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THE ADOPTION OF LEAN OPERATIONS AND LEAN ACCOUNTING ON THE FINANCIAL-PERFORMANCE MEASURES OF PUBLICLY TRADED COMPANIES

A Dissertation

presented in partial fulfillment of the requirements

for the Doctor of Philosophy degree

in the Department of Accountancy

The University of Mississippi

by

DANIEL CARL HARRIS

August 2012

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ABSTRACT

For fiscal years 2008 through 2010, manufacturers and service providers that adopted lean operations outperformed companies that did not adopt lean operations. Using non-parametric tests and a matched-pairs design, lean companies had greater returns on both net operating assets (RNOA) and total assets (ROA). Lean companies also experienced better operating cash flows and cash adequacy than non-lean companies. The profit margins and financing-assets ratios were marginally better for lean companies than non-lean companies. Several working-capital measures, however, were not significantly different. Lean companies also experienced higher total-inventory turnover and raw-materials inventory turnover than non-lean companies. Although work-in-process inventory turnover did not differ significantly between the two groups, the test for that hypothesis contained the fewest number of matched pairs due to fewer companies reporting values for work-in-process. Lean companies experienced lower days'-sales in inventory and marginally higher finished-goods inventory turnover than non-lean companies.

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Research Problem

For producers of goods and providers of services, *lean* describes a way of doing "more and more with less and less – less human effort, less equipment, less time, and less space – while coming closer and closer to providing customers with exactly what they want (Womack and Jones 2003 p. 15)." The origins of lean operations come from Japan, most notably from the automobile manufacturer, Toyota, and the Toyota Production System (TPS) (Liker 2004 p. 6). This dissertation was designed to determine whether companies that have adopted lean operations ("Lean" companies) have achieved the benefits promised by the theory. In other words, are Lean companies better off financially as compared to companies that have not implemented lean operations ("Non-Lean" companies)?

During Japan's reconstruction period in the aftermath of World War II, Taiichi Ohno and his colleagues from Toyota, including Shigeo Shingo, determined that their challenge was to create continuous-flow production in small lots of dozens or hundreds of units, instead of millions of units. "This is the *general case* because the humble streams – not the few mighty rivers – account for the great bulk of human needs." Through Ohno and his associates, Toyota achieved continuous-flow, low-volume production by learning to changeover tools quickly from one product to another and by "right-sizing" (miniaturizing) machines so that different processing steps (e.g., molding, painting, and assembly) could be conducted immediately next to one another (Womack and Jones 2003 p. 23). The TPS classified 14 fundamental principles into four categories:

> **Philosophy** (Long-Term Thinking): Base management decisions on a long-term philosophy, even at the expense of short-term financial goals.
>
> **Process** (Eliminate Waste): Create process 'flow' to service problems. Use pull-systems to avoid overproduction. Level out the workload (Heijunka). Stop when there is a quality problem (Jidoka). Standardize tasks for continuous improvement. Use visual control so no problems are hidden. Use only reliable, thoroughly tested technology.
>
> **People and Partners** (Respect, Challenge, and Grow Them): Grow leaders who live the philosophy. Respect, develop, and challenge your people and teams. Respect, challenge, and help your suppliers.
>
> **Problem Solving** (Continuous Improvement and Learning): Continual organizational learning through Kaizen. Go see for yourself to thoroughly understand the situation (Genchi Genbutsu). Make decisions slowly by consensus, thoroughly considering all options; implement rapidly (Liker 2004 p. 6).

A more detailed description of the TPS' fourteen fundamental principles is set forth in Appendix A.

In their seminal book, <u>Lean Thinking</u>, James Womack and Daniel Jones identified five principles that are the foundation of a Lean company: (1) value; (2) value streams; (3); flow; (4) pull; and (5) perfection. To become a Lean company, an organization first precisely specifies *value* for each of its products and/or services from the customer's perspective, rather than the company's own perspective as the producer. Specifying value involves the identification of both value-added and non-value-added (wasteful) processes. Second, a Lean company defines the *value stream* for each product, service, or family of products/services (Womack and Jones 2003 p. 10). That is, a Lean company identifies each and every action that is necessary to transform its products and/or services from: (a) concept to launch; (b) customer order to delivery; and (c) raw materials to finished goods (or services) in the hands of customers (Womack and Jones 2003 p. 276). Typically, a value stream consists of a group of related products that utilize the same sequence of production processes (Maskell and Baggaley 2004 p. 297).

To accomplish the third lean principle, a Lean company makes value *flow* without interruptions. Achieving continuous flow requires the removal from the value stream of all of the actions that do not create value (from the customer's perspective). Fourth, a Lean company allows customers to *pull* value from it – instead of trying to push value onto the customer – by producing only what the customer is buying right now (and no more). And fifth, a Lean company always pursues *perfection*. A Lean company improves its value streams through repeatedly evaluating its processes, analyzing results, and implementing changes (i.e., continuous improvement). Maskell and Baggaley propose an additional lean principle, *empowerment*, a system of measurements and controls that provide employees with the information and authority to take necessary improvement actions (Maskell and Baggaley 2004 p. 297).

Lean advocates claim that an organization's successful transformation from being a traditional producer to being a Lean company not only will increase productivity dramatically, but also significantly reduce errors, inventories (raw materials, work-in-process and finished goods), accidents, production-space requirements, time and cost for product development, lead times, and overall costs (Womack and Jones p. 295). Despite requiring little capital investment, lean transformations can help organizations escape cycles of stagnation and provide resources for research and product/service development (Womack and Jones p. 295).

An organization's transformation from a traditional producer to a Lean company likely will be a lengthy and difficult one, however. It takes several years to become a mature Lean company and requires a total culture change and strong commitment from every level of the company, but particularly from the CEO who must lead the transformation. Most American companies that attempt a lean transformation, but fail to achieve and/or sustain the benefits do so because of the failure of the CEO and/or top management to commit fully to lean principles.

> CEOs want to delegate improvement activities, partly because they are timid about going out on the shop floor or to the engineering area or to the order-taking and scheduling departments to work hands-on making improvements. As a result, they never really learn anything about change at the level where value is really created. They continue to manage in their old by-the-numbers manner, which kills the improvement activities they thought they started (Womack and Jones 2003 p. 133 – 134)...

Commitment from the very top of a company is especially critical during the early years of a lean transformation when the financial-reporting results required by generally accepted accounting principles (GAAP) – particularly those based upon absorption costing of inventory – frequently are negative when compared to results from the years immediately prior to a lean transformation. Among the typical results from the *early* stages of a lean transformation are:

> Revenue that stays the same, although there may be some reduced backlog that brings revenue in quicker; Costs stay much the same, although overtime and scrap costs may reduce a little; Operating profits may go down owing to the impact of reduced inventory on cost-of-sales; Cash flow from operations may increase owing to inventory reduction; other financial indicators have not improved, or have worsened; Sales per employee have stayed the same; average cost per unit sold has increased due to increased costs (Maskell and Baggaley 2004 p. 52).

Just-In-Time Production versus Traditional Batch-and-Queue Production

W. Edwards Deming stressed that every person and/or step in a process – whether it be a manufacturing or other process – should be treated like a customer and be supplied with exactly what that step needs at the exact time it is needed. That is, a subsequent process is the customer of its preceding process. W. Edwards Deming was a prominent engineer, statistician, professor, and manufacturing consultant, the latter role most prominently occurred in post-World War II Japan. Beginning in 1941, however, Deming taught courses in America that were based upon Walter A. Shewhart's methods of statistical quality control (or statistical process control) to various persons, including engineers, inspectors, businessmen, and government employees (Walton p. 6 – 16).

For just-in-time (JIT) production to work properly, the preceding process must do what the subsequent process specifically directs (Liker 2004 p. 23 – 24).

> JIT is a set of principles, tools, and techniques that allows a company to produce and deliver products in small quantities, with short lead times, to meet specific customer needs. Simply put, JIT delivers the right items at the right time in the right amounts. The power of JIT is that it allows you to be responsive to the day-by-day shifts in customer demand (Liker 2004 p. 23).

JIT is one of the pillars of lean manufacturing. To facilitate JIT production, factories typically reorganize their layouts by grouping machines according to the expected sequence-of-operations, instead of by the similarity-of-function, thereby dramatically reducing the total travel time for raw-materials, work-in-process, and finished-goods inventories (Johnson and Kaplan p. 215).

Although it had been practiced in Japan for decades prior thereto, JIT was reintroduced to the United States in the late 1970s/early 1980s. Post-World War II America experienced a tremendous economic boom that included unparalleled demand for consumer goods with limited competition. In the prior decades, American manufacturers had been practicing industrial engineer, Frederick Taylor's, scientific-management practices of work standards/rules that were based upon "time-and-motion studies to break jobs down into simple steps to be performed over and over without deviation by different workers." After the war's conclusion, American manufacturers generally prioritized production quantity over production quality (Walton p. 8 – 9).[1] Thereafter, Dr. Deming went to Japan (Walton p. 9 – 10).

JIT-production represents a significant departure from the traditional batch-and-queue production system that developed in the United States throughout the twentieth century. To maximize capacity, traditional batch-and-queue manufacturers typically try to keep every worker and every machine as active as possible. All too frequently, however, batch-and-queue manufacturing pushes output from one process to the next, regardless of whether the next process is ready for the output and/or whether that output meets quality standards (Johnson and Kaplan p. 214 – 215). While a batch-and-queue production system may contribute to the maximization of localized, standard-cost efficiency measures, it can do so at the expense of overall company performance.

Few non-accountants comprehend a standard-cost, profit-and-loss (income) statement. On a standard-cost income statement, cost of goods sold and gross profit are expressed in terms of what they would have been if pre-determined standards for materials, direct labor, and overhead had been achieved by a company. The respective differences between a company's actual performance and these applied standards – expressed in terms of up to eight variances – then are added to, or deducted from, gross profit (Cunningham and Fiume 2003 p. 94). The eight standard-costing variances are: materials price variance, materials usage (or quantity) variance, labor rate variance, labor efficiency variance, variable overhead spending variance, variable overhead efficiency variance, fixed overhead spending variance, and fixed overhead volume variance.

---

[1] "Although a few control charts lingered here and there for a time, particularly in defense industries, for the most part the techniques taught by Dr. Deming and his colleagues were now regarded as time-consuming and unnecessary, and they faded from use. By 1949, Dr. Deming says mournfully, 'there was nothing – not even smoke (Walton p. 9 – 10).'"

Production and purchasing managers know that they want to avoid unfavorable variances. Accordingly, a manager can engage in conduct that is detrimental to the overall company in order to improve the variance(s) for which that manager has responsibility and/or upon which some portion of his or her compensation is based. Examples of this dysfunctional managerial behavior include a purchasing manager's negotiating price reductions, thereby, sacrificing the quality of raw materials/components and/or causing increased scrap (Cunningham and Fiume 2003 p. 95), or a production manager's increasing labor hours in order to improve overhead absorption, thereby unnecessarily increasing inventory and consuming valuable cash, space, and other resources (Cunningham and Fiume 2003 p. 110 – 111). It is better for a company to have a low labor-efficiency than it is for a company to build products that it does not need (Maskell 2009 p. 27). Unneeded and unwanted (i.e., overproduced) inventory also frequently has to be sold-off at severely reduced prices, is written-off as obsolete, and/or results in layoff-and-hire cycles (Cunningham and Fiume 2003 p. 95).

One of the immediate goals and benefits of JIT and lean operations is the significant reduction of all inventories. In addition to the resulting lower carrying costs, financing costs, and money tied up in materials, inventory reduction frees up tremendous amounts of floor space. Through the minimization of work-in-process inventories, manufacturers metaphorically can find another factory inside their old factory (Johnson and Kaplan p. 215). In contrast, by maintaining higher-than-necessary inventory levels, manufacturers hide production problems: "quality problems, bottlenecks, coordination problems, obsolescence, 'shrinkage,' and supplier unreliability, among others" (Johnson and Kaplan p. 215). The implementation of both JIT-production and lean operations forces managers to fix problems, instead of burying them under buffers of inventory (Johnson and Kaplan p. 215 – 216). Lean operations and lean accounting represent the current evolution of the JIT philosophy. Whereas JIT methods initially may have been viewed by American industry as being limited to production activities and/or inventory management, lean operations and lean accounting comprise a more holistic system.

Lean operations are not limited to manufacturers. The principles can be applied to service-providing companies. Furthermore, for a manufacturer, lean principles are not limited to production activities. Instead, lean principles apply to research and development, design and engineering, management, sales, administration, accounting, and other production and office functions. For service and office processes, lean principles encourage waste-elimination in a similar way as they do in manufacturing processes. That is, a substantial portion of service, office, and other processes are non-value-added from the customer's perspective. Lean companies seek to eliminate wasteful transactions, the service- and office-process equivalent of waste (Maskell and Baggaley 2004 p. 77).

Hypotheses

Two seminal studies compared the financial performance of JIT-adopting manufacturers during its re-introductory period in the United States against the financial performance of manufacturers that had not adopted JIT-production: Balakrishnan et al. (1996) for the period from 1985 to 1989; and Kinney and Wempe (2002) for the period from 1977 to 1995. Both studies were event studies that used a matched-pairs design, but they found conflicting results as to the impact of JIT-adoption upon traditional return on assets (ROA). While Balakrishnan et al. (1996) did not find a significant ROA response to JIT-adoption, Kinney and Wempe (2002) found that JIT-adopters had an improved ROA relative to non-JIT companies.

Return on Investment (ROI) has the same basic formula as traditional ROA: net income divided by average assets employed. Whereas companies tend to utilize ROI to analyze returns below the company level (e.g., for investment centers or value streams), ROA typically is a company-level measurement (i.e., for total assets). Although Lean companies tend to eschew most traditional external, financial-reporting measures, ultimately, if a lean transformation is successful, these results should be achieved.

> If a company is constantly improving its processes, the results in the ROI will come. This focus on improving the individual elements of the process, by eliminating waste and increasing velocity, has great impact on the bottom line, but only when we are not focused exclusively on that bottom line (Cunningham and Fiume 2003 p. 40).

This study examines companies' returns on net operating assets (RNOA), in addition to traditional ROA and profit margin. Traditional ROA includes "financial assets in its base and excludes operating liabilities, so it confuses operating and financing activities" (Nissim and Penman 2001). RNOA "distinguishes operating profitability from the profitability identified with the financing activities" (Nissim and Penman 2001). RNOA is a similar ratio to the return on invested capital, however, RNOA underscores the fact that operating liabilities reduce the net operating assets employed (Nissim and Penman 2001). RNOA is measured by dividing Operating Income by lagged Net Operating Assets (Operating Assets minus Operating Liabilities): $OI_t \div NOA_{t-1}$.

Although the RNOA formula appears to be simple, the components of the RNOA equation are more complex. Accordingly, the RNOA components have been broken down into three series of equations as follows, one each for Operating Income, (lagged) Operating Assets, and (lagged) Operating Liabilities. Operating Income (OI), the numerator of RNOA (hereinafter, equation series 1), equals the sum of Comprehensive Net Financial Expense, Comprehensive Net Income, and Minority Interest in Income:

1(a) OI = NFE + CNI + MII, where

Net Financial Expense equals Core Net Financial Expense plus Unusual Financial Expense:

1(b) NFE = Core NFE + UFE

Core Net Financial Expense (Core NFE) equals after-tax Interest Expense plus Preferred Dividends minus after-tax Interest Income:

1(c) Core NFE = XINT x (1 – marginal tax rate) + DVP – (IDIT x (1 – marginal tax rate))

Unusual Financial Expense (UFE) equals the difference between the lagged Marketable Securities Adjustment and the current Marketable Securities Adjustment:

1(d) UFE = MSA_{t-1} – MSA

Comprehensive Net Income (CNI) equals Net Income minus Preferred Dividends plus the Clean-Surplus Adjustment to net income:

1(e) CNI = NI – DVP + CSA, and

The Clean-Surplus Adjustment to Net Income (CSA) equals the sums of the differences between the current and lagged Marketable-Securities Adjustments and the current and lagged Cumulative Translation Adjustments:

1(f) CSA = (MSA – MSA_{t-1}) + (RECTA – $RECTA_{t-1}$).

Accordingly (after cancelling out the appropriate components algebraically), Operating Income (OI), the numerator of RNOA, is measured as Net Income plus after-tax Interest Expense minus after-tax Interest Income plus the change in Cumulative Translation Adjustment plus Minority Interest in Income:

1(g) OI = NI + (XINT x (1 – marginal tax rate) – (IDIT x (1 – marginal tax rate))) + (RECTA – $RECTA_{t-1}$) + MII

Lagged Net Operating Assets (NOA_{t-1}), the denominator of RNOA, equal the difference between lagged Operating Assets and lagged Operating Liabilities (all balance sheet numbers for the following sequence of calculations for H1 are *lagged*): $NOA_{t-1} = OA_{t-1} - OL_{t-1}$, where Operating Assets (hereinafter, equation series 2) equal the difference between Total Assets and Financial Assets:

2(a) OA = AT – FA, and

Financial Assets (FA) equal the sum of Cash and Short-term Investments and Investments and Advances-Other:

2(b) FA = CHE + IVAO

Operating Liabilities (hereinafter, equation series 3), equal the difference between Operating Assets and Net Operating Assets: OL = OA – NOA, where

Net Operating Assets (NOA) equals the sum of Net Financial Obligations, Common Stockholders' Equity, and Minority Interest (balance sheet):

3(a) NOA = NFO + CSE + MIB, where

Net Financial Obligations (NFO) equals the difference between Financial Obligations and Financial Assets:

3(b) NFO = FO – FA;

Financial Obligations (FO) equal Debt in Current Liabilities plus Long-term Debt plus Preferred Stock minus Preferred Treasury Stock plus Preferred Dividends in Arrears:

3(c) FO = DLC + DLTT + PSTK – TSTKP + DVPA, and

Common Stockholders' Equity (CSE) equals Common Equity plus Preferred Treasury Stock minus Preferred Dividends in Arrears:

3(d) CSE = CE + TSTKP – DVPA.

In addition, the study also examined traditional ROA, measured as Net Income divided by average total assets (NI – [AT – AT_{t-1}]) and Profit Margin, measured as Net Income divided by Sales (NI ÷ SALE). Accordingly, stated in the null:

$H1a_0$: Lean companies' returns on net operating assets will be equal to Non-Lean companies' returns on net operating assets.

$H1b_0$: Lean companies' returns on total assets will be equal to Non-Lean companies' returns on total assets.

$H1c_0$: Lean companies' profit margins will be equal to Non-Lean companies' profit margins.

In the alternative:

$H1a_A$: There will be a difference between Lean companies' returns on net operating assets and Non-Lean companies' returns on net operating assets.

$H1b_A$: There will be a difference between Lean companies' returns on assets and Non-Lean companies' returns on assets.

$H1c_A$: There will be a difference between Lean companies' profit margins and Non-Lean companies' profit margins.

"There are probably many better indicators of the company's short-term performance than its quarterly earnings. Certainly, cash flow is important; we would want to know the pattern and structure of the company's cash receipts and cash expenditures (Johnson and Kaplan p. 17)." Resulting from inventory reduction, improved cash flow from operations is one of the typical financial results even in the early stages of a lean transformation (Maskell and Baggaley 2004 p. 52). "The expensing of costs of production as incurred makes value-stream profit essentially equivalent to period cash flow (Maskell and Baggaley 2004 p. 59)." Some prior research has *not* found there to have been superior cash-flow performance by either JIT or lean-adopters; however, those studies can be distinguished from the current one. Fullerton et al. (2003) looked at 54 self-identified JIT-adopters – but no non-JIT companies – and examined whether the *degree* of JIT implementation, as measured by ten factors, affected certain financial-performance measures, including cash-flow margin.[2] Boyd et al. (2006) used data-envelopment analysis (DEA), a form of linear programming, on a very limited sample of 18 survey-identified Lean companies, but did not include any non-Lean companies. Ahmad et al. (2004) used survey data to examine the *perception* of financial results, including cash flow from operations, of managers from 86 JIT-adopting companies, most of them manufacturing managers.

This study examines three different cash-flow measures: (a) cash flows from operating activities, scaled by lagged total assets (OANCF ÷ AT_{t-1}); (b) the cash-adequacy ratio, measured as cash flows from operating activities ÷ current liabilities (OANCF ÷ LCT); and (c) the financing-assets ratio, measured as cash flows from operating activities divided by the absolute value of cash flows from investing activities (OANCF ÷ |IVNCF|). However, for sub-hypothesis 1(c), the financing-assets ratio, the study only analyzed those companies that had *negative* net cash flows from investing activities, since those companies were in an investing position rather than a disinvesting position. Stated in the null:

$H2a_0$: Lean companies' cash flows from operating activities will be equal to Non-Lean companies' cash flows from operating activities.

$H2b_0$: Lean companies' cash-adequacy ratios will be equal to Non-Lean companies' cash-adequacy ratios.

$H2c_0$: Lean companies' financing-assets ratios will be equal to Non-Lean companies' financing-assets ratios.

[2] Fullerton et al. (2003) calculated cash-flow margin as income, net of extraordinary items, depreciation, and amortization divided by sales.

In the alternative:

$H2a_A$: There will be a difference between Lean companies' cash flows from operating activities and Non-Lean companies' cash flows from operating activities.

$H2b_A$: There will be a difference between Lean companies' cash adequacy ratios and Non-Lean companies' cash adequacy ratios.

$H2c_A$: There will be a difference between Lean companies' financing-assets ratios and Non-Lean companies' financing-assets ratios.

Although capital plans typically focus on property, plant, and equipment (PPE), other areas such as accounts receivable, inventory, and working capital are large users of cash and funding. Rarely, however, do companies have "top-level" improvement targets on working-capital performance measures (Cunningham and Fiume 2003 p. 147 – 148). Days'-sales uncollected (or accounts receivable days outstanding) can be improved by close attention to customers' compliance with sales terms. "The capital savings can be fundamental to a company's ability to grow (Cunningham and Fiume 2003 p. 148)." There is an absence of significant academic research on the impact of lean adoption on these working-capital performance measures.

Accordingly, this study examines several working capital measures and other liquidity ratios: (a) net working capital, measured as the difference between current assets and current liabilities, scaled by lagged total assets ($[ACT – LCT] \div AT_{t-1}$); (b) working-capital turnover, measured as sales divided by average net working-capital ($SALE \div [(ACT – LCT + ACT_{t-1} – LCT_{t-1}] \div 2$); (c) the current ratio, measured as current assets divided by current liabilities ($ACT \div LCT$); (d) the acid-test ratio, measured as the sum of cash, short-term investments, and accounts receivable divided by current liabilities ($[CHE + RECT] \div LCT$); (e) accounts receivable turnover, measured as net sales divided by average net receivables (SALE ÷ [(RECT

+ $RECT_{t-1}$) ÷ 2]); and (f) days'-sales uncollected, measured as 365 days multiplied by net receivables and divided by net sales (365 x RECT ÷ SALE). Stated in the null:

$H3a_0$: Lean companies' proportionate net working capital will be equal to Non-Lean companies' proportionate net working capital.

$H3b_0$: Lean companies' working-capital turnovers will be equal to Non-Lean companies' working-capital turnover.

$H3c_0$: Lean companies' current ratios will be equal to Non-Lean companies' current ratios.

$H3d_0$: Lean companies' acid-test ratios will be equal to Non-Lean companies' acid-test ratios.

$H3e_0$: Lean companies' accounts-receivable turnovers will be equal to Non-Lean companies' accounts-receivable turnovers.

$H3f_0$: Lean companies' days'-sales-uncollected will be equal to Non-Lean companies' days'-sales-uncollected.

In the alternative:

$H3a_A$: There will be a difference between Lean companies' proportionate net working capital and Non-Lean companies' proportionate net working capital.

$H3b_A$: There will be a difference between Lean companies' working-capital turnovers and Non-Lean companies' working-capital turnovers.

$H3c_A$: There will be a difference between Lean companies' current ratios and Non-Lean companies' current ratios.

$H3d_A$: There will be a difference between Lean companies' acid-test ratios and Non-Lean companies' acid-test ratios.

$H3e_A$: There will be a difference between Lean companies' accounts-receivable turnovers and Non-Lean companies' accounts-receivable turnovers.

$H3f_A$: There will be a difference between Lean companies' days'-sales-uncollected and Non-Lean companies' days'-sales-uncollected.

Instead of trying to "optimize" the level of inventory based upon company resources – for example, by using Economic Order Quantities (EOQ) – Lean companies examine and improve the conditions that have caused them to maintain higher inventory levels: (a) as protection against bad-quality materials and manufactured goods; (b) the long set-up times on much U.S. equipment; and (c) the uncertainty of delivery from suppliers (Johnson and Kaplan p. 213 – 214). Lean proponents assert that a significant reduction in inventory levels is one of the immediate benefits of a lean transformation. For Lean companies, inventory level and inventory turnover are key metrics of success (Cunningham and Fiume 2003 p. 148).

Although previous research has looked at various inventory turnover measures in either JIT or Lean contexts, their respective methodologies can be distinguished from the current study. While Huson and Nanda (1995) found that inventory turnover increased, their study looked only at JIT-adopters (55 companies) during the period 1977 through 1992. Also, looking at JIT-adopters only (74 companies), Biggert and Gargeya (2002) found that JIT-adoption reduced inventory-to-sales ratios for total inventory and raw-materials inventory, but not for work-in-process or finished-goods inventories. Comparing 44 matched pairs, Chang and Lee (1995) found that each of the finished-goods, raw-materials, and work-in-process inventory turnovers improved for JIT companies over Non-JIT companies; however, only two single years were compared to another (1984 and 1990). Furthermore, for the first such year, the Non-JIT companies had better performance than the JIT-adopters for all the respective inventory turnovers. Comparing 60 JIT and 40 Non-JIT Toronto-centric *plants*, Callen et al. (2000) found that: (a) the JIT plants utilized less work-in-process inventory and finished-goods inventory than Non-JIT plants; and (b) greater experience with JIT further reduced work-in-process inventories, but not finished-goods inventories. However, Callen et al. (2000) was limited to two industries, one metropolitan area, and one *single year* of financial data (1990).

Here, inventory turnover was examined for each of total inventory (INVT), raw-materials (INVRM), work-in-process (INVWIP), and finished-goods (INVFG) and was measured as cost of goods sold divided by the average inventory for each of the respective inventory categories: (COGS ÷ [(INV + INV_{t-1}) ÷ 2]). Days'-sales in inventory is measured for finished-goods inventory as: 365 days multiplied by the quotient of ending inventory and cost of goods sold (365 x [INVFG ÷ COGS]). Stated in the null:

$H4a_0$: Lean companies' total-inventory turnovers will be equal to Non-Lean companies' total-inventory turnovers.

$H4b_0$: Lean companies' raw-materials inventory turnovers will be equal to Non-Lean companies' raw-materials inventory turnovers.

$H4c_0$: Lean companies' work-in-process inventory turnovers will be equal to Non-Lean companies' work-in-process inventory turnovers.

$H4d_0$: Lean companies' finished-goods inventory turnovers will be equal to Non-Lean companies' finished-goods inventory turnovers.

$H4e_0$: Lean companies' days'-sales-in-inventory will be equal to Non-Lean companies' days'-sales-in-inventory.

In the alternative:

$H4a_A$: There will be a difference between Lean companies' total-inventory turnovers and Non-Lean companies' total-inventory turnovers.

$H4b_A$: There will be a difference between Lean companies' raw-materials inventory turnovers and Non-Lean companies' raw-materials inventory turnovers.

$H4c_A$: There will be a difference between Lean companies' work-in-process inventory turnovers and Non-Lean companies' work-in-process inventory turnovers.

$H4d_A$: There will be a difference between Lean companies' finished-goods inventory turnovers and Non-Lean companies' finished-goods inventory turnovers.

$H4e_A$: There will be a difference between Lean companies' days'-sales-in-inventory and Non-Lean companies' days'-sales-in-inventory.

Motivation/Contribution

Using traditional batch-and-queue production methods typically results in companies' maintaining significant inventories of raw materials, work-in-process, and finished goods. Not only do significant inventories tie up valuable capital and other resources, they hide problems in production processes that otherwise could be revealed and improved by a Lean company that is striving for continuous-flow production. Companies that use traditional financial-reporting practices for managerial-accounting purposes frequently make important decisions without knowing the true costs of their products. Through the use of standard-costing variance analysis, traditional management frequently makes decisions that maximize localized performance measurements at the expense of a company's overall performance.

Proponents of lean operations and lean accounting believe that they have solutions for the problems caused by traditional batch-and-queue production and the use of traditional financial-accounting practices for management-accounting purposes. Although a number of lean metrics are non-financial, ultimately, a successful lean transformation should impact a company's financial-performance measurements. This study contributes to the accounting literature by using archival data to examine financial-performance measurements that proponents of lean operations and accounting assert ultimately will be improved as a result of having implemented lean practices.

Early literature in this field addressed the effects of *JIT*-production and covered periods of time before the more recent lean evolution. There is a conflict in that literature with regard to the impact of JIT-production on traditional return on total assets. This study examines return on total assets, as well as an additional measure, return on *net* operating assets, which does not confound operating and financing activities. The improvement of operating cash flows, another principal financial-performance measurement according to proponents of lean, so far has not been supported widely with archival data in peer-reviewed accounting literature. This study examines operating cash flows from numerous angles, using archival data. Additionally, this study examines several working-capital measurements. Furthermore, with respect to inventory levels and turnover, principal financial-performance measurements that lean proponents assert will improve as a result of a successful lean transformation, this study addresses both the conflicts and design limitations that may limit the findings of prior literature.

ORGANIZATION OF THE REMAINDER OF THE DISSERTATION

A full review of the relevant prior literature is presented in chapter 2. The complete methodology used to test the hypotheses is included in chapter 3. Chapter 4 reviews the data analysis and research results. Finally, chapter 5 gives an overview of the conclusions drawn from this research.

CHAPTER II

PRIOR RESEARCH

Balakrishnan et al. (1996) found no significant return-on-asset (ROA) response to the adoption of *JIT* manufacturing. Their sample consisted of 46 matched pairs of public companies, the treatment group for which publicly had disclosed the adoption of JIT production during the period from 1985 to 1989. It is important to note that returns had declined market-wide during the period of study. Companies having fewer WIP-inventory turns during the year of JIT adoption exhibited a smaller decline in ROA post-JIT adoption; however, similar results did not occur for total inventory. Balakrishnan et al. (1996) analyzed returns for a period of three years before adoption, the adoption year itself, and three years after adoption (four years, if available). Furthermore, JIT-adopting firms that had a diffuse customer base had a superior ROA response than those with a greater customer concentration (Balakrishnan et al. 1996).[3] Firms with higher a proportion of committed costs did not exhibit a smaller ROA response than firms with lower proportions of committed costs at the time of JIT adoption, using the ratio of depreciation to cost-of-sales as a measure of committed costs. Callen et al. (2000) criticized Balakrishnan et al. (1996) for having categorized as JIT, companies that had implemented JIT practices in a minority of their manufacturing business. In one example, a company that had three JIT plants and nine non-JIT plants had been labeled as a JIT Company (Callen et al. 2000).

[3] Customer concentration was characterized pursuant to then SFAS 14, *Financial Reporting for Segments of a Business Enterprise* (FASB [1976]), later replaced by SFAS 131, *Disclosures about Segments of an Enterprise and Related Information* (FASB [1997]).

Contrary to Balakrishnan et al. (1996), Kinney and Wempe (2002) found that JIT-adopters improved their ROA performance relative to non-JIT companies. Profit margin (income/sales), rather than asset turnover (sales/average total assets), was the primary source of the ROA improvement (Kinney and Wempe 2002). Smaller JIT-adopting companies did *not* experience improved financial performance, thereby, somewhat reconciling the Kinney and Wempe (2002) study with Balakrishnan et al. (1996), the latter of which largely examined small public companies. Relative to their non-adopting counterparts, JIT-adopters: (a) enjoyed an inventory-turnover increase six to eight times greater than that of non-adopters; (b) reduced inventory-to-total assets more substantially than did non-adopters; and (c) improved both the profit-margin and asset-turnover components of ROA. Kinney and Wempe (2002), which included 201 matched pairs of public companies for the years from 1977 to 1995, compared financial-performance changes from a three-year pre-adoption period to a three-year post-adoption period. On average, JIT-adopters improved ROA relative to non-adopters. This relation did not vary with the concentration of the adopters' customer bases (Kinney and Wempe 2002).

Huson and Nanda (1995) found that JIT adoption led to an increase in earnings per share. After the adoption of just-in-time manufacturing, inventory turnover increased by almost 24%. Analysis of financial statements showed that even though manufacturing costs per unit increased after JIT adoption, this increase was offset by a reduction in interest expenses and other financing costs previously needed to service larger inventory levels. There was also a significant reduction in employees per sales dollar. The study, which included 55 JIT companies – but not non-JIT companies – for the years from 1977 to 1992, compared companies' financial performance for the four-year pre-adoption period to the four-year post-adoption period (or 1992, whichever was earlier). Like they did to the Balakrishnan et al. (1996) study, Callen et al. (2000)

also criticized Huson and Nanda (1995) for their failure to "limit their sample to firms composed entirely or even primarily of JIT plants."

Fullerton et al. (2003) analyzed the effects of the *degree* of JIT implementation, overall and over time, for three measures of profitability: return on assets, return on sales, and cash-flow margin.[4] Fullerton found a positive relationship between firm profitability and the degree to which waste-reducing production practices had been implemented, including reduced setup times, preventative maintenance programs, and a uniform workload. Survey responses provided the measures for a company's degree of JIT implementation, which broke down 10 JIT factors into three categories: JIT-manufacturing (6), JIT-quality (2), and JIT-unique (2). The degree of JIT implementation revolved around the implementation of 10 practices: focused factory, group technology, reduced setup times, total productive maintenance, multi-function employees, uniform workload, kanban, JIT purchasing, total quality control, and quality circles. Companies that had implemented a higher degree of JIT-manufacturing practices had significantly higher ROA post-JIT adoption compared to pre-JIT adoption. Beyond that, evidence did not support the proposition that the degree of JIT-manufacturing practice implementation affected long-term financial returns. Due to their higher implementation costs, the benefits of JIT practices were realized only over time. Results suggested that there were improved returns for JIT-unique investments over time (post-adoption year 3), even for a modest implementation. Although a negative relationship to profit existed for firms that implemented higher degrees of JIT-unique practices, results suggested an improvement from significantly lower pre-adoption profitability

[4] To test profitability *over time*, the self-identified JIT companies had to have financial data available for two years prior to JIT adoption and three years after adoption. This limitation reduced the number of JIT companies from 95 to 54. Cash-flow margin equaled income net of extraordinary items, depreciation, and amortization ÷ sales.

levels. Furthermore, the lower inventory levels had a significant effect on ROA and ROS, but not on cash-flow margin.

Biggert and Gargeya (2002) found that the respective ratios of total inventory to sales and raw-material inventory to sales had decreased post-JIT adoption, but no comparison was made to non-JIT companies. However, no statistically significant change occurred for the respective ratios of work-in-process inventory to sales or finished-goods inventory to sales. The study, which included 74 predominantly very large companies during the period from 1975 to 1995, compared the differences between two sets of two-year averages for the inventory-to-sales ratios – years one and two compared to years six and seven.

Using a non-parametric technique of data-envelopment analysis (DEA), an application of linear programming, Boyd et al. (2006) found that there were improvements to net sales, EBITDA, EBT, and net income after lean-systems implementation.[5] Improvement came in the first year after implementation with further improvement coming in the following year. Comparing the pre-adoption years with all three post-adoption years, the results were significant at $\alpha = 0.10$. When comparing the pre-adoption years to just years 2 and 3 post-adoption, however, the results were significant at $\alpha = 0.01$ for all variables except gross profit. The study was limited to 18 survey-identified, lean-adopting companies and focused on the lean-adoption year, the two years pre-adoption, and the three years post-adoption.

Comparing two single years of data to one another – 1984 (pre-adoption) and 1990 (post-adoption) – Chang and Lee (1995) found that there were *no* significant differences in performance between JIT companies and non-JIT companies in: (a) sales per employee; (b) operating profit margin; or (c) return on investment. Although the sample of non-JIT companies

[5] Since DEA disallows negative values, all negative values for EBT and cash flows were adjusted upward by a constant sufficient to make the lowest value slightly positive.

had better pre-adoption performance for each of finished-goods, raw-materials, and work-in-process inventory turnovers than their non-JIT counterparts, the JIT companies improved in each of the respective inventory turnovers relative to the non-JIT companies. The study matched 44 pairs of survey-identified JIT companies and non-JIT companies; however, the sales and revenue volumes of the JIT companies were much larger than those of the non-JIT companies.

Using a *single year's* data (1990) from privately owned, Toronto-centric, manufacturing plants from two industries, Callen et al. (2000) found that JIT manufacturing at the *plant level* (i.e., as opposed to at the company level) was associated with greater productivity, inventory usage, lower total costs, and higher profits.[6] The success of JIT plants was found to have been related to the length of their experience with JIT manufacturing, process quality, and leanness. In order to have been classified as JIT, the plant had to have employed a global JIT philosophy. Production managers classified their plant as JIT or non-JIT based on a narrow definition that emphasized the stockless-production aspect of JIT (or the ideal of zero inventories). Then, JIT plant managers were asked the extent of the plant's use of each of 17 JIT techniques on 5-point Likert scales. *Both* a minimum sum of 51 total points and a plant's using two thirds of the 17 JIT techniques at least half the time were required for a final JIT classification. The final sample consisted of 60 JIT and 40 non-JIT plants. JIT plants utilized significantly less work-in-process inventory and finished-goods inventory in comparison to non-JIT companies. Unlike work-in-process inventory, experience with JIT showed no significant impact on finished-goods inventory. JIT plants were significantly more profitable than non-JIT plants, as measured by profit margin and contribution margin. Plants that had adopted JIT earlier were significantly

[6] Eighty-five percent of the plants had adopted JIT in the three years prior to 1990, with over 46% adopting JIT in 1988.

more profitable than those that had adopted JIT more closely in time to 1990, the single year examined.

Mia (2000) found an interaction between a company's JIT adoption and its provision of management-accounting-system (MAS) information to managers upon the company's ROI (calculated as the previous *one* year's EBT ÷ total assets). The final sample of this Australian study compared 28 JIT and 27 non-JIT survey participants. The measure on the provision of MAS information to managers was the aggregate score collected on four personal-interview questions, answered on seven-point Likert scales, regarding performance targets, actual performance, and performance benchmarking.

Howton et al. (2000) found that while the market reacted positively to JIT adoption (in terms of expected changes in cash flows), analysts did not react to the JIT-adoption announcement (in terms of expected changes in earnings).[7] The results were not entirely consistent with either the costly-capital hypothesis or the change-in-inventory-accounting hypothesis.[8] It is noteworthy that the authors: (a) characterized JIT as having a large up-front expenditure, which is not necessarily true for a lean transformation; and (b) stated that firms that had been using LIFO-inventory accounting at the time of JIT was adopted should have experienced an increase in short-term earnings as a result of the costing of cheaper layers of inventory, which would not necessarily be true of manufacturing companies (i.e., due to a manufacturer's having to expense previously capitalized fixed overhead cost when inventory manufactured in a previous period is sold in a subsequent period).

[7] One-year earnings revisions were shown to be directly related to the firms' LIFO reserves. Abnormal current-year, following-year, and five-year growth forecast revisions were dependent variables. The announcement day standardized abnormal return and the inventory measure based on the firm's LIFO reserve were explanatory variables. Control variables were the average ROI three years before JIT adoption and the change in ROI from three years prior to three years after JIT adoption.

[8] The authors stated that if JIT adoption was viewed simply as an inventory-accounting change, the market should react neutrally and analysts should have a neutral-to-positive reaction to the announcement.

Using a *single year* of financial data, 2001, Fullerton and Wempe (2009) found that the utilization of non-financial performance measures (NFPM) was positively associated with return on sales. Further, the extent of utilization of NFPM mediated the association between financial performance and the implementation of the lean-manufacturing activities of setup-time reduction, cellular manufacturing, and quality improvement. The authors suggested that this finding sheds light on the inconsistent results of prior studies that examine the relationships between financial performance and lean strategies without considering the corresponding alignment of NFMP measures. The mediating effect for the quality-improvement lean activity was supported at $\alpha = 0.10$. The respective direct relationships between both setup-time reduction and profitability and cellular manufacturing and profitability were significant when no NFPM variable was included in regression-based tests. There was no direct relationship between quality improvement and profitability. The study used data provided by 121 US manufacturing executives that had been identified from a 1997 questionnaire.

Brief Management-Accounting History

Management-accounting systems can be traced back to the early nineteenth century (Johnson and Kaplan p. xx). Before then, almost all business exchanges took place between an owner and individuals who were not a part of that business organization, including raw-material suppliers, piecework labor (i.e., not long-term employees), and customers. That is, all transactions were external to the business. Hierarchical organizations as we know them did not yet exist (Johnson and Kaplan p. 6). The Industrial Revolution saw the proliferation of companies trying to achieve economies of scale. Nineteenth-century businesses not only committed significant capital to production, but also hired workers on a long-term basis (Johnson and Kaplan p. 6 – 7).

With the development of hierarchical businesses, a need arose for those businesses to determine the price of output from *internal* processes. Previously, it had been easy for a business to determine if it had collected more cash from sales to customers than it had paid to the external suppliers of the basic production inputs of contract labor and material. The Industrial Revolution, however, created significant overhead costs that now needed to be factored into companies' cost calculations (Johnson and Kaplan p. 6). Furthermore, the inventions of the railroad and the telegraph provided additional opportunities, including the acquisition of raw materials and the distribution of products over vastly larger geographical areas (Johnson and Kaplan p. 8). Process-type industries – particularly textiles, steel, transportation, and distribution – drove the development of management accounting. However, "these organizations really had to do only one activity well: convert raw materials into a single final product such as cloth or steel, move passengers or freight, or resell purchased goods (Johnson and Kaplan 1987 p. 9)."

Previously, if owners and creditors had needed periodic financial statements, those could be produced. At that time, management and financial accounting systems operated independently of one another (Johnson and Kaplan 1987 p. 9). There were few to no demands for external financial reporting (Johnson and Kaplan 1987 p. xx). "Unit costs were calculated to aid managerial decisions…not to produce external financial statements. Therefore, there was little demand for having the unit cost information be 'consistent' with the books of transactions used to prepare summary financial statements (Johnson and Kaplan 1987 p. 10)."

The early twentieth century saw substantial growth of multi-activity, diversified corporations. To improve management accounting and control, senior managers of Du Pont developed operating and budgeting methods, most notably the return-on-investment (ROI) measure (Johnson and Kaplan 1987 p. 10 – 11).

> The decentralized, multidivisional corporation developed to capture economies of scope - the gains from sharing common organizational functions across a broad spectrum of products… It was no longer possible for the corporate-level departments of marketing, purchasing, and finance to have the requisite information to function effectively or efficiently in all the markets served by their organization. Decentralization was necessary. Each operating division required its own staff functions to support its activities. Thus, central managers were now in the position of providing capital to diverse operating units and attempting to coordinate, motivate, and evaluate the performance of their divisional managers (Johnson and Kaplan 1987 p. 11 – 12).

Thereafter, a stagnation in management-accounting occurred that can be attributed to the dominance of the external financial accounting statements. Publicly traded corporations proliferated as did the demand for audited financial statements (Johnson and Kaplan 1987 p. 13).

> Sixty years of literature emerged advocating the separation of costs into fixed and variable components for making good product decisions and for controlling costs. This literature, very persuasive when illustrated in the simple one-product settings used by academic economists and accountants, never fully addressed the question of where fixed costs came from and how these costs needed to be covered by each of the products in the corporations' repertoire. Nor did the academic researchers attempt to implement their ideas in the environment of actual organizations, with hundreds or thousands of products and with complex, multistage production processes (Johnson and Kaplan 1987 p. 15).

Whereas until the 1920s, corporate managers almost exclusively had relied on information about the processes, transactions, and events (i.e., management-accounting information), by the 1960s and 1970s, managers commonly relied on financial-accounting numbers alone (Johnson and Kaplan 1987 p. 125 – 126). Technological advances notwithstanding, most of the substantive management-accounting practices still used in the late twentieth century already had been developed by 1925 (Johnson and Kaplan 1987 p. 12). These management-accounting practices included: cost accounts for labor, material, and overhead; budgets for cash, income, and capital; flexible budgets, sales forecasts, standard costs, variance analysis, transfer prices, and divisional performance measures (Johnson and Kaplan 1987 p. 12).

In the early 1980s, quality, again, became a major focus for U.S. manufacturers. Japanese manufacturers were making products of significantly higher quality than their American counterparts. Japanese manufacturing "secrets" were (re)introduced to American industry, including "statistical process control to reduce variation, quality at source instead of inspection, PDCA (plan, do, check, act) problem solving, design for manufacture, and certified suppliers delivering on time with zero defects (Maskell 2009 p. 2)."

> At first, US manufacturers believed that the inroads being made in their traditional markets by foreign, particularly Japanese, manufacturers could be attributed to lower overseas wage costs. Only with some delay did they recognize the onset of a revolution in manufacturing operations. The revolution was triggered by innovative practices developed by Japanese manufacturers during the 1970s and by the availability of new technology that greatly reduced the direct labor content of manufactured goods. Leading the revolution were new practices emphasizing total quality control, just-in-time inventory systems, and computer-integrated-manufacturing systems (Johnson and Kaplan 1987 p. 210).

Compared to American manufacturers, these Japanese competitors introduced new products faster, were more responsive to their customers, had shorter lead times (i.e., from order to delivery) and much lower costs. To return to competitiveness, American (and European) manufacturers implemented lean-manufacturing techniques: "short cycle times, small batches, [machine] changeovers of less than 10 minutes, cellular manufacturing, synchronized production flow, kanban, and low, low inventories." These techniques were a substantial departure from what had become traditional batch-and-queue manufacturing (Maskell 2009 p. 2). In addition to these changes, American manufacturers began to understand that traditional costing methods that had not changed substantively in over half a century were no longer appropriate.

> The patterns of product costs had changed over the years as technology, production methods, and the market had changed. Studies showed that the standard product costs generated by the cost accountants were misleading and wrong. There were fundamental flaws in the tried-and-true accounting practices (Maskell 2009 p. 3).

Lean Operations and Accounting

Value

A Lean company focuses primarily on value creation rather than cost reduction. When a traditional organization focuses primarily on cost, it can continue to do the wrong things more efficiently or inflict irreparable injury upon itself through across-the-board mandated cuts (Bell and Orzen 2011 p. 143). Value is defined not only from the perspective of the ultimate customer, but also it is expressed in terms of a specific product or service that meets the customer's needs at a specific price at a specific time (Womack and Jones 2003 p. 16). It is hard to define value correctly since most companies want to continue to produce what they already are producing and a lot of customers do not know enough to ask for more than a limited variant of the product or service that they already are receiving.

> They simply start in the wrong place and end up at the wrong destination. Then, when providers or customers do decide to rethink value, they often fall back on simple formulas – lower cost, increase product variety through customization, instant delivery – rather than jointly analyzing value and challenging old definitions to see what's really needed (Womack and Jones 2003 p. 31)

Everything that a company does is a process. Although traditional business organizations manage themselves through functional departments, an organization's processes frequently cross many departmental barriers (Maskell 2009 p. 119). To improve its processes, a Lean company identifies and eliminates the wasteful activities that are entrenched within the processes (Maskell 2009 p. 35). In Japanese, the term, *muda*, means waste. Muda is "any human activity which absorbs resources but creates no value" (Womack and Jones 2003 p. 15). All business activities can be classified in one of three categories: (a) value-added; (b) non-value added, but required; and (c) non-value added, not required (Cunningham and Fiume 2003 p. 46). A *value-added* activity transforms a product or service toward what a customer wants or needs. Value-added activities include sales activities and the manufacturing of a product and/or the performance of a service for a customer (Maskell 2009 p. 123). A Lean company strives to eliminate its non-value-added activities and to improve its value-added activities, including by eliminating the non-value-added elements of value-added activities (Maskell 2009 p. 125). Initially, Lean companies should focus on eliminating the *non*-value-added activities, rather than improving the value-added activities. Since a manufacturing company spends substantially more time on non-value-added activities, a focus on the elimination of non-value-added activities has a much more significant impact on the enterprise as a whole (Cunningham and Fiume 2003 p. 123).

Waste occurs in every process that an organization performs (Cunningham and Fiume 2003 p. 70). Wasteful actions, however, do not contribute to the transformation of a given product and/or service (Maskell 2009 p. 124). Waste consists of:

> mistakes which require rectification, production of items no one wants so that inventories and remaindered goods pile up, processing steps which aren't actually needed, movement of employees and transport of goods from one place to another without any purpose, groups of people in a downstream activity standing around waiting because an upstream activity has not delivered on time, and goods and services which don't meet the needs of the customer (Womack and Jones 2003 p. 15).

Toyota identified seven major types of wastes that exist in commercial processes. These wastes apply not only to manufacturing processes, but also to product development, order taking, and office processes:

1. *Overproduction*. Producing items for which there are no orders, which generates such wastes as overstaffing and storage and transportation costs because of excess inventory.

2. *Waiting (time on hand)*. Workers merely serving to watch an automated machine or having to stand around waiting for the next processing step, tool, supply, part, etc., or just plain having no work because of stockouts, lot processing delays, equipment downtime, and capacity bottlenecks.

3. *Unnecessary transport or conveyance*. Carrying work in process (WIP) long distances, creating inefficient transport, or moving materials, parts, or finished goods into or out of storage or between processes.

4. *Overprocessing or incorrect processing*. Taking unneeded steps to process the parts. Inefficiently processing due to poor tool and product design, causing unnecessary motion and producing defects. Waste is generated when providing higher-quality products than is necessary.

5. *Excess inventory*. Excess raw material, WIP, or finished goods causing longer lead times, obsolescence, damaged goods, transportation and storage costs, and delay. Also, extra inventory hides problems such as production imbalances, late deliveries from suppliers, defects, equipment downtime, and long setup times.

6. *Unnecessary movement*. Any wasted motion employees have to perform during the course of their work, such as looking for, reaching for, or stacking parts, tools, etc. Also, walking is waste.

7. *Defects*. Production of defective parts or correction. Repair or rework, scrap, replacement production, and inspection mean wasteful handling, time, and effort (Liker 2004 p. 28 – 29).

Liker identified another waste: “*Unused employee creativity*. Losing time, ideas, skills, improvements, and learning opportunities by not engaging or listening to your employees (Liker 2004 p. 28).”

The most significant waste is overproduction (Rother and Shook 2009 p. 37). The obvious consequences of overproduction are excess inventory and the money tied up therein. Overproduction, however, has other significant negative costs, including those for storage of excess inventory, as well as and the people and equipment necessary to handle, sort, and rework it. Overproduction of a given product also causes shortages of other items, since processes are kept busy making the wrong things, requiring the use of extra operators and equipment capacity. Furthermore, overproduction lengthens lead times, thereby impairing an organization's flexibility to respond to its customers (Rother and Shook 2009 p. 37).

In addition to muda (waste), Lean companies strive to reduce two additional operational situations that inhibit productivity. In Japanese, the terms are *muri* and *mura*. Muri is the overburdening of people beyond their natural limits – resulting in safety and quality problems – or the overburdening of equipment, causing breakdowns and defects (Liker 2004 p. 114). Muri leads to stress, mistakes, rework, and poor morale (Bell and Orzen 2011 p. 34). Mura is unevenness in production levels – whether externally or internally driven – that is due either to there being more work than people or machines can handle, or alternatively, not enough work. Mura causes an organization to keep on hand the equipment, materials, and workers necessary to perform at its highest production level, even if the organization's typical production level is much lower (Liker 2004 p. 114). Reduction of variability (mura) can be achieved through proper market selection, product design, and pricing. Reduction of overburden (muri) can be achieved through implementing flow, quality, and standardized work into processes, cross-training employees, and balancing resources (Bell and Orzen 2011 p. 36). By reducing overburden (muri) and variability/unevenness (mura), a Lean company levels its production and frees-up capacity, giving workers greater opportunities to eliminate waste and continuously improve value streams (Bell and Orzen 2011 p. 36).[9]

In his book Office Kaizen, William Lareau refers to easily seen wastes as *surface wastes*.[10] Lareau warns that surface wastes create a large blind spot for management who mistakenly believe that they are addressing serious underlying problems when instead they are grabbing the low-hanging fruit (Lareau 2003 p. 12). Particularly in an office setting, significant waste can hide beneath the surface. Examples of significant wastes include: requirements for superfluous approvals, delays of responses to phone or electronic mail inquiries, having multiple people performing the same work on different systems (perhaps even with different data), poorly run meetings, and employees working without direction (Lareau 2003 p. 20). Lareau described four categories of surface wastes: (a) *people wastes*, the failure to harness the potential within work groups; (b) *process wastes*, poor process design and execution; (c) *information waste*, resulting from less than optimum information; and (d) *asset waste*, poor utilization of material and property (Lareau 2003 p. 21 – 37). Specifically, Lareau identified 26 specific subcategories of waste:

> People Wastes: goal alignment waste; assignment waste; waiting waste; motion waste; processing waste. Process Wastes: control waste; variability waste; tampering waste; strategic waste; reliability waste; standardization waste; sub-optimization waste;

[9] Even technological improvements that were accepted and implemented throughout American industry contributed to waste. The computerized Material Requirements Planning systems (MRP) that were introduced to U.S. manufacturers in the 1970s are one example: "MRP had a number of problems. If even one part was not properly logged into the system as it proceeded from one production station to the next, errors began to accumulate that played havoc with the reorder 'triggers' telling a department when to switch over to the next type of part. As a result, downstream manufacturing operations often had too many parts (the *muda* of overproduction) or too few parts to meet production schedule (producing the *muda* of waiting)…MRP systems which were very simple in concept therefore became exceedingly complex in practice… In the end, most MRP applications were better than manual systems, but they operated day-to-day at a level of performance far below what was theoretically possible and what had been widely expected when MRP was first introduced (Womack and Jones 2003 p. 57 – 58)."

[10] Office Kaizen is a service mark of the Kaufman Consulting Group, LLC.

> scheduling waste; work-around waste; uneven flow waste; checking waste; error waste. Information Waste: translation waste; missing information waste; hand-off waste; irrelevancy waste; inaccuracy waste. Asset Waste: inventory waste; work-in-process waste; fixed asset waste; moving things waste (Lareau 2003 p. 21 – 37).

Whether or not they are aware of it, all customers pay for a significant amount of waste (Lareau 2003 p. 139). Although they may not identify it as waste, many workers accept wasteful activities as the normal business practice. In order to eliminate waste, a Lean company must change its culture by not only admitting that all processes contain waste, but also by putting the appropriate tools in place to identify and allow employees to eliminate it (Cunningham and Fiume 2003 p. 45). Conceptually, value-added activities are those for which customers would be willing to pay, if they knew about the activity. Alternatively, customers would find a product or service to be less valuable if the activity were not performed. Businesses have a tendency to *mis*classify most of their non-value-added activities as required activities. If a "requirement" to perform an activity is internal to a business, it is likely to be a changeable policy rather than a necessity. Even external "requirements" may be changeable (Cunningham and Fiume 2003 p. 46). Once an enterprise removes the non-value-added and *not*-required activities from its processes, it can work to improve the non-value-added-but-required steps through the use of flow, pull, and perfection techniques (Womack and Jones 2003 p. 38). Through the elimination of all forms of waste, Lean companies can become time-based competitors (Cunningham and Fiume 2003 p. 8).

A critical task in specifying value is the determination of target *costs* that are based on the resources available and the effort required to make a product (or provide a service) of a given specification, if all the currently visible waste were to be removed from the process (Womack and Jones 2003 p. 35). Lean companies determine target costs for products, sub-assemblies, processes, and materials. The establishment of target costs then leads to the "development of action plans and continuous improvement initiatives designed to change the company's products and processes to meet or exceed the customer's requirements for additional value (Maskell and Baggaley 2004 p. 20)." This process requires a collective effort from all value-stream areas – including, marketing, sales, design, production, engineering, and purchasing – focusing everybody upon the creation of customer value (Maskell and Baggaley 2004 p. 20). If a company achieves success in their lean transformation, its target costs should be far below its competitors' costs, thereby allowing a Lean company to:

> reduce prices (another way to increase sales volume and utilize freed-up resources); add features or capabilities to the product (which should also increase sales); add services of the physical product to create additional value (and jobs); expand the distribution and service network (again increasing sales, although with a time lag); or take profits to underwrite new products (which will increase sales in the longer term) (Womack and Jones 2003 p. 35 – 36).

Traditional companies, however, typically determine target *selling prices* based on what they believe the market will bear and then work backwards to determine what costs would ensure an adequate profit margin (Womack and Jones 2003 p. 35).

Value Streams

Every product that has a customer also has a value stream (Rother and Shook 2009 p. 91). A value stream consists of all of the processes necessary to bring a product and/or service from its concept to the ultimate customer throughout its life cycle. In a production context, a *process* is a series of actions that bring about an end or a result (Maskell 2009 p. 120). Complex processes involve many functional areas of a business. Through a process, inputs are transformed into output. Maskell identified eight mechanisms, or the eight *M*s, that can be applied to inputs to create an output: machines; material; manpower; methods; measurement; maintenance; management; and money (Maskell 2009 p. 121). Naturally, one's first image of converting an input into an output might be the conversion of a raw-material input into a finished-product output. An input, however, could be a product idea or a sales order, and the corresponding output a product design or a customer invoice (Maskell 2009 p. 120).

There are two primary categories of value streams: (1) order-fulfillment value streams; and (2) new-product-development value streams. An order-fulfillment value stream follows the flow of *material* through the production and distribution processes: "from the sales process, through customer service, to configuration, to purchasing, to production (together with all the processes supporting production, like maintenance, quality, materials handling, etc.), to shipping, to installation, to invoicing, and finally to cash collection (Maskell 2009 p. 73)." A new-product-development value stream follows the flow of *information* required to design and launch new products: "from the identification of customer or market needs, through the understanding of those needs and the value of the new product, to the design and testing of the product, to the introduction of the product into the market (Maskell 2009 p. 73 – 74)."

Businesses have both internal and external customers (Bell and Orzen 2011 p. 33). In fact, a product or service might have several internal customers before it ever reaches an external customer. A value-stream perspective is a holistic perspective. Instead of locally optimizing the performance of individual processes, a value-stream perspective focuses on improving the whole (Rother and Shook 2009 p. 1). A Lean company continually seeks to improve the quality of its products and services. It achieves this through a detailed understanding of its processes, coupled with the continuous elimination of waste within those processes. In defining their value streams, Lean companies stop looking at aggregate activities. Instead, Lean companies focus on all of the specific actions required to produce specific products, as well as how they interact. Upon doing so, Lean companies then can confront those actions that do not create or optimize value, whether individually or in combination with one another (Womack and Jones 2003 p. 44). To save cost, a Lean company's management and employees must have committed focus upon process improvement, zero defects, and customer satisfaction. Maskell refers to this focus as a step of faith. Through taking care of the right things, the costs will take care of themselves. Costs should not be ignored, but rather have a lower relative priority than quality and customer service (Maskell 2009 p. 88).

Value-stream analysis exposes waste, but also requires changed behavior from both management and employees (Rother and Shook 2009 p. 91). To best understand an enterprise's value streams, one physically should walk the actual path of the flow of material and/or information and calculate the time and distance traveled (Liker 2004 p. 29 – 30). *Gemba* is the Japanese term for "real or actual place." In a Lean company, gemba or gemba walking emphasizes the need for management and/or office personnel to leave the comfort of their office or workspace to see how internal and/or external customers are using the company's products or services. Personal observation is critical (Bell and Orzen 2011 p. 42). To be effective, the practice of gemba-walking should begin with top management and then work its way down through the organization once management learns enough to teach others (Mann 2010 p. 124).

> Learning through gemba walking requires patience and tolerance for frustration. It is not fast. One of the main ways of learning is from experience as you work to make the corrections and refinements you find necessary…as you try new things. There is no good alternative to gemba walks as the method to learn lean management. That is because lean management is a mindset, and mindsets necessarily change and develop over time through personal experience (Mann 2010 p. 125).

To facilitate its lean transformation, a Lean company continually prepares value-stream maps. Value-stream mapping is a detailed flowcharting technique that uses symbols to depict both the flow of material and the flow of information as a product and/or service makes its way through a value stream. Through the mapping methodology, an enterprise quantifies its wastes, both of time and of quality (Bell and Orzen 2011 p. 37). It pays particular attention to cycle times, lead times, and queues (Lareau 2003 p. 118) – where flow is stopped and material or information inventory accumulates and waits to be processed (Rother and Shook 2009 p. 16). Information flow is treated with equal importance as material flow (Rother and Shook 2009 p. 3).

> [Companies should] immediately form teams to rethink the value stream and flow of value for every product in the plant, and then every step in order-taking and product development… Lineup essential activities required to design, order, and manufacture…and perform them in sequence, one machine, one design, one order at a time. Batches, queues, backflows, and waste – *muda* of all sorts - would be banished. The *value stream* - the irreducible minimum set of activities needed to design, order, and make a [product] - would flow smoothly, continuously, and rapidly (Womack and Jones 2003 p. 112).

In value-stream mapping, a Lean company first carefully draws a current-state map of every process in both the material and information flows. Then, it draws a future-state map based upon data-supported predictions on the improvements that will yield the greatest results (Bell and Orzen 2011 p. 40).[11] The future-state map is derived from the current-state map (Bell and Orzen 2011 p. 40). Physical production processes, administrative processes involving the movement of documents, and logical processes performed by computers and people all should be

[11] For each process step, Womack and Jones suggest that managers ask: "Does the step create value for the customer? Is the step capable? (That is, does it produce a good result every time?) Is available? (That is, can it produce the desired output, not just the desired quality, every time?) Is it flexible? (Can it be changed over quickly from one product to the next so that items can be produced in small lots or even lots of one?) Is capacity for the step adequate so the product doesn't need to wait on the process? Or is there too much capacity (due to designing equipment in large increments of capacity based on demand forecasts that are often wrong)?" Womack and Jones 2003 p. 316

mapped (Maskell 2009 p. 127). The more complex a value stream, the more functional areas it crosses. Accordingly, accurate and practical value-stream maps require input from each of the people involved (Maskell 2009 p. 125). Value-stream mapping forces a Lean company's employees to become aware of each other's needs and constraints, as well as the enterprise's future path, which by the nature of lean, may necessitate frequent modification (Womack and Jones 2003 p. 326).

A future-state vision should include: (a) work centers aligned with the value streams to support (as near as possible) one-piece flow; (b) cross-functional, co-located teams to avoid handoffs; (c) quality built into processes, rather than inspection of output after the fact; (d) standardized and clearly documented work to be performed for a given process; (e) elimination of redundant systems; and (f) visual displays and controls to make work status easy to see and understand (Liker 2004 p. 281 – 282). As once future-state value streams become a reality, a Lean company continually draws new future-state maps (Rother and Shook 2009 p. 7). Future-state maps should be designed so as to eliminate the *sources* of the waste within the value stream. Ad hoc teams improve processes to achieve the lean goals of service to its customers, trimming costs, reducing cycle times, and eliminating quality problems (Maskell 2009 p. 134). Root cause analysis of waste and value-stream problems is critical to process improvement (Maskell 2009 p. 134). A Lean company seeks to build a production sequence whereby the individual processes not only are linked to their customers, but produce only what their customers need when they need it, or as close to that goal as possible (Rother and Shook 2009 p. 49).

Well-drawn maps alone, however, are not enough. There needs to be an implementable plan *and* an individual with the responsibility and authority for managing, improving, and perfecting the value stream.[12] It is important for companies striving to achieve a lean transformation not make the mistake of delegating the process of value-stream mapping to managers of various areas with the intention of later stitching together separately created maps of individual company segments. Lean companies do not map their organization. Instead, they map the flow of products through the organization (Rother and Shook 2009 p. 6). Furthermore, it is important for a company striving for a lean transformation not to specify value stream that consists of either too small or too large a part of the company's products or services. Recall that value streams typically are made up of groups of products or services (i.e., families) that share common processes. A good rule is that a value stream should neither represent less than ten percent nor greater than 60 percent of a company's output. Frequently, Lean companies have two or three primary value streams and one value stream for the remainder of the output (Maskell and Baggaley 2004 p. 108).

Flow

After an enterprise has implemented the first two lean principles, precisely specifying value by product/service from the customer's perspective and identifying the value streams (through value-stream mapping and waste-elimination techniques), a Lean company strives to make the remaining value-creating steps flow (Womack and Jones 2003 p. 21). Flow is a particularly challenging lean principle because it is counterintuitive to the ways most managers and employees have been educated or trained.

[12] "We found overwhelming acceptance of this [value-stream mapping] tool across the world and we now find many managers with beautiful Current State maps and with equally beautiful Future State maps indicating the potential for major leaps in performance. But, when we take a walk along the value stream, there is no actual Future State. The promised leap in performance has never occurred or has been achieved to only a fraction of the extent possible…And this is the great problem: usually there is no real plan, or at least no implementable plan, because no one has the responsibility. There is no value stream manager to perfect the process (Womack and Jones 2003 p. 319 – 320)."

> According to the cost-accounting rules that everybody has used in the past, we're supposed to balance capacity with demand first, then try to maintain the flow…But instead, we shouldn't be trying to balance capacity at all; we need excess capacity. The rule we should be following is to balance the *flow* with demand, not the capacity (Goldratt p. 259).[13]

In creating flow, Lean companies link together operations that otherwise are disjointed, thereby increasing teamwork, rapid feedback on quality problems, control over processes, and pressure for people to solve problems (Liker 2004 p. 101). Flow is the continuous development of the materials, services, and information for a value stream. A value stream that has not achieved flow experiences interruptions, delays, rework, and increased costs (Bell and Orzen 2011 p. 29). Whether it is in the form of materials, services, or information, work-in-process inventory "causes congestion, confusion, and delays; hides problems; must be managed and tracked; often becomes obsolete; and is often reworked or discarded." In turn, this causes additional interruptions, delays, rework, and cost (Bell and Orzen 2011 p. 29). Traditional businesses hide problems with inefficient processes and high inventories. In contrast, Lean companies (through the creation of flow) "lower the water level" and expose inefficiencies that demand immediate solutions (Liker 2004 p. 88).

Any activity within the creation, ordering, or provision functions for any product or service can be made to flow by lining up all of the essential steps with no wasted motions, stoppages, expediting, batches, or queues (Womack and Jones 2003 p. 51, 61). To achieve continuous flow, a Lean company must ensure that every machine and every worker be

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[13] Although Goldratt's book, The Goal: a Process of Ongoing Improvement, is a novel – and thus its messages are delivered from the mouths of fictional characters – its introduction of the Theory of Constraints has made great contributions to both manufacturing and cost-accounting thought.

Goldratt's Theory of Constraints: "1. IDENTIFY the system's constraint(s). 2. Decide how to EXPLOIT the constraint(s). 3. SUBORDINATE everything else to the above decision. 4. ELEVATE the system's constraint(s). 5. WARNING!!!! If, in a previous step, a constraint has been broken go back to step 1, but do not allow INERTIA to cause a system's constraint (Goldratt p. 307).

completely “capable.” In other words, every machine and every worker always must be ready to run precisely when needed. Furthermore, every process must be performed exactly as it was designed (Womack and Jones 2003 p. 60). With flow systems, Lean companies have an everything-works-or-nothing-works mentality. Every worker in a production team should be cross-trained in many tasks in case someone is absent or needed for another task (Womack and Jones 2003 p. 60). Process steps are arranged in a sequence and typically organized within a work cell. Products, services, and/or information moves from one step to the next with no buffer of work-in-process in between.

Many traditionally massive machines should be replaced by “right-sized” machines that frequently are simpler, less automated, and slower, but often are more accurate and repeatable. Right-sized machines typically can be converted very quickly from one product specification to the next (Womack and Jones 2003 p. 60). This approach necessitates having excellent tools and equipment, as well as a maintenance system that keeps them in perfect condition and ready for use (Maskell 2009 p. 44). Through empowerment and cross-training initiatives, total productive maintenance (TPM) gives shop-floor operators the responsibility for machine, equipment, and tooling maintenance. The maintenance department becomes responsible for training, coaching, and handling the more complex and specialist repair tasks (Maskell 2009 p. 44).

Products, services, and/or information do not live in just one department. Instead, a process must move through numerous functional areas, including for example, production, engineering, purchasing, and accounting. A company that organizes itself by functional department can cause delays each time that a value-stream process enters into a new functional area (Liker 2004 p. 92). This is especially true where different value streams each have to cross multiple functional departments and compete for shared resources. This causes backlogs, inventory build-up, confusion, interruptions, quality problems, cost overruns, and delays (Bell and Orzen 2011 p. 152). Accordingly, Lean companies locate entire value-stream teams together. A lean manufacturing cell is comprised of all of the personnel and equipment necessary to produce a product, part, or subassembly, including the team leader, engineer, buyer, maintenance, and the operators (Womack and Jones 2003 p. 63).

The goal of continuous flow is to eliminate any and all stoppages in a complete production process (Womack and Jones 2003 p. 61). Machine changeovers that stop production and machines that run at rates far outside of the remaining production sequence create waste (Womack and Jones 2003 p. 61). Another lean goal is the elimination of production expediting. To achieve these goals, a Lean company produces according to *takt* time (Womack and Jones 2003 p. 55). In order to produce to takt time – the optimum cycle time – Lean companies take great pains to plan and organize their production layout and cellular-manufacturing teams (Maskell 2009 p. 40). In German, takt means rhythm or meter. Takt time precisely synchronizes the rate of production (i.e., cycle time) to the rate of sales to customers at a given point in time (Womack and Jones 2003 p. 55). If an enterprise produces faster than takt time, it will overproduce. If it produces slower than takt time, it will create at least one bottleneck (Liker 2004 p. 94). As the volume of customer orders increases or decreases over time, takt time is adjusted so that production always is synchronized with customer demand (Womack and Jones 2003 p. 56). Takt time is calculated by dividing the daily per unit customer demand rate into the available working time per day in seconds (Rother and Shook 2009 p. 38).

Some of the steps and effects of converting to cellular organization are:

> Improved factory layouts also greatly reduced the need to hold and move large quantities of inventory. Grouping machines according to expected sequence of operations, rather than the traditional grouping according to similarity of function, reduced a product's

> total travel distance (incoming materials to finished goods shipment) from several miles to several hundred yards, an order-of-magnitude reduction (Johnson and Kaplan p. 215).

According to Maskell, a Lean company's cellular organization offers the following advantages over a traditional business' functional department organization: (a) it eliminates the movement of materials since all of the work is done within the relatively small area; (b) it reduces work-in-process inventories since production is in small batches with short cycle times and minimal inventory queues; (c) it creates teamwork due to the interdependency, responsibility, and authority among the people; (d) it eliminates the complex recording of transactions since materials are only in a cell for a short period of time and the production process is more predictable; and (e) product quality is improved both due to the responsibility of the workers for quality and the use of the product immediately by the next process, thereby resulting in identification and immediate correction of problems without large numbers of reject product ever being made (Maskell 2009 p. 39 – 40).

In continuous-flow manufacturing, a customer order triggers a company to obtain only those raw materials needed. Workers immediately acquire the ordered components and then assemble the order. The completed order then flows immediately to the customer (Liker 2004 p. 90). Implementing flow is essential to reducing the production time (from raw material to finished good or service), which also leads to the achievement of the lean goals of highest quality, lowest cost, and shortest delivery time (Liker 2004 p. 87). Flow also enables a just-in-time response to customer requests, based on customer-demand signals. Workers are able to spot and solve problems quickly. When production is stable, customer production and/or service agreements can be promised and met consistently (Bell and Orzen 2011 p. 104). The aspirational/theoretical goal for Lean companies (albeit not achievable by most companies) is single-piece flow – a batch size of one (Liker 2004 p. 92). Among its benefits are that flow:

1. *Builds in Quality.* It is much easier to build in quality in one-piece flow. Every operator is an inspector and works to fix any problems in station before passing them on. But if defects do get missed and passed on, they will be detected very quickly and the problem can be immediately diagnosed and corrected.

2. *Creates Real Flexibility*. If we dedicate equipment to a product line, we have less flexibility in scheduling it for other purposes. The lead time to make product is very short, we have more flexibility to respond and make with the customer really wants. Instead of putting in new orders into the system and waiting weeks to get that product out, if lead times are matter mere hours we can fill a new order in a few hours. And changing over to a different product mix to accommodate changes in customer demand can be almost immediate.

3. *Creates Higher Productivity*. The reason it appears the productivity is highest when your operation is organized by department is because each department is measured by equipment utilization…In a one-piece flow cell, there is very little non-value-added activity like moving materials around. You quickly see who is too busy and who is idle. It is easy to calculate the value-added work and then figure out how many people are needed to reach a certain production rate…

4. *Frees up Floor Space*. When equipment is organized by department, there are a lot of bits of space between equipment that are wasted, but most of the space is wasted by inventory - piles and piles of it. In a cell, everything is pushed close together and there is very little space wasted by inventory. By making greater use of the floor space you often eliminate the need to build more capacity.

5. *Improves Safety*… Smaller batches meant getting rid of forklift trucks, which are a major cause of accidents. It meant lifting and moving smaller containers of material, so accidents related to lifting went away. Safety was getting better because of a focus on flow - even without focusing on safety.

6. *Improves Morale*… In one-piece flow, people do much more value-added work and can immediately see the results of that work, giving them both a sense of accomplishment and job satisfaction.

7. *Reduces Cost of Inventory*. You free up capital to invest elsewhere when it's not invested in inventory sitting on the floor. And companies do not have to pay the carrying costs of the capital they free up. Also your inventory obsolescence goes down (Liker 2004 p. 95 – 96).

Standardized Work

After stabilizing a process, a Lean company standardizes it, and then continues to simplify and improve it (Mann 2010 p. 27). Standardized work is simply a detailed description of the most effective method to accomplish a task at any given time (Bell and Orzen 2011 p. 42). The implementation of standardized work is necessary to achieve continuous flow since all jobs are linked directly, without buffers. Through its standardized work, a Lean company seeks to produce a product (or provide a service) in accordance with cycle time and do it right the first time, every time (Womack and Jones 2003 p. 113). Variation in work practices and procedures causes undesired variation in time, quality, and cost (Bell and Orzen 2011 p. 42). A value-stream team decides upon the current standard to which they all agree to adhere. Through its improvement process, a value-stream team seeks continuously to establish a newer version of the standardized work (Bell and Orzen 2011 p. 42). Toyota President Cho identified three elements of standardized work: takt time, the sequence of processes, and the specific quantity of inventory on hand that an individual worker needs to have in order to produce to standard (Liker 2004 p. 142).

It is important that the work be standardized by the value-stream team and not by a remote, industrial-engineering team (Womack and Jones 2003 p. 60). A value-stream team knows the intricacies of its processes and will be the ones charged with continually improving them. Standardized work also helps to build-in quality. If a defect is discovered, the first inquiry should be whether or not the standardized work was followed. If standardized work has been followed, but defects still occur, then the standardized work needs to be changed (Liker 2004 p. 142 – 143). In addition to standardized work for associates, leader standard-work provides supervisors and management with clear expectations of their own performance (Mann 2010 p. 37). Leader standard-work facilitates the stability and continuity of lean management during personnel changes and either improves the management performance, or highlights those managers who are not making the grade (Mann 2010 p. 38).

Pull

Cunningham and Fiume identify flow production and takt time as two of the three tenets for eliminating waste. The third tenet, pull scheduling, means that a Lean company produces only what the customer is buying right now, instead of producing to a long-range forecast (Cunningham and Fiume 2003 p. 8). A process that cannot be made to flow by design should be connected to a subsequent process (that does flow) through the use of a pull mechanism. Through a customer-demand signal, a pull mechanism triggers work to be performed just-in-time for the subsequent steps in the process (Bell and Orzen 2011 p. 30).

In Japanese, *kanban* means sign, sign board, poster, billboard or card. In a Lean company, a kanban is taken more broadly as a signal of some kind. For example, if a downstream process sends an empty bin to an upstream process, it is a signal for the upstream process to refill the bin with a specific number of parts (Liker 2004 p. 106 – 107). A pull system allows an upstream process to receive accurate production instructions from a downstream process without having to try to predict downstream demand and schedule upstream production (Rother and Shook 2009 p. 41). Implementing pull regulates work activity and eliminates the possibility of overproduction (Bell and Orzen 2011 p. 30). Rather than pushing frequently unwanted products onto customers, a Lean company lets the customer pull the product as needed. Customer demand also becomes more stable when customers know that they can get what they want when they want it. Furthermore, producers can stop running promotions on unwanted inventory since significant quantities do not accumulate (Womack and Jones 2003 p. 24).

"Supermarkets" on a factory floor supply a pull system. By locating supermarkets near a supplying process, visual control of customer usage and requirements can be maintained. Remember that a company has internal customers as well as external customers. When a customer goes to its supplier's supermarket and withdraws what it needs, that withdrawal triggers the supermarket to convey a kanban to the supplier process. The kanban is the sole production instruction for that process (Rother and Shook 2009 p. 41). Although a kanban is usually a card, it can be a container, a tote, or a square painted on the floor (Maskell and Baggaley 2004 p. 36). According to Bell and Orzen 2011, the kanban system has several purposes: (a) it triggers work only when it is ordered by the customer; (b) it specifies the work to be done, both in description and sequence; (c) it limits the amount of work-in-process inventory; (d) it buffers against production interruptions by keeping a small, carefully measured safety stock (a supermarket); and (e) it orchestrates the pace of work (Bell and Orzen 2011 p. 104 – 105).

Heijunka (Level Scheduling)

Although Lean companies tend to do a good job of identifying and eliminating waste, many organizations struggle with creating evenness in their production flow. In Lean companies, evenness is created by the practice of level scheduling, or *heijunka*, in Japanese. Liker believes that heijunka may be the Toyota Way's most counterintuitive principle. In order to eliminate muri (overburden) and muda (waste), a Lean company needs to eliminate mura (variability or unevenness). But to eliminate mura, a Lean company needs to achieve heijunka (Liker 2004 p. 115). Heijunka levels both the production volume and the product mix. Instead of building products in strict adherence to actual customer orders, a Lean company looks at the total volume of orders for a short-term period, divides that by the available time, and then produces the same quantity and mix each day (Liker 2004 p. 116).

Customer orders can vary dramatically from week to week and month to month. Accordingly, an organization that follows a strict make-to-order model could produce large quantities one week, incur significant overtime costs, and overburden workers and equipment, but then have little to do the following week. This variation in customer orders can cause organizations to overcompensate when ordering from vendors, which results in excess inventory (materials, work-in-process, and finished goods), hidden problems, and poorer quality (Liker 2004 p. 113 – 114). Unevenness and overburden hinder quality, standardized work, productivity, and continuous improvement (Liker 2004 p. 115). Level scheduling requires more frequent equipment changeover; however, the overall benefits to a Lean company outweigh this localized burden in the production cell (Rother and Shook 2009 p. 44). A common way to practice level scheduling is through the use of a load-leveling (or heijunka) box that has a column of kanban slots for each batch size and a row of kanban slots for each product type. The kanban indicates both the quantity of product to be produced and the takt time to produce them. After having been loaded into the box based on the desired product mix, the kanban are withdrawn and brought to the "pacemaker" process one at a time, based on the batch size (Rother and Shook 2009 p. 47).

> The causes of high WIP inventories are large batch sizes, long cycle times, and production queues. Production queues are caused by a lack of balance throughout the plant so that the next work center is unavailable when a batch of product has been completed in the previous work center… When production is synchronized through the plant, the materials and products flow evenly through

> the production cells and never stop for a moment. The various cells and activities within the cells are carefully planned so that there is a similar cycle time at each step in the process. This synchronization ensures that the material flows through the production facility according to a fixed and planned "drum beat" or takt time… This synchronization is achieved through careful planning and cell design, and by *heijunka* scheduling to ensure synchronization and level loads (Maskell 2009 p. 41 – 42).

Visual Controls

Kanban and heijunka are both examples of the lean technique of visual control. At a glance, visual controls tell management and employees how work should be performed and whether the work is deviating from its standard (Liker 2004 p. 152). Lean companies desire prompt feedback on whether actual results differ from expected results. Remember that lean operations focus on processes: stabilizing, standardizing, and improving them by repeatedly exposing and eliminating problems. Visual controls provide quick status updates of the processes and the problems within the processes (Mann 2010 p. 86). Both factory and office employees perform better when they can see and understand what is going on. Accordingly, Lean companies gather, report, and display cell-level and value-stream-level performance measurements on highly visible boards right where the work is performed (Maskell 2009 p. 142). Furthermore, having employees spend a few minutes per shift, or process cycle, recording performance data can cost a Lean company substantially less in hardware, software, and support than an automated data-collection system (Mann 2010 p. 83). Beyond the cost savings, operators that record performance measurements in a timely manner are more involved in observing, analyzing, and improving the value streams (Mann 2010 p. 83).

Frequently production personnel ignore computer-generated reports, even if they are posted in work or common areas and particularly if the information is contained within tables or graphs. We tend to forget that it often takes a trained eye to understand information presented in this format. Mann believes that the "fingerprint factor" is important. People are more likely to read and interpret information that they helped to create than they would for impersonal, computer-generated information, even if it had fancy graphics (Mann 2010 p. 81). Since office work resides and moves hidden within the information-technology network, visual controls may be even more critical for office processes (Mann 2010 p. 53). Office "misses," actual results that fall short of the standard, can be tracked just like production misses and, thereafter be the subject of root-cause improvement analysis (Mann 2010 p. 111). Accordingly, it is important that operators be involved either in the recording of performance measurements or working through the measurements with their team leader (Mann 2010 p. 81).

Perfection

Lean thinking goes beyond its first four fundamental principles. It requires progressive continuous improvement, root-cause analysis for problem solving, and an efficient response thereto (Mann 2010 p. 163).

> The four initial principles interact with each other in a virtuous circle. Getting value to flow faster always exposes hidden *muda* in the value stream. And the harder you pull, the more impediments to flow are revealed so they can be removed (Womack and Jones 2003 p. 25).

Perfection, the fifth fundamental principle of lean thinking, is "the process of reducing effort, time, space, cost and mistakes while offering a product which is evermore nearly what the customer actually wants (Womack and Jones 2003 p. 25)." In pursuing perfection, a Lean company recognizes that processes, standards, and value-stream maps are temporary. Change is constant, and new ideas are sought continuously. All workers and management should see their respective jobs as having two inseparable components: daily work and daily improvement (Bell and Orzen 2011 p. 22).

> Our earnest advice to lean firms today is simple: to hell with your competitors; compete against *perfection* by identifying all activities that are *muda* and eliminating them. This is an absolute rather than a relative standard which can provide the essential North Star for any organization (Womack and Jones 2003 p. 49).

Quality-at-the-source is a lean goal. It means doing things right the first time, every time. Higher quality does not come from having more inspectors. Work that does not meet the standard is not sent on to the next process or ultimately, to the customer (Bell and Orzen 2011 p. 27). Lean companies instill with the people who do the job both the responsibility for quality and the authority to effectuate change (Maskell 2009 p. 36 – 37).

In order to maximize the impact of their pursuit of perfection, Lean companies need to set and follow timetables for their progress. Womack and Jones note that the biggest difference between companies that have great success in a lean transformation and companies that have accomplished very little is that successful companies set specific timetables by which to accomplish difficult tasks and then routinely met or exceeded them. Unsuccessful companies on the other hand "asked what would be reasonable for their current organization and disconnected value streams to accomplish, and generally defeated themselves before they ever set out (Womack and Jones 2003 p. 95)." In applying the lean technique of policy deployment (*hoshin kanr*i in Japanese), top management must agree on a few simple goals for transitioning from traditional to lean production. That is, top management selects only a few projects at a time, specifically identifies the people and resources that will achieve these goals, and importantly, establishes quantitative improvement targets to be achieved within a specific time frame (Womack and Jones 2003 p. 95). Furthermore, the most successful Lean companies learn how to deselect projects in order to align projects with available resources (Womack and Jones 2003 p. 97).

Kaizen

The principal means through which Lean companies perform continuous improvement are *kaizen* activities. In Japanese, *kai* means little, ongoing, and good. *Zen* means both good and "for the better" (Lareau 2003 p. 5). Kaizen is a systematic methodology whereby Lean companies make many incremental improvements to their processes or value streams (Bell and Orzen 2011 p. 40). Cunningham and Fiume refer to Lean as a game of singles, not of home runs (Cunningham and Fiume 2003 p. 70). There are two broad categories of kaizen activities: system (or flow) kaizen and process kaizen. System (or flow) kaizen – which management performs – is a more holistic approach that focuses on improving overall value through improvement of both material and information flows. Process kaizen – which individuals and value-stream teams perform – focuses on reducing the waste in specific areas within a value stream (Bell and Orzen 2011 p. 40). Both system (flow) and process kaizen activities are necessary in a Lean company. Improvement through one type of kaizen facilitates improvement through the other (Rother and Shook 2009 p. 6). Regardless of the category, a kaizen has three phases: (a) preparation; (b) the kaizen itself; and (c) sustaining the achievements and continuous improvement afterwards (Liker 2004 p. 276 - 277).

Using this methodology, a Lean company identifies a target process for improvement and forms a small team of employees from several of the functional areas through which that target process travels. A kaizen team includes the manager responsible for the target process, who serves as the team leader, and several people from other functional areas who actually perform the work within the process (i.e., not a bunch of managers). Liker recommends that the kaizen team include both customers and suppliers of the targeted process (Liker 2004 p. 276 – 277). Liker has stated that a kaizen team should be limited to no more than 15 people (Liker 2004 p. 277). Mann believes that the composition usually should be seven or fewer persons, plus the leader (Mann 2010 p. 172). Lareau believes in a range of 7±2 persons (Lareau 2003 p. 56). A kaizen team focuses on the targeted process for a relatively short window of time – usually between two and five days (Cunningham and Fiume 2003 p. 10).

The results of kaizen activities are cumulative and gradual. Through kaizen activities, Lean companies improve production flow, ease the physical demands upon their workers, reduce inventory, shorten machine setup times, improve equipment, and increase quality (Mann 2010 p. 172). Examples of kaizen activities include:

> Re-layout of work areas to facilitate one-piece flow; workplace organization (5S and visual displays); creation of standard work instructions; revision of corporate procedures; redesign forms and documents; problem-solving activities to uncover root causes of quality problems; specifications or even some changes for any information technology required to support the improved process; training people in the new process (Liker 2004 p. 282).

As with most lean tools and methodologies, kaizen activities do not need to be limited to the factory. Office processes can benefit from kaizen activities, including those within: "human resources; sales; purchasing; materials management; product design engineering; marketing; contract; accounts payable/receivable; records/document administration; government affairs; customer service; engineering support; research; software engineering; loan processing; order entry; quality; sales support; legal; regulatory compliance (Lareau 2003 p. 6 – 7)."

A common lean technique is industrial housekeeping, also known as 5S. 5S improves an enterprise's efficiency and safety by promoting a clean and efficiently ordered workplace. Through 5S, all plant employees are responsible for everyday cleaning, maintaining and inspecting all equipment, and systematically arranging all of the tools and materials necessary for their respective jobs (Maskell 2009 p. 45). The purpose of industrial housekeeping is to eliminate the wastes that contribute to errors, defects, and injuries. Like much of lean thinking, 5S has its origins in Japan. In Japanese, the five S's are: *seiri, seiton, seiso*, *seiketsu*, and *shitsuke*. Roughly translated into English, the 5Ss are: sort, straighten, shine, standardize, and sustain (Liker 2004 p. 150).

> 1. Sort - Sort through items and keep only what is needed while disposing of what is not.
>
> 2. Straighten (orderliness) – 'A place for everything and everything in its place.'
>
> 3. Shine (cleanliness) - The cleaning process often acts as a form of inspection that exposes abnormal and pre-failure conditions that could hurt quality or cause machine failure.
>
> 4. Standardize (create rules) – Develop systems and procedures to maintain and monitor the first three S's.
>
> 5. Sustain (self-discipline) - Maintaining the stabilized workplace is an ongoing process of continuous improvement (Liker 2004 p. 150).

Not feeling compelled to translate five Japanese s-words into five English s-words, Maskell describes 5S as the Japanese words for the five concepts of: organization, orderliness, cleanliness, standardized cleanup, and discipline (Maskell 2009 p. 200 – 201).The fifth element of 5S, *sustain* (or discipline), is similar the fifth fundamental lean principle, *perfection*. It also may be the most difficult. To sustain its industrial housekeeping benefits, a Lean company needs to train and reward its workers not only to maintain its progress, but to improve continuously (Liker 2004 p. 36). As with much of lean operations, some of the reasons underlying industrial housekeeping are grounded in industrial psychology. If their workspaces are well-organized and supplied, employees work more effectively and efficiently. Safety is improved (Maskell 2009 p.

201). Human beings respond better to visual information and 5S is another example of visual control (Maskell 2009 p. 45 – 46).

There is also a psychological benefit to performing kaizen activities. Since kaizen are visible to the workforce and can require a large commitment of time and resources, they send a strong message to employees that change is expected (Cunningham and Fiume 2003 p. 61). Becoming a Lean company requires a change in culture. One type of process kaizen also known as daily kaizen (or a kaizen blitz) is a spontaneous improvement activity performed by an individual or a small group as a need is identified. The highest proportion of problem-solving in a Lean company occurs as a result of daily kaizens (Bell and Orzen 2011 p. 41). In addition to kaizen (incremental improvement) activities, some Lean companies engage in strategic breakthrough initiatives called *kaikaku*. Kaikaku activities, which strive for radical improvement, are typically initiated by senior leadership (Bell and Orzen 2011 p. 42).

Another common lean technique is the use of A3-sized piece of paper (11.69 x 16.54 inches or 297 x 420 millimeters) for root-cause analysis. A3 is an international standard (ISO) paper size. The A does not stand for anything. There are 11 A paper sizes (A0 to A10), 11 B paper sizes (B0 to B10), and even more C paper sizes. Each successive paper-size number is half of the size of the previous number. For example, an A1-sized paper is half the size of an A0-sized paper, and so forth. In Lean companies, A3 has come to mean much more than a paper size. The A3 technique uses the scientific method for solving problems: observation, the development of a tentative hypothesis of cause and effect, a prediction of results, testing, and evaluation (Bell and Orzen 2011 p. 37). In business, some also refer to this as the Deming Cycle, or Plan-Do-Check-Act (PDCA). The A3-technique constrains people to using a *single* piece of paper to communicate the definition, scope, discovery process, findings, proposed countermeasures, and results of a problem. The implication being that if people need more than a single A3-sized piece of paper to communicate the pertinent information, then they have not honed the information down to only its essential elements (Bell and Orzen 2011 p. 36 – 37). "Benefits from applying A3 thinking include fact-based decision-making, consensus building, clearly documented assumptions, defined targets, fast results, and follow-up to ensure that improvements are sustained (Bell and Orzen 2011 p. 37)." Lean companies should begin with only a handful of lean tools, sharpen their process-improvement skills, and then learn and apply additional tools, as needed (Bell and Orzen 2011 p. 36).

Frequently, the most difficult step in a lean transformation is simply getting started.

> You'll need a change agent [typically an outsider] plus the core of lean knowledge (not necessarily from the same person), some type of crisis to serve as a lever for change, a map of your value streams, and a determination to *kaikaku* quickly to your value-creating activities in order to produce rapid results which your organization can't ignore (Womack and Jones 2003 p. 247).

It is often best to start a lean transformation with an activity that is very important to the company, but which is performing poorly. "That way, you can't afford to fail, the potential for improvements is very large, and you will find yourself drawing on resources and strengths you didn't know you had in order to ensure success (Womack and Jones 2003 p. 253)." Furthermore, it is critical in a lean transformation not only to produce some dramatic results quickly, but to do so in an area that is visible to everyone in the company (usually in a production area). Then once the first round of improvements has been achieved, the company should focus on linking the different parts of the value stream for a family of products or services (Womack and Jones 2003 p. 254).

> The amount of human effort, time, space, tools, and inventories needed to design and provide a given service or good can typically be *cut in half* very quickly, and steady progress can be maintained

> from this point onward to cut inputs in half again within a few years (Womack and Jones 2003 p. 52).

Partnerships

Lean companies see their customers and suppliers as business partners so much so that they include these third-party organizations in value-stream, process-improvement, and waste-elimination planning and activities (Maskell and Baggaley 2004 p. 21). To produce high-quality products just-in-time with no significant inventory, a Lean company needs to receive its raw materials and components just-in-time for production. Accordingly, it is beneficial for a Lean company to develop close relationships with a limited number of suppliers, who will work together with the company for mutual benefit instead of as adversaries trying to outwit each other (Maskell 2009 p. 46 – 47).

Vendor single-source privileges for certain items and vendor-certification programs that establish strict requirements are among the means for building partnership relationships. Certified suppliers can deliver directly to the factory floor, bypassing inspection and receiving and eliminating the corresponding non-value-added invoicing and receipt transactions (Maskell 2009 p. 47). The elimination of non-value-added activities is fundamental to lean operations. Visual controls in the plant eliminate what otherwise would be more formal, time-consuming, and costly control transactions. Similarly, reliable daily delivery of high-quality materials by certified suppliers eliminates additional quality-control and inspection transactions. Control then occurs on the shop floor when and where the transactions are initiated. Control is built into the production process, rather than waiting to inspect products after significant production costs already have been incurred (Maskell and Baggaley 2004 p. 88). Partnerships that extend beyond the four walls of the enterprise are especially important in an environment where businesses are outsourcing more and insourcing less (Womack and Jones 2003 p. 21).[14]

Businesses need to have a relationship orientation, as opposed to a transaction orientation. To Johnson, a sale is simply one moment in a (hopefully lengthy) buyer-seller relationship, not just a one-time moment of truth. Relationships involve time. The connection neither begins nor ends when the sale is made. In fact, it can intensify after the sale (Johnson 1992 p. 76). By seizing the opportunities to learn and inform that exist in every customer encounter, Lean companies can create a *relationship advantage* in the market and turn customers into loyal advocates (Johnson 1992 p. 81). A commitment to building customer loyalty requires not only an underlying belief that profits will result from finding, satisfying and keeping loyal, recurring customers, but also by focusing every process toward those goals and ensuring that all employees understand how their work contributes to the achievement of those goals (Johnson 1992 p. 75). While it is critical to attract new customers, more resources should be spent on drawing existing customers back again and again. Numerous studies show that it costs five to ten times as much to attract a new customer as it does to keep an existing one. Furthermore, the costs of displeasing an existing customer can go beyond simply the loss of that customer, but also include that customer's driving away other potential customers (Johnson 1992 p. 86).

Freed Capacity

The implementation of lean principles frees up large amounts of resources that can be used for other value-creating activities. Lean companies that empower their employees to eliminate waste and continuously improve processes should not as a consequence, terminate employees when they free-up capacity. Otherwise, a lean initiative will be short-lived.

[14] This is not to suggest that lean thinking encourages the practice of outsourcing.

Employees will not commit to improvement projects if the result will be their termination or that of their friends (Maskell 2009 p. 107). “The reluctance to ensure employment is a major barrier to successfully implementing lean, and amounts to an admission by senior managers that they cannot grow the business fast enough to absorb significant productivity gains (Cunningham and Fiume 2003 p. 115).”

> If they are to defend their employees and find the best economic use for their assets as they strike out on a new path, they need to find more sales right now. Beginning with a better specification of value can often provide the means (Womack and Jones 2003 p. 35).

By eliminating recently freed-up resources, an organization also forfeits significant potential benefits that could result from using those resources in more creative and profitable ways (Maskell and Baggaley 2004 p. 315). Instead of terminating employees, immediate responses to freed-up manpower include reducing overtime, cutting the work week for everyone, and/or employing the freed-up workers on kaizen teams (Womack and Jones 2003 p. 140). A Lean company also can in-source some components from marginal suppliers with whom it otherwise would have discontinued business (Womack and Jones 2003 p. 140). Ideally, a Lean company can increase its revenues by producing and selling new products or services (Maskell 2009 p. 107). If freed capacity – both in manpower and machines – can be used elsewhere, the only additional costs incurred for new sales will be those for variable costs, most significantly, materials. Labor – although treated as a variable cost by many businesses (and accounting academics) – is actually a fixed cost for most businesses. Accordingly, there is no incremental labor cost for new sales (Maskell and Baggaley 2004 p. 68 – 69).

That being said, lean proponents estimate that roughly ten percent of the management in a company striving for a lean transformation will be unwilling, or flat out will refuse, to adapt to the lean methodology. In lean circles, these people have been referred to as “anchor draggers” and “concrete heads.” They are the exception to the guaranteed employment of a lean transformation. “They are poison. It is bad enough to try to change an organization with all the normal mistakes that well-intentioned people make. Allowing a ‘concrete head’ to remain makes the journey 10 times more difficult (Lareau 2003 p. 146).”

> Lean thinking is profoundly corrosive of hierarchy and some people just don't seem to be able to make the adjustment. It's essential that these anchor-draggers find some other place to work - after all, there's still plenty of hierarchy on the world - or the whole campaign will fail (Womack and Jones 2003 p. 132 *quoting* Art Byrne of the Wiremold Company).

Office Processes

Although office processes do not involve the physical transformation of products, lean concepts should not be confined to the plant (Cunningham and Fiume 2003 p. 8). In office processes, the progression of work typically cannot be seen (Mann 2010 p. 107). People work at computers, on the telephone, and in conference rooms. They move about from task to task. Projects can vary greatly in size, complexity, number of people, and lead time. There may be hundreds, if not thousands, of activities or transactions (Liker 2004 p. 270 – 271). Office processes cross many internal functional boundaries, have competing priorities, and frequently do not have specialized performance measurements or budgets (Mann 2010 p. 115).

In office (and service) processes, waste typically is information waiting in queues for someone to act upon it. A lack of coordination between processes causes batches of information and other inventory to build up before being moved along to the next process where it may sit and wait again. Information inventory is often more difficult to determine and quantify than tangible inventory (Liker 2004 p. 271). Office work-in-process inventory is comprised of paper and electronic documents, including electronic mail. Similar to tangible inventory, the more office work-in-process inventory there is, the less it flows and the more slowly it is finished (Bell and Orzen 2011 p. 29). Approximately half of office time is spent on non-value-added activities, including rework, correction of errors, requesting information, seeking clarifications, waiting for authorization, or waiting for responses (Mann 2010 p. 107). Although the value-stream mapping of office (and service) processes presents some different challenges than the mapping of production processes, a similar methodology can be used to make an information-flow map (Liker 2004 p. 275 – 276).

The overwhelming majority of office processes has an *internal* customer (or a series of internal customers) and does not touch an external customer directly. Most office and administrative workers have no direct contact with external customers. If external customers do not complain, substantial quantities of waste can remain hidden within internal processes. Accordingly, big potential savings are also hidden within those internal processes (Lareau 2003 p. 139 – 140). Similar to mapping production processes, office- (and service-) process mapping starts with defining value from the customer's perspective and then mapping the processes that add value for the customer (Liker 2004 p. 270 – 271).

Lean Accounting

"Lean accounting applies the principles of lean thinking (value, value streams, flow, pull, empowerment, perfection) to the accounting processes themselves (Maskell and Baggaley 2004 p. 19)." As an enterprise progresses in its lean implementation, all categories of inventory – raw materials, work-in-process, and finished goods – should decrease dramatically (Cunningham and Fiume 2003 p. 87). When a manufacturing company significantly reduces inventory, however, it also decreases the profits *reported* under traditional financial accounting with absorption costing of inventory. That is, when finished-goods inventory is reduced significantly, that portion of inventory is “de-capitalized” from the balance sheet to the income statement as cost of goods sold (an expense), which in turn reduces the reported profits (Maskell 2009 p. 24). Unfortunately for both lean operations and managerial accounting in general, traditional financial-accounting methods frequently will show negative results when good things actually are occurring.

> When lean pilots are introduced, it is unusual to see significant improvement to the company's financial reports. There can be some inventory reduction that leads to beneficial cash flow improvement, but this often takes some time to be realized. There is rarely any short-term improvement in cost or profitability, and, almost always, lean changes have a negative impact on the major financial variance reports… It is important in the early stages of the lean implementation to calculate the financial benefits of the changes being made. Most companies make the mistake of trying to identify the financial benefits of lean changes using the old mass production measurements… This inevitably leads to conflict and wrong decisions (Maskell and Baggaley 2004 p. 16).

Due in large part to the external financial and tax reporting authorities that mandate U.S. accounting practices, including the Financial Accounting Standards Board (FASB), the Securities and Exchange Commission (SEC), and the Internal Revenue Service (IRS), management accounting has become subservient to financial accounting and reporting (Johnson and Kaplan p. 198). Accordingly, corporate management fundamentally needs to comprehend that traditional financial-accounting statements – with absorption costing of inventory and standard-cost, variance-analysis reports – are *not* designed to address lean issues (Maskell 2009 p. 24). The measurement of factory variances comparing actual cost versus standard cost detrimentally focuses an organization on maximizing the efficiency of individual resources (local optimums) at the expense of the enterprise as a whole. "We must *not* seek to optimize every resource in the system… A system of local optimums is not an optimum system at all; it is a very inefficient system (Goldratt p. 211).” Accordingly, variance-analysis reports need to be eliminated as early as possible in a lean transformation (Maskell and Baggaley 2004 p. 83).

Traditional accounting practices provide a misleading understanding of a product’s cost and can lead corporate management to make incorrect decisions on critical issues, such as whether to make or buy a component, the profitability of sales orders, and the rationalization of products or customers (Maskell and Baggaley 2004 p. 2). Production cost, however, is an estimate that is dependent upon the allocation method used (Cunningham and Fiume 2003 p. 101). When standard cost accounting was established in the early twentieth century, the breakdown of a typical manufacturer’s production cost was approximately 30 percent for materials, 60 percent for direct labor, and 10 percent for manufacturing overhead (Cunningham and Fiume 2003 p. 87). Since overhead cost was proportionally small compared to direct labor cost (1:6 in that example), the practice of allocating overhead as a function of direct labor typically did not create a significant product-cost distortion. Today, however, a manufacturer might have a cost structure that is 60 percent for materials, 10 percent for direct labor, and 30 percent for overhead (3:1, overhead to direct labor). For other capital-intensive manufacturers, the overhead-labor disparity may be even more dramatically lopsided toward overhead, even as high as 10:1 (Johnson and Kaplan p. 188). Under such a structure, traditional allocation methods lead to potentially significant product-cost distortions (Cunningham and Fiume 2003 p. 87).

When organizations use direct-labor hours (or machine hours) to allocate overhead, they often create enormous cross-subsidies between products (Johnson and Kaplan p. 2). That is, companies systematically over-cost high-volume, commodity-type products that are mass-produced using older labor-intensive technologies. Conversely, companies systematically under-cost low-volume, custom-made products that use more expensive equipment and require more design, scheduling, and rework, but that do not have a proportionally high direct-labor content (Johnson 1992 p. 143). These cost distortions cancel each other out at the company level – since they do not affect reported *total* income or assets directly. These cost distortions, however, can lead to inappropriate organizational actions, including both: (a) the abandonment of incorrectly over-costed, commodity-type product lines (i.e., that if properly costed, would reveal their profitability); and (b) a focus upon incorrectly under-costed, high-tech product lines (Johnson 1992 p. 143). For most companies, however, accounting reports arrive too late to be of practical use. This is especially true where a problematic job order was completed in the early part of a month, but the financial reports were completed weeks after the end of the month. In those circumstances, it is virtually impossible to perform root-cause analysis on the conditions that created a standard-costing variance, much less to take successful remedial action (Cunningham and Fiume 2003 p. 92).[15]

According to Johnson, many American and European manufacturers that continued to follow traditional overhead-allocation practices (i.e., despite the dramatic product-cost composition changes), not only experienced depressed earnings, but many times, "generated a 'death spiral' that led companies to the edge of bankruptcy" (Johnson 1992 p. 143). Often, companies believe that costs will be lower if they outsource the production of parts or components (often overseas). Frequently misunderstood, however, is that much of overhead cost is not driven by direct-labor hours (Johnson and Kaplan p. 189). Overhead costs actually tend to *increase* with subcontracting due to the increased demands placed upon the purchasing, scheduling, receiving and inspection, materials-handling, and accounts-payable departments.

[15] Companies that perform lot identification, such as the pharmaceutical industry, are better able to perform root-cause analysis after-the-fact (Cunningham and Fiume 2003 p. 92).

> Subcontracting imposes additional demands on the purchasing department to generate specifications for the components and investigate qualified vendors; on the scheduling department to provide delivery schedules to the vendor; and the receiving and inspection department to process incoming items; and materials handling departments to place purchased components into storage and bring them out to production when needed; and on the accounts payable department to pay the vendor (Johnson and Kaplan p. 189).

A purchased component has no direct-labor content. Accordingly, these additional overhead costs that are incurred frequently are not traced to the purchased component, but instead are shifted onto other non-outsourced, labor-intensive products (Johnson and Kaplan p. 189).

Since traditional financial accounting and a significant amount of traditional cost accounting practice are not appropriate for lean operations, it is critical that Lean companies implement *lean accounting* practices, including *value-stream costing*. Proponents of lean manufacturing and lean accounting believe that it is more important for management to understand the profitability of a portfolio of related products rather than the profitability or unit cost of individual products (Cunningham and Fiume 2003 p. 101).

> The routine decisions related to quoting, profitability, make/buy, sourcing, product "rationalization," and so forth are best made by looking at the impact on the value-stream as a whole, rather than the individual product. The value-stream statements will give you accurate information about what will happen financially as you make changes to revenues, material costs, employee costs, machine cost, and other operations costs. And this information is calculated in simple and understandable ways (Maskell 2009 p. 111).

Similar to value-stream mapping, which facilitates the elimination of non-value-added operations, value-stream costing facilitates the elimination of non-value-added production-control, inventory, and product-costing transactions (Maskell and Baggaley 2004 p. 17). In value-stream costing, there is no allocation of indirect product costs (overhead) to activities or job orders. Instead, all costs are treated as direct costs of a specific value stream (to the extent possible). Only those indirect product costs (including indirect labor, rent, and utilities) that easily can be identified and traced to multiple value streams are treated as shared costs (Bell and Orzen 2011 p. 142). All production wages, machinery, outside processing costs, and supplies should be assigned directly to a value stream. Any other cost should be assigned to an administration and overhead category (Maskell and Baggaley 2004 p. 221). A Lean company need not make a distinction between direct and indirect costs. All costs other than those for materials are classified as "conversion costs," which costs are identified by value stream.

Through value-stream costing, a Lean company can produce "plain-English" financial statements that address lean issues.

> The income statements are largely cash-based and show the financial information in a way that is straightforward and clear. Anyone in the company would be able to understand these income statements and use them for controlling costs, reducing costs, and making decisions. They involve none of the opaque accounting methods like standard costs, variances, or absorption (Maskell 2009 p. 101 – 102).

The value-stream P & L does not include changes in inventory level when calculating value-stream profit, since Lean companies want to provide the proper motivation for value-stream teams. Reductions in inventory from selling a greater number of units than were produced for a given period of time will show higher profits and lower average unit costs, whereas increases in inventory over a period will show the opposite (Maskell and Baggaley 2004 p. 144). Of course, detailed information is recorded in the books of original entry, including the cash receipts, disbursements, payroll, purchases, and sales journals, as well as the asset and liability ledgers (Maskell and Baggaley 2004 p. 221 – 222).

For lean accounting to work, it is critical that lean processes be stable and under control. Maskell and Baggaley refer to this as a chicken-and-egg situation. Lean accounting both requires and enables lean operations. Accordingly, lean accounting needs to be implemented in parallel with the implementation of lean operations (Maskell and Baggaley 2004 p. 13). Lean operations enhance controls. Therefore, the implementation of lean operations eliminates the need for many traditional accounting processes, including standard costing (Maskell and Baggaley 2004 p. 13).

> The introduction of lean methods brings inventory levels down and creates short production cycle times. The kanbans, the pull system, the standardized work, and the performance measurements create operational control. It is not necessary to have separate financial control, because the operational control has been built into the process, and detailed inventory records are no longer necessary (Maskell and Baggaley 2004 p. 13).

The financial information generated by value-stream costing supports sound business decisions consistent with lean operations (Bell and Orzen 2011 p. 142). It may be necessary for a newly Lean company to perform a limited parallel run of traditional financial accounting practices and lean accounting changes. For that limited period of time, additional work will be necessary to run the old and the new systems. It is critical that the parallel run be short, purposeful, and carefully planned (Maskell and Baggaley 2004 p. 311). If the parallel run continues for any length of time, however, it will undermine the lean transformation as many employees will continue to rely on the old familiar information (Maskell and Baggaley 2004 p. 311).

Box Scores

Maskell and Baggaley have developed a three-dimensional way to present operating performance, financial performance, and value stream's resource utilization in one report – the box score – thereby enabling managers to plan and evaluate lean results (Maskell and Baggaley 2004 p. 52). The box score has three categories of data listed down the left-hand margin:

operational, resource capacity, and financial (Maskell and Baggaley 2004 p. 53). “In the operational section, six items of data are included to monitor the value-stream's performance and drive continuous improvement”: dock-to-dock days; first time through; on-time shipment; floor space; sales per person; and average cost per unit (Maskell and Baggaley 2004 p. 55, 105). The resource-capacity section reports the breakdown of the respective productive, non-productive, and available capacity of both workers and machines used in the value-stream production cells (Maskell 2009 p. 105, 109). "Five items make up the financial data to be included in the box score. These are the items that are most often the concern of both accounting and finance and the senior officers of the company": inventory value; revenues; materials costs; conversion costs; and value stream profit (Maskell and Baggaley 2004 p. 57 – 58).

Usually the box score reports weekly information, as well as several weeks of prior history (Maskell and Baggaley 2004 p. 138). Also, a box score can present information in terms of four columns: (1) current state (“the status of the items measured prior to completion of any planned initiatives”); (2) future state (“the status of measured items if the planned initiatives provide the expected benefits; usually the time horizon is six months or less”); (3) change from the current state (“the difference between the current and future states”); and (4) long-term future state (“an estimate of the business benefits that are expected to accrue over the long term”) (Maskell and Baggaley 2004 p. 54, 59).

Performance Measurements

"If you measure the right things, people will do the right things. Traditional measures measure the wrong things for companies striving toward a lean transformation (Maskell 2009 p. 139).” It is critical for lean accountants and executives to ensure that measurements are aligned with company goals. “Experience teaches us that when goals are set, people will do whatever they can to achieve the target, even if it results in dysfunctional behavior (Cunningham and Fiume 2003 p. 38).” Measures should be simple and limited to the most important aspects of the business, instead of combining many aspects into a single measurement. Complex measures only serve to confuse people (Maskell 2009 p. 144). For example, the ubiquitous and often the dominant business measurement, return on investment (ROI), attempts “to capture many complex and interrelated events, thus creating one monster of a metric that few people can relate to their daily activities (Cunningham and Fiume 2003 p. 40)." Lean companies do not use too many measures. Traditional production companies, however, measure too much; they work on the false assumption that more measuring creates more control. Instead, overuse of measurements creates confusion and lack of focus (Maskell 2009 p. 145).

> [The] seven common, deadly sins of performance measures (paraphrased below): 1. Measuring only what you are good at; 2. Measuring departmental process, not the entire process; 3. Measuring corporate goals, not customer satisfaction; 4. Not investing adequate effort to determine what should be measured; 5. Measuring only small pieces of the process; 6. Not considering the impact of measurements on behavior; 7. Not taking measurements seriously (Bell and Orzen 2011 p. 85 *quoting* Michael Hammer).

"Many short-term measures are appropriate for motivating and evaluating managerial performance. It is unlikely, however, that monthly or quarterly profits, especially when based on the practices mandated and used for external constituencies, would be one of them (Johnson and Kaplan p. 3).” Instead a company should utilize a variety of nonfinancial indicators that are focused upon achieving the company's strategies (Johnson and Kaplan p. 256).[16] Lean companies

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[16] “The company emphasizing quality could measure internal-failure indicators - scrap, rework, part-per-million defect rates, unscheduled machine downtime - and external-failure indicators - customer complaints, warranty expenses, and service calls...

Measures that support this [just-in-time production and delivery] objective include average set-up times, throughput times, lead times, and average number of days’ production in inventory. Other measures of success in a more responsive manufacturing system are average distance traveled by products in the factory and percentage of delivery commitments met each period…

should incorporate measurements at least three different company levels (if not four, depending on the size of the company): (1) the production-cell level; (2) the value-stream level; and (3) the plant-level and/or the company-level (if separate, the latter would be a fourth level) (Maskell and Baggaley 2004 p. 8). Cell-level measurements focus on the daily activity of the operations people. They are tracked visually and often hourly (Maskell and Baggaley 2004 p. 8). Cell-level performance is measured in both the production cells and those non-production departments that support production cells. These cell-level measurements "reflect the primary issues of lean thinking: making to takt time, standardized work, flow, and pull (Maskell and Baggaley 2004 p. 15 – 16)."

> Lean measures for manufacturing performance should adhere to the following principles: Principle 1: Measures should encourage desired behavior by the front lines. Principle 2: Measures should provide information for senior managers to make decisions. Principle 3: Principle 1 takes precedence over Principle 2 (Rother and Shook 2009 p. 89).

Transaction Elimination

Lean companies seek to eliminate complex and wasteful processes from their operations (Maskell 2009 p. 3). Financial accounting processes contain a significant amount of waste, much of which can be removed in the early stages of a lean transformation (Maskell and Baggaley 2004 p. 17).

> Traditional accounting systems are expensive and complex to operate. They require a lot of recording of data, entry of data, validation and checking of data, as well as analysis of reports and

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Measures such as absenteeism, turnover, recruiting success, morale, skills, and promote ability seem to be relevant for evaluating trends in the organization's human resources…[Safety] indicators include number of consecutive days without an injury or accident and number of workdays lost due to accidents (Johnson and Kaplan 1987 p. 256 – 258)."

> results. The production, distribution, and clerical support staffs are forever filling out forms, typing in data, and reviewing reports… Couple these problems with the dubious assignment of overhead costs and the complex, time-wasting, and spurious variance reporting, and you have a system that is an appalling burden to organization (Maskell 2009 p. 70).

Budgeting, inventory valuation, labor reporting, accounts payable, and cost accounting are among the most complex and wasteful processes and systems (Maskell 2009 p. 4). "Transactions are to lean accounting as inventory is to lean manufacturing." They are pure waste (Maskell and Baggaley 2004 p. 77). Companies transitioning to lean operations may find that their transaction volumes initially *increase*, since vendor deliveries, production batches, and customer shipments occur more frequently, but in smaller lots. Purchase orders, receiving reports, vendor invoices, work orders, batch tickets, shipping documents, and customer invoices are among the transactions that initially could see volume increases (Maskell and Baggaley 2004 p. 77).

One significant transaction-reduction technique is the elimination of detailed job-step tracking on work orders through tracking only the starts and completions of jobs (and none of the steps in between). Previously, work orders were important costing documents that traveled throughout the entire production process and on which an organization recorded the labor incurred in each production step. As an enterprise progresses in its lean transformation, causing shorter production lead times, very low work-in-process inventories, and predictable production cycle-times, it can calculate its product costs by production flow rather than by the resources added to an individual product (Maskell and Baggaley 2004 p. 82). If there is operational control of the steps in between, tracking the starts and stops is sufficient to calculate product cost (Maskell and Baggaley 2004 p. 83). Furthermore, after implementation of cellular manufacturing, it can eliminate from work orders the detailed posting of materials used (Maskell and Baggaley 2004 p. 84).

Another transaction-laden, time-consuming accounting process is the accounts payable three-way match, which consists of the inspection of vendor invoices and matching them with the corresponding purchase orders and receiving reports. Lean proponents suggest that there is no need for an accounts payable department at all. Consistent with the Pareto principle, strict vendor certification programs can build-in control for as much as 80 percent of total dollar purchases. The remaining 20 percent of purchases likely are comprised of the vendors that create the greatest number of *transactions*, including purchase orders, approvals, invoices, receiving reports, and three-way matches, most of which can be eliminated by authorizing key employees to make purchases with company credit cards. When a Lean company has close working relationships with a small number of vendors that deliver the correct quantity of high-quality items directly to the lean cells on a daily basis, invoices become unnecessary. A Lean company can eliminate vendor invoices by paying for materials contemporaneously with their use through an electronic transfer of funds. Invoices now represent the materials used for one day's production. Using the backflushing technique, payment amounts can be determined from bills of materials (Maskell and Baggaley 2004 p. 90 – 91).

Similar to accounts payable, a Lean company strives to simplify its accounts receivable by eliminating transactions and building-in controls. It can seek to become a certified vendor to key customers. Invoicing can occur automatically with shipment. Where a Lean company has been designated as a certified vendor, it can encourage invoice elimination through automated wire transfer receipts from customers and the use of shipping information to post to accounts receivable (Maskell and Baggaley 2004 p. 92).

Yet another complex, transaction-intensive accounting function is the monthly closing of the books to create financial statements. The length and complexity of an organization's closing process increases with the number of its functional departments and the size of its chart of accounts. Charts of accounts typically grow over time, but rarely shrink again, even if the reason(s) for having certain accounts have been satisfied. Similarly, *internal* reporting "requirements" also tend to grow over time, even if the manager who previously required them has moved on (Maskell and Baggaley 2004 p. 92 – 93). A substantial amount of unnecessary time – waste – is spent by traditional organizations maintaining accounts and preparing reports that do not benefit the organization as a whole (Maskell and Baggaley 2004 p. 93). Accordingly, Maskell and Baggaley recommend that a Lean company dramatically reduce the number of general-ledger accounts, specifically eliminating all accounts below the value stream level (by plant). Furthermore, a move to a cash-basis of accounting eliminates the need for end-of-period accruals and allocations (Maskell and Baggaley 2004 p. 218 – 219).

Maskell and Baggaley further recommend that inventory accounting be eliminated. Instead, a Lean company simply can record an end-of-period adjustment to account for changes in the value of inventory (Maskell and Baggaley 2004 p. 223). To convert from cash-basis income (for internal, management purposes) to accrual-basis income (for external, financial-reporting purposes in accordance with GAAP), a Lean company needs only to make a simple inventory adjustment. The change in units in each value stream from the beginning of the period to the end is multiplied by the average cost per unit manufactured in its respective value stream (Maskell and Baggaley 2004 p. 223). Mature Lean companies have only one or two weeks of work-in-process inventory on hand that requires direct labor/overhead allocations. At a macro level, direct labor and overhead are relatively easy to estimate for a monthly adjusting journal entry (Cunningham and Fiume 2003 p. 102). Even if this estimated adjustment were wrong by an entire week, it still may not be a significant financial-reporting misstatement (Cunningham and Fiume 2003 p. 102).

> [In a mature lean company], we no longer need to report or backflush the labor and overhead costs... As companies progress with lean manufacturing, they replace the work orders with kanban and other pull systems to authorize and control production. At this point, product-oriented costing using standard costing can be replaced by a process-oriented method called value stream costing. When value stream costing is introduced, we can stop backflushing the labor and overhead costs. They are no longer needed because costs are not collected by production job; they are collected for the value stream as a whole. Thus, very few transactions are required to support value stream costing (Maskell and Baggaley 2004 p. 133).

Generally Accepted Accounting Principles/Audited Financial Statements

None of the lean accounting practices discussed herein violates generally accepted accounting principles (GAAP). Recall that the four basic tenets of accounting are materiality, conservatism,[17] consistency,[18] and matching (Cunningham and Fiume 2003 p. 29 – 30).

> Materiality is where precision and accuracy get confused. Precision is nailing the answer down to the third decimal point. Accuracy is the answer that is correct for the decision you're trying to make... When defining materiality, ask if you would change the business decision you're about to make if you knew the answer to the question within plus or minus 1 percent, 5 percent, or 10 percent? This will tell you materiality threshold for that issue, and where the borderline is between precision and accuracy (Cunningham and Fiume 2003 p. 32).

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[17] "In plain language, conservatism means that you should not over-emphasize the good news or under-emphasize the bad news. Anticipate your losses but not your gains (Cunningham and Fiume 2003 p. 32)."

[18] "Consistency guides us to present facts in the same manner each time they occur. By presenting or reporting them consistently, the trends presented over time will have meaning because they are based on a common method of presenting similar facts. It is all about providing information that is helpful to interpret the situation" (Cunningham and Fiume 2003 p. 34).

With respect to the matching principle, all manufacturing costs must be recognized as an expense (cost of goods sold) in the month that the corresponding revenue is recognized. Costs of materials, labor, and manufacturing overhead are kept on the balance sheet as inventory until the products are sold – which can be months later, even the next fiscal year. However, as lead times shrink and products are made and shipped within the same month, Lean companies can simplify their accounting procedures. In such circumstances, Lean companies can expense these costs directly as they occur while still complying with the matching principle (Cunningham and Fiume 2003 p. 35).

Another initial concern that companies have with lean accounting is the acceptance of their procedures by their external auditors. However, the standard unqualified audit opinion uses phrases such as "free of material misstatement," "assessing significant estimates," and "presents fairly, in all material respects, the financial position of the Company." These statements acknowledge that financial-statement items, including inventories, are based on estimates and also give recognition to the materiality principle (Cunningham and Fiume 2003 p. 101 – 102).

CHAPTER III

METHODOLOGY

The focus of this study was whether Lean companies experienced better results on various financial-performance measures than Non-Lean companies did. Recall that the four classifications of hypotheses were: (1) three return/profit measures; (2) three cash-flow measures; (3) six working-capital measures; and (4) five inventory measures. Each of the hypothesis compared Lean companies to Non-Lean companies by using individual company averages for a given financial-performance measure for three fiscal years of data: 2008, 2009, and 2010. For 16 of the 17 hypotheses, the study also compared the Lean companies to Non-Lean companies by examining the financial-performance measures for each of the three fiscal years studied. Hypothesis 2c, the financing-assets ratio, was tested only through the three-year average of the financial data. It was excluded from the individual-years analysis since the metric is appropriate only for those companies that were in an investing position, as opposed to a disinvesting position, and companies can fluctuate between investing and disinvesting positions year to year. Due to the lengthy period of time that lean transformations take, companies that were in the earliest stages of their respective lean transformations were not included in this study. "Three years is about the minimum time required to put the rudiments of the lean system fully in place and two more years may be required to teach enough employees to see so that the system becomes self-sustaining (Womack and Jones 2003 p. 148)." Accordingly, no company was classified as a Lean company for the purposes of this study if it had not *publicly* articulated its adoption of lean operations by fiscal year 2008 in a 10-k annual report.

Matched-Pairs Design

The study used a matched-pairs design. Matched-pairs designs are appropriate where the sample size is relatively small and heterogeneous for the dependent variable (here, the various financial-performance measures). "In the matching design, we are trying to make each pair of participants as though they were the same participant by matching on a criterion relevant to the dependent variable (Gliner and Morgan 2000 p. 186)." Since financial-performance accounting ratios vary systematically by industry and firm size, each Lean company was matched with a Non-Lean company on two measures: (a) their four-digit SIC code; and (b) company size, based on total assets for the three-year period. Choice-based and matched-pairs samples are not random samples. Accordingly, it is necessary to perform different statistical analysis upon them than would be appropriate for random samples, so that results can be generalized to the larger populations (Cram et al. 2007). Matched-pairs designs are considered to be repeated-measures designs and accordingly, use similar statistical procedures (Gliner and Morgan 2000 p. 240).

Wilcoxon Ranks Tests

The Wilcoxon signed-ranks test is appropriate for matched-pairs where, as here: (a) there is one independent variable with two levels (here, Lean company or Non-Lean company); (b) the pairs of participants have been matched on one or more relevant variables (here, both the four-digit SIC code and total assets); and (c) the dependent-variable data are at least ordinal (here, continuous data) and not normally distributed (Gliner and Morgan 2000 p. 245). The main inferential question for Wilcoxon tests for each of the hypotheses was whether of the respective financial-performance measures for Lean companies, the treatment (T) group, significantly differed from those financial-performance measures for the Non-Lean companies, the control (C) group:

H_0: $_{T} = {}_{C}$. The alternative hypotheses were: H_A: $_{T} \neq {}_{C}$.

Wilcoxon Rank-Sum Test

Conceptually, consider a simplified case of where there is a significant difference on the values of some measure between members of two different groups. As an example, assume that the respective values on some measure are generally lower for the observations in one group than the values are for the observations in a second group. If the individual values were to be ranked from lowest to highest (1 to N) without regard to the group from which the observations originated, one would expect that the lower ranks generally would have come from group one and that the higher ranks generally would have come from group two. Then, if one were to sum the ranks of the observations from group one and group two, respectively, one would expect the sum of the ranks in group two to be significantly higher than the sum of the ranks from group one (and thus, reject the null hypothesis that there is no difference between the two groups). This is the basic logic behind the Wilcoxon *rank-sum* test (Howell p. 649).

Wilcoxon Signed-Ranks Test

Since the pairs for this study were matched on two relevant variables, a within-subjects repeated-measures design is appropriate. Where there is a matched-pairs design, the samples are treated as dependent. Now imagine this study as a comparison between the pre-test control group, Non-Lean companies, and the post-test treatment-group, Lean companies. This design tests the *differences* between the respective values within each matched pair. That is, for each matched pair, the observation value for a company from the treatment group is subtracted from the observation value for the company from the control group. For this design, the basic Wilcoxon rank-sum test is not appropriate. Instead, the Wilcoxon *signed-ranks* test – which incorporates the direction (or sign) of the differenced observation – is appropriate.

In the Wilcoxon signed-ranks test, the respective sign for each differenced observation, positive (+1) or negative (-1), is multiplied by the rank of its value among each of the values for all of the differenced observations, going from the smallest difference to the largest difference (1 to N). Thereafter, the signed and ranked differenced observations are separated into two groups, negative ranks and positive ranks, that correspond with: (a) the number of times that the observation value for treatment group was greater than the observation value for the control group (i.e., from the same matched pair); and (b) the number of times that the observation value for the control group was greater than the observation value for the treatment group. Then, the absolute values of each of the signed ranks are summed within each of the negative-ranks group and the positive-ranks group. For hypothesis testing, the absolute-value sums of the signed ranks generate a score that is compared to a critical value, based on the sample size and significance level.

Any matched pair for which the differenced observation has a zero value is excluded from further statistical analysis. Where two or more sets of matched pairs have the same differenced-observation value (i.e., there is a tie between two or more sets of matched pairs, [$(C_1 – T_1) = (C_2 – T_2)$]), the rank assigned to each differenced observation is the average of the ranks spanned by the differenced observations. For example, assume that after ranking all of the differenced observations from the smallest difference to the largest difference, two separate differenced observations had the same value and were the sixth and seventh values in the total-ranking order. In that case, each of those differenced observations would be given a rank of 6.5 (i.e., the average of the two ranks spanned). Thereafter, those ranks of 6.5 would be multiplied by the appropriate positive or negative sign (as would all of the other ranks) and the remaining steps, as hereinabove set forth, would be performed.

As the sample size increases, the sampling distribution for the test statistic, W, approaches a normal distribution (Howell p. 651). If the number of pairs, N, is greater than or equal to ten, a z-score can be measured where:

$$z = \frac{W - 0.5}{\sigma_W} \quad \text{and}$$

$$\sigma_w = \sqrt{\frac{N(N+1)(2N+1)}{6}}$$

If the z-score for the hypothesis test is greater than $z_{critical}$, then reject the null hypothesis, H_0, that there is no difference between the observations in the control group and the observations in the treatment group.

Lean/Non-Lean Variable

Lean Companies

No reliable and thorough database of publicly traded companies exists that identifies companies by their Lean status or Non-Lean status. Therefore, the Lean/Non-Lean variable for this study had to be hand-collected. The identification process for the Lean/Non-Lean variable was a multi-step process. The preliminary sample of companies that were tested for “Leanness” consisted of: (a) each company that was listed on the Standard & Poor’s 500 Composite Index (at the time of the data collection); (b) each company that was listed on the Russell 2000 (Small-Cap) Index (on June 27, 2011) *and* was classified within 38 of the 154 sub-industries within the

Global Industry Classification (GIC) Codes that were deemed most likely to identify Lean companies (hereinafter, “Russell 2000/Select GIC”); and (c) each of the publicly traded companies that had been represented by one or more registrants at each of the 2005 through 2010 annual Lean Accounting Summits, an annual conference that began in 2003, the participants in which include representatives from industry (particularly, executive, operations, and accounting functions), business consultants, vendors of lean and related products, and academics (among others).

The following 38 GIC sub-industries were selected as a filter that was most likely to identify Lean companies (i.e., from the Russell 2000 index): eight Industrials (20101010 through 20106020, in ascending numerical order), nine Consumer Discretionary (25101010 through 25203030), nine Consumer Staples (30201010 through 30302010), two Health Care (35101020 through 35102010), and ten Information Technology (45201010 through 45205020).

> The Russell 2000 Index measures the performance of the small-cap segment of the U.S. equity universe. The Russell 2000 is a subset of the Russell 3000® Index representing approximately 10% of the total market capitalization of that index. It includes approximately 2000 of the smallest securities based on a combination of their market cap and current index membership.
>
> The Russell 2000 Index is constructed to provide a comprehensive and unbiased small-cap barometer and is completely reconstituted annually to ensure larger stocks do not distort the performance and characteristics of the true small-cap opportunity set (Russell Index Website).

For each company within the preliminary identification sample, every 10-K, Annual Report Pursuant to Section 13 or 15(d) of the Securities Exchange Act of 1934, for the twelve fiscal-year period from 1999 through 2010 was examined for the keywords: “lean,” “just-in-time,” and “sigma” (i.e., for the business-management strategy, Six-Sigma, that originally was developed by the telecommunications company, Motorola).

The EDGAR database supplied the 10-Ks. Each appearance of one of the three keywords in a company’s 10-K and the corresponding fiscal year in which the keyword(s) appeared were noted. Where a company used the keyword, “lean,” as an adjective that was not in a lean-production or service-provider context, it was disregarded. For example, if a company used the term, “lean,” as an adjective only to describe a company’s having a small number of employees, that company was not considered to be Lean. Implementing the Lean business methodology is not synonymous with having a small staff. Also, where a company used either of the keywords, “lean” or “sigma,” but only within an executive’s brief biography and not to describe the company’s operations anywhere else within that company’s 10-K, the use of the keyword alone was not sufficient to designate that company as a Lean company. Furthermore, where a company used the keyword, “just-in-time,” but only when specifically referring to *delivery* activities – as opposed to production activities – that keyword reference alone was not sufficient to designate the company as a Lean company. For example, there were numerous instances in 10-K reports where a company merely referred to its having to maintain high inventories – a decidedly non-lean practice – in order to make just-in-time *deliveries* to their customers, but made no further reference to the company’s practice of just-in-time production activities. Ultimately, in order to have been designated as a Lean company for this study, a company within the preliminary identification sample of public companies (i.e., from the S&P 500, Russell 2000/Select GIC, and Lean Accounting Summit lists) specifically had to refer to its lean operations (as hereinabove defined) within its 10-K reports using the keyword, “lean:” (a) at least once within fiscal years

2006 through 2010; (b) for at least two consecutive fiscal years over the 12-year period from 1999 through 2010; and (c) with the first such reference being no later than fiscal year 2008.

Of the 500 companies then on the S&P 500, only 34 companies met the Lean-company criteria of the 10-k keyword search. Of the 411 companies that were on the Russell 2000/Select GIC list, 38 companies met the Lean-company criteria. And, of the 129 publicly traded companies from which at least one representative had attended at least one of the annual Lean Accounting Summits from 2005 through 2010, 45 companies met the Lean-company criteria. Ten Lean companies (as defined herein) were on both the S&P 500 and Lean Accounting Summit lists. No Lean companies were on all three preliminary identification lists. Furthermore, no Lean companies appeared on both of the Russell 2000/Select GIC list and either of the other two preliminary identification lists. After eliminating the duplicates, there were 107 potential Lean companies which to attempt to match with a Non-Lean company, based on the industry and size criteria.

Six-Sigma

The respective Lean and Six-Sigma business methodologies have many similarities, including a focus on customer-defined value, the reduction of non-value-added work, and a “disciplined closed-loop [continuous] improvement methodology (Bell and Orzen 2011 p. 313).”

> Six-Sigma is a process-improvement methodology emphasizing data analysis with the primary objective of reducing process variation to improve quality. The Greek letter sigma (σ) represents variability. The sigma level of a process indicates the probability of defects; the higher the sigma level, the more stable and the reliable process and the lower the likelihood of defects. A process functioning at Six-Sigma level equates to 3.4 defects per 1 million opportunities, which is equivalent to 99.9997 percent defect-free work (Bell and Orzen 2011 p. 313).

Although the respective Lean and Six-Sigma business methodologies have many similarities, they also have many differences. The Six-Sigma methodology focuses on improving value-added processes ("e.g., find the source of the quality problems or downtime on the machine center and put in countermeasures to fix it." The Lean methodology focuses on creating flow within the whole value stream in (Liker 2004 p. 296).

> A major difference between Lean and Six Sigma is the principal focus: Six Sigma emphasizes quality control and process variation, while Lean's primary focus is flow attained from eliminating non-value-added activities (waste). In most organizations, the vast majority of improvement opportunities are found in wasteful business practices. It is not surprising that many companies discover that focusing on waste (not process variation) is the best place to begin their improvement efforts. Lean quickly prepares organizations to address obvious *low-hanging fruit* improvement opportunities that are relatively easy to achieve and deliver a noticeable impact. Harvesting these opportunities creates early wins, preparing employees for more challenging projects. After non-value-added activities are removed from the process, it is easier to identify high-value problems deserving rigorous attention (Bell and Orzen 2011 p. 315).

Non-Lean Companies

After Lean companies had been identified, the Non-Lean companies to be matched, one to each Lean company, were identified. First, all of the publicly traded companies that had the same four-digit SIC codes (as identified in the Compustat database) as every previously identified Lean company were sorted by their total assets (AT) for the fiscal years 2008 through 2010. Companies that had the lowest squared differences in aggregate total assets between themselves and the previously identified Lean companies for the three fiscal years then went through a series of filters to test the companies for "Non-Leanness." Company that: (a) passed the remaining Non-Lean identification tests; *and* (b) had substantially the same total assets as one of the Lean companies for the three-year fiscal period; were matched to Lean companies. Unlike previous studies, this study was not limited to the manufacturing sector. Service-providing companies that were members of the three categories of the preliminary identification sample also were analyzed.

For the Non-Lean-company identification process, the study utilized a four-step filtering process to maximize confidence that the companies ultimately identified as Non-Lean matches had not implemented either substantial Lean practices or Six-Sigma practices. That is, while a company from the preliminary identification sample had to refer directly to its Lean practices in its 10-K, a reference to Six-Sigma practices (as hereinafter set forth) would disqualify a company from being designated as a Non-Lean company, due to some similarities between the business methodologies.

> There is an obvious case for a harmonious marriage between Six Sigma, which fixes individual processes, and Lean, which fixes the connections among processes (Liker 2004 p. 296).

Each of the preliminarily identified potential Non-Lean companies first went through the identical 10-K keyword search for the same twelve fiscal years, 1999 through 2010, and also using the keywords, “lean,” “just-in-time,” and “sigma.” For a company to move on to the next stages of *Non-Lean* classification, however, it first could have *no* references in any of its 10-K reports to any of the three keywords for the 12-year period. Second, each of the potential Non-Lean match companies that passed the first classification stage went through a newswire search within the Lexis-Nexis® Academic database.[19] Companies’ names were searched in various forms, including those of predecessor entities. Third, each of the potential Non-Lean match

[19] Power Search, Source: All News (English), for the search terms: “(“[COMPANY NAME]") /p ("lean manufacturing") OR ("lean production") OR ("lean operation") OR ("lean practice") OR ("six sigma") OR ("lean sigma") OR ("lean principle") OR ("kaizen") OR ("cellular manufacturing") OR ("cellular production") OR ("continuous flow") OR ("just-in-time manufacturing") OR ("just-in-time production") OR (“one-piece flow”).”

companies that passed the first two filtering stages was Google-searched for the company name, together with the terms, “lean” and “six-sigma.” Each link within the first five pages of search responses was examined for evidence of significant lean and/or six-sigma activity by that company. Significant activity was deemed to be an article describing the Lean and/or Six-Sigma operations of the company. A mere reference to Lean and/or Six-Sigma on a person’s LinkedIn or other resume by itself was insufficient to disqualify a company from being designated as a Non-Lean company.

Lastly, the Benchmarking Community of Practice Coordinator for the Association of Manufacturing Excellence (AME) circulated a list of the Non-Lean match potentials that remained after the first three Non-Lean-company identification filters to benchmarking-practice group members, soliciting from them comments with respect to their knowledge of any significant Lean and/or Six-Sigma practices having been performed by any of those potential Non-Lean companies. All of these steps were performed to minimize the possibility that a company that had performed significant Lean and/or Six-Sigma activities was not misclassified as a Non-Lean company for its failure to make public reference to those business methods.

There were multiple reasons for eliminating potential *Non-Lean* companies from further analysis (i.e., from matching with a Lean company and ultimately, hypothesis testing), including: (a) the reporting of the select keywords in their 10-K reports; (b) direct references to significant Lean and/or Six-Sigma activities found through a Lexis-Nexis search; (c) direct references to significant Lean and/or Six-Sigma activities found through a Google search; or (d) confirmation from a member of the AME’s benchmarking-practice group that the company had practiced significant Lean and/or Six Sigma activities. Ultimately, 78 of the 107 potential Lean companies did not have an acceptable Non-Lean company within the same four-digit SIC code and of *substantially the same size* with which to be matched. Certain four-digit SIC codes were replete with Lean companies, but only the Lean companies closest in size with a Non-Lean company could be matched together. Non Non-Lean companies were matched with more than one Lean company. For example, there were many prominent Lean companies, such as 3M, Boeing, General Electric, and Harley-Davidson, that did not have an appropriate Non-Lean company with which to be matched. Due to the small sample sizes, companies from certain industries were excluded from analysis despite their having been identified as Lean companies through the aforementioned criteria: (1) conglomerates, due both to the uncertainty of industry comparability to any potential matched company, as well as the uncertainty of the company's having extended lean production across its varied enterprises; (2) home construction, due both to the extreme lack of comparability of its inventories and assets to those of any of the other Lean companies and the effects it could have on statistical tests based on measures of central tendency; and (3) insurance and financial services, due to their being highly regulated industries, the inclusion of which likely could result in unknown and uncontrolled-for effects of potentially omitted variables.

CHAPTER IV

DATA ANALYSIS AND RESULTS

Samples for Hypothesis Testing

The final sample of this study consisted of 29 matched pairs of companies, or 58 companies in total. Each matched pair was comprised of one Lean company and one Non-Lean company that was matched together based first, by four-digit SIC code and second, by total assets over the three-year fiscal period from 2008 through 2010. The final sample contained matched pairs from 19 different four-digit SIC codes.

Twelve different SIC codes each had a single matched pair of companies: 1600, Heavy Construction Other than Building Construction – Contractors; 2670, Converted Paper and Paperboard Products (No Containers/Boxes); 2780, Blank Books, Loose-Leaf Binders and Bookbinding and Related Work; 3559, Special Industry Machinery, NEC; 3560, General Industrial Machinery and Equipment; 3577, Computer Peripheral Equipment, NEC; 3743, Railroad Equipment; 3823, Industrial Instruments for Measurement, Display, and Control; 3826, Laboratory Analytical Instruments; 3842, Orthopedic, Prosthetic, and Surgical Appliances and Supplies; 3843, Dental Equipment and Supplies; and 5961, Retail-Catalog and Mail-Order Houses. Four different SIC codes each had two matched pairs: 3312, Steel Works, Blast Furnaces and Rolling Mills (Coke Ovens); 3350, Rolling, Drawing, and Extruding of Nonferrous Metals; 3690, Miscellaneous Electrical Machinery, Equipment, and Supplies; and 8071, Services - Medical Laboratories. Lastly, three different SIC codes each had three matched pairs: 3714, Motor Vehicle Parts and Accessories; 3841, Surgical and Medical Instruments and Apparatus; and 3990, Miscellaneous Manufacturing Industries.

In addition to excluding Lean companies from statistical analysis due to the absence of an appropriate Non-Lean-company match, two other circumstances removed one or more matched pairs from the statistical analysis for certain *individual* hypotheses: (1) insufficient financial data for one-half (or both halves) of a matched pair; and (2) very small denominators for a given financial ratio. First, in order for a particular matched pair to have been analyzed for a given hypothesis, the requisite financial data for that hypothesis had to have been reported in the Compustat database for *both* companies of that matched pair. If the necessary financial data to test a given hypothesis had not been reported for one-half of a matched pair of companies, the matched pair had to be excluded from the analysis of that hypothesis, even if the corresponding financial data had been reported for the other half of the matched pair. For example, recall that the fourth set of hypotheses includes five hypotheses related to inventory measures. Not all companies that maintain inventories report values for all four of the common inventory categories: total inventory, raw materials, work-in-process, and finished goods. Additionally, companies that primarily provide services may not have traditional inventory. Accordingly, as a hypothesis classification, the inventory hypotheses generally tested fewer matched pairs than the returns/profit margin, cash-flow, or working-capital hypotheses.

Second, this study complied with practice of excluding from statistical analysis any financial ratio that had a denominator of less than one (i.e., due to its propensity to create extreme outliers and disrupt statistical analyses based upon measures of central tendency, particularly those with small sample sizes). Accordingly, if one-half of a matched pair of companies had a financial-ratio denominator of less than one for a given hypothesis, that pair was excluded from the analysis for that hypothesis, regardless of whether the other half of the matched pair had a denominator of greater than or equal to one. That being said, 11 of the 17 hypotheses utilized between 27 and all 29 of the matched pairs in their respective analyses, with five hypotheses utilizing all 29 matched pairs. Two hypotheses utilized 25 of the matched pairs. The inventory hypotheses (set four) utilized the fewest matched pairs in their statistical analysis, most frequently due to companies' failures to report values for all of the inventory categories. Most notably, H4c tested only 16 matched pairs for work-in-process inventory turnover, the fewest number for any hypothesis. H4d and H4e each tested 19 matched pairs for finished-goods inventory turnover and days'-sales in inventory (which is based on finished-goods inventory), respectively, together the second fewest number for any hypothesis. The total number of matched pairs utilized in the statistical analysis for each of the 17 hypotheses is as follows: H1a: Return on Net Operating Assets (25); H1b: Return on Total Assets (29); H1c: Profit Margin (29); H2a: Operating Cash Flows (29); H2b: Cash-Adequacy Ratio (29); H2c: Financing-Assets Ratio (25); H3a: Net Working Capital (28); H3b: Working Capital Turnover (27); H3c: Current Ratio (28); H3d: Acid-Test Ratio: (28); H3e: Accounts-Receivable Turnover (28); H3f: Days'-Sales Uncollected (29); H4a: Total Inventory Turnover (27); H4b: Raw-Materials Turnover (22); H4c: Work-in-Process Turnover (16); H4d: Finished-Goods Turnover (19); and H4e: Days'-Sales in Inventory (19). For hypothesis testing and due to the small sample sizes, observations were winsorized at three standard deviations.

Descriptive Statistics

Analysis of averaged balance-sheet, income-statement, and statement-of-cash-flows summary-account values revealed some interesting differences between Lean companies and

Non-Lean companies, despite the pairs' having been matched by total assets and four-digit SIC code. Not surprisingly due to design, the Lean and Non-Lean companies had three-year average total assets of $1.883 billion and $1.706 billion, respectively, a difference of ten percent from the perspective of the control group, Non-Lean companies. From the perspective of the treatment group, Lean companies, the difference between the Lean companies and the Non-Lean companies in terms of average total assets was nine percent. Similarly, the Lean and Non-Lean companies had three-year average total liabilities of $1.036 billion and $1.025 billion, respectively, a difference of one percent.

The respective differences in asset composition and liability composition between the two groups for the three-year period, however, were striking. Lean companies had average current assets 77 percent higher and average long-term assets 19 percent *lower* than Non-Lean companies. Lean Companies had average current assets of $932 million and average long-term assets of $951 million. On the other hand, Non-Lean companies had current assets of $527 million and average long-term assets of $1.179 billion. Similarly, Lean companies had average current liabilities 66 percent higher and average long-term liabilities 28 percent *lower* than Non-Lean companies. Lean Companies had average current liabilities of $530 million and average long-term liabilities of $506 million. On the other hand, Non-Lean companies had current liabilities of $319 million and average long-term liabilities of $706 million. Whereas the respective ratios of current-to-long-term assets and current-to-long-term liabilities both essentially were 1:1 for the Lean companies, the respective ratios for the Non-Lean companies were less than 1:2 (current: long-term) for both assets and liabilities. That is, Lean companies had a current-to-long-term asset ratio of 0.98 and a current-to-long-term liability ratio of 1.05.

Conversely, Non-Lean companies had a current-to-long-term asset ratio of 0.45 and a current-to-long-term liability ratio of 0.45.

The differences between the groups of Lean and Non-Lean companies also were striking for other select three-year average current balance-sheet accounts. Lean companies had a cash-and-cash-equivalents average balance that was 151 percent greater than that of Non-Lean companies, $384 million to $153 million, respectively. Additionally, Lean companies had an average accounts-receivable balance that was 52 percent greater than that of Non-Lean companies, $267 million to $176 million, respectively. For accounts payable, the difference was even more dramatic. Lean companies' average accounts-payable balance was 249 percent greater than that of Non-Lean companies: $299 million to $86 million, respectively.

The differences between three-year average summary income-statement values for the groups of Lean and Non-Lean companies also were prominent. Lean companies' average net sales, cost of goods sold, and net income all were greater than those of the Non-Lean companies. Lean companies had average net sales 83 percent larger than Non-Lean companies, $2.444 billion to $1.332 billion, respectively. Similarly, Lean companies had average cost of goods sold 89 percent larger than Non-Lean companies, $1.763 billion to $932 million, respectively. Furthermore, Lean companies had average net income 199 percent larger than Non-Lean companies, $114 million to $38 million, respectively.

Recall that the inventory hypotheses for this study generally used fewer of the 29 matched pairs than hypotheses from the other three classifications: 27 (for total-inventory turnover), 22 (for raw-materials inventory turnover), 16 (for work-in-process inventory turnover), and 19 (for each of finished-goods inventory turnover and days'-sales in inventory), respectively. Accordingly, some caution should be utilized when interpreting the data and results for those hypotheses that utilized the fewest matched pairs. That being said, there are significant results for multiple inventory categories as set forth later in this section. Additionally, when looking at the respective three-year average inventory-category balances of Lean companies and Non-Lean companies, it is also important to keep in mind that Lean companies generated three-year average net sales that were 83 percent larger than those of Non-Lean companies, despite having total assets within ten percent of one another. Lean companies had a three-year average total inventory 17 percent larger than that of Non-Lean companies, $157.3 million to $133.9 million, respectively, and a three-year average finished-goods inventory 22 percent larger than that of Non-Lean companies, $60.4 million to $49.4 million, respectively. These figures do not include the total inventory balances of Amazon.com, a large outlier that had a three-year average total inventory of $2.26 billion, (i.e., compared three-year averages of $157.3 million for Lean companies and $133.9 million Non-Lean companies), nor its matched company. Additionally, Lean companies' three-year average work-in-process inventory was 251 percent larger than that of Non-Lean companies, $59.5 million to $17.0 million, respectively. Perhaps the most striking difference between Lean companies and Non-Lean companies with respect to the inventory categories – given that Lean companies' net sales approached twice those of Non-Lean companies – was that Lean companies' three-year average raw-materials inventory was 35 percent *lower* than that of Non-Lean companies, $44.8 million to $69.3 million, respectively.

Lastly, Lean companies, had close to twice the three-year average net cash flows for each cash-flow category – whether inflows or outflows – than their Non-Lean counterparts. Lean companies had average net operating cash *in*flows 96 percent larger than Non-Lean companies, $241 million to $123 million, respectively. Additionally, Lean companies had average net investing cash *out*flows 89 percent larger than Non-Lean companies, $152 million to $76 million, respectively. Lastly, Lean companies had average net financing cash *out*flows 87 percent larger than Non-Lean companies, $54 million to $29 million, respectively. Descriptive statistics for the fiscal 2008 through 2010 three-year average account balances for the Lean companies, the Non-Lean companies, and the percentage differences from the viewpoint of the control group, Non-Lean companies, are set forth in Table 1.

Tests of Normality

Frequently when financial-performance measures comprise the sample observations, the data is not normally distributed. Not surprisingly, that is the case with this study, especially given the small respective sample sizes for each of the hypotheses. If the samples had been normally distributed, a dependent-measures t-test would have been appropriate. With non-parametric data, however, the Wilcoxon signed-ranks test is appropriate. One uses the Shapiro-Wilk test to test for normality of distribution with small sample sizes. For each hypothesis, the three-year average observation values for the Lean companies and Non-Lean companies were tested for normality both separately as groups and as one combined group, after excluding both observations of a matched-pair where one or both halves had insufficient data and/or very small denominators. The combined observations for only two of the 17 hypotheses had a normal distribution, using the Shapiro-Wilk test at $\alpha = 0.05$: H3a (net working capital) and H3f (days'-sales uncollected). Fourteen of the remaining 15 hypotheses were significantly non-normally distributed at a p-value of less than 0.001. H3c (the current ratio) was significantly non-normally distributed at a p-value of 0.002. Examining separately, only six of the 34 the Lean and Non-Lean groups were normally distributed.[20] Results for the Shapiro-Wilk tests of normality are set forth in Table 2.

[20] H2b, Lean: Cash-Adequacy Ratio; H3a, both Lean and Non-Lean: Net Working Capital; H3c, Lean: Current Ratio; H3f, Non-Lean: Days'-Sales Uncollected; and H4e, Non-Lean: Days'-Sales in Inventory.

Table 1: Descriptive Statistics, Three-Year Averages: 2008 through 2010 (in millions)
Lean Companies, Non-Lean Companies, and Differences from Non-Lean Company

	Balance Sheet - Assets				Balance Sheet - Select Current		
	Total Assets	Current Assets	Long-Term Assets	Current/LT Ratio	Cash and Equivalents	Accounts Receivable	Accounts Payable
Lean	$1,882.9	$932.1	$950.8	0.98	$384.2	$267.4	$298.6
Non-Lean	1,705.9	527.3	1,178.6	0.45	153.1	176.4	85.5
Difference	10%	77%	-19%	119%	151%	52%	249%

	Balance Sheet - Liabilities				Income Statement		
	Total Liabilities	Current Liabilities	Long-Term Liabilities	Current/LT Ratio	Net Sales	Cost of Goods Sold	Net Income
Lean	$1,035.8	$529.9	$505.9	1.05	$2,444.4	$1,763.2	$114.1
Non-Lean	1,024.8	318.8	706.0	0.45	1,332.2	932.0	38.2
Difference	1%	66%	-28%	132%	83%	89%	199%

	Balance Sheet – Inventory [a]				Statement of Cash Flows		
	Raw Materials	Work-in-Process	Finished Goods [b]	Total Inventory [c]	Operating Cash Flows	Investing Cash Flows	Financing Cash Flows
Lean	$44.8	$59.5	$60.4	$157.3	$240.9	-$151.8	-$54.0
Non-Lean	69.3	17.0	49.4	133.9	123.0	-76.2	-28.9
Difference	-35%	251%	22%	17%	96%	99%	87%

[a] Not every company reported each of the inventory components. For several companies, the sum of the inventory components reported does not equal the total inventory reported. Accordingly, the sums of the inventory component averages do not equal the average total inventory.

[b] Does not include, General Steel Holdings, which only reported work-in-process for 2008.

[c] Does not include large outlier, Amazon.com, that had average total inventory of $2.26 billion (nor its match, Liberty Interactive Corp.).

Table 2: Shapiro-Wilk Tests of Normality

Hypo	Measure	n, df	Combined Companies statistic	Combined Companies p-value
H1a	Return on Net Operating Assets	25	0.831	< 0.001
H1b	Return on Total Assets	29	0.731	< 0.001
H1c	Profit Margin	29	0.538	< 0.001
H2a	Operating Cash Flows	29	0.823	< 0.001
H2b	Cash Adequacy	29	0.910	< 0.001
H2c	Financing Assets	25	0.631	< 0.001
H3a	Net Working Capital	28	0.974	0.274
H3b	Working Capital Turnover	27	0.774	< 0.001
H3c	Current Ratio	28	0.927	0.002
H3d	Acid-Test Ratio	28	0.878	< 0.001
H3e	Accounts-Receivable Turn	28	0.640	< 0.001
H3f	Days'-Sales Uncollected	29	0.964	0.082
H4a	Total Inventory Turnover	27	0.613	< 0.001
H4b	Raw-Materials Turnover	22	0.753	< 0.001
H4c	Work-in-Process Turnover	16	0.685	< 0.001
H4d	Finished Goods Turnover	19	0.691	< 0.001
H4e	Days'-Sales in Inventory	19	0.867	< 0.001

Hypo	Measure	n, df	Lean Companies statistic	Lean Companies p-value	Non-Lean Companies statistic	Non-Lean Companies p-value
H1a	Return on Net Operating Assets	25	0.866	< 0.001	0.790	< 0.001
H1b	Return on Total Assets	29	0.730	< 0.001	0.772	< 0.001
H1c	Profit Margin	29	0.891	0.006	0.609	< 0.001
H2a	Operating Cash Flows	29	0.903	0.012	0.788	< 0.001
H2b	Cash Adequacy	29	0.976	0.738	0.898	0.009
H2c	Financing Assets	25	0.538	< 0.001	0.875	0.006
H3a	Net Working Capital	28	0.975	0.722	0.949	0.187
H3b	Working Capital Turnover	27	0.792	< 0.001	0.818	< 0.001
H3c	Current Ratio	28	0.959	0.322	0.876	0.003
H3d	Acid-Test Ratio	28	0.939	0.106	0.807	< 0.001
H3e	Accounts-Receivable Turn	28	0.649	< 0.001	0.640	< 0.001
H3f	Days'-Sales Uncollected	29	0.915	0.022	0.984	0.926
H4a	Total Inventory Turnover	27	0.629	< 0.001	0.571	< 0.001
H4b	Raw-Materials Turnover	22	0.810	0.001	0.737	< 0.001
H4c	Work-in-Process Turnover	16	0.777	0.001	0.711	< 0.001
H4d	Finished Goods Turnover	19	0.720	< 0.001	0.622	< 0.001
H4e	Days'-Sales in Inventory	19	0.859	0.009	0.922	0.126

Hypothesis 1a, Return on Net Operating Assets

For return on net operating assets (operating income ÷ lagged net operating assets), Lean Companies had a three-year average return of 8.3 percent, while Non-Lean Companies had a three-year average return of 0.7 percent. Hypothesis 1a utilized 25 matched-pairs in its statistical analysis with four matched pairs having to be excluded: (a) two pairs due to one-half of each pair's both having positive operating income (the numerator) and negative lagged net operating assets (the denominator) – an incongruous result for comparative analysis; and (b) two pairs due to one-half of each pair's both having negative operating income and positive net operating assets – also an incongruous result for comparative analysis. For H1a, there were 18 negative ranks (totaling 246) and seven positive ranks (totaling 79) for the three-year average return on net operating assets. For this hypothesis, where a given observation value was greater for the Non-Lean company than it was for the Lean company, the differenced observation resulted in a positive rank. Conversely, where a given observation value was greater for the Lean company than it was for the Non-Lean company, the differenced observation resulted in a negative rank. The z-score for the three-year differenced average return – based upon the positive ranks – was -2.247 for a p-value of 0.025. Accordingly, the null hypothesis for H1a was rejected since there was a significant difference between the respective average returns on net operating assets for Lean companies and Non-Lean companies. Here, Lean companies had significantly larger returns on net operating assets than Non-Lean companies.

Examining the years individually, average return on net operating assets was 9.4 percent for Lean companies and -4.5 percent for Non-Lean companies in 2008. For 2009, the average returns were 4.0 percent and 1.9 percent for Lean companies and Non-Lean companies, respectively. Lastly, Lean companies' average return on net operating assets for 2010 was 11.6

percent compared to 9.2 percent for Non-Lean companies. Of the individual years, only 2008 had a statistically significant difference – a p-value of 0.042 with a positive-rank based z-score of -2.031. Individually, fiscal 2008 had 18 negative ranks (totaling 238) and seven positive ranks (totaling 87) for return on net operating assets.[21] Results for H1a, return on net operating assets, are set forth in Table 3.

Hypothesis 1b, Return on Total Assets

For traditional return on total assets (net income ÷ average total assets), Lean Companies had a three-year average return of 3.9 percent, while Non-Lean Companies had a three-year average return of -1.6 percent. Hypothesis 1b utilized all 29 matched-pairs in its statistical analysis with no matched pairs having to be excluded. The z-score for the three-year differenced average return – based upon the positive ranks – was -2.173 for a p-value of 0.030. There were 20 negative ranks (totaling 318) and nine positive ranks (totaling 117) for the three-year average return on total assets. Accordingly, the null hypothesis for H1b was rejected since there was a statistically significant difference between the respective average returns on total assets for Lean companies and Non-Lean companies. Here, Lean companies had significantly higher returns on total assets than Non-Lean companies.

Examining the years individually, average return on total assets was 4.9 percent for Lean companies and -5.3 percent for Non-Lean companies in 2008. For 2009, the average returns on total assets were 1.6 percent and -2.8 percent for Lean companies and Non-Lean companies, respectively. Lastly, Lean companies' average return on total assets for 2010 was 5.7 percent

[21] For 2009, return on net operating assets had a p-value of 0.288, a positive-rank based z-score of -1.063, 17 negative ranks (totaling 202) and 8 positive ranks (totaling 123). For 2010, return on net operating assets had a p-value of 0.737, a positive-rank based z-score of -0.336, 12 negative ranks (totaling 175) and 13 positive ranks (totaling 150).

compared to 3.4 percent for Non-Lean companies. Of the individual years, only 2008 had a significant difference – a p-value of 0.003 with a positive-rank based z-score of -2.93.

Table 3a: Return on Net Operating Assets (H1a)
Descriptive Statistics
pairs: n = 25

Period / Co. Type	3-Year Average Lean	3-Year Average Non-Lean	2008 Lean	2008 Non-Lean	2009 Lean	2009 Non-Lean	2010 Lean	2010 Non-Lean
Mean	0.083	0.007	0.094	-0.045	0.040	0.019	0.116	0.092
Std. Dev.	(0.128)	(0.162)	(0.172)	(0.255)	(0.141)	(0.184)	(0.123)	(0.102)
Minimum	-0.363	-0.455	-0.506	-0.813	-0.357	-0.662	-0.070	-0.188
Maximum	0.295	0.199	0.401	0.426	0.199	0.375	0.524	0.274

Table 3b: Return on Net Operating Assets (H1a)
Wilcoxon Signed-Ranks Test Descriptive Statistics
pairs: n = 25

Period / Ranks	3-Year Average Negative	3-Year Average Positive	2008 Negative	2008 Positive	2009 Negative	2009 Positive	2010 Negative	2010 Positive
Number	18_a	7_b	18_a	7_b	17_a	8_b	12_a	13_b
Mean	13.67	11.29	13.22	12.43	11.88	15.38	14.58	11.54
Sum	246	79	238	87	202	123	175	150

a: Lean > Non-Lean
b: Non-Lean > Lean

Table 3c: Return on Net Operating Assets (H1a)
Wilcoxon Signed-Ranks Test Results
pairs: n = 25

3-Year Average $_c$ Z	3-Year Average $_c$ p-value	2008_c Z	2008_c p-value	2009_c Z	2009_c p-value	2010_c Z	2010_c p-value
-2.247	0.025	-2.031	0.042	-1.063	0.288	-0.336	0.737

c: Z is based on the positive ranks.
d: Z is based on the negative ranks.

Results for H1b, return on total assets, are set forth in Table 4.

Table 4a: Return on Total Assets (H1b)

Descriptive Statistics

pairs: n = 29

Period Co. Type	3-Year Average Lean	 Non-Lean	2008 Lean	 Non-Lean	2009 Lean	 Non-Lean	2010 Lean	 Non-Lean
Mean	0.039	-0.016	0.049	-0.053	0.016	-0.028	0.057	0.034
Std. Dev.	(0.073)	(0.132)	(0.106)	(0.185)	(0.086)	(0.143)	(0.057)	(0.079)
Minimum	-0.269	-0.387	-0.434	-0.641	-0.269	-0.448	-0.105	-0.215
Maximum	0.116	0.117	0.149	0.168	0.113	0.141	0.198	0.164

Table 4b: Return on Total Assets (H1b)

Wilcoxon Signed-Ranks Test Descriptive Statistics

pairs: n = 29

Period Ranks	3-Year Average Negative	 Positive	2008 Negative	 Positive	2009 Negative	 Positive	2010 Negative	 Positive
Number	20_a	9_b	22_a	7_b	18_a	11_b	17_a	12_b
Mean	15.90	13.00	16.05	11.71	15.67	13.91	15.35	14.50
Sum	318	117	353	82	282	153	261	174

a: Lean > Non-Lean

b: Non-Lean > Lean

Table 4c: Return on Total Assets (H1b)

Wilcoxon Signed-Ranks Test Results

pairs: n = 29

3-Year Average $_c$ Z	 p-value	2008_c Z	 p-value	2009_c Z	 p-value	2010_c Z	 p-value
-2.173	0.030	-2.93	0.003	-1.395	0.163	-0.941	0.347

c: Z is based on the positive ranks.

d: Z is based on the negative ranks.

Individually, fiscal 2008 had 22 negative ranks (totaling 353) and 7 positive ranks (totaling 82) for return on assets.[22]

Hypothesis 1c, Profit Margin

For profit margin (net income ÷ net sales), Lean Companies had a three-year average of 4.4 percent of net sales, while Non-Lean Companies had a three-year average of -6.4 percent of net sales. Hypothesis 1c utilized all 29 matched-pairs in its statistical analysis with no matched pairs having to be excluded. The z-score for the three-year differenced average profit margin – based upon the positive ranks – was -1.697 for a p-value of 0.090. There were 17 negative ranks (totaling 296) and 12 positive ranks (totaling 139) for the three-year average profit margin. Accordingly, there was marginal significance for H1c with respect to the difference between the respective average profit margins for Lean companies and Non-Lean companies. Here, Lean companies had marginally significantly higher profit margins than Non-Lean companies.

Examining the years individually, average profit margin was 4.8 percent of net sales for Lean companies and -14.5 percent of net sales for Non-Lean companies in 2008. For 2009, the average profit margins were 1.4 percent and -12.0 percent for Lean companies and Non-Lean companies, respectively. Lastly, Lean companies' average profit margin for 2010 was 5.5 percent compared to 3.3 percent for Non-Lean companies. For the individual years, only fiscal 2008 had a statistically significant difference – a p-value of 0.003 with a z-score of -3.016.[23] Individually,

[22] For 2009, return on total assets had a p-value of 0.163, a positive-rank based z-score of -1.395, 18 negative ranks (totaling 282) and 11 positive ranks (totaling 153). For 2010, return on total assets had a p-value of 0.347, a positive-rank based z-score of -0.941, 17 negative ranks (totaling 261) and 12 positive ranks (totaling 174).

[23] For 2009, profit margin had a p-value of 0.230, a positive-rank based z-score of -1.200, 16 negative ranks (totaling 273) and 13 positive ranks (totaling 162). For 2010, profit margin had a p-value of 0.888, a negative-rank based z-score of -0.141, 12 negative ranks (totaling 211) and 17 positive ranks (totaling 224).

fiscal 2008 had 21 negative ranks (totaling 357) and 8 positive ranks (totaling 78) for profit margin. Results for H1c, profit margin, are set forth in Table 5.

Table 5a: Profit Margin (H1c)
Descriptive Statistics
pairs: n = 29

Period	3-Year Average		2008		2009		2010	
Co. Type	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**
Mean	0.044	-0.064	0.048	-0.145	0.014	-0.120	0.055	0.033
Std. Dev.	(0.062)	(0.263)	(0.079)	(0.389)	(0.093)	(0.440)	(0.067)	(0.121)
Minimum	-0.155	-0.848	-0.271	-1.214	-0.225	-2.066	-0.133	-0.316
Maximum	0.128	0.126	0.142	0.124	0.131	0.117	0.192	0.176

Table 5b: Profit Margin (H1c)
Wilcoxon Signed-Ranks Test Descriptive Statistics
pairs: n = 29

Period	3-Year Average		2008		2009		2010	
Ranks	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**
Number	17_a	12_b	21_a	8_b	16_a	13_b	12_a	17_b
Mean	17.41	11.58	17.00	9.75	17.06	12.46	17.58	13.18
Sum	296	139	357	78	273	162	211	224

a: Lean > Non-Lean
b: Non-Lean > Lean

Table 5c: Profit Margin (H1c)
Wilcoxon Signed-Ranks Test Results
pairs: n = 29

3-Year Average $_c$		2008_c		2009_c		2010_d	
Z	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**
-1.697	0.090	-3.016	0.003	-1.2	0.230	-0.141	0.888

c: Z is based on the positive ranks.
d: Z is based on the negative ranks.

Hypothesis 2a, Operating Cash Flows

Lean Companies had three-year average operating cash flows of 11.3 percent of lagged total assets, while Non-Lean Companies had three-year average operating cash flows of 4.8 percent of lagged total assets. Hypothesis 2a utilized all 29 matched-pairs in its statistical analysis with no matched pairs having to be excluded. The z-score for the three-year differenced average operating cash flows – based upon the positive ranks – was -2.281 for a p-value of 0.023. There were 18 negative ranks (totaling 323) and 11 positive ranks (totaling 112) for the three-year average operating cash flows. Accordingly, the null hypothesis for H2a was rejected since there was a significant difference between the respective average operating cash flows for Lean companies and Non-Lean companies. Here, Lean companies had significantly higher operating cash flows than Non-Lean companies.

Examining the years individually, average operating cash flows were 11.4 percent of lagged total assets for Lean companies and 2.2 percent of lagged total assets for Non-Lean companies in 2008. For 2009, the average operating cash flows were 11.5 percent and 5.4 percent for Lean companies and Non-Lean companies, respectively. Lastly, Lean companies' average operating cash flows for 2010 were 10.8 percent compared to 6.5 percent for Non-Lean companies. Of the individual years, both 2008 and 2009 had statistically significant differences in operating cash flows between Lean and Non-Lean companies: a p-value of 0.006 with a positive-rank based z-score of -2.757 for 2008; and p-value of 0.050 with a positive-rank based z-score of -1.957 for 2009. Individually, 2008 had 20 negative ranks (totaling 345) and nine positive ranks (totaling 90) while 2009 had had 18 negative ranks (totaling 308) and 11 positive ranks (totaling 127).[24] Results for H2a, operating cash flows, are set forth in Table 6.

[24] For 2010, operating cash flows had a p-value of 0.336, a positive-rank based z-score of -0.962, 14 negative ranks (totaling 262) and 15 positive ranks (totaling 173).

Table 6a: Operating Cash Flows (H2a)

Descriptive Statistics

pairs: n = 29

Period	3-Year Average		2008		2009		2010	
Co. Type	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**
Mean	0.113	0.048	0.114	0.022	0.115	0.054	0.108	0.065
Std. Dev.	(0.058)	(0.103)	(0.074)	(0.167)	(0.075)	(0.118)	(0.075)	(0.092)
Minimum	0.038	-0.264	-0.078	-0.619	0.008	-0.330	-0.018	-0.187
Maximum	0.297	0.182	0.284	0.236	0.396	0.203	0.367	0.183

Table 6b: Operating Cash Flows (H2a)

Wilcoxon Signed-Ranks Test Descriptive Statistics

pairs: n = 29

Period	3-Year Average		2008		2009		2010	
Ranks	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**
Number	18_a	11_b	20_a	9_b	18_a	11_b	14_a	15_b
Mean	17.94	10.18	17.25	10.00	17.11	11.55	18.71	11.53
Sum	323	112	345	90	308	127	262	173

a: Lean > Non-Lean

b: Non-Lean > Lean

Table 6c: Operating Cash Flows (H2a)

Wilcoxon Signed-Ranks Test Results

pairs: n = 29

3-Year Average $_c$		2008_c		2009_c		2010_c	
Z	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**
-2.281	0.023	-2.757	0.006	-1.957	0.050	-0.962	0.336

c: Z is based on the positive ranks.

d: Z is based on the negative ranks.

Hypothesis 2b, Cash-Adequacy Ratio

For the cash-adequacy ratio (operating cash flows ÷ current liabilities), Lean Companies had a three-year average ratio of 62.2 percent of current liabilities, while Non-Lean Companies had a three-year average ratio of 33.3 percent of current liabilities. Hypothesis 2b utilized all 29 matched-pairs in its statistical analysis with no matched pairs having to be excluded. The z-score for the three-year differenced average cash-adequacy ratio – based upon the positive ranks – was -2.198 for a p-value of 0.028. There were 17 negative ranks (totaling 319) and 12 positive ranks (totaling 116) for the three-year average cash-adequacy ratio. Accordingly, the null hypothesis for 2b was rejected since there was a significant difference between the respective average cash-adequacy ratio for Lean companies and Non-Lean companies. Here, Lean companies had a significantly higher cash-adequacy ratio than Non-Lean companies.

Examining the years individually, the average cash-adequacy ratio was 65.8 percent for Lean companies and 18.3 percent for Non-Lean companies in 2008. For 2009, the average cash-adequacy ratios were 67.1 percent and 40.8 percent for Lean and Non-Lean companies, respectively. Lastly, Lean companies' average cash-adequacy ratio for 2010 was 59.0 percent compared to 45.0 percent for Non-Lean companies. Of the individual years, only 2008 had a significant difference – a p-value of 0.004 with a positive-rank based z-score of -2.887. Individually, 2008 had 21 negative ranks (totaling 351) and 8 positive ranks (totaling 84) for the cash-adequacy ratio. That being said, 2009 was close to having marginal significance, having a p-value of 0.103, a z-score of -1.633, 19 negative ranks (totaling 293) and 10 positive ranks (totaling 142).[25] Results for H2b, the cash-adequacy ratio, are set forth in Table 7.

[25] For 2009, the cash-adequacy ratio had a p-value of 0.103, a positive-rank based z-score of -1.633, 19 negative ranks (totaling 293) and 10 positive ranks (totaling 142). For 2010, the cash-adequacy ratio had a p-value of 0.567, a positive-rank based z-score of -0.573, 13 negative ranks (totaling 244) and 16 positive ranks (totaling 191).

Table 7a: Cash-Adequacy Ratio (H2b)

Descriptive Statistics

pairs: n = 29

Period	3-Year Average		2008		2009		2010	
Co. Type	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**
Mean	0.622	0.333	0.658	0.183	0.671	0.408	0.590	0.450
Std. Dev.	(0.311)	(0.525)	(0.425)	(0.686)	(0.436)	(0.572)	(0.516)	(0.467)
Minimum	0.112	-0.956	-0.192	-1.487	0.023	-1.105	-0.231	-0.922
Maximum	1.329	1.093	1.597	1.428	2.174	1.347	2.503	1.204

Table 7b: Cash-Adequacy Ratio (H2b)

Wilcoxon Signed-Ranks Test Descriptive Statistics

pairs: n = 29

Period	3-Year Average		2008		2009		2010	
Ranks	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**
Number	17_a	12_b	21_a	8_b	19_a	10_b	13_a	16_b
Mean	18.76	9.67	16.71	10.50	15.42	14.20	18.77	11.94
Sum	319	116	351	84	293	142	244	191

a: Lean > Non-Lean

b: Non-Lean > Lean

Table 7c: Cash-Adequacy Ratio (H2b)

Wilcoxon Signed-Ranks Test Results

pairs: n = 29

3-Year Average $_c$		2008_c		2009_c		2010_c	
Z	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**
-2.195	0.028	-2.887	0.004	-1.633	0.103	-0.573	0.567

c: Z is based on the positive ranks.

d: Z is based on the negative ranks.

Hypothesis 2c, Financing-Assets Ratio

For the financing-assets ratio (cash flows from operating activities ÷ the absolute value of cash flows from investing activities, but only analyzing those companies that had *negative* cash flows from investing activities), Lean Companies had a three-year average ratio of 3.80, while Non-Lean Companies had a three-year average ratio of 1.35. Hypothesis 2c utilized 25 matched-pairs in its statistical analysis with four matched pairs having to be excluded: three pairs due to one-half of each pair's having positive net financing cash flows; and one pair due to both halves of the pair's having positive net financing cash flows. The z-score for the three-year differenced average financing-assets ratio – based upon the positive ranks – was -1.735 for a p-value of 0.083. There were 16 negative ranks (totaling 227) and nine positive ranks (totaling 98) for the three-year average financing-assets ratio. Accordingly, there was marginal significance for H2c with respect to the difference between the respective average financing-assets ratios for Lean companies and Non-Lean companies. Here, Lean companies had marginally significantly larger financing-assets ratios than Non-Lean companies. For this hypothesis only, the individual years were not compared to one another due to the inappropriateness of comparing fluctuating years of cash inflows versus outflows. Results for H2c, the financing-assets ratio, are set forth in Table 8.

Hypothesis 3a, Net Working Capital

For net working capital (the difference between current assets and current liabilities, scaled by lagged total assets), Lean Companies had a three-year average ratio of 30.0 percent, while Non-Lean Companies had a three-year average ratio of 26.1 percent. Hypothesis 3a utilized 28 matched-pairs in its statistical analysis with one matched pair having to be excluded due to one-half of that pair's failing to classify its balance sheet to enumerate current assets.

Table 8a: Financing-Assets Ratio (H2c)
Descriptive Statistics
pairs: n = 25

Period	3-Year Average	
Co. Type	**Lean**	**Non-Lean**
Mean	3.80	1.35
Std. Dev.	(5.56)	(2.65)
Minimum	0.61	-6.43
Maximum	22.79	5.84

Table 8b: Financing-Assets Ratio (H2c)
Wilcoxon Signed-Ranks Test Descriptive Statistics
pairs: n = 25

Period	3-Year Average	
Ranks	**Negative**	**Positive**
Number	16_a	9_b
Mean	14.19	10.89
Sum	227	98

Table 8c: Financing-Assets Ratio (H2c)
Wilcoxon Signed-Ranks Test Results
pairs: n = 25

3-Year Average $_c$	
Z	**p-value**
-1.735b	0.083

c: Z is based on the positive ranks.
d: Z is based on the negative ranks.

The z-score for the three-year differenced average net working capital – based upon the positive ranks – was -0.478 for a p-value of 0.633. There were 16 negative ranks (totaling 224) and 12 positive ranks (totaling 182) for the three-year average net working capital. Accordingly, the null hypothesis for H3a failed to be rejected since there was not a significant difference between the respective average net working capital for Lean companies and Non-Lean companies.

The sample distribution for H3a was one of two of the 17 hypotheses where one or both of the Lean-company observations or the Non-Lean-company observations did not fail the Shapiro-Wilk test for normality. Accordingly, dependent-samples t-tests also are an appropriate method through which to analyze the data. The three-year average of net working capital (as a percentage of lagged total assets), had a t-score of 0.673 with a p-value of 0.507. Therefore, under both parametric and non-parametric matched-pairs tests, the null hypothesis for H3a failed to be rejected since there was not a significant difference between the respective average net working capital for Lean companies and Non-Lean companies. Furthermore, the respective t-scores and p-values for the individual years were: (a) for 2008, 0.717 and 0.480; (b) for 2009, 0.414 and 0.682; and (c) for 2010, 0.929 and 0.361. That is, none of the individual years had a statistically significant difference in net working capital between Lean companies and Non-Lean companies when analyzed using t-tests.

Examining the years individually, average net working capital was 28.4 percent of lagged total assets for Lean companies and 23.3 percent for Non-Lean companies in 2008. For 2009, the average net working capital was 28.3 percent and 25.7 percent for Lean and Non-Lean companies, respectively. Lastly, Lean companies' average net working capital for 2010 was 34.7 percent compared to 29.5 percent for Non-Lean companies. Although Lean companies had higher average net working capital for each of the three individual years, none of the individual years had a statistically significant difference between Lean and Non-Lean companies.[26] Results for H3a, net working capital, are set forth in Table 9.

[26] For 2008, net working capital had a p-value of 0.633, a positive-rank based z-score of -0.478, 16 negative ranks (totaling 224) and 12 positive ranks (totaling 182). For 2009, net working capital had a p-value of 0.585, a positive-

Table 9a: Net Working Capital (H3a)

Descriptive Statistics

pairs: n = 28

Period Co. Type	3-Year Average Lean	 Non-Lean	2008 Lean	 Non-Lean	2009 Lean	 Non-Lean	2010 Lean	 Non-Lean
Mean	0.300	0.261	0.284	0.233	0.283	0.257	0.347	0.295
Std. Dev.	(0.195)	(0.265)	(0.178)	(0.323)	(0.237)	(0.260)	(0.206)	(0.283)
Minimum	-0.122	-0.431	-0.096	-0.589	-0.494	-0.488	-0.033	-0.395
Maximum	0.663	0.755	0.655	1.097	0.663	0.663	0.886	0.851

Table 9b: **Net Working Capital (H3a)**

Wilcoxon Signed-Ranks Test Descriptive Statistics

pairs: n = 28

Period Ranks	3-Year Average Negative	 Positive	2008 Negative	 Positive	2009 Negative	 Positive	2010 Negative	 Positive
Number	16_a	12_b	16_a	12_b	17_a	11_b	19_a	9_b
Mean	14.00	15.17	14.00	15.17	13.35	16.27	13.00	17.67
Sum	224	182	224	182	227	179	247	159

a: Lean > Non-Lean

b: Non-Lean > Lean

Table 9c: Net Working Capital (H3a)

Wilcoxon Signed-Ranks Test Results

pairs: n = 28

3-Year Average c Z	 p-value	2008c Z	 p-value	2009c Z	 p-value	2010c Z	 p-value
-0.478	0.633	-0.478	0.633	-0.547	0.585	-1.002	0.316

c: Z is based on the positive ranks.

d: Z is based on the negative ranks.

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rank based z-score of -0.547, 17 negative ranks (totaling 227) and 11 positive ranks (totaling 179). For 2010, net working capital had a p-value of 0.316, a positive-rank based z-score of -1.002, 19 negative ranks (totaling 247) and 9 positive ranks (totaling 159).

Hypothesis 3b, Working-Capital Turnover

For working-capital turnover (net sales ÷ average working capital), Lean Companies had a three-year average of 3.67 turns, while Non-Lean Companies had a three-year average of 4.25 turns. Hypothesis 3b utilized 27 matched-pairs in its statistical analysis with two matched pairs having to be excluded: one pair due to one-half of that pair's failing to classify its balance sheet to enumerate current assets; and one pair due to one-half of that pair's having an extreme outlier-creating denominator of less than one. The z-score for the three-year differenced average working-capital turnover – based the negative ranks – was -0.096 for a p-value of 0.923. There were 14 negative ranks (totaling 185) and 13 positive ranks (totaling 193) for the three-year average working-capital turnover. Accordingly, the null hypothesis for H3b failed to be rejected since there was not a significant difference between the respective average working-capital turnovers for Lean companies and Non-Lean companies.

Examining the years individually, average working-capital turnover was 4.53 turns for Lean companies and 4.80 turns for Non-Lean companies in 2008. For 2009, the average working-capital turnover was 3.41 turns and 4.49 turns for Lean companies and Non-Lean companies, respectively. Lastly, Lean companies' average working-capital turnover for 2010 was 3.04 turns compared to 0.48 turns for Non-Lean companies. None of the individual years had a statistically significant difference in working-capital turnover between Lean companies and Non-Lean companies.[27] Results for H3b, working-capital turnover, are set forth in Table 10.

[27] For 2008, working-capital turnover had a p-value of 0.866, a positive-rank based z-score of -0.168, 15 negative ranks (totaling 196) and 12 positive ranks (totaling 182). For 2009, working-capital turnover had a p-value of 0.665, a negative-rank based z-score of -0.432, 14 negative ranks (totaling 171) and 13 positive ranks (totaling 207). For 2010, working-capital turnover had a p-value of 0.400, a positive-rank based z-score of -0.841, 16 negative ranks (totaling 224) and 11 positive ranks (totaling 154).

Table 10a: Working-Capital Turnover (H3b)

Descriptive Statistics

pairs: n = 27

Period	3-Year Average		2008		2009		2010	
Co. Type	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**
Mean	3.7	4.2	4.5	4.8	3.4	4.5	3.0	0.5
Std. Dev.	5.4	4.8	6.3	5.4	4.8	5.0	6.1	14.7
Minimum	-14.5	-4.3	-13.2	-5.1	-11.7	-4.0	-22.3	-71.4
Maximum	19.5	22.9	26.0	19.8	16.7	19.6	14.6	12.6

Table 10b: Working-Capital Turnover (H3b)

Wilcoxon Signed-Ranks Test Descriptive Statistics

pairs: n = 27

Period	3-Year Average		2008		2009		2010	
Ranks	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**
Number	14_a	13_b	15_a	12_b	14_a	13_b	16_a	11_b
Mean	13.21	14.85	13.07	15.17	12.21	15.92	14.00	14.00
Sum	185	193	196	182	171	207	224	154

a: Lean > Non-Lean

b: Non-Lean > Lean

Table 10c: Working-Capital Turnover (H3b)

Wilcoxon Signed-Ranks Test Results

pairs: n = 27

3-Year Average $_d$		2008_c		2009_d		2010_c	
Z	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**
-0.096	0.923	-0.168	0.866	-0.432	0.665	-0.841	0.400

c: Z is based on the positive ranks.

d: Z is based on the negative ranks.

Hypothesis 3c, Current Ratio

For the current ratio (current assets ÷ current liabilities), Lean Companies had a three-year average ratio of 2.7 times, while Non-Lean Companies had a three-year average ratio of 2.8 times. Hypothesis 3c utilized 28 matched-pairs in its statistical analysis with one matched pair having to be excluded due to one-half of that pair's failing to classify its balance sheet to enumerate current assets. The z-score for the three-year differenced average current ratio – based the negative ranks – was -0.114 for a p-value of 0.909. There were 16 negative ranks (totaling 198) and 12 positive ranks (totaling 208) for the three-year average current ratio. Accordingly, the null hypothesis for H3c failed to be rejected since there was not a significant difference between the respective average current ratios for Lean companies and Non-Lean companies.

Examining the years individually, the average current ratio was 2.7 times for Lean companies and 2.8 times for Non-Lean companies in 2008. For 2009, the average current ratio was 2.9 times and 3.0 times for Lean companies and Non-Lean companies, respectively. Lastly, Lean companies' average current ratio for 2010 was 2.9 times compared to 3.0 times for Non-Lean companies. None of the individual years had a statistically significant difference in current ratio between Lean companies and Non-Lean companies.[28] Results for H3c, the current ratio, are set forth in Table 11.

Hypothesis 3d, Acid-Test Ratio

For the acid-test ratio (the sum of cash, short-term investments, and net receivables ÷ current liabilities), Lean Companies had a three-year average ratio of 1.83 times, while Non-

[28] For 2008, the current ratio had a p-value of 0.802, a positive-rank based z-score of -0.250, 15 negative ranks (totaling 214) and 13 positive ranks (totaling 192). For 2009, the current ratio had a p-value of 0.964, a negative-rank based z-score of -0.046, 7 negative ranks (totaling 49) and 13 positive ranks (totaling 161). For 2010, the current ratio had a p-value of 0.750, a negative-rank based z-score of -0.319, 12 negative ranks (totaling 189) and 16 positive ranks (totaling 217).

Table 11a: Current Ratio (H3c)

Descriptive Statistics

pairs: n = 28

Period	3-Year Average		2008		2009		2010	
Co. Type	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**
Mean	2.74	2.83	2.74	2.83	2.88	3.02	2.89	2.99
Std. Dev.	1.26	1.88	1.35	2.31	1.55	2.08	1.34	1.80
Minimum	0.67	0.36	0.59	0.33	0.30	0.46	0.81	0.33
Maximum	5.06	7.80	5.37	8.74	6.04	8.51	6.47	7.73

Table 11b: Current Ratio (H3c)

Wilcoxon Signed-Ranks Test Descriptive Statistics

pairs: n = 28

Period	3-Year Average		2008		2009		2010	
Ranks	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**
Number	16_a	12_b	15_a	13_b	7_a	13_b	12_a	16_b
Mean	12.38	17.33	14.27	14.77	7.00	12.38	15.75	13.56
Sum	198	208	214	192	49	161	189	217

a: Lean > Non-Lean

b: Non-Lean > Lean

Table 11c: Current Ratio (H3c)

Wilcoxon Signed-Ranks Test Results

pairs: n = 28

3-Year Average $_d$		2008$_c$		2009$_d$		2010$_d$	
Z	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**
-0.114	0.909	-0.25	0.802	-0.046	0.964	-0.319	0.750

c: Z is based on the positive ranks.

d: Z is based on the negative ranks.

Lean Companies had a three-year average ratio of 1.91 times. Hypothesis 3d utilized 28 matched-pairs in its statistical analysis with one matched pair having to be excluded due to one-half of that pair's failing to classify its balance sheet to enumerate current liabilities. The z-score for the three-year differenced average acid-test ratio – based the positive ranks – was -0.137 for a p-value of 0.891. There were 14 negative ranks (totaling 209) and 14 positive ranks (totaling 197) for the three-year average acid-test ratio. Accordingly, the null hypothesis for H3d failed to be rejected since there was not a significant difference between the respective average acid-test ratio for Lean companies and Non-Lean companies.

Examining the years individually, average acid-test ratio was 1.76 times for Lean companies and 1.80 times for Non-Lean companies in 2008. For 2009, the average acid-test ratio was 1.97 times and 1.95 times for Lean companies and Non-Lean companies, respectively. Lastly, Lean companies' average acid-test ratio for 2010 was 1.94 times compared to 1.95 times for Non-Lean companies. None of the individual years had a statistically significant difference in acid-test ratio between Lean companies and Non-Lean companies.[29] Results for H3d, the acid-test ratio, are set forth in Table 12.

Hypothesis 3e, Accounts-Receivable Turnover

For the accounts-receivable turnover (net sales ÷ average net receivables), Lean Companies had a three-year average of 8.2 turns, while Non-Lean Companies had a three-year average of 7.4 turns. Hypothesis 3e utilized 28 matched-pairs in its statistical analysis with one matched pair having to be excluded due to one-half of that pair's failing to report net receivables

[29] For 2008, the acid-test ratio had a p-value of 0.682, a positive-rank based z-score of -0.410, 15 negative ranks (totaling 221) and 13 positive ranks (totaling 185). For 2009, the acid-test ratio had a p-value of 0.733, a positive-rank based z-score of -0.342, 15 negative ranks (totaling 218) and 13 positive ranks (totaling 188). For 2010, the acid-test ratio had a p-value of 0.802, a positive-rank based z-score of -0.250, 15 negative ranks (totaling 214) and 13 positive ranks (totaling 192).

Table 12a: Acid-Test Ratio (H3d)

Descriptive Statistics

pairs: n = 28

Period	3-Year Average		2008		2009		2010	
Co. Type	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**
Mean	1.82	1.91	1.76	1.80	1.97	1.95	1.94	1.95
Std. Dev.	1.03	1.45	1.09	1.72	1.32	1.52	1.02	1.32
Minimum	0.17	0.26	0.21	0.22	0.04	0.33	0.23	0.26
Maximum	3.83	5.88	4.11	6.45	4.85	6.33	4.37	5.72

Table 12b: Acid-Test Ratio (H3d)

Wilcoxon Signed-Ranks Test Descriptive Statistics

pairs: n = 28

Period	3-Year Average		2008		2009		2010	
Ranks	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**
Number	14_a	14_b	15_a	13_b	15_a	13_b	15_a	13_b
Mean	14.93	14.07	14.73	14.23	14.53	14.46	14.27	14.77
Sum	209	197	221	185	218	188	214	192

a: Lean > Non-Lean

b: Non-Lean > Lean

Table 12c: Acid-Test Ratio (H3d)

Wilcoxon Signed-Ranks Test Results

pairs: n = 28

3-Year Average $_c$		2008_c		2009_c		2010_c	
Z	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**
-0.137	0.891	-0.41	0.682	-0.342	0.733	-0.25	0.802

c: Z is based on the positive ranks.

d: Z is based on the negative ranks.

for all years studied. The z-score for the three-year differenced average accounts-receivable turnover – based the positive ranks – was -0.023 for a p-value of 0.982. There were 13 negative ranks (totaling 204) and 15 positive ranks (totaling 202) for the three-year average accounts-receivable turnover. Accordingly, the null hypothesis for H3e failed to be rejected since there was not a significant difference between the respective average accounts-receivable turnover for Lean companies and Non-Lean companies.

Examining the years individually, average accounts-receivable turnover was 8.3 turns for Lean companies and 8.0 turns for Non-Lean companies in 2008. For 2009, the average accounts-receivable turnover was 7.9 turns and 7.2 turns for Lean companies and Non-Lean companies, respectively. Lastly, Lean companies' average accounts-receivable turnover for 2010 was 8.6 turns compared to 7.8 turns for Non-Lean companies. None of the individual years had a statistically significant difference in accounts-receivable turnover between Lean companies and Non-Lean companies.[30] Results for H3e, accounts-receivable turnover, are set forth in Table 13.

Hypothesis 3f, Days'-Sales Uncollected

For days'-sales uncollected (365 x net receivables ÷ net sales), Lean Companies had a three-year average of 58.7 days, while Non-Lean Companies had a three-year average of 59.8 days. Hypothesis 3f utilized all 29 matched-pairs in its statistical analysis with no matched pairs having to be excluded. The z-score for the three-year differenced average days'-sales uncollected – based the negative ranks – was -0.184 for a p-value of 0.854. There were 14 negative ranks

[30] For 2008, accounts-receivable turnover had a p-value of 0.982, a positive-rank based z-score of -0.023, 14 negative ranks (totaling 205) and 14 positive ranks (totaling 201). For 2009, accounts-receivable turnover had a p-value of 0.909, a positive-rank based z-score of -0.114, 14 negative ranks (totaling 208) and 14 positive ranks (totaling 198). For 2010, accounts-receivable turnover had a p-value of 0.982, a positive-rank based z-score of -0.023, 12 negative ranks (totaling 204) and 16 positive ranks (totaling 202).

Table 13a: Accounts-Receivable Turnover (H3e)
Descriptive Statistics
pairs: n = 28

Period	3-Year Average		2008		2009		2010	
Co. Type	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**
Mean	8.2	7.3	8.3	8.0	7.9	7.2	8.6	7.8
Std. Dev.	5.9	4.6	5.4	5.9	6.6	5.9	7.1	5.4
Minimum	2.8	3.3	3.1	2.9	2.5	2.4	2.9	3.9
Maximum	27.2	27.2	27.1	27.1	29.1	29.1	31.7	31.8

Table 13b: Accounts-Receivable Turnover (H3e)
Wilcoxon Signed-Ranks Test Descriptive Statistics
pairs: n = 28

Period	3-Year Average		2008		2009		2010	
Ranks	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**
Number	13_a	15_b	14_a	14_b	14_a	14_b	12_a	16_b
Mean	15.69	13.47	14.64	14.36	14.86	14.14	17.00	12.63
Sum	204	202	205	201	208	198	204	202

a: Lean > Non-Lean
b: Non-Lean > Lean

Table 13c: Accounts-Receivable Turnover (H3e)
Wilcoxon Signed-Ranks Test Results
pairs: n = 28

3-Year Average $_c$		2008_c		2009_c		2010_c	
Z	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**
-0.023	0.982	-0.046	0.964	-0.114	0.909	-0.023	0.982

c: Z is based on the positive ranks.
d: Z is based on the negative ranks.

(totaling 208) and 15 positive ranks (totaling 226) for the three-year average days'-sales uncollected. Accordingly, the null hypothesis for H3f failed to be rejected since there was not a significant difference between the respective average days'-sales uncollected for Lean companies and Non-Lean companies.

The sample distribution for H3f was one of two of the 17 hypotheses where one or both of the Lean-company observations or the Non-Lean-company observations did not fail the Shapiro-Wilk test for normality. Accordingly, dependent-samples t-tests also are an appropriate method through which to analyze the data. The three-year average of days'-sales uncollected, had a t-score of -0.167 with a p-value of 0.868. Therefore, under both parametric and non-parametric matched-pairs tests, the null hypothesis for H3f failed to be rejected since there was not a significant difference between the respective average days'-sales uncollected for Lean companies and Non-Lean companies. Furthermore, the respective t-scores and p-values for the individual years were: (a) for 2008, -0.529 and 0.601; (b) for 2009, -0.432 and 0.669; and (c) for 2010, 0.596 and 0.556. That is, none of the individual years had a statistically significant difference in days'-sales uncollected between Lean companies and Non-Lean companies when analyzed using t-tests.

Examining the years individually, average days'-sales uncollected was 55.8 days for Lean companies and 59.3 days for Non-Lean companies in 2008. For 2009, the average days'-sales uncollected were 60.4 days and 63.4 days for Lean companies and Non-Lean companies, respectively. Lastly, Lean companies' average days'-sales uncollected for 2010 was 62.3 days compared to 58.3 days for Non-Lean companies. None of the individual years had a statistically significant difference in days'-sales uncollected between Lean companies and Non-Lean companies.[31] Results for H3f, days'-sales uncollected, are set forth in Table 14.

[31] For 2008, days'-sales uncollected had a p-value of 0.496, a negative-rank based z-score of -0.681, 13 negative ranks (totaling 186) and 16 positive ranks (totaling 249). For 2009, days'-sales uncollected had a p-value of 0.596, a negative-rank based z-score of -0.530, 15 negative ranks (totaling 193) and 14 positive ranks (totaling 242). For

Table 14a: Days' Sales Uncollected (H3f)

Descriptive Statistics

pairs: n = 29

Period	3-Year Average		2008		2009		2010	
Co. Type	Lean	Non-Lean	Lean	Non-Lean	Lean	Non-Lean	Lean	Non-Lean
Mean	58.7	59.8	55.8	59.3	60.4	63.4	62.3	58.3
Std. Dev.	25.8	21.0	24.2	23.7	31.3	25.0	26.4	23.2
Minimum	13.5	8.3	13.5	10.3	0.0	7.1	14.1	7.1
Maximum	132.0	109.3	120.8	131.3	149.8	109.4	136.8	103.8

Table 14b: Days' Sales Uncollected (H3f)

Wilcoxon Signed-Ranks Test Descriptive Statistics

pairs: n = 29

Period	3-Year Average		2008		2009		2010	
Ranks	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive
Number	14_a	15_b	13_a	16_b	15_a	14_b	16_a	13_b
Mean	14.93	15.07	14.31	15.56	12.87	17.29	14.69	15.38
Sum	209	226	186	249	193	242	235	200

a: Lean > Non-Lean

b: Non-Lean > Lean

Table 14c: Days' Sales Uncollected (H3f)

Wilcoxon Signed-Ranks Test Results

pairs: n = 29

3-Year Average $_d$		2008_d		2009_d		2010_c	
Z	p-value	Z	p-value	Z	p-value	Z	p-value
-0.184	0.854	-0.681	0.496	-0.53	0.596	-0.378	0.705

c: Z is based on the positive ranks.

d: Z is based on the negative ranks.

2010, days'-sales uncollected had a p-value of 0.705, a positive-rank based z-score of -0.378, 16 negative ranks (totaling 235) and 13 positive ranks (totaling 200).

Hypothesis 4a, Total Inventory Turnover

For the total-inventory turnover (cost of goods sold ÷ average total inventory), Lean Companies had a three-year average of 6.1 turns, while Non-Lean Companies had a three-year average of 4.3 turns. Hypothesis 4a utilized 27 matched-pairs in its statistical analysis with two matched pairs having to be excluded due to one-half of each pair's not reporting any inventory. The z-score for the three-year differenced average total-inventory turnover – based the positive ranks – was -0.240 for a p-value of 0.016. There were 19 negative ranks (totaling 270) and seven positive ranks (totaling 81) for the three-year average total-inventory turnover. For the total-inventory turnover, hypothesis 4a, there was one differenced observation with a zero value that the Wilcoxon signed-ranks test excluded. For that differenced observation, both halves of a matched pair were outliers beyond three standard deviations. Accordingly, both halves of the matched pair were winsorized to the same value, thereby giving the differenced observation a zero value. Accordingly, the null hypothesis for H4a was rejected since there was a significant difference between the respective average total-inventory turnover for Lean companies and Non-Lean companies. Here, Lean companies had significantly higher total-inventory turnover than Non-Lean companies.

Examining the years individually, average total-inventory turnover was 6.3 turns for Lean companies and 4.8 turns for Non-Lean companies in 2008. For 2009, the average total-inventory turnover was 5.7 turns and 5.2 turns for Lean companies and Non-Lean companies, respectively. Lastly, Lean companies' average total-inventory turnover for 2010 was 6.4 turns compared to 4.3 turns for Non-Lean companies. All three of the individual years had statistically significant differences in total-inventory turnover between Lean companies and Non-Lean companies: (1) for 2008, a p-value of 0.041, positive-rank based z-score of -2.045, 19 negative ranks (totaling

256), and seven positive ranks (totaling 95); (2) for 2009, a p-value of 0.030, positive-rank based z-score of -2.172, 19 negative ranks (totaling 261), and seven positive ranks (totaling 90); and (3) for 2010, a p-value of 0.006, positive-rank based z-score of -2.756, 19 negative ranks (totaling 284), and seven positive ranks (totaling 67). Results for H4a, total-inventory turnover, are set forth in Table 15.

Hypothesis 4b, Raw-Materials Inventory Turnover

For raw-materials inventory turnover (cost of goods sold ÷ average raw-materials inventory), Lean Companies had a three-year average of 18.1 turns, while Non-Lean Companies had a three-year average of 8.8 turns. Hypothesis 4b utilized 22 matched-pairs in its statistical analysis with seven matched pairs having to be excluded: three pairs due to both halves of those pairs' not reporting any raw-materials inventory; and four other pairs due to one-half of each such pair's not reporting any raw-materials inventory. The z-score for the three-year differenced average raw-materials inventory turnover between – based the positive ranks – was -3.165 for a p-value of 0.002. There were 17 negative ranks (totaling 224) and five positive ranks (totaling 29) for the three-year average raw-materials inventory turnover between. Accordingly, the null hypothesis for H4b was rejected since there was a significant difference between the respective average raw-materials inventory turnover between for Lean companies and Non-Lean companies. Here, Lean companies had significantly higher raw-materials inventory turnover than Non-Lean companies.

Examining the years individually, average raw-materials inventory turnover between was 19.7 turns for Lean companies and 9.8 turns for Non-Lean companies in 2008. For 2009, the average raw-materials inventory turnover was 16.7 turns and 8.4 turns for Lean companies and

Table 15a: Total-Inventory Turnover (H4a)

Descriptive Statistics

pairs: n = 27

Period	3-Year Average		2008		2009		2010	
Co. Type	Lean	Non-Lean	Lean	Non-Lean	Lean	Non-Lean	Lean	Non-Lean
Mean	6.1	4.3	6.3	4.8	5.7	4.2	6.4	4.3
Std. Dev.	5.6	4.9	5.5	5.7	5.6	4.9	5.9	5.1
Minimum	1.4	0.2	1.3	0.1	1.5	0.1	1.6	0.6
Maximum	26.6	26.6	26.7	26.7	26.1	26.1	28.4	28.4

Table 15b: Total-Inventory Turnover (H4a)

Wilcoxon Signed-Ranks Test Descriptive Statistics

pairs: n = 27

Period	3-Year Average		2008		2009		2010	
Ranks	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive
Number*	19_a	7_b	19_a	7_b	19_a	7_b	19_a	7_b
Mean	14.21	11.57	13.47	13.57	13.74	12.86	14.95	9.57
Sum	270	81	256	95	261	90	284	67

a: Lean > Non-Lean

b: Non-Lean > Lean

* There was one differenced observation with a zero value that the Wilcoxon signed-ranks test excluded from further analysis.

Table 15c: Total-Inventory Turnover (H4a)

Wilcoxon Signed-Ranks Test Results

pairs: n = 27

3-Year Average $_c$		2008_c		2009_c		2010_c	
Z	p-value	Z	p-value	Z	p-value	Z	p-value
-2.400	0.016	-2.045	0.041	-2.172	0.030	-2.756	0.006

c: Z is based on the positive ranks.

d: Z is based on the negative ranks.

Non-Lean companies, respectively. Lastly, Lean companies' average raw-materials inventory turnover between for 2010 was 18.5 turns compared to 9.0 turns for Non-Lean companies. All three of the individual years had statistically significant differences in raw-materials inventory turnover between Lean companies and Non-Lean companies: (1) for 2008, a p-value of 0.001, positive-rank based z-score of -3.165, 19 negative ranks (totaling 233), and three positive ranks (totaling 20); (2) for 2009, a p-value of 0.003, positive-rank based z-score of -3.003, 16 negative ranks (totaling 219), and six positive ranks (totaling 34); and (3) for 2010, a p-value of 0.002, positive-rank based z-score of -3.036, 17 negative ranks (totaling 220), and five positive ranks (totaling 33). Results for H4b, raw-materials inventory turnover, are set forth in Table 16.

Hypothesis 4c, Work-in-Process Inventory Turnover

For work-in-process inventory turnover (cost of goods sold ÷ average work-in-process inventory), Lean Companies had a three-year average of 24.1 turns, while Non-Lean Companies had a three-year average of 37.7 turns. Hypothesis 4c utilized *only 16* matched-pairs in its statistical analysis with 13 matched pairs having to be excluded: seven pairs due to both halves of those pairs' either not reporting any work-in-process inventory or having an extreme outlier-creating denominator of less than one; and six pairs due to at least one-half of each such pair's not reporting any work-in-process inventory or having an extreme outlier-creating denominator of less than one. The z-score for the three-year differenced average work-in-process inventory turnover – based the negative ranks – was -0.517 for a p-value of 0.605. There were nine negative ranks (totaling 58) and eight positive ranks (totaling 78) for the three-year average work-in-process inventory turnover.

Table 16a: Raw-Materials Inventory Turnover (H4b)

Descriptive Statistics

pairs: n = 22

Period / Co. Type	3-Year Average Lean	3-Year Average Non-Lean	2008 Lean	2008 Non-Lean	2009 Lean	2009 Non-Lean	2010 Lean	2010 Non-Lean
Mean	18.1	8.8	19.7	9.8	16.7	8.4	18.5	9.0
Std. Dev.	15.1	7.0	16.8	8.4	14.5	7.2	15.6	7.3
Minimum	3.5	0.2	3.0	0.1	2.7	0.1	3.7	0.7
Maximum	62.4	33.9	64.6	35.3	64.5	33.1	62.5	33.2

Table 16b: Raw-Materials Inventory Turnover (H4b)

Wilcoxon Signed-Ranks Test Descriptive Statistics

pairs: n = 22

Period / Ranks	3-Year Average Negative	3-Year Average Positive	2008 Negative	2008 Positive	2009 Negative	2009 Positive	2010 Negative	2010 Positive
Number	17_a	5_b	19_a	3_b	16_a	6_b	17_a	5_b
Mean	13.18	5.80	12.26	6.67	13.69	5.67	12.94	6.60
Sum	224	29	233	20	219	34	220	33

a: Lean > Non-Lean

b: Non-Lean > Lean

Table 16c: Raw-Materials Inventory Turnover (H4b)

Wilcoxon Signed-Ranks Test Results

pairs: n = 22

3-Year Average $_c$ Z	3-Year Average $_c$ p-value	2008_c Z	2008_c p-value	2009_c Z	2009_c p-value	2010_c Z	2010_c p-value
-3.165	0.002	-3.458	0.001	-3.003	0.003	-3.036	0.002

c: Z is based on the positive ranks.

d: Z is based on the negative ranks.

Accordingly, the null hypothesis for H4c failed to be rejected since there was not a significant difference between the respective average work-in-process inventory turnover for Lean companies and Non-Lean companies.

Examining the years individually, average work-in-process inventory turnover was 24.6 turns for Lean companies and 39.7 turns for Non-Lean companies in 2008. For 2009, the average work-in-process inventory turnover was 22.4 turns and 34.4 turns for Lean companies and Non-Lean companies, respectively. Lastly, Lean companies' average work-in-process inventory turnover for 2010 was 27.0 turns compared to 34.8 turns for Non-Lean companies. None of the individual years had a statistically significant difference in work-in-process inventory turnover between Lean companies and Non-Lean companies.[32] Results for H4c, work-in-process inventory turnover, are set forth in Table 17.

Hypothesis 4d, Finished-Goods Inventory Turnover

For finished-goods inventory turnover (cost of goods sold ÷ average finished-goods inventory), Lean Companies had a three-year average of 17.6 turns, while Non-Lean Companies had a three-year average of 14.6 turns. Hypothesis 4d utilized 19 matched-pairs in its statistical analysis with ten matched pairs having to be excluded: four pairs due to both halves of those pairs' either not reporting any work-in-process inventory or having an extreme outlier-creating denominator of less than one; and six pairs due to at least one-half of each such pair's not reporting any work-in-process inventory or having an extreme outlier-creating denominator of less than one.

[32] For 2008, work-in-process inventory turnover had a p-value of 0.605, a negative-rank based z-score of -0.517, 9 negative ranks (totaling 58) and 7 positive ranks (totaling 78). For 2009, work-in-process inventory turnover had a p-value of 0.642, a negative-rank based z-score of -0.465, 9 negative ranks (totaling 59) and 7 positive ranks (totaling 77). For 2010, work-in-process inventory turnover had a p-value of 0.918, a negative-rank based z-score of -0.103, 7 negative ranks (totaling 66) and 9 positive ranks (totaling 70).

Table 17a: Work-in-Process Inventory Turnover (H4c)

Descriptive Statistics

pairs: n = 16

Period	3-Year Average		2008		2009		2010	
Co. Type	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**
			-					
Mean	24.1	37.7	24.6	39.7	22.4	34.4	27.0	34.8
Std. Dev.	19.4	45.3	19.0	43.3	19.2	42.3	21.4	44.3
Minimum	4.2	5.0	4.7	5.0	3.5	4.3	4.4	5.5
Maximum	84.8	144.6	82.1	133.6	83.3	138.9	89.5	181.3

Table 17b: Work-in-Process Inventory Turnover (H4c)

Wilcoxon Signed-Ranks Test Descriptive Statistics

pairs: n = 16

Period	3-Year Average		2008		2009		2010	
Ranks	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**
Number	9_a	7_b	9_a	7_b	9_a	7_b	7_a	9_b
Mean	6.44	11.14	6.44	11.14	6.56	11.00	9.43	7.78
Sum	58	78	58	78	59	77	66	70

a: Lean > Non-Lean

b: Non-Lean > Lean

Table 17c: Work-in-Process Inventory Turnover (H4c)

Wilcoxon Signed-Ranks Test Results

pairs: n = 16

3-Year Average$_d$		**2008$_d$**		**2009$_d$**		**2010$_d$**	
Z	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**
-0.517	0.605	-0.517	0.605	-0.465	0.642	-0.103	0.918

c: Z is based on the positive ranks.

d: Z is based on the negative ranks.

The z-score for the three-year differenced average finished-goods inventory turnover – based the positive ranks – was -1.771 for a p-value of 0.077. There were 12 negative ranks (totaling 139) and eight positive ranks (totaling 51) for the three-year average finished-goods inventory turnover. Accordingly, there was marginal significance for H4d with respect to the difference between the respective average finished-goods inventory turnover for Lean companies and Non-Lean companies. Here, Lean companies had a marginally significantly larger inventory turnover than Non-Lean companies.

Examining the years individually, average finished-goods inventory turnover was 18.2 turns for Lean companies and 18.1 turns for Non-Lean companies in 2008. For 2009, the average finished-goods inventory turnover was 15.6 turns and 13.1 turns for Lean companies and Non-Lean companies, respectively. Lastly, Lean companies' average finished-goods inventory turnover for 2010 was 19.4 turns compared to 13.9 turns for Non-Lean companies. Of the individual years, both 2009 (marginally) and 2010 had statistically significant differences in finished-goods inventory turnover between Lean companies and Non-Lean companies: (1) for 2009, a p-value of 0.070 with a positive-rank based z-score of -1.328; and (2) for 2010, a p-value of 0.049 with a positive-rank based z-score of -1.972. Individually, fiscal 2009 had 12 negative ranks (totaling 140) and seven positive ranks (totaling 50) while fiscal 2010 had 12 negative ranks (totaling 144) and seven positive ranks (totaling 46) for finished-goods inventory turnover.[33] Results for H4d, finished-goods inventory turnover, are set forth in Table 18.

[33] For 2008, finished-goods inventory turnover had a p-value of 0.184, a positive-rank based z-score of -1.328, 11 negative ranks (totaling 128) and 8 positive ranks (totaling 62).

Table 18a: Finished-Goods Inventory Turnover (H4d)

Descriptive Statistics

pairs: n = 19

Period	3-Year Average		2008		2009		2010	
Co. Type	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**
Mean	17.6	14.6	18.2	18.1	15.6	13.1	19.4	13.9
Std. Dev.	14.7	19.3	13.9	27.4	14.2	16.5	16.6	17.4
Minimum	3.5	2.1	3.0	2.4	3.6	1.5	3.9	2.5
Maximum	70.1	83.9	64.6	116.8	68.9	68.9	77.1	77.2

Table 18b: Finished-Goods Inventory Turnover (H4d)

Wilcoxon Signed-Ranks Test Descriptive Statistics

pairs: n = 19

Period	3-Year Average		2008		2009		2010	
Ranks	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**
Number	12_a	7_b	11_a	8_b	12_a	7_b	12_a	7_b
Mean	11.58	7.29	11.64	7.75	11.67	7.14	12.00	6.57
Sum	139	51	128	62	140	50	144	46

a: Lean > Non-Lean

b: Non-Lean > Lean

Table 18c: Finished-Goods Inventory Turnover (H4d)

Wilcoxon Signed-Ranks Test Results

pairs: n = 19

3-Year Average $_c$		2008_c		2009_c		2010_c	
Z	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**
-1.771	0.077	-1.328	0.184	-1.811	0.070	-1.972	0.049

c: Z is based on the positive ranks.

d: Z is based on the negative ranks.

Hypothesis 4e, Days'-Sales in Inventory

For days'-sales in inventory (365 days x net sales ÷ average finished-goods inventory), Lean Companies had a three-year average of 32.4 days, while Non-Lean Companies had a three-year average of 58.2 days. Hypothesis 4e utilized 19 matched-pairs in its statistical analysis with ten matched pairs having to be excluded: four pairs due to both halves of those pairs' either not reporting any finished-goods inventory or having an extreme outlier-creating denominator of less than one; and six pairs due to at least one-half of each such pair's not reporting any finished-goods inventory or having an extreme outlier-creating denominator of less than one. The z-score for the three-year differenced average days'-sales in inventory – based the negative ranks – was -2.093 for a p-value of 0.036. There were seven negative ranks (totaling 43) and 12 positive ranks (totaling 147) for the three-year average days'-sales in inventory. Accordingly, the null hypothesis for H4e was rejected since there was a significant difference between the respective average days'-sales in inventory between for Lean companies and Non-Lean companies. Here, Lean companies had significantly lower days'-sales in inventory than Non-Lean companies.

Examining the years individually, average days'-sales in inventory was 33.4 days for Lean companies and 58.6 days for Non-Lean companies in 2008. For 2009, the average days'-sales in inventory were 31.8 days and 61.3 days for Lean and Non-Lean companies, respectively. Lastly, Lean companies' average days'-sales in inventory for 2010 was 32.0 days compared to 56.5 days for Non-Lean companies. All three of the individual years had statistically significant differences (2008, marginally so): (1) for 2008, a p-value of 0.0070, negative-rank based z-score of -1.811, eight negative ranks (totaling 50), and 11 positive ranks (totaling 140); (2) for 2009, a p-value of 0.022, negative -rank based z-score of -2.294, five negative ranks (totaling 38), and 14 positive ranks (totaling 152); and (3) for 2010, a p-value of 0.011, negative -rank based z-score of -2.535, six negative ranks (totaling 32), and 13 positive ranks (totaling 158). Results for H4e, days'-sales in inventory, are set forth in Table 19.

Table 19a: Days' Sales in Inventory (H4e)
Descriptive Statistics
pairs: n = 19

Period	3-Year Average		2008		2009		2010	
Co. Type	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**	**Lean**	**Non-Lean**
Mean	32.4	58.2	33.4	58.6	31.8	61.3	32.0	56.5
Std. Dev.	23.7	43.2	28.2	47.0	22.8	44.5	22.3	42.2
Minimum	4.7	2.9	4.9	1.9	4.7	4.6	4.5	2.9
Maximum	102.2	162.2	129.3	173.2	101.3	171.4	79.8	153.2

Table 19b: Days' Sales in Inventory (H4e)
Wilcoxon Signed-Ranks Test Descriptive Statistics
pairs: n = 19

Period	3-Year Average		2008		2009		2010	
Ranks	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**
Number	7_a	12_b	8_a	11_b	5_a	14_b	6_a	13_b
Mean	6.14	12.25	6.25	12.73	7.60	10.86	5.33	12.15
Sum	43	147	50	140	38	152	32	158

a: Lean > Non-Lean
b: Non-Lean > Lean

Table 19c: Days' Sales in Inventory (H4e)
Wilcoxon Signed-Ranks Test Results
pairs: n = 19

3-Year Average$_d$		2008$_d$		2009$_d$		2010$_d$	
Z	**p-value**	**Z**	**p-value**	**Z**	**p-value**	**Z**	**p-value**
-2.093	0.036	-1.811	0.070	-2.294	0.022	-2.535	0.011

c: Z is based on the positive ranks.
d: Z is based on the negative ranks.

Summary of Results

Overall, both returns hypotheses (H1a and H1b) were significant, as were two cash-flows hypotheses (H2a and H2b) and three inventory hypotheses (H4a, H4b, and H4e). Additionally, profit margin (H1c), the financing-assets ratio (H2c), and finished-goods inventory turnover (H4d) all were marginally significant at $\alpha = 0.10$. With larger sample sizes, it is possible that each of the three marginally significant hypotheses could have been significant at lower than or equal to $\alpha = 0.05$. None of the working-capital hypotheses (set 3) were statistically significant. A summary of the results for all hypotheses is set forth in Table 20.

Table 20: Summary of Results

Hypo	Measure	statistic	p-value	Lean/N-L direction
H1a	Return on Net Operating Assets	-2.247	**0.025**	Lean
H1b	Return on Total Assets	-2.173	**0.030**	Lean
H1c	Profit Margin	-1.697	*0.090*	Lean
H2a	Operating Cash Flows	-2.281	**0.023**	Lean
H2b	Cash Adequacy	-2.195	**0.028**	Lean
H2c	Financing Assets	-1.735	*0.083*	Lean
H3a	Net Working Capital	-0.478	0.633	Lean
H3b	Working Capital Turnover	-0.096	0.923	Non-Lean
H3c	Current Ratio	-0.114	0.909	Non-Lean
H3d	Acid-Test Ratio	-0.137	0.891	Non-Lean
H3e	Accounts-Receivable Turn	-0.023	0.982	Lean
H3f	Days'-Sales Uncollected	-0.184	0.854	Lean*
H4a	Total Inventory Turnover	-2.400	**0.016**	Lean
H4b	Raw-Materials Turnover	-3.165	**0.002**	Lean
H4c	Work-in-Process Turnover	-0.517	0.605#	Non-Lean
H4d	Finished Goods Turnover	-1.771	*0.077*	Lean
H4e	Days'-Sales in Inventory	-2.093	**0.036**	Lean*

* group had a lower value, where a lower value is a better result

\# interpret with caution: hypothesis tested the fewest matched pairs (16)

CHAPTER V

CONCLUSIONS

Inter alia, Lean companies outperformed Non-Lean companies on several important financial-performance measures for the three-year period from 2008 through 2010. Over the period, Lean companies also were more balanced than Non-Lean companies. Lean companies had current-to-long-term assets and current-to-long-term liabilities ratios that both were roughly 1:1, as compared to Non-Lean companies' ratios of roughly 1:2 (current: long-term) for the both assets and liabilities. Despite having substantially the same total assets, the Lean companies and Non-Lean companies studied herein had strikingly different compositions of assets and liabilities, as well as different summary-account balances for income-statement and statement-of-cash-flows accounts for the respective three-year average balances for fiscal years 2008 through 2010. For the years and companies studied herein, Lean companies had average current assets 77 percent higher and average long-term assets 19 percent *lower* than Non-Lean companies. Similarly, Lean companies had average current liabilities 66 percent higher and average long-term liabilities 28 percent *lower* than Non-Lean companies. It appears that Lean companies not only were retaining current assets – particularly cash and cash equivalents – in anticipation of growth, but also reduced long-term assets to become smaller and more flexible.

For the years and companies studied herein, Lean companies had average net sales, cost of goods sold, and net income that were 83, 89, 199 percent larger than Non-Lean companies, respectively. Results suggest that with their sales advantage, Lean companies do not need as high a contribution-margin ratio to achieve a greater profit. Furthermore, Lean companies had close to twice the net cash flows for each cash-flow category than the Non-Lean companies: 96 percent larger average net operating cash *in*flows, 89 percent larger average net investing cash *out*flows, and 87 percent larger average net financing cash *out*flows.

Lean companies and Non-Lean companies had significant differences for fiscal years 2008 through 2010 in multiple different measures for each of returns, cash flows, and inventory turnover. For returns, compared to Non-Lean companies, Lean companies had significantly higher: (a) returns on net operating assets; and (b) returns on total assets, as well as marginally significantly higher profit margins. For cash flows, compared to Non-Lean companies, Lean companies had significantly higher: (a) operating cash flows; and (b) cash-adequacy ratios, as well as marginally significantly higher financing-assets ratios.

There was no significant difference between Lean companies and Non-Lean companies on any of six respective working capital measures tested. It appears that after enjoying the improved cash flows promised by a lean transformation, Lean companies do not necessarily keep their greater amount of cash in current-asset form and/or have not been shown to be overly concerned about maintaining current-liability balances. Accordingly, little to nothing negative should be read into the absence of statistical significance among the working-capital ratios.

There were many significant differences, however, with respect to inventory measures. Compared to Non-Lean companies, Lean companies had significantly higher: (a) total-inventory turnover; and (b) raw-materials inventory turnover, as well as marginally significantly higher finished-goods inventory turnover. Although there was no significant difference in work-in-process inventory turnover between Lean Companies and Non-Lean companies, that hypothesis had the fewest number of matched pairs tested – 16 – due to the failure of many companies to report work-in-process inventory. Accordingly, some caution should be exercised in interpreting or extending the *failure to reject* H4c: that there was no significant difference between Lean companies and Non-Lean companies insofar as work-in-process inventory turnover. Lastly, Lean companies had significantly lower days'-sale in inventory than Non-Lean companies.

Limitations and Future Research

The years studied herein, fiscal years 2008 through 2010, were poor economic years in the United States. Accordingly, some of the results – both the significant results and non-significant results – may have been due to omitted variables. The companies that were identified as Lean throughout this study were done so mostly from self-reported data - 10-K reports and media mentions. Granted, media mentions are an external source, but their occurrence with respect to a company's business methodologies is less likely to have occurred without some self-promotion on the part of the company. Great diligence was taken to increase confidence that companies that were designated as Lean companies herein were in fact lean and that companies that were designated as Non-Lean were in fact Non-Lean. Ultimately, however, there was a subjective element to the classification.

Due to the need to match Lean and Non-Lean companies on both their four-digit SIC code and relative total assets, as well as the inappropriateness of matching a given Non-Lean company to more than one Lean company, 78 of the 107 preliminarily identified Lean companies did not have an appropriate Lean match. Additionally, proponents of lean operations and lean accounting state that it takes several years for a company to be considered a mature Lean company. Companies that had not adopted Lean operations by fiscal 2008 were excluded from analysis. Even so, the analysis inevitably uses companies at different stages of their respective lean transformations. Furthermore, many companies involved in lean transformations are non-public companies or relatively small public companies that are not included due to unavailability of financial data or the scope of the study. Lastly, certain desired and potentially informative cost/managerial accounting data – the accounting area most related to Lean companies - is not publicly available and thus not analyzed in this study.

Future research should be performed as an event study, comparing the years before and years after a commencement of companies' lean transformations. Future research also could be done comparing the differences between Lean and Six-Sigma companies, although difficulty arises in companies that characterize their business method by the amalgam Lean Sigma. Also, future research could separate Lean Accounting Summit attendees and non-attendees.

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LIST OF APPENDICES

APPENDIX A

THE TOYOTA PRODUCTION SYSTEM (TPS)

SECTION I: LONG-TERM PHILOSOPHY

Principle 1: Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals.

- Have a philosophical sense of purpose that supersedes any short-term decision-making. Work, grow, and align the whole organization toward a common purpose that is bigger than making money. Understand your place in the history of the company and work to bring the company to the next level. Your philosophical mission is the foundation for all the other principles.
- Generate value for the customer, society and the economy - it is your starting point. Evaluate every function in the company in terms of its ability to achieve this.
- Be responsible. Strive to decide your fate. Act with self-reliance and trust in your own abilities. Accept responsibility for your conduct and maintain and improve the skills that enable you to produce added value.

SECTION II: THE RIGHT PROCESS WILL PRODUCE THE RIGHT RESULTS

Principle 2: Create continuous process flow to bring problems to the surface.

- Redesign work processes to achieve high value-added continuous flow. Strive to cut back to zero the amount of time that any work project is sitting idle or waiting for someone to work on it.
- Create flow to move material and information fast as well as to link processes and people together so that problems surface right away.
- Make flow evident throughout your organizational culture. It is the key to the true continuous improvement process and to developing people.

Principle 3: Use "pull" systems to avoid overproduction.

- Provide your downline customers in the production process with what they want, when they want it, and in the amount they want. Material replenishment initiated by consumption is the basic principle of just-in-time.
- Minimize your work in process and warehousing of inventory by stocking small amounts of each product and frequently restocking based on what the customer actually takes away.
- Be responsive to the day-by-day shifts in customer demand rather than relying on computer schedules and systems to track wasteful inventory.

Principle 4: Level out the workload (*heijunka*). (Work like the tortoise, not the hare.)

- Eliminating waste is just one-third of the equation for making lean successful. Eliminating overburden to people and equipment and eliminating unevenness in the production schedule are just as important - yet generally not understood at companies attempting to implement lean principles.
- Work to level out the workload of all manufacturing and service processes as an alternative to the stop/start approach of working on projects in batches that is typical of most companies.

Principle 5: Build a culture of stopping to fix problems, to get quality right first time.

- Quality for the customer drives your value proposition.
- Use all the modern quality assurance methods available.
- Build into your equipment the capability of detecting problems and stopping itself. Develop a visual system to alert team or project leaders that a machine or process needs assistance. *Jidoka* (machines with human intelligence) is the foundation for 'building in' quality.
- Build into your organization support systems to quickly solve problems and put in place countermeasures.
- Build into your culture the philosophy of stopping or slowing down to get quality right first time to enhance productivity in the long run.

Principle 6: Standardized tasks are the foundation for continuous improvement and employee empowerment.

- Use stable, repeatable methods everywhere to maintain the predictability, regular timing, and regular output of your processes. It is the foundation for flow and pull.
- Capture the accumulated learning about process up to a point in time by standardizing today's best practices. Allow creative and individual expression to improve upon the standard; then incorporate it into the new standard so that when a person moves on you can hand off the learning to the next person.

Principle 7: Use visual control so no problems are hidden.

- Use simple visual indicators to help people determine immediately whether they are in a standard condition or deviating from it.
- Avoid using a computer screen when it moves the worker's focus away from the workplace.
- Design simple visual systems at the place where the work is done, to support flow and pull.
- Reduce your reports to one piece of paper whenever possible, even for your most important financial decisions.

Principle 8: Use only reliable, thoroughly tested technology that serves your people and processes.

- Use technology to support people, not to replace people. Often it is best to work out a process manually before adding technology to support the process.
- New technology is often unreliable and difficult to standardize and therefore endangers "'flow." A proven process that works generally takes precedence over new and untested technology.
- Conduct actual tests before adopting new technology and business processes, manufacturing systems, or products.
- Reject or modify technologies that conflict with your culture or that might disrupt stability, reliability, and predictability.
- Nevertheless, encourage people to consider new technologies when looking into new approaches to work. Quickly implement a thoroughly considered technology if it is been proven in trials and it can improve flow in your processes.

SECTION III: ADD VALUE TO THE ORGANIZATION BY DEVELOPING YOUR PEOPLE AND PARTNERS

Principle 9: Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others.

- Grow leaders from within, rather than buying them from outside the organization.
- Do not view the leader's job as simply accomplishing tasks and having good people skills. Leaders must be role models of the company's philosophy and way of doing business.
- A good leader must understand the daily work in great detail so he or she can be the best teacher of your company's philosophy.

Principle 10. Develop exceptional people and teams who follow your company's philosophy.

- Create a strong, stable culture in which company values and beliefs are widely shared and lived out over a period of many years.
- Train exceptional individuals and teams to work within the corporate philosophy to achieve exceptional results. Work very hard to reinforce the culture continually.
- Use cross-functional teams to improve quality and productivity and enhance flow by solving difficult technical problems. Empowerment occurs when people use the company's tools to improve the company.
- Make an ongoing effort to teach individuals how to work together as teams for common goals. Teamwork is something that has to be learned.

Principle 11: Respect your extended network of partners and suppliers by challenging them and helping them improve.

- Have respect for your partners and suppliers and treat them as an extension of your business.
- Challenge your outside business partners to grow and develop. It shows that you value them. Set challenging targets and assist partners in achieving them.

SECTION IV: CONTINUOUSLY SOLVING ROOT PROBLEMS DRIVES ORGANIZATIONAL LEARNING

Principle 12: Go and see for yourself to thoroughly understand the situation (*genchi genbutsu*).

- Solve problems and improve processes by going to the source and personally observing and verifying data rather than theorizing on the basis of what other people or the computer screen tell you.
- Think and speak based on personally verify data.
- Even high-level managers and executives should go and see things for themselves, so they will have more than a superficial understanding of the situation.

Principle 13: Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly.

- Do not pick a single direction and go down that one path until you have thoroughly considered alternatives. When you have picked, move quickly but cautiously down the path.
- *Nemawashi* is the process of discussing problems and potential solutions with all those affected, to collect their ideas and get agreement on a path forward. This consensus process, though time-consuming, helps to broaden the search for solutions, and once a decision is made, the stage is set for rapid implementation.

Principle 14: Become a learning organization through relentless reflection (*hansei*) and continuous improvement (*kaizen*).

- Once you have established a stable process, use continuous improvement tools to determine the root cause of inefficiencies and apply effective countermeasures.
- Design processes that require almost no inventory. This will make wasted time and resources visible for all to see. Once waste is exposed, have employees use a continuous improvement process (kaizen) to eliminate it.
- Protect the organizational knowledge base by developing stable personnel, slow promotion, and very careful succession systems.
- Use *hansei* (reflection) at key milestones and after you finish a project openly identify all the shortcomings of the project. Develop countermeasures to avoid the same mistakes again.
- Learn by standardizing the best practices, rather than reinventing the wheel with each new project and each new manager. (Liker 2004 p. 37 – 41)

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CONFERENCES - PRESENTER

American Accounting Association Annual Meeting, August 2011,
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American Accounting Association Southeast Region Meeting, April 2011
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American Accounting Association Southeast Region Meeting, April 2010,
"A Manufacturer's Transition to Value Stream and Lean Accounting"

American Accounting Association Southeast Region Meeting, May 2009,
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CONFERENCES - ATTENDEE

American Accounting Association Annual Meeting, August 2011
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Management Accounting Conference, Doctoral Consortium, January 2011
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American Accounting Association Southeast Region Meeting, April 2010
Lean Accounting Summit, September 2009
American Accounting Association Southeast Region Meeting, May 2009
Financial Accounting Conference, Doctoral Consortium January 2009
American Tax Association/KPMG Tax Doctoral Consortium, February 2008
Mid-South Doctoral Consortium, February 2008

AWARDS AND SCHOLARSHIPS

2011 University of Mississippi Accountancy Doctoral Teaching Award
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2010 Lean Accounting Summit Scholarship
2009 Lean Accounting Summit Scholarship

ACCOUNTANCY PH.D. SEMINARS

Accountancy 602 **-** Contemporary Accounting Theory (Behavioral)
Accountancy 607 **-** Research Methodology and Accounting History
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TEACHING EXPERIENCE

University of Mississippi, Oxford, Mississippi
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Accountancy 309, Cost Accounting: Spring (2) and Fall 2011 (2)

Accountancy 201, Financial Accounting Principles: Spring 2011 (2), Fall 2010 (2), Spring 2008, Spring 2009 (2), May 2008, and Fall 2007

Accountancy 202, Managerial Accounting Principles: First Summer 2010, Spring 2010, Fall 2009, First Summer 2009, and Fall 2008 (2)

PAPERS

"The Effects of Outcome Severity, Contributory Negligence and Demographic Characteristics on Juror Decision Making in Tax Malpractice Litigation," first author

"The Effects of Plaintiff Type and Investment Loss on Jurors' Determinations of Negligence and Damages in Auditor Malpractice Litigation," first author

"A Manufacturing Company's Transition to Value Stream and Lean Accounting," first author (different paper than the dissertation)

"Case Studies of Alleged Embezzlement and Fraudulent Accounting Practices by Company Controllers," sole author

"Earnings Management through Discretionary Accruals as the Cause of the Kink in Cumulative Earnings Distributions," second author

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Cole, Scott & Kissane, P.A., Law Firm, Plantation, Florida,
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Draft motions, pleadings, discovery, and legal memoranda for civil litigation practice, relating to the defense of accountant malpractice, attorney malpractice, real estate broker/agent malpractice and general liability litigation. Argue pre-trial hearings. Conduct discovery, depositions and mediations. Prepare litigation budgets, resolution plans, and case analyses. Perform text and on-line legal research.

Schmidt, Pheterson & Bleau, Law Firm, Boca Raton, Florida,
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Draft motions, pleadings, discovery, and legal memoranda for civil litigation practice, relating to the issues of contract, fiduciary duty, civil RICO, fraud, lender liability, negligence, professional malpractice, and trust litigation. Research and draft appellate brief. Argue pre-trail hearings. Conduct discovery and depositions. Perform text and on-line legal research.

English, McCaughan & O'Bryan, Law Firm, Fort Lauderdale, Florida,
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Law Clerk, June, 1998 to January 2000
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Meyers & Associates, Accounting Firm, Baltimore, Maryland,
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Perform audits and compilations of the financial statements of commercial business entities. Prepare and post month-end and year-end journal entries to general ledger and subsidiary ledgers. Post transaction detail including, but not limited to, accounts receivable, accounts payable, and payroll. Reconcile bank statements. Perform tests of transactions and balances. Prepare state and federal tax returns, including, but not limited to, Forms 1120, 1040, and 941.

Nadim E. Salti, P.A., Accounting Firm, Washington, D.C.,
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Perform audits and compilations of financial statements of non-profit institutions. Create and maintain charts of accounts and cost centers. Prepare and post month-end and year-end journal entries to general ledger and subsidiary ledgers. Post transaction detail including, but not limited to, accounts receivable, accounts payable, and payroll. Reconcile bank statements. Create and maintain schedules of depreciation and amortization. Prepare state and federal tax and information returns, including, but not limited to, Forms 1120, 1040, 990, and 941.

Roland Foods, Food Distributors, Hyattsville, Maryland,
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Perform all internal accounting functions for subsidiary company having $1.5 million in sales. Create and maintain charts of accounts and cost centers. Prepare and post month-end and year-end journal entries to general ledger and subsidiary ledgers. Post transaction detail including, but not limited to, accounts receivable, accounts payable, and payroll. Reconcile bank statements. Create and maintain schedules of depreciation and amortization.

Roland Foods, Food Distributors, Hyattsville, Maryland,
Customer Service Manager, June 1993 to March 1994
Supervise three-person customer service staff for food distributor selling to roughly 500 grocery stores.

Habeck-Zaitz & Associates, Food Brokers, Hanover, Maryland
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Coordinate marketing activity between food-service broker, broker sales representatives, and manufacturer sales representatives for nine national food manufacturers/processors in the Baltimore-Washington market.