	2834
In vitro & in vitro diagnostic substances	2835
Biological products, except diagnostic substances	2836
Soap, detergents, & cleaning preparations; perfumes, cosmetics, & other toilet preparations	2840
Soap & other detergents, except specialty cleaners	2841
Specialty cleaning, polishing, & sanitation preparations	2842
Surface active agents, finishing agents, sulfonated oils, & assistants	2843
Perfumes, cosmetics, & other toilet preparations	2844
Paints, varnishes, lacquers, enamels, & allied products	2851
Industrial organic chemicals	2860
Gum & wood chemicals	2861
Cyclic organic crudes & intermediates, & organic dyes & pigments	2865
Industrial organic chemicals, n.e.c.*	2869
Agricultural chemicals	2870
Nitrogenous fertilizers	2873
Phosphatic fertilizers	2874
Fertilizers, mixing only	2875
Pesticides & agricultural chemicals, n.e.c .*	2879
Misc. chemical products	2890

Industry Description	SIC
Adhesives & sealants	2891
Explosives	2892
Printing ink	2893
Carbon black	2895
Chemicals & chemical preparations, n.e.c .*	2899
Petroleum refining & related industries	**2910**
Petroleum refining	2911
Asphalt paving & roofing materials	2950
Asphalt paving mixtures & blocks	2951
Asphalt felts & coatings	2952
Misc. products of petroleum & coal	2990
Lubricating oils & greases	2992
Products of petroleum & coal, n.e.c.*	2999
Rubber & misc. plastics products	**3000**
Tires & inner tubes	3011
Rubber & plastics footwear	3021
Gaskets, packing, & sealing devices & rubber & plastic hose & belting	3050
Rubber & plastics hose & belting	3052
Gaskets, packing, & sealing devices	3053
Fabricated rubber products, n.e.c.*	3060
Molded, extruded, & lathe-cut mechanical rubber goods	3061
Fabricated rubber products, n.e.c .*	3069
Misc. plastics products	3080
Unsupported plastics film & sheet	3081
Unsupported plastics profile shapes	3082
Laminated plastics plate, sheet, & profile shapes	3083
Plastics pipe	3084
Plastics bottles	3085
Plastics foam products	3086
Custom compounding of purchased plastics resins	3087
Plastics plumbing fixtures	3088
Plastics products, n.e.c.*	3089
Leather & leather products	**3100**
Leather tanning & finishing	3111
Boot & shoe cut stock & findings	3131
Footwear, except rubber	3140
House slippers	3142
Men's footwear, except athletic	3143
Women's footwear, except athletic	3144
Footwear, except rubber, n.e.c.*	3149
Leather gloves & mittens	3151
Luggage	3161

Industry Description	SIC
Handbags & other personal leather goods	3170
Women's handbags & purses	3171
Personal leather goods, except women's handbags & purses	3172
Leather goods, n.e.c.*	3199
Stone, clay, glass, & concrete products	**3200**
Flat glass	3211
Glass & glassware, pressed or blown	3230
Glass containers	3221
Pressed & blown glass & glassware, n.e.c .*	3229
Glass products, made of purchased glass	3231
Cement, hydraulic	3241
Structural clay products	3250
Brick & structural clay tile	3251
Ceramic wall & floor tile	3253
Clay refractories	3255
Structural clay products, n.e.c.*	3259
Pottery & related products	3260
Vitreous china plumbing fixtures & china & earthenware fittings & bathroom accessories	3261
Vitreous china table & kitchen articles	3262
Fine earthenware (whiteware) table & kitchen articles	3263
Porcelain electrical supplies	3264
Pottery products, n.e.c.*	3269
Concrete, gypsum, & plaster products	3270
Concrete block & brick	3271
Concrete products, except block & brick	3272
Ready-mixed concrete	3273
Lime	3274
Gypsum products	3275
Cut stone & stone products	3281
Abrasive, asbestos, & misc. nonmettalic mineral products	3290
Abrasive products	3291
Asbestos products	3292
Minerals & earths, ground or otherwise treated	3295
Mineral wool	3296
Nonclay refractories	3297
Nonmetallic mineral products, n.e.c.*	3299
Primary metal industries	**3300**
Steel works, blast furnaces, & rolling & finishing mills	3310
Steel works, blast furnaces (including coke ovens), & rolling mills	3312
Electrometallurgical products, except steel	3313
Steel wiredrawing & steel nails & spikes	3315
Cold-rolled steel sheet, strip, & bars	3316

Industry Description	SIC
Steel pipe & tubes	3317
Iron & steel foundries	3320
Gray & ductile iron foundries	3321
Malleable iron foundries	3322
Steel investment foundries	3324
Steel foundries, n.e.c .*	3325
Primary smelting & refining of nonferrous metals	3330
Primary smelting & refining of copper	3331
Primary production of aluminum	3334
Primary smelting & refining of nonferrous metals, except copper & aluminum	3339
Secondary smelting & refining of nonferrous metals	3341
Rolling, drawing, & extruding of nonferrous metals	3350
Rolling, drawing, & extruding of copper	3351
Aluminum sheet, plate, & foil	3353
Aluminum extruded products	3354
Aluminum rolling & drawing, n.e.c .*	3355
Rolling, drawing, & extruding of nonferrous metals, except coppery & aluminum	3356
Drawing & insulating of nonferrous wire	3357
Nonferrous foundries (castings)	3360
Aluminum die-castings	3363
Nonferrous die-castings, except aluminum	3364
Aluminum foundries	3365
Copper foundries	3366
Nonferrous foundries, except aluminum & copper	3369
Misc. primary metal products	3390
Metal heat treating	3398
Primary metal products, n.e.c.*	3399
Fabricated metal products, except machinery & transportation equipment	**3400**
Metal cans & shipping containers	3410
Metal cans	3411
Metal shipping barrels, drums, kegs, & pails	3412
Cutlery, handtools, & general hardware	3420
Cutlery	3421
Hand & edge tools, except machine tools & handsaws	3423
Saw blades & handsaws	3425
Hardware, n.e.c .*	3429
Heating equipment, except electric & warm air; & plumbing fixtures	3430
Enameled iron & metal sanitary ware	3431
Plumbing fixture fittings & trim	3432
Heating equipment, except electric & warm air furnaces	3433
Fabricated structural metal products	3440
Fabricated structural metal	3441

Industry Description	SIC
Metal doors, sash, frames, molding, & trim	3442
Fabricated plate work (boiler shops)	3443
Sheet metal work	3444
Architectural & ornamental metal work	3446
Prefabricated metal bldgs. & components	3448
Misc. structural metal work	3449
Screw machine products, & bolts, nuts, screws, rivets, & washers	3450
Screw machine products	3451
Bolts, nuts, screws, rivets, & washers	3452
Metal forgings & stampings	3460
Iron & steel forgings	3462
Nonferrous forgings	3463
Automotive stampings	3465
Crowns & closures	3466
Metal stampings, n.e.c.*	3469
Coating, engraving, & allied services	3470
Electroplating, plating, polishing, anodizing, & coloring	3471
Coating, engraving, & allied services, n.e.c.*	3479
Ordnance & accessories, except vehicles & guided missiles	3480
Small arms ammunition	3482
Ammunition, except for small arms	3483
Small arms	3484
Ordnance & accessories, n.e.c .*	3489
Misc. fabricated metal products	3490
Industrial valves	3491
Fluid power valves & hose fittings	3492
Steel springs, except wire	3493
Valves & pipe fittings, n.e.c .*	3494
Wire springs	3495
Misc. fabricated wire products	3496
Metal foil & leaf	3497
Fabricated pipe & pipe fittings	3498
Fabricated metal products, n.e.c .*	3499
Industrial & commercial machinery & computer equipment	**3500**
Engines & turbines	3510
Steam, gas, & hydraulic turbines, & turbine generator set units	3511
Internal combustion engines, n.e.c.*	3519
Farm & garden machinery & equipment	3520
Farm machinery & equipment	3523
Lawn & garden tractors & home lawn & garden equipment	3524
Construction, mining, & materials handling machinery & equipment	3530
Construction machinery & equipment	3531

Industry Description	SIC
Mining machinery & equipment, except oil & gas field machinery & equipment	3532
Oil & gas field machinery & equipment	3533
Elevators & moving stairways	3534
Conveyors & conveying equipment	3535
Overhead traveling cranes, hoists, & monorail systems	3536
Industrial trucks, tractors, trailers, & stackers	3537
Metalworking machinery & equipment	3540
Machine tools, metal cutting types	3541
Machine tools, metal forming types	3542
Industrial patterns	3543
Special dyes & tools, die sets, jigs & fixtures, & industrial molds	3544
Cutting tools, machine tool accessories, & machinists' precision measuring devices	3545
Power-driven handtools	3546
Rolling mill machinery & equipment	3547
Electric & gas welding & soldering equipment	3548
Metalworking machinery, n.e.c .*	3549
Special industry machinery, except metalworking machinery	3550
Textile machinery	3552
Woodworking machinery	3553
Paper industries machinery	3554
Printing trades machinery & equipment	3555
Food products machinery	3556
Special industry machinery, n.e.c.*	3559
General industrial machinery & equipment	3560
Pumps & pumping equipment	3561
Ball & roller bearings	3562
Air & gas compressors	3563
Industrial & commercial fans & blowers & air purification	3564
Packaging machinery	3565
Speed changers, industrial high-speed drives, & gears	3566
Industrial process furnaces & ovens	3567
Mechanical power transmission equipment, n.e.c.*	3568
General industrial machinery & equipment, n.e.c.*	3569
Computer & office equipment	3570
Electronic computers	3571
Computer storage devices	3572
Computer terminals	3575
Computer peripheral equipment, n.e.c.*	3577
Calculating & accounting machines, except electronic computers	3578
Office machines, n.e.c.*	3579
Refrigeration & service industry machinery	3580
Automatic vending machines	3581

Industry Description	SIC
Commercial laundry, drycleaning, & pressing machines	3582
Air-conditioning & warm air heating equipment & commercial & industrial refrigeration equipment	3585
Measuring & dispensing pumps	3586
Service industry machinery, n.e.c .*	3589
Misc. industrial & commercial machinery & equipment	3590
Carburetors, pistons, piston rings, & valves	3592
Fluid power cylinders & actuators	3593
Fluid power pumps & motors	3594
Scales & balances, except laboratory	3596
Industrial & commercial machinery & equipment, n.e.c.*	3599
Electronic & other electrical equipment & components, except computer equipment	**3600**
Electric transmission & distribution equipment	3610
Power, distribution, & specialty transformers	3612
Switchgear & switchboard apparatus	3613
Electrical industrial apparatus	3620
Motors & generators	3621
Carbon & graphite products	3624
Relays & industrial controls	3625
Electrical industrial apparatus, n.e.c .*	3629
Household appliances	3630
Household cooking equipment	3631
Household refrigerators & home & farm freezers	3632
Household laundry equipment	3633
Electric housewares & fans	3634
Household vacuum cleaners	3635
Household appliances, n.e.c .*	3639
Electric lighting & wiring equipment	3640
Electric lamp bulbs & tubes	3641
Current-carrying wiring devices	3643
Noncurrent-carrying wiring devices	3644
Residential electric lighting fixtures	3645
Commercial, industrial, & institutional electric lighting fixtures	3646
Vehicular lighting equipment	3647
Lighting equipment, n.e.c.*	3648
Household audio & video equipment, & audio recordings	3650
Household audio & video equipment	3651
Phonograph records & prerecorded audio tapes & disks	3652
Communications equipment	3660
Telephone & telegraph apparatus	3661
Radio & TV broadcasting & communications equipment	3663
Communications equipment, n.e.c.*	3669
Electronic components & accessories	3670

Industry Description	SIC
Electron tubes	3671
Printed circuit boards	3672
Semiconductors & related devices	3674
Electronic capacitors	3675
Electronic resistors	3676
Electronic coils, transformers, & other inductors	3677
Electronic connectors	3678
Electronic components, n.e.c .*	3679
Misc. electrical machinery, equipment, & supplies	3690
Storage batteries	3691
Primary batteries, dry & wet	3692
Electrical equipment for internal combustion engines	3694
Magnetic & optical recording media	3695
Electrical machinery, equipment, & supplies, n.e.c .*	3699
Transportation equipment	**3700**
Motor vehicles & motor vehicles equipment	3710
Motor vehicles & passenger car bodies	3711
Truck & bus bodies	3713
Motor vehicle parts & accessories	3714
Truck trailers	3715
Motor homes	3716
Aircraft & parts	3720
Aircraft	3721
Aircraft engines & engine parts	3724
Aircraft parts & auxiliary equipment, n.e.c.*	3728
Ship & boat bldg. & repairing	3730
Ship building & repairing	3731
Boat building & repairing	3732
Railroad equipment	3743
Motorcycles, bicycles, & parts	3751
Guided missiles & space vehicles & parts	3760
Guided missiles & space vehicles	3761
Guided missile & space vehicle propulsion units & propulsion unit parts	3764
Guided missile & space vehicle parts & auxiliary equipment, n.e.c.*	3769
Misc. transportation equipment	3790
Travel trailers & campers	3792
Tanks & tank components	3795
Transportation equipment, n.e.c.*	3799
Measuring, analyzing, & controlling instruments; photographic, medical & optical goods; watches & clocks	**3800**
Search, detection, navigation, guidance, aeronautical, & nautical systems, instruments, & equipment	3812
Laboratory apparatus & analytical, optical, measuring, & controlling instruments	3820

Industry Description	SIC
Laboratory apparatus & furniture	3821
Automatic controls for regulating residential & commercial environments & appliances	3822
Industrial instruments for measurement, display, & control of process variables; & related products	3823
Totalizing fluid meters & counting devices	3824
Instruments for measuring & testing of electricity & electrical signals	3825
Laboratory analytical instruments	3826
Optical instruments & lenses	3827
Measuring & controlling devices, n.e.c.*	3829
Surgical, medical, & dental instruments & supplies	3840
Surgical & medical instruments & apparatus	3841
Orthopedic, prosthetic, & surgical appliances & supplies	3842
Dental equipment & supplies	3843
X-ray apparatus & tubes & related irradiation apparatus	3844
Electromedical & electrotherapeutic apparatus	3845
Ophthalmic goods	3851
Photographic equipment & supplies	3861
Watches, clocks, clockwork operated devices, & parts	3873
Misc. manufacturing industries	**3900**
Jewelry, silverware, & plated ware	3910
Jewelry, precious metal	3911
Silverware, plated ware, & stainless steel ware	3914
Jewelers' findings & materials, & lapidary work	3915
Musical instruments	3930
Musical instruments	3931
Dolls, toys, games & sporting & athletic goods	3940
Dolls & stuffed toys	3942
Games, toys, & children's vehicles, except dolls & bicycles	3944
Sporting & athletic goods, n.e.c.*	3949
Pens, pencils, & other artists' materials	3950
Pens, mechanical pencils, & parts	3951
Lead pencils, crayons, & artists' materials	3952
Marking devices	3953
Carbon paper & inked ribbons	3955
Costume jewelry, costume novelties, buttons, & misc. notions, except precious metal	3960
Costume jewelry & costume novelties, except precious metal	3961
Fasteners, buttons, needles, & pins	3965
Misc. manufacturing industries	3990
Brooms & brushes	3991
Signs & advertising specialties	3993
Burial caskets	3995
Linoleum, asphalted-felt-base, & other hard surface floor coverings, n.e.c .*	3996
Manufacturing industries, n.e.c .*	3999

Industry Description	SIC

*** “n.e.c.” = not elsewhere classified**

APPENDIX C. COMPANIES INCLUDED IN STUDY

Global Company Key	Name	SIC
1013	ADC TELECOMMUNICATIONS INC	3661
1034	ALPHARMA INC -CL A	2834
1072	AVX CORP	3670
1078	ABBOTT LABORATORIES	2834
1161	ADVANCED MICRO DEVICES	3674
1209	AIR PRODUCTS & CHEMICALS INC	2810
1239	ALBERTO-CULVER CO	2844
1300	HONEYWELL INTERNATIONAL INC	3728
1356	ALCOA INC	3350
1380	HESS CORP	2911
1408	FORTUNE BRANDS INC	3490
1429	AMERICAN CRYSTAL SUGAR CO	2060
1478	WYETH	2834
1567	TRANE INC	3585
1593	AMERON INTERNATIONAL CORP	3270
1598	AMETEK INC	3823
1602	AMGEN INC	2836
1632	ANALOG DEVICES	3674
1651	ANDREW CORP	3357
1663	ANHEUSER-BUSCH COS INC	2082
1690	APPLE INC	3571
1704	APPLIED MATERIALS INC	3559
1706	ACTUANT CORP -CL A	3640
1722	ARCHER-DANIELS-MIDLAND CO	2070
1913	AVERY DENNISON CORP	2670
1932	BAT-BRITISH AMER TOBACCO PLC	2111
1976	BAKER HUGHES INC	3533
1981	BALDOR ELECTRIC CO	3621
1988	BALL CORP	3411
2044	BARD (C.R.) INC	3841
2086	BAXTER INTERNATIONAL INC	2836
2111	BECTON DICKINSON & CO	3841

Global Company Key	Name	SIC
2154	BEMIS CO INC	2670
2220	BIO-RAD LABORATORIES INC	3826
2255	BLACK & DECKER CORP	3540
2285	BOEING CO	3721
2337	ABITIBIBOWATER INC	2621
2346	BOWNE & CO INC	2750
2352	BRADY CORP	3990
2393	BRIGGS & STRATTON	3510
2403	BRISTOL-MYERS SQUIBB CO	2834
2410	BP PLC	2911
2435	BROWN-FORMAN -CL B	2085
2436	BROWN SHOE CO INC	3140
2577	CTS CORP	3679
2593	CABOT CORP	2890
2663	CAMPBELL SOUP CO	2030
2710	CONSTELLATION BRANDS	2084
2721	CANON INC	3577
2787	CARPENTER TECHNOLOGY CORP	3312
2817	CATERPILLAR INC	3531
2916	CHAMPION ENTERPRISES INC	2451
2953	CHECKPOINT SYSTEMS INC	3669
2982	CHESAPEAKE CORP	2631
2991	CHEVRON CORP	2911
3026	CHURCH & DWIGHT INC	2840
3041	MILACRON INC	3559
3062	CINTAS CORP	2320
3093	CLARCOR INC	3564
3121	CLOROX CO/DE	2842
3126	COACHMEN INDUSTRIES INC	2452
3138	COCA-COLA BTLNG CONS	2086
3144	COCA-COLA CO	2080
3170	COLGATE-PALMOLIVE CO	2844
3246	COMMERCIAL METALS	3312
3362	CONAGRA FOODS INC	2000
3497	COOPER INDUSTRIES LTD	3640
3505	MOLSON COORS BREWING CO	2082
3532	CORNING INC	3679
3580	CRANE CO	3490
3607	CHEMTURA CORPORATION	2820
3619	CROWN HOLDINGS INC	3411
3639	CUBIC CORP	3812
3650	CUMMINS INC	3510

Global Company Key	Name	SIC
3734	DANA HOLDING CORP	3714
3735	DANAHER CORP	3823
3863	DELUXE CORP	2780
3918	DRS TECHNOLOGIES INC	3812
3946	DIEBOLD INC	3578
4036	DONALDSON CO INC	3564
4040	DONNELLEY (R R) & SONS CO	2750
4060	DOW CHEMICAL	2821
4087	DU PONT (E I) DE NEMOURS	2820
4108	FLOWSERVE CORP	3561
4145	PERKINELMER INC	3826
4194	EASTMAN KODAK CO	3861
4199	EATON CORP	3714
4213	ECOLAB INC	2842
4321	EMERSON ELECTRIC CO	3600
4439	ERICSSON (LM) TELEFON	3663
4462	NEWMARKET CORP	2860
4503	EXXON MOBIL CORP	2911
4510	FMC CORP	2800
4600	FEDERAL-MOGUL CORP	3714
4768	FLEETWOOD ENTERPRISES INC	3716
4802	FLORIDA ROCK INDUSTRIES INC	3270
4809	FLOWERS FOODS INC	2050
4843	FOREST LABORATORIES -CL A	2834
4926	FULLER (H. B.) CO	2891
4988	GANNETT CO	2711
5020	GENENTECH INC	2834
5071	GENERAL MILLS INC	2040
5142	GERBER SCIENTIFIC INC	3559
5180	GLAXOSMITHKLINE PLC	2834
5229	GOODRICH CORP	3728
5234	GOODYEAR TIRE & RUBBER CO	3011
5250	GRACE (W R) & CO	2810
5252	GRACO INC	3561
5338	GREIF INC -CL A	2650
5492	HARRIS CORP	3663
5496	HARSCO CORP	3390
5505	HARTMARX CORP	2300
5518	HASBRO INC	3944
5568	HEINZ (H J) CO	2030
5589	HERCULES INC	2890
5597	HERSHEY CO	2060

Global Company Key	Name	SIC
5606	HEWLETT-PACKARD CO	3570
5608	HEXCEL CORP	2821
5650	HITACHI LTD	3570
5690	HNI CORP	2522
5709	HORMEL FOODS CORP	2011
5764	HUBBELL INC -CL B	3640
5824	PEPSIAMERICAS INC	2086
5860	ITT CORP	3812
5878	ILLINOIS TOOL WORKS	3540
5980	TERRA INDUSTRIES INC	2870
5987	GRIFFON CORP	3442
6008	INTEL CORP	3674
6025	FURNITURE BRANDS INTL INC	2510
6078	INTL FLAVORS & FRAGRANCES	2860
6081	NAVISTAR INTERNATIONAL CORP	3711
6097	INTL GAME TECHNOLOGY	3990
6104	INTL PAPER CO	2600
6109	INTL RECTIFIER CORP	3674
6140	INTERSTATE BAKERIES CORP	2050
6158	INVACARE CORP	3842
6242	SMURFIT-STONE CONTAINER CORP	2631
6266	JOHNSON & JOHNSON	2834
6268	JOHNSON CONTROLS INC	2531
6304	KLA-TENCOR CORP	3827
6375	KELLOGG CO	2040
6386	KENNAMETAL INC	3540
6433	KIMBALL INTERNATIONAL -CL B	3679
6435	KIMBERLY-CLARK CORP	2621
6529	LSI CORP	3674
6543	LA-Z-BOY INC	2510
6565	LAM RESEARCH CORP	3559
6573	LANCASTER COLONY CORP	2030
6574	LANCE INC	2052
6639	LEE ENTERPRISES INC	2711
6649	LEGGETT & PLATT INC	2510
6730	LILLY (ELI) & CO	2834
6737	LINCOLN ELECTRIC HLDGS INC	3540
6768	LIZ CLAIBORNE INC	2330
6774	LOCKHEED MARTIN CORP	3760
6821	LOUISIANA-PACIFIC CORP	2400
6830	LUBRIZOL CORP	2990
6946	MAGNA INTERNATIONAL -CL A	3714

Global Company Key	Name	SIC
6994	MANITOWOC CO	3530
7017	MARATHON OIL CORP	2911
7116	MATTEL INC	3942
7146	MCCORMICK & COMPANY INC	2090
7152	MCDERMOTT INTL INC	3730
7203	MEDIA GENERAL -CL A	2711
7228	MEDTRONIC INC	3845
7260	MEREDITH CORP	2721
7343	MICRON TECHNOLOGY INC	3674
7401	MILLER (HERMAN) INC	2520
7409	MILLIPORE CORP	3826
7420	MINE SAFETY APPLIANCES CO	3842
7435	3M CO	2670
7486	MODINE MANUFACTURING CO	3714
7506	MOLEX INC	3678
7549	MOOG INC -CL A	3728
7585	MOTOROLA INC	3663
7620	MURPHY OIL CORP	2911
7637	MYLAN INC	2834
7772	NATIONAL SEMICONDUCTOR CORP	3674
7798	NBTY INC	2834
7906	NIKE INC	3021
7921	NORDSON CORP	3569
7938	NACCO INDUSTRIES -CL A	3537
7980	NORTEL NETWORKS CORP	3661
7985	NORTHROP GRUMMAN CORP	3812
7991	TEREX CORP	3531
8009	NOVA CHEMICALS CORP	2860
8030	NUCOR CORP	3312
8215	OWENS-ILLINOIS INC	3221
8247	PPG INDUSTRIES INC	2851
8304	PALL CORP	3569
8463	PENTAIR INC	3561
8488	APPLIED BIOSYSTEMS INC	2835
8546	PHILIPS ELECTRONICS (KON) NV	3600
8549	CONOCOPHILLIPS	2911
8551	PHILLIPS-VAN HEUSEN CORP	2300
8582	SENECA FOODS CORP -CL B	2033
8606	PITNEY BOWES INC	3579
8692	POTLATCH CORP	2421
8762	PROCTER & GAMBLE CO	2840
8859	QUANEX CORP	3312

Global Company Key	Name	SIC
8867	QUANTUM CORP	3572
8902	RPM INTERNATIONAL INC	2890
8972	RAYTHEON CO	3812
9016	REGAL-BELOIT CORP	3621
9135	RICOH CO LTD	3861
9173	ROBBINS & MYERS INC	3443
9203	ROCKWELL AUTOMATION	3620
9217	ROHM AND HAAS CO	2821
9340	VALEANT PHARMACEUTICALS INTL	2834
9372	ST JUDE MEDICAL INC	3845
9459	SCHERING-PLOUGH	2834
9466	SCHOLASTIC CORP	2731
9472	SCHULMAN (A.) INC	2821
9555	SEALED AIR CORP	2670
9667	SHERWIN-WILLIAMS CO	2851
9699	SIGMA-ALDRICH CORP	2836
9771	SMITH (A O) CORP	3630
9772	SMITH INTERNATIONAL INC	2890
9778	SNAP-ON INC	3420
9815	SONOCO PRODUCTS CO	2650
9818	SONY CORP	3651
9921	SPARTECH CORP	3080
10000	STANDARD MOTOR PRODS	3690
10005	STANDARD REGISTER CO	2761
10016	STANLEY WORKS	3420
10056	STEPAN CO	2840
10115	STRYKER CORP	3842
10156	SUNOCO INC	2911
10195	SUPERIOR INDUSTRIES INTL	3714
10275	TDK CORP	3679
10405	ALLEGHENY TECHNOLOGIES INC	3312
10407	TELEFLEX INC	3841
10420	TELLABS INC	3661
10443	TENNECO INC	3714
10453	TERADYNE INC	3825
10466	TESORO CORP	2911
10498	TEXAS INDUSTRIES INC	3241
10499	TEXAS INSTRUMENTS INC	3674
10540	THOMAS & BETTS CORP	3640
10549	THOR INDUSTRIES INC	3790
10553	3COM CORP	3576
10581	TIMKEN CO	3562

Global Company Key	Name	SIC
10618	TORO CO	3523
10622	TOSHIBA CORP	3600
10793	TYSON FOODS INC -CL A	2011
10816	USG CORP	3270
10839	UNIFI INC	2200
10840	UNIFIRST CORP	2300
10857	UNION CARBIDE CORP	2860
10974	UST INC	2100
10983	UNITED TECHNOLOGIES CORP	3720
10991	SCIENTIFIC GAMES CORP	3570
11012	SENSIENT TECHNOLOGIES CORP	2860
11060	VF CORP	2300
11094	VALMONT INDUSTRIES INC	3440
11096	VALSPAR CORP	2851
11115	VARIAN MEDICAL SYSTEMS INC	3845
11191	VISHAY INTERTECHNOLOGY INC	3670
11217	VOLVO AB	3711
11257	FRONTIER OIL CORP	2911
11300	WASHINGTON POST -CL B	2711
11315	WAUSAU PAPER CORP	2621
11376	WEST PHARMACEUTICAL SVSC INC	3060
11399	WESTERN DIGITAL CORP	3572
11446	MEADWESTVACO CORP	2631
11465	WHIRLPOOL CORP	3630
11499	WILEY (JOHN) & SONS -CL A	2721
11537	WINNEBAGO INDUSTRIES	3716
11566	WOLVERINE WORLD WIDE	3140
11580	WOODWARD GOVERNOR CO	3620
11600	WORTHINGTON INDUSTRIES	3310
11609	WRIGLEY (WM) JR CO	2060
11636	XEROX CORP	3577
11721	OSHKOSH CORP	3711
11749	SKF AB	3562
12053	EMC CORP/MA	3572
12136	SUN MICROSYSTEMS INC	3571
12215	CYPRESS SEMICONDUCTOR CORP	3674
12216	LINEAR TECHNOLOGY CORP	3674
12233	GENZYME CORP	2836
12262	ASTEC INDUSTRIES INC	3531
12379	AMERICAN WOODMARK CORP	2430
12384	ROYAL DUTCH SHELL PLC	2911
12389	HARLEY-DAVIDSON INC	3751

Global Company Key	Name	SIC
12445	WATTS WATER TECHNOLOGIES INC	3490
12478	JOURNAL COMMUNICATIONS INC	2711
12578	VALHI INC	2810
12756	COCA-COLA ENTERPRISES INC	2086
12785	PILGRIM'S PRIDE CORP	2015
12788	HARMAN INTERNATIONAL INDS	3651
12868	QUIKSILVER INC	2320
12895	GEORGIA GULF CORP	2810
12945	PLEXUS CORP	3672
13003	JOY GLOBAL INC	3532
13323	SANDERSON FARMS INC	2015
13365	BARR PHARMACEUTICALS INC	2834
13407	WELLMAN INC	2820
13554	TIMBERLAND CO -CL A	3140
13623	CONMED CORP	3845
13634	EXIDE TECHNOLOGIES	3690
13700	DENTSPLY INTERNATL INC	3843
13971	METHANEX CORP	2860
13990	WARNACO GROUP INC	2300
14049	GERDAU AMERISTEEL CORP	3312
14163	MCCLATCHY CO -CL A	2711
14256	MAXIM INTEGRATED PRODUCTS	3674
14282	AMPHENOL CORP	3678
14311	POLARIS INDUSTRIES INC	3790
14324	ALTERA CORP	3674
14385	RESPIRONICS INC	3842
14450	WOLVERINE TUBE INC	3350
14489	DELL INC	3571
14503	IMPERIAL SUGAR CO	2060
14555	KINETIC CONCEPTS INC	2836
14620	ELECTROLUX AB	3630
14623	NOVELLUS SYSTEMS INC	3559
15106	BECKMAN COULTER INC	3826
15247	VALERO ENERGY CORP	2911
15267	IDEX CORP	3561
15334	AKZO NOBEL NV	2851
15343	MUELLER INDUSTRIES	3350
15406	BENETTON GROUP SPA	2330
15459	TREDEGAR CORP	3081
15704	THOMSON-REUTERS CORP (CDN)	2731
15708	ALLERGAN INC	2834
15709	PLUM CREEK TIMBER CO INC	2400

Global Company Key	Name	SIC
16476	LEVI STRAUSS & CO	2300
16477	LEAR CORP	2531
16582	POTASH CORP SASK INC	2870
17420	ATLAS COPCO AB	3560
17436	BASF SE	2800
17828	DAIMLER AG	3711
20185	SCOTTS MIRACLE-GRO CO	2870
20196	LUXOTTICA GROUP SPA	3851
20338	COTT CORP QUE	2086
20779	CISCO SYSTEMS INC	3576
21496	ORBITAL SCIENCES CORP	3760
22049	DOREL INDUSTRIES INC	2511
22325	XILINX INC	3674
22815	TRIMBLE NAVIGATION LTD	3829
23084	BENCHMARK ELECTRONICS INC	3672
23220	ALLIANT TECHSYSTEMS INC	3480
23252	ETHAN ALLEN INTERIORS INC	2511
23671	NOKIA (AB) OY	3663
23767	ATMEL CORP	3674
23945	CEPHALON INC	2834
23978	UNITED STATES STEEL CORP	3312
24283	DEL MONTE FOODS CO	2000
24405	ZEBRA TECHNOLOGIES CP -CL A	3560
24463	NATIONAL BEVERAGE CORP	2086
24625	TOTAL	2911
24701	VITRO SAB DE CV	3220
24720	WABASH NATIONAL CORP	3715
24782	PERRIGO CO	2834
24800	QUALCOMM INC	3663
24943	INTERTAPE POLYMER GROUP INC	2670
24978	CALLAWAY GOLF CO	3949
25119	MOHAWK INDUSTRIES INC	2273
25124	PRAXAIR INC	2810
25130	NCI BUILDING SYSTEMS INC	3448
25180	AGCO CORP	3523
25279	BOSTON SCIENTIFIC CORP	3841
25291	QUEBECOR WORLD INC -SUB VTG	2750
25305	ARACRUZ CELULOSE SA	2611
25313	STERIS CORP	3842
25389	GRAPHIC PACKAGING HOLDING CO	2631
25405	GENERAL CABLE CORP/DE	3350
25773	CREATIVE TECHNOLOGY LTD	3577

Global Company Key	Name	SIC
25777	CARAUSTAR INDUSTRIES INC	2631
25870	MINERALS TECHNOLOGIES INC	2810
26019	HAYES LEMMERZ INTL INC	3714
27760	NAUTILUS INC	3949
27845	WATSON PHARMACEUTICALS INC	2834
27965	MICROCHIP TECHNOLOGY INC	3674
28004	REVLON CONSUMER PRODUCTS CP	2844
28018	GYMBOREE CORP	2300
28118	FOSSIL INC	3873
28169	AGRIUM INC	2870
28176	APTARGROUP INC	3089
28194	POLYONE CORP	2821
28195	JABIL CIRCUIT INC	3672
28262	NATUZZI SPA	2510
28295	TITAN INTERNATIONAL INC	3312
28518	SHILOH INDUSTRIES INC	3460
28742	BORGWARNER INC	3714
28844	COCA-COLA FEMSA SAB DE CV	2086
28883	SOC QUIMICA Y MINERA DE CHI	2870
28917	MONACO COACH CORP	3711
28940	BELDEN INC	3357
29001	OM GROUP INC	3341
29156	UNIVERSAL FOREST PRODS INC	2421
29241	JDS UNIPHASE CORP	3663
29341	FOAMEX INTERNATIONAL INC	3086
29392	EASTMAN CHEMICAL CO	2821
29511	CYTEC INDUSTRIES INC	2890
29751	ALBEMARLE CORP	2890
29830	ROCK-TENN CO	2650
29942	RALCORP HOLDINGS INC	2000
29955	BIOVAIL CORP	2834
29968	AK STEEL HOLDING CORP	3312
30032	EAGLE MATERIALS INC	3270
30098	GARDNER DENVER INC	3560
30170	FLEXTRONICS INTERNATIONAL	3672
30219	BLYTH INC	3990
30260	SIMPSON MANUFACTURING INC	3420
30310	CONSOLIDATED GRAPHICS INC	2750
30436	EMBOTELLADORA ANDINA SA	2086
31142	STMICROELECTRONICS NV	3674
31205	FOMENTO ECONOMICO MEXICANO	2086
60894	CAMERON INTERNATIONAL CORP	3533

Global Company Key	Name	SIC
60898	BWAY CORP	3411
60979	WABTEC CORP	3743
60992	MEMC ELECTRONIC MATRIALS INC	3674
61095	PALM HARBOR HOMES INC	2452
61153	GRAFTECH INTERNATIONAL LTD	3620
61214	ASML HOLDING NV	3559
61519	SCHWEITZER-MAUDUIT INTL INC	2621
61552	LEXMARK INTL INC -CL A	3577
61567	LAUDER (ESTEE) COS INC -CL A	2844
61574	WATERS CORP	3826
61591	NETAPP INC	3572
61596	BUCKEYE TECHNOLOGIES INC	2611
61763	ELIZABETH ARDEN INC	2844
62221	COLUMBUS MCKINNON CORP	3530
62290	REVLON INC -CL A	2844
62516	CENTURY ALUMINUM CO	3350
62640	LORAL SPACE & COMMUNICATIONS	3663
62685	BUILDING MATERIALS CORP AMER	2950
62836	POLYMER GROUP INC	2200
62897	TUPPERWARE BRANDS CORP	3089
63138	IMATION CORP	3695
63447	GUESS INC	2330
63483	DURA AUTOMOTIVE SYS -CL B	3714
63637	MILLENNIUM CHEMICALS INC	2810
63876	TRIUMPH GROUP INC	3728
63892	NATIONAL OILWELL VARCO INC	3533
63914	CNH GLOBAL NV	3523
64030	STEEL DYNAMICS INC	3312
64389	SILGAN HOLDINGS INC	3411
64690	AUTOLIV INC	3714
64853	RF MICRO DEVICES INC	3674
64891	POLO RALPH LAUREN CP -CL A	2320
65009	EXTERRAN HOLDINGS INC	3533
65142	COMMSCOPE INC	3357
65248	ARCELORMITTAL SA	3312
65399	ARVINMERITOR INC	3714
65590	STONERIDGE INC	3679
65643	FAIRCHILD SEMICONDUCTOR INTL	3674
65676	INTERMEC INC	3577
65772	METTLER-TOLEDO INTL INC	3826
66016	CORN PRODUCTS INTL INC	2040
66290	STEELCASE INC	2522

Global Company Key	Name	SIC
66440	TEKNI-PLEX INC	3080
66544	ASSOCIATED MATERIALS LLC	3089
66708	BROADCOM CORP	3674
100080	BAYER AG	2800
100477	JAMES HARDIE INDUSTRIES NV	3270
101020	STORA ENSO OYJ	2621
101310	NOVARTIS AG	2834
101718	UPM-KYMMENE CORP	2621
102345	METSO OYJ	3530
102422	SAPPI LTD	2670
102696	LOGITECH INTERNATIONAL SA	3577
105089	CEMEX SAB DE CV	3241
105936	COLUMBIA SPORTSWEAR CO	2300
110039	AMKOR TECHNOLOGY INC	3674
110533	SAUER-DANFOSS INC	3590
110685	L-3 COMMUNICATIONS HLDGS INC	3663
111941	GERDAU SA	3312
112033	KING PHARMACEUTICALS INC	2834
112158	CELESTICA INC	3674
112759	USEC INC	2810
116526	CONEXANT SYSTEMS INC	3674
117768	NVIDIA CORP	3674
117861	AMERICAN AXLE & MFG HOLDINGS	3714
117862	ARCH CHEMICALS INC	2800
118122	DELPHI CORP	3714
118577	LIFE TECHNOLOGIES CORP	2836
119216	VARIAN INC	3826
119417	PEPSI BOTTLING GROUP INC	2086
120774	BROCADE COMMUNICATIONS SYS	3576
120877	REYNOLDS AMERICAN INC	2111
121142	SKECHERS U S A INC	3140
122380	LENNOX INTERNATIONAL INC	3585
124254	OMNOVA SOLUTIONS INC	2821
124996	EPCOS AG	3670
125094	UNITED REFINING CO	2911
125533	PACTIV CORP	3089
126554	AGILENT TECHNOLOGIES INC	3825
126721	TELEDYNE TECHNOLOGIES INC	3663
127254	APPLERA CORP-CONSOLIDATED	3826
128978	PACKAGING CORP OF AMERICA	2650
132740	INFINEON TECHNOLOGIES AG	3674
133170	GRANT PRIDECO INC	3533

Global Company Key	Name	SIC
133366	EDWARDS LIFESCIENCES CORP	3842
134932	ON SEMICONDUCTOR CORP	3674
136648	VISTEON CORP	3714
138143	MEDIANEWS GROUP INC	2711
139662	AVAYA INC	3663
141459	GARMIN LTD	3812
141760	EQUISTAR CHEMICALS LP	2860
142260	OIL STATES INTL INC	3533
142811	FMC TECHNOLOGIES INC	3533
142953	KRAFT FOODS INC	2000
144066	ROCKWELL COLLINS INC	3728
144435	BUNGE LTD	2040
144559	ZIMMER HOLDINGS INC	3842
146017	ACUITY BRANDS INC	3640
146075	BERRY PLASTICS HOLDING CORP	3089
147202	WIMM BILL DANN FOODS	2020
147449	ALCON INC	3851
148210	CHEVRON PHILLIPS CHEM CO LLC	2911
148221	GRAHAM PACKAGING HLDGS CO	3089
148271	KOPPERS INC	2860
148276	LAND O'LAKES INC	2020
148309	PLIANT CORP	2670
148870	ADVANCED MEDICAL OPTICS INC	3845
148950	ENPRO INDUSTRIES INC	3050
201140	CIA DE BEBIDAS DAS AMERICAS	2082
201395	TAIWAN SEMICONDUCTOR MFG CO	3674
206457	LUKOIL OIL COMPANY	2911
210418	ABB LTD	3613
213288	EMBRAER-EMPRESA BRAS AERO SA	3721
213412	ADVANCED SEMICON ENGINEERING	3674
220546	STATOILHYDRO ASA	2911
221261	COCA-COLA HELLENIC BOTTLING	2086
221545	INDUSTRIAS BACHOCO SAB DE CV	2015
221821	NIDEC CORP	3621
222111	PETROBRAS-PETROLEO BRASILIER	2911
222519	GRUMA SAB DE CV	2040
224604	DELTA GALIL INDUSTRIES LTD	2340