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Inventory Optimization in Manufacturing Organizations

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This is to certify that the doctoral study by

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has been found to be complete and satisfactory in all respects,
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Abstract

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Doctoral Study Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Abstract

Inventories totaling 1.7 trillion U.S. dollars represent an opportunity for U.S. manufacturers. This exploratory case study researched supply chain strategies used to manage inventory in manufacturing operations of a U.S. manufacturing company. A mature value chain contained within a single organization using the value chain framework was the basis for this study. Individual interviews conducted with 16 managers responsible for defining and implementing inventory control strategies, and 4 internal users provided primary information for the study. Other sources of information included a value chain map created through the observation of operations, various inventory measurements, and policies and guidelines related to managing inventory levels. An inductive content analysis employing zero-level coding of the interview transcripts identified 4 themes that describe inventory control strategies as economic order quantity, kanban, vendor managed inventory, and process integration. Physical observation of the value chain, review of supporting documents, and analysis of inventory data ensured the trustworthiness of interpreted themes. Findings identified no single inventory control strategy that fit all applications. Findings also revealed that the financial governing bodies' measurements were not the best tools for operational managers' improvement activities related to inventory control. Included are measures providing alternative means to gauge inventory efficiency. With the results of this study, managers may develop effective strategies to optimize inventory and improve material flow. Manufacturing managers improving material flow may promote sustainability of raw materials and business efficiencies through reduced waste, improved environmental conditions, and increased employment opportunities in associated communities.

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Dedication

I dedicate this study to my spouse, Jeanne, and my daughters, Jenny, Angie, Boo, and Emma, who encouraged me to continue learning, helped Dad with new technology, and allowed quiet time for study.

Acknowledgments

I am extremely appreciative of my chair, Dr. Charlotte Carlstrom (Dr. C), for her continued guidance, support, and patience while I developed writing skills and her encouragement to stay continue the study. I would like to thank Dr. Judith Blando, Dr. Al Endres, and Dr. Gene Fusch for reviewing thoughts into a professional presentation. Their insights made this study possible. Thanks to my colleagues and coworkers for their support of my entire program.

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Section 1: Foundation of the Study

Inventory is a significant asset in most manufacturing companies, and efficient use of inventory has a positive effect on the company's cash flow and continued viability. Inefficient management of inventory may lead to poor customer service because of lack of available product, higher operating costs caused by interest payments on borrowed cash, and potentially failure of the enterprise. Managers employ various strategies to control inventory, with varied success. In a 2014 review of the top 25 U.S. supply chains, inventory turns ranged from 153.0 for McDonalds to 3.0 for Caterpillar (Aronow, Hofman, Burkett, Romano, & Nilles, 2014). *Inventory turns* is a standard measure of inventory efficiency calculated by dividing annual sales by the quarterly average inventory for the same period. Some managers control inventory efficiency well, whereas others have significant investments in inventory and opportunities for improving.

Background of the Problem

Manufacturing products began as a process of filling orders one at a time. A customer wanting a product either made it or went to a skilled craftsperson to deliver the product requested. Manufacturers looked for alternate methods of production to improve cost and availability of products. Several manufacturers worked on the idea of producing more than one product at a time, or *mass production*. Mass production relies on building products, in most instances, to address a forecast. Producing items based on a forecast versus actual orders requires purchasing and making materials ahead of sales in many instances. The unsold material creates inventory, which includes (a) raw materials, (b) raw materials partly processed into semifinished goods, and (c) assembled finished products.

A financial analysis of companies includes a review of working capital, which provides a view of the companies' cash flow, determining the liquidity of the business. *Working capital* is the sum of inventory dollars and accounts-receivable dollars minus accounts-payable dollars (Duggal & Budden, 2012; Lifland, 2011; Mauboussin & Callahan, 2014). Another useful measure of liquidity is *cash cycle time*, which is the time between paying for raw materials and receiving payment from customers for the finished goods using the raw materials (Alipour, Jamshidinavid & Dastgir, 2015). Working capital dollars and the working capital cycle time have an effect on the company's profitability (Charitou, Elfani, & Lois, 2010). Small working capital requirements and short working capital cycle times correspond to fast cash conversion requiring less money to operate. Efficient use of working capital leads to lower borrowing costs and increases funds available for use in other investments. As inventoried materials are a part of manufacturing companies' working capital, efficient use of inventory is vital to business success. The basis for this study was exploring strategies to improve the efficiency of inventory, thereby improving business liquidity.

Problem Statement

U.S. manufacturers have more than 1.7 trillion U.S. dollars (USD) of unsold inventory in stock (U.S. Census Bureau News, 2015). Many manufacturing companies have more than 50% of total assets invested in working capital, which includes inventory, as well as accounts receivable and accounts payable (Beheshti, 2010; Darun, Roudaki, Radford, 2015; Gill, Biger, & Mathur, 2010). The general business problem is that excessive levels of working capital invested in inventory negatively affect a company's profitability (Aktas, Croci, Petmezas, 2015; Bagchi, Chakrabarti, & Roy, 2012; Charitou et al., 2010; Chisti, 2013; Mojtahedzadeh, Tabari, & Mosayebi, 2011). The specific business problem is that some managers lack strategies for efficient inventory control (Basu & Wang, 2011; Hatefi & Torabi, 2015).

Purpose Statement

The purpose for this qualitative case study was exploring strategies that managers use to optimize and control inventory levels in manufacturing processes. While previous researchers determined several possible reasons leading to inventory, exploring strategies for optimizing and controlling inventory presents an opportunity for improving managers' ability to reduce and control inventory levels throughout the manufacturing process (Bakker, Bohme, & van Donk, 2012; Brüggen, Krishnan, & Sedatole, 2011; de Leeuw, Holweg, & Williams, 2011; He, Xu, & Hayya, 2011; Ranganatham, 2011; Sana & Chaudhuri, 2013; Willems, 2012). The boundary for this study was the manufacturing process of one product produced by a company in the Midwestern United States using a case study design. According to the U.S. Census Bureau News (January 2015), 1.76 trillion USD of inventory supported sales of 1.30 trillion USD. This level of inventory means that nearly 41 days of inventory exist when compared to sales, representing a significant opportunity to improve operating efficiencies and thereby profitability in U.S. businesses. Efficient management of business operations supports companies' solvency, providing employment, maintaining affordable pricing, and supporting communities through jobs and taxes.

Nature of the Study

A qualitative case study design was suitable for this research exploring strategies influencing inventory levels in a manufacturing company and the human interactions within these strategies. The data collection process for this study had several characteristics of qualitative research as defined by Yin (2013). The characteristics included (a) observation of the system as it works in its usual manner, (b) use of multiple sources of information to draw conclusions, (c) collecting information from participants involved in the system, (d) inductive data analysis to develop themes, and (e) development of a holistic account of inventory opportunities. Sources of information included (a) software systems and corresponding input parameters, (b) purchasing and manufacturing policies, (c) manufacturing data from process equipment, and (d) interviews with people, leaders, and decision makers using the systems and information to make decisions regarding inventory levels. The manufacturing data enhance the results of the study. Findings from qualitative studies provide insight into human interactions within the processes that quantitative studies cannot (Yin, 2013).

Quantitative designs are most appropriate when examining the size and interrelationships among variables. A quantitative study is appropriate when testing a hypothesis, or applying a treatment to an independent variable and testing to determine whether there is a change in the dependent variable. The mixed methods design is another possible form of study, which is a combination of quantitative and qualitative research designs. Using mixed methods design provides researchers with the benefits of both quantitative and qualitative design, enabling them to explore and test subjects. In this study, I used qualitative design to explore strategies affecting inventory levels. Using a mixed methods design was a possibility for this study, as it would have enabled an evaluation of the relationship between one or more strategies identified (independent variables) and efficient inventory (the dependent variable). A mixed methods design would be a reasonable follow-up study, but, because of time constraints, I decided not to use mixed method design for this study.

An exploratory case study design was suitable for this research because (a) the subject matter was within a bounded system, (b) several sources provided information, (c) the focus of the study was answering *how* and *why* questions, and (d) the focus for the investigation was on understanding the real-life system, not controlling it (Crowe et al., 2011). A case study design is appropriate when the researcher is answering a how or why question and when the researcher has little control over what is happening (Vissak, 2010). This research did not match (a) narrative design (focus on life stories of individuals or a small group of individuals), (b) phenomenological research design (focus on the experience of a group of individuals around an event or circumstance), or (c) ethnographic research design (focus on a cultural group). A grounded theory design was an option, as a review of information collected could have led to theory development, but theory development was not the objective for this study. The purpose of this study was to explore strategies managers use to optimize and control inventory levels in manufacturing processes.

Determining the unit of analysis is an important aspect of case study design (Yin, 2013). In this study, the unit of analysis, or the *case boundary*, was a unique value chain for one finished product manufactured within one company. A *value chain map* is a visual representation of the process steps showing product flow, information flow, and cash flow from raw materials to the customer's final product (Rother & Shook, 2003). The terms *value chain* and *value stream* are interchangeable throughout this research paper. The value chain mapping tool, which showed the process steps and material flow, demonstrated where inventory accumulated and identified interview candidates. An example of a generic value chain map representing a product composed of three inputs or raw materials and seven process steps is in Appendix A.

A value chain map identifies the production process, including (a) locations and levels of inventory, (b) people involved, (c) available reports, (d) physical manufacturing data, and (e) policies determining the levels of inventory. In the example value chain, each of the three subassemblies (Processes 4, 5, & 6), consists of two materials: one harvested from the earth, and the other received from another manufacturer (see Appendix A). Materials harvested from the earth are indeed raw materials and could be plant, animal, mineral, or liquid. A complete value stream map can trace the origin of each component in the product back to the primary material harvested from the earth. Although some value chains have all process steps contained within one organization, most value chains have employees from multiple companies contributing to one or more process steps. The person ordering raw materials and components determines the amount of inventory before the next process. The person scheduling each of the processes determines the amount of inventory after each process. Inventory in a single site includes incoming materials (such as raw materials), work-in-process materials, and the output of the location (finished goods for the location). Defining the boundary of the study using a value stream map identified the location of inventory and the people responsible for managing inventory levels throughout the manufacturing process. This case study involved an established product for which manufacturing steps take place at more than one manufacturing facility.

Research Question

A qualitative, exploratory case study is appropriate to answer how and why questions about optimizing the creation and buildup of inventory in manufacturing operations. The following question was the basis for the research: What strategies do production managers need for efficient inventory control?

Interview Questions

The following list contains the interview questions for participants. All participants answered each question. The participants had a copy of the value chain under study to refer to during each interview.

1. Is the value chain operating at an optimum inventory level?
2. How do you measure inventory efficiency in this value chain?
3. Describe the process and criteria for selecting a supplier and manufacturing location.
4. What role does inventory play in your purchasing and manufacturing ordering decisions?

5. What parameters determine the amount of material ordered and manufactured?
6. What tools and systems do you use when deciding to place orders?
7. How are just-in-time (JIT) and lean philosophies included in your decision making?
8. Who owns the inventory in the manufacturing process?
9. What, if any, inventory-level criteria are you measured on for your annual performance review?
10. What is the most challenging task in managing input and output inventory in your value chain?
11. What suggestions do you have for improving the material flow in your value chain?

Conceptual Framework

The conceptual framework for this study was the value chain framework originally introduced by Michael Porter in 1985, as illustrated in Figure 1. Porter's (1998) purpose in defining the value chain framework was to evaluate activities providing a competitive advantage for a firm and to help the firm's leadership understand strategies making the firm better than its competitors. The value chain framework is a tool for identifying activities performed by the firm's employees sorting the activities into primary and support activities. Activities are essential to the value chain framework because there is a cost associated with activities creating value for the customer. Profits result when the cost to perform an activity is less than the value to the customer.

The value chain framework helps managers determine activities that add value and those that do not (Hemmatfar, Salehi, & Bayat, 2010). The value chain also defines the role each function has in the organization. People in an effective organization understand internal hand-offs among functions and strive to improve linkages between them (Patnaik & Sahoo, 2009). Each activity requires inputs and produces outputs. Inputs include items such as raw materials, labor, and customer information.

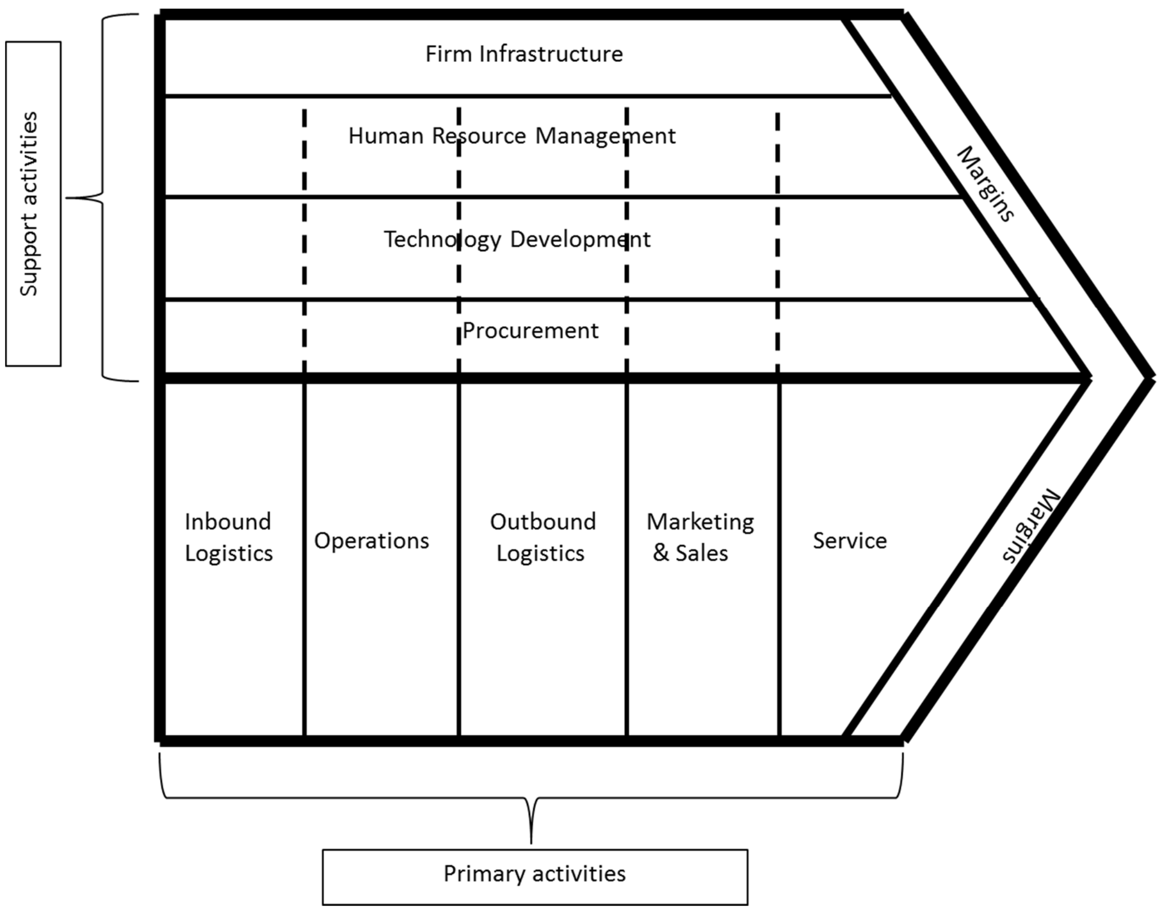

Figure 1. A generic value chain representing one company. From *Competitive Advantage Creating and Sustaining Superior Performance* (p. 37), by M. Porter, 1998, New York, NY: Free Press. Reprinted with permission.

Outputs include (a) process information, (b) products and services, and (c) financial assets, including (d) accounts payable, (e) accounts receivable, and (f) inventory (Porter, 1998). Determining strategies to provide lean inventory control requires input from managers responsible for (a) people, (b) practices, (c) expectations, (d) measurement, and (e) systems creating inventory and material flow. Figure 1 is an example of an internal value stream map modeled after Porter's (1998) value chain. The example represents a single organization, which may contain one or several process steps (see Appendix A).

Several people may affect inventory levels throughout the manufacturing-related processes in each location. Possible participants for this study included managers and supervisors of (a) purchasing agents, (b) supply chain analysts, (c) production operation leaders, (d) product and process engineers, (e) marketers, (f) logistics analysts, (g) warehouse and distribution center management, and (h) corporate lean resources. Interviewing managers and supervisors of these positions was the primary source of information. Other participants included people in these areas who provided additional information as part of data triangulation for increasing the study's reliability and validity.

Expanding on Porter's model, Figure 2 represents one process step in a value chain made up of three operational process steps. Inventory exists in front, between, and after each operational process step. Applying Porter's process map model facilitates identifying locations where inventory exists as well as defines individuals responsible for creating and managing inventory (see Appendix A). The model in Figure 2 demonstrates the complexity in manufacturing a product depending on the number of organizations involved in the process.

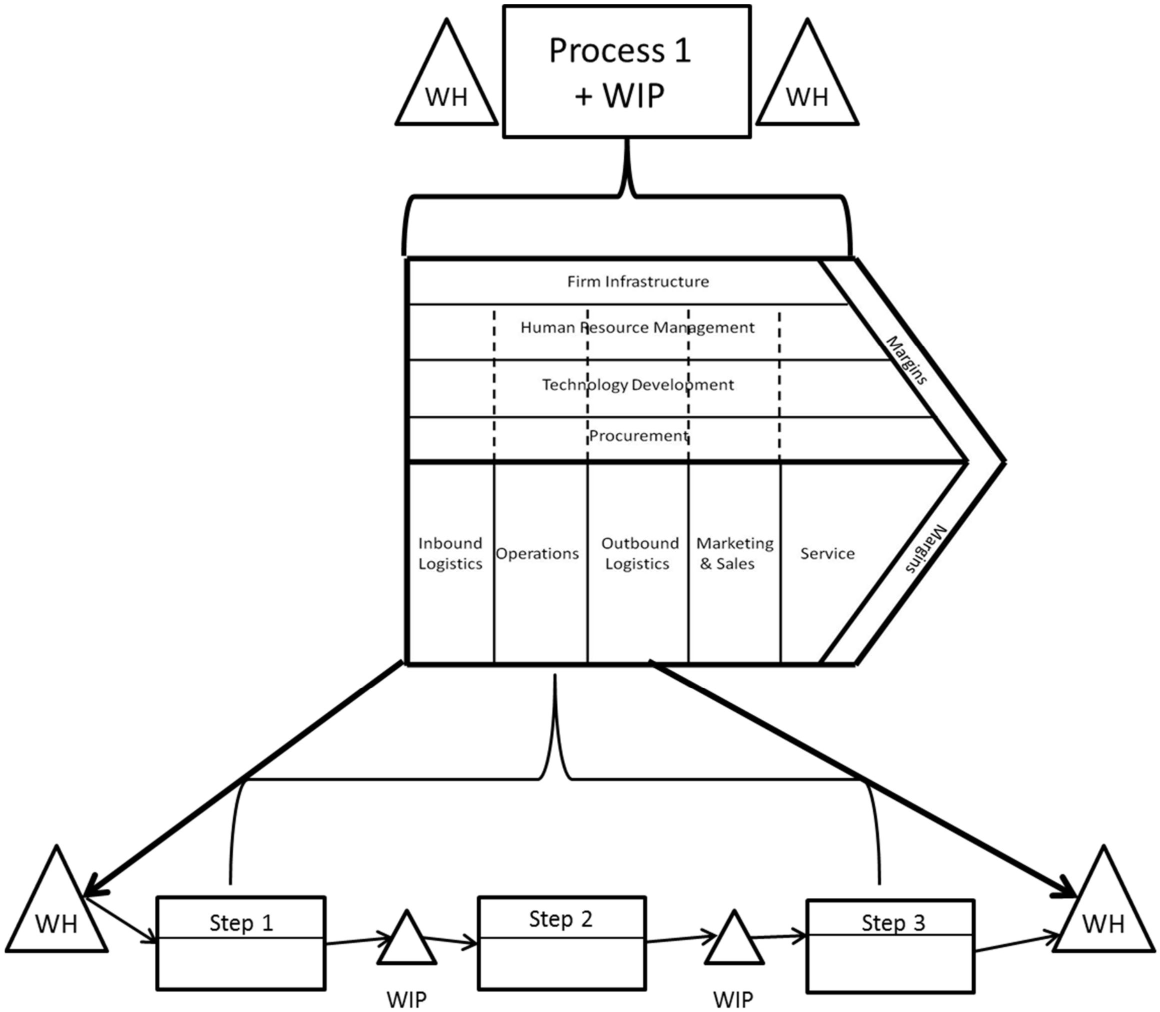

Figure 2. Internal value stream map representing one process step.

Working capital consists of accounts payable, accounts receivable, and inventory, used to fund daily operations (Charitou et al., 2010). The value chain framework is suitable for exploring inventory creation through activities including procurement, inbound logistics, operations, outbound logistics, marketing and sales, and service with inventory as an output of some activities, as well as input to the following activity. The value chain framework provides a tool for describing a firm's processes. Exploring the value chain of a single firm may help the company to become more competitive and profitable.

The value chain concept also applies to improving the competitiveness of entire industries. For example, when analyzed as a value chain, the U.S. dairy industry connected linkages and created Dairy Management Incorporated (Whalen, 2012). The analysis resulted in members of the dairy industry value chain that in the past were competitors working together to solve industry-wide problems. The value chain mapping concept provides a visual representation of the links required for organizations' managers creating products and services. Porter's (1998) value chain model provides a reasonable framework for analysis and improvement that was relevant for conducting this study.

Definition of Terms

Batch size: The batch size, also known as the *make-order size*, is the amount of the same material made in one production run on a piece of manufacturing equipment (Cruz & Nunez, 2011).

Cash conversion cycle: The cash conversion cycle is the time between the outlay of cash to pay for raw materials and the collection of cash from the customer for those processed raw materials. Expressed as a financial formula: cash conversion cycle = days of accounts receivable + days of inventory – days of accounts payable (Charitou et al., 2010; Gill et al., 2010; Raheman, Qayyum, & Afza, 2011).

Cash-to-cash cycle: The time between the outlay of cash to pay for raw materials and the collection of cash from the customer of those processed raw materials. The formula is the same as that for the cash conversion cycle (Akgün & Gürünlü, 2010).

Current assets: Assets available for conversion to cash used to pay short-term debts including accounts receivable (Manisha, 2012).

Current liabilities: Debts due in the near term, including accounts payable and short-term debt (Manisha, 2012).

Customer relationship management: An understanding of customers' needs and preferences to provide complete, effective, and efficient services to them by servicing the customer, collecting marketing data, and managing sales (Tohidi, 2012).

Days of inventory: Defined by dividing average inventories (inventory at the beginning of the period + inventory at the end of the period/2) by cost of sales per day in the same period (Raheman et al., 2011).

Days of accounts receivable: Defined by dividing average accounts receivables (accounts receivable at the beginning of the period + accounts receivable at the end of the period/2) by net sales per day in the same period (Raheman et al., 2011).

Days of accounts payable: Defined by dividing average accounts payables (accounts payable at the beginning of the period + accounts payable at the end of the period/2) by cost of sales per day in the same period (Raheman et al., 2011).

Economic manufacturing quantity: The economic manufacturing order quantity is the batch size of the same material that optimizes the cost of the operation. The batch size is a result of comparing the cost to change over to the product versus the cost to store it (Michalski, 2009).

Economic order quantity: The economic order quantity is the amount of material to order at one time. The order size is a result of comparing the cost of the material versus the cost to finance and hold the material. The economic order quantity is a concept similar to the economic manufacturing quantity (Kannan, Grigore, Devika, & Senthilkumar, 2013).

End-of-period reporting: End-of-period reporting is the concept of generating reports for a defined time interval. In the case of inventory, end-of-period reporting defines inventory levels on the last day of the period. In publically traded companies, financial reports periods are quarterly and annually (Ward & Ward, 2013).

First in first out (FIFO): This term refers to a valuation method for inventory. In this case, the assumption is that material sent to the customer is always the oldest inventory (Harris, 2011).

Jidoka: Jidoka refers to the practice of stopping the production line whenever there is a quality issue with the product. The operator may stop the line automatically or manually (Helman, 2012).

Kaizen: Two Japanese words comprise the word *kaizen*: *kai*, meaning changing, and *zen*, meaning better. Kaizen is a method and philosophy of continuous improvement driven by the people in the workplace (Vieira, Balbinotti, Varasquin, & Gontijo, 2012).

Kanban: A kanban is a signaling system allowing authorization to produce and withdraw the product in a pull system (Satoglu, Durmusoglu, & Ertay, 2010).

Last in first out (LIFO): This term refers to a valuation method for inventory. In this case, the assumption is that material sent to the customer is always the newest material (Harris, 2011).

Liquid assets: Liquid assets are assets owned by an organization used to pay short-term bills. The assets may be cash or assets capable of conversion to cash in a short time (Manisha, 2012).

Periodic review: Periodic review is an analysis of information during a particular time interval. In this study, the periodic reviews were financial data reviewed quarterly and annually. Some financial data listed represent the amount on the last day of the review period (Rudi, Groenevelt, & Randall, 2009).

Production order quantity: The production order quantity is the batch size of the same material that optimizes the cost of the operation. The batch size is a result of comparing the cost to change over to the product versus the cost to finance and store it (Michalski, 2009).

Pull production: A manufacturing philosophy in which product from one process step moves directly to the next without accumulating between steps. In an ideal state, this would be one-piece flow, in which one piece moves directly from one process step to the next. Pull production is the opposite of a push manufacturing system (Lu, Yang, & Wang, 2011).

Standard work: Standard work is the defined, best-known method to perform an operation. People perform the operation the same way until defining a better way, creating a new standard (Vieira et al., 2012).

Takt time: The rate at which customers purchase a product compared to the production rate. The purpose of knowing takt time in a production operation is to provide the customer the product when requested. Following takt time minimizes late orders and extra inventory (Lu et al., 2011).

Third-party logistics: An organization providing logistics services to another company that may include sourcing, material management, and distribution. Some third-party logistics providers are extending services to include handling returns and minor repairs rather than send them back to the firms' factory (Jayaram & Tan, 2010).

U-shaped manufacturing cells: U-shaped manufacturing cells are production lines with multiple process steps arranged in proximity in a "U" shape (Satoglu et al., 2010). In this manufacturing setup, operators may perform duties on several pieces of equipment to produce a product.

Value chain: A value chain, also known as a *value stream*, is a tool describing the flow of material and information in schematic form, called a *map*. Typical elements on a value stream map include (a) cycle time, (b) setup time of process steps, and (c) material in the process at and between steps, work-in-process in days, and lead time (Chen & Meng, 2010).

Vendor managed inventory: Inventory and supplies in which the supplier makes replenishment decisions on behalf of the purchaser, providing benefits to both the supplier to control costs—and the purchaser to optimize inventory (Kauremaa, Småros, & Holmström, 2009).

Vertical integration: The extent to which a company owns the upstream and downstream processes in a value chain (González & Chacón, 2014).

Working capital: Working capital is the difference between current assets and current liabilities (Ding, Guariglia, & Knight, 2010).

Work-in-process (WIP): Work-in-process describes inventory that has started through the manufacturing process and not completed all manufacturing steps (Wantuck, 1989).

Assumptions, Limitations, and Delimitations

Assumptions

An assumption for this study was that documents analyzed as part of the literature review provided an adequate summary of the existing state of the topic and identified gaps for study. Another assumption was that personal experience and the documents provided information to determine appropriate interview questions to answer the research questions. Both assumptions were true, as the literature review identified gaps and the responses to the interview questions answered the research question. An assumption in the interview process was that interviewees provided truthful information to the best of their ability with no personal biases. Each interviewee reviewed the summary of transcripts from the interview via member checking and agreed with the interpretation. An assumption was that supporting data for triangulating information from interviews were accurate, and that online financial information provided by the companies' finance specialists for the background and significance of the study sections accurately represented the various comparisons regarding financial performance. The final assumption was that the summary of data collected and analyzed with the aid of qualitative software accurately reflected findings of this study. Based on the results of the study and the feedback from the participants, there was no evidence for doubting the assumptions' validity.

Limitations

Findings from this study provided an in-depth review of a single value chain's strategies used to control inventory levels. Access to documents, inventory records, and individuals defining and implementing strategies was necessary to complete the study. The value chain was a product offering in my employer's company, which allowed access to value chain information. This value chain is mature and has been in place for several years. Throughout the product life cycle, there have been several changes in raw materials and technology advancements, so the entire manufacturing process is a mix of established and new processes. The old and new components in the value chain provided an opportunity to study various efficiency levels of inventory process management. The value chain is part of a separate organization in which I have no influence over people or outcomes. I have been part of the company culture for several years. To overcome this potential bias, interviewing occurred with individuals at several levels in the company hierarchy. The focus of this study was to understand strategies improving levels of inventory within the company and promoting efficient use of capital.

The individuals in the value chain determined the available sample population and the number of possible interviews. Member checking was part of the process to overcome time limits and facilitate accurate reflections of the information collected. Inventory measurements provided information showing the effect of control and improvement strategies. The value assigned to inventory changed daily based on the delivery dates of raw materials. Value increased as materials went through the manufacturing system until the materials became a finished product. Accountants calculated work-in-process and finished goods inventory values. Several methods exist to value inventory. The leadership of each company may choose a method of calculating inventory values, and the methods are not necessarily the same in all businesses.

Delimitations

A single value chain within one manufacturing company defined the boundaries of this study. The value chain began with the manufacturing organization ordering raw materials, through manufacturing and assembly processes, to the company-owned distribution centers. In this case, the product evolving through the value chain sold through retailers, not the final user. The process throughout this value chain activity was make-to-stock versus make-to-order planning for product fulfillment. Raw materials included inputs from other manufacturing facilities within the same company as well outside suppliers.

The population included managers responsible for the manufacturing processes in the selected value chain, managers in roles supporting the manufacturing processes, and supply chain analysts making decisions regarding levels of material to purchase and manufacture. Case study evidence may come from several sources. Yin (2013) mentioned six of them: (a) documents, (b) archival records, (c) interviews, (d) direct observation, (e) participant observation, and (f) physical artifacts. Observations were not included in the study initially. After mapping the process observation of material flowing through the production process revealed significant information. Physical artifacts such as devices, tools, and physical objects were not part of this study. Documents containing the amount of inventory provided a better indicator regarding strategies' effectiveness.

Based on the value chain characteristics and study design, results of the study may not be applicable to all value chains.

Interviewing managers and supervisors responsible for determining strategies controlling and optimizing inventory levels, as well as people responsible for creating or purchasing materials within a manufacturing organization, was the basis of information for this study. Interviewees included individuals responsible for setting policy and parameters. Originally, the preference was to conduct interviews face to face. Face to face interviewing was not possible in all cases because of scheduling conflicts and location. Four of the interviews occurred face to face, with the other 16 occurring over the telephone. The use of a speakerphone for all phone interviews allowed recording of both questions and responses. There was no difference in the depth of answers or the followup discussion based on the interview method. In both cases, participants clarified and, in some instances, justified answers. Follow-up member checking ensured that my interpretations were correct.

Significance of the Study

Contribution to Business

Businesses leaders in the private sector provided approximately 113,419,000 jobs in the United States and paid approximately 379,043,000,000 USD in taxes to the U.S. federal government in 2011 (U.S. Department of Commerce Bureau of Economic Analysis, 2013). Private businesses play a meaningful role in the nation's economy and in the quality of life of individuals and families. Survival of an enterprise depends on paying bills in a timely manner. The term *working capital* describes assets used for financing daily operations providing money for paying bills on time (Charitou et al., 2010). Proper management of working capital is an essential function of a successful business. Excessive working capital suboptimizes the use of a company's assets, and too little working capital can lead to bankruptcy (Mojtahedzadeh et al., 2011). In a review of corporate failures in Malaysia, Bee, and Abodollahi (2011) found debt ratio to be the most significant predictor of failure, followed closely by liquidity ratios. Liquidity ratios are an indicator of business managers' ability to pay bills. Jones (2011) identified the working capital to total assets ratio as a top three predictor for business survival.

The U.S. Small Business Administration (2013) identified the top 10 reasons for small business failure. Three reasons included in this list relate to nonoptimal working capital: (a) insufficient capital, (b) poor inventory management, and (c) low sales. These reasons are significant, as approximately half of new firms do not survive 5 years (U.S. Small Business Administration Office of Advocacy, 2010). In another study on new firm survival, Coleman, Cotei, and Farhat (2010) found that companies with higher debt levels and reduced working capital have a positive correlation with failed companies. As an important element of working capital and enterprise survival, optimal inventory provides a balance between servicing customers and improving funds available for business sustenance, alleviating financing constraints (Ding et al., 2010).

Small business leaders employ approximately 50% of people in the private sector and are responsible for 75% of new job creation (Longley, 2012). In the United States, approximately 500,000 small businesses start each year (Longley, 2012). The effect on the economy from small businesses is significant. Lack of optimal inventory is not the only source of business failure, but it is a component of it. Excessive inventory reduces the amount of funds available for investments and reduces profits for organizations (Ding et al., 2010; Losbichler & Mahmoodi, 2012).

Inventory dollars divided by sales dollars is a ratio commonly used to calculate inventory efficiency. Since 2004, inventory-to-sales ratios for U.S. businesses ranged from 1.48 to 1.25 (U.S. Census Bureau News, 2015). For the month of January 2015, total inventories in the United States were 1.76 trillion USD versus sales of 1.30 trillion USD, resulting in an inventory-to-sales ratio of 1.35. These statistics yield an estimate of 40.5 days of inventory based on 30 days in a month. In this case, a reduction in inventory of 1 day would increase cash available to U.S. businesses by 43.5 billion USD. By observation, excessive inventory results in less efficient operations, leading to increased waste and increased costs. Increased costs may reduce profits or increase selling price, making the business less competitive.

Implications for Social Change

For the leaders of positive social change, the influence of nonoptimized inventory affects each supplier in every product value chain, from the raw materials harvested from the earth to the finished product on a store shelf. The potential scope of this research is far reaching with respect to the number of organizations that would be able to take advantage of the research. Efficient use of inventory results in less waste going to landfills and other methods of disposal, relating directly to sustainability of natural resources (Wolf, 2011). Social implications of inefficient operations include business failure, unemployment, higher prices, and higher cost of living. Finally, in the global economic environment, job creation and unemployment are concerns. Sustaining current businesses and developing viable businesses are important factors influencing the welfare of entire nations.

A Review of the Professional and Academic Literature

The purpose of this research was to gain an understanding of strategies influencing inventory levels in manufacturing organizations. Interviewing people making inventory decisions associated with a particular value chain in a manufacturing operation provided the majority of information for research. I recorded, transcribed, and analyzed each interview, establishing themes and perceptions regarding inventory levels. The literature review explored (a) the business case regarding value and level of inventory, (b) the progress of manufacturing practices and effects on inventory decisions, (c) uses and measurements of inventory, (d) inventory planning tools, and (e) research strategies and designs authors used to complete their studies. Search engines in the Management and Business databases through the Walden University library located peer-reviewed articles for the literature review. Search engines included (a) ProQuest Central, (b) Business Source Complete, (c) ABI/Inform Complete, and (d) Emerald Management Journal. The Google and Google Scholar search engines provided peer-reviewed articles as well. Searches included parameter settings for current articles (within the past 5 years) and peer review. Searches used keywords and phrases such as (a) *just-in-time,* (b) *lean manufacturing,* (c) *Toyota Production System,* (d) *inventory management,* (e) *working capital,* and (f) *value chains*. References consist of 207 articles, of which 189 or 91.3% are peer-reviewed and 187 or 90.3% are less than 5 years old.

Business Case

Inventory plays a significant role in the success of most businesses. A complete set of financial statements for corporations in the United States as defined by the Financial Accounting Standards Board and the U.S. Generally Accepted Accounting Principles include a balance statement, income statement, statement of cash flows, and retained earnings statement (Ward & Ward, 2013). Inventory is a line item in two of the four recommended financial statements, the balance sheet, and the statement of cash flows. The balance sheet lists inventory as a current asset, and a statement of cash flows records changes in inventory. The definition of a *current asset* is an asset capable of conversion to cash in the short term and includes cash reserves held by a corporation, accounts receivable, prepaid expenses, and inventory. Although some sources adhere to the concept that inventory is a readily available source of cash, others have reservations about calling inventory *cash that is not moving* (Manisha, 2012; Sprague & Callarman, 2010). Valuation of inventory includes the purchase price of raw materials, the cost to process and evaluate the materials, the cost to ship the materials to storage and distribution locations, and the fixed cost derived from equipment and facilities depreciation. Considering inventory as a current asset depends on the age of the inventory, the demand for it at the time of conversion, and the length of time it takes to convert it to cash.

Basu and Wang (2011) reviewed changes in inventory levels in U.S. companies and the effect inventory had on firm performance and firm value over a 55-year period (1955–2005). The findings are consistent with studies in the literature review that show that increases in inventory have an adverse effect on earnings growth and lower stock price. Researchers also found that the strength of the relationship is dependent upon the data collection period. Basu and Wang found that a negative correlation does not apply to companies maintaining lower levels of inventory. An important finding from this research is that external factors affect financial performance of companies less if they carry optimal inventory levels.

The level of inventory varies considerably by organization. Table 1 shows the dollar value of inventory and the percentage of inventory compared to current assets and sales of several companies. A brief overview of automobile manufacturing companies showed that inventory as a percentage of total sales at the end of 2012 ranged from 4.3% to 9.5% (Daimler AG, 2012; Ford Motor Company, 2012; General Motors Company, 2012; Honda Motor Company, LTD, 2012; Toyota Motor Company, 2012).

Table 1

Inventory, Current Assets, and Sales Data From Manufacturing Firms

	Ford	GM	Toyota	Daimler[a]	Honda	Deere	CAT
Inventory	7,362	14,714	18,219	17,720	12,906	5,170	15,547
Current assets	125,643	69,996	146,375	67,458	56,523	42,719	42,524
Sales	134,252	152,256	234,289	114,297	104,889	36,157	65,875
Inventory/CA	5.9 %	21.0 %	12.5 %	26.3 %	22.8 %	12.1 %	36.6 %
Inventory/Sales	5.5 %	9.7 %	7.8 %	15.5 %	12.3 %	14.3 %	23.6 %

Note. CA = current assets. Information retrieved from 2012 annual reports published in Yahoo Finance.com. Inventory, current assets, and sales data in millions of USD.
[a] Inventory, current assets, and sales data in millions of EUR, 1 euro equals 1.37 USD (Yahoo Finance, October 20, 2013).

The dollar value invested in inventory for these companies ranges from 5.9 billion USD to 24.3 billion USD (17,720,000 Euros). If Ford (4.3%) operated at the same inventory efficiency as General Motors (9.5%), Ford would require an additional 7.1 billion USD. Using the same measure in the agriculture equipment manufacturing industry, inventory as a percent of total assets ranged from 13.7% to 24.2% (Caterpillar, 2012; Deere, 2012). If Deere (13.7%) ran at the same inventory efficiency as Caterpillar (24.2%), Deere would require an additional 3.4 billion USD.

In a longitudinal study of companies in a turnaround situation, cash flow and inventory management were significant factors for the success or failure of returning to profitability (Zimmerman, 1990). Zimmerman (1990) completed a case study comparing the turnaround results between the Chrysler Corporation and International Harvester. During Chrysler's successful turnaround, the average sales dollar-to-inventory dollar ratio was 11.02: during this same period, International Harvester's sales-to-inventory ratio was 2.56 (Zimmerman, 1990). Compared to Chrysler's ratio, International Harvester required an additional 1.6 billion USD to operate. Clearly, optimizing inventory efficiency in manufacturing operations is an opportunity for many manufacturing companies.

Money used for purchasing and manufacturing inventory is unavailable for other finance requirements and may require borrowing funds to sustain operations. In this case, Ford and Deere, with a smaller percentage of funds invested in inventory, may have an advantage over peer companies. Authors of several studies have reported that working capital and inventory have an effect on both profitability and liquidity (Bagchi et al., 2012; Chisti, 2013; Gill et al., 2010; Mojtahedzadeh et al., 2011; Raheman et al., 2011).

Another method to evaluate liquidity measures the length of time it takes to recoup a dollar invested in raw materials. This measurement, termed *cash conversion cycle*, is the number of days for inventory to turnover plus the number of days to collect accounts receivable minus the number of days to pay accounts payable (Alipour, Jamshidinavid, & Dastgir, 2015; Charitou et al., 2010; Gill et al., 2010; Raheman, Qayyum, & Afza, 2011). The definition of inventory turnover is the dollar value of inventory divided by the dollar value of the cost of goods sold, multiplied by 365 days (1 year). Similarly, the accounts payable term in this calculation is the accounts payable in dollars divided by total purchases for the year in dollars multiplied by 365. The accounts receivable term in this calculation is the accounts receivable in dollars divided by the sales for the year in dollars multiplied by 365. The shorter the cash conversion cycle, the quicker cash returns to the business, which improves cash flow. This definition is essential for conducting studies allowing comparisons of companies of varying sizes regardless of the dollar value of the inputs and outputs.

Chisti (2013) conducted a quantitative study involving 16 Indian firms, testing relationships between profitability, the dependent variable, and the three components of working capital: (a) debt ratio, equal to total debt divided by total assets; (b) current ratio equal to current assets divided by current liabilities (also the traditional measurement of liquidity); and (c) cash conversion cycle, the independent variables. Chisti's conclusion showed a strong negative correlation with each of independent variables. In other words, profitability decreased as the independent variables increased. The findings are consistent with previous studies cited in the literature review.

Bagchi et al. (2012) surveyed 10 Indian firms, analyzing the effect of cash conversion cycle, debt-to-equity ratio, debt-to-total assets ratio, days of accounts receivable, days of accounts payable, and days of inventory on return on total assets and return on investments. The availability of financial data for the period limited the sample size. The authors' findings showed that debt, days of accounts receivable, days of accounts payable, and days of inventory had a negative correlation with the return on total assets. Cash conversion cycle, debt to total assets, and days of accounts payable had a negative correlation with the return on investment. The authors made the point that short-term liquidity and longer term profitability are at odds, and the company must balance them to be successful (Bagchi et al., 2012). Liquidity allows a company to avoid bankruptcy and pay creditors on time, leading to higher amounts of working capital: greater amounts of working capital lead to lower profits.

Mojtahedeh et al. (2011) evaluated the three components of working capital and the cash conversion cycle versus firm profitability for 101 companies listed on the Tehran Stock Exchange. The authors' findings showed that days of accounts receivable, days of accounts payable, and cash conversion cycle have a negative correlation with firm profitability. Unlike the Mojtahedeh et al. study, days of inventory were not a significant factor in the results of this study. Part of the reason given is that new, small companies are likely to outsource manufacturing steps and have longer supply chains. These companies need inventory to grow. Managers in larger, newer businesses focus on cash management, as they are likely to have small sales. The company's working capital position has an effect on profitability, but the company's focus may differ based on its situation in the market, its age, and its size (Mojtahedeh et al., 2011). In a 10 year study of 204 companies listed on the Karachi Stock Exchange, Raheman et al. (2011) analyzed working capital management performances using the cash conversion cycle and its components as independent variables, and return on total assets and industry sector as the dependent variables. Companies considered dominant and lagging would improve their working capital management the most by reducing days of inventory and accounts receivables. In both types of businesses, the days of inventory affected the cash conversion cycle.

Gill et al. (2010) conducted a quantitative study evaluating 88 American firms' working capital and its effect on profitability. The authors studied various financial information, including (a) accounts receivable, (b) accounts payable, (c) inventory, (these first three variables comprise working capital), (d) cash conversion cycle, (e) firm size, (f) financial debt ratio (defined as short-term loans plus long-term loans divided by total assets), and (g) fixed financial asset ratio (defined as fixed financial assets divided by total assets) as independent variables with profit as the dependent variable. The findings of this research showed a negative correlation between accounts receivable and profit, which is consistent with previous studies, and a positive relationship between cash conversion cycle and profitability. The positive correlation between cash conversion and profitability is in direct conflict with four studies cited in the literature review (Bagchi et al., 2012; Chisti, 2013; Mojtahedeh et al., 2011; Raheman et al., 2011). In this case, Gill et al. found no correlation between any of the other variables and profits.

In an analysis of more than 120,000 Chinese firms during a 7-year period, Ding et al. (2010) found that firms adjusted working capital to minimize external financing. In addition, firms with extensive external financing typically had higher working capital. Favorable working capital management could reduce the need for external financing, providing less expensive and faster growth (Ding et al., 2010). The literature review included as part of this study contains information indicating that liquidity and profitability have a negative correlation, and successful organizations require balance. Higher inventories and generous payment terms lead to growth yet also tie up working capital, potentially resulting in unfavorable external loans.

Table 2

Working Capital From Manufacturing Firms

	Ford	GM	Toyota	Daimler[a]	Honda	Deere	Cat
Inventory	7,362	14,714	18,219	17,720	12,906	5,170	15,547
Accounts receivable	82,338	23,868	87,831	7,543	26,367	31,426	20,499
Accounts payable	68,715	48,474	47,311	8,832	16,976	9,288	15,309
Total working capital	20,985	-9,892	58,739	16,431	22,297	27,308	20,737
Working capital/sales	15.6 %	-6.5 %	25.1 %	14.4 %	21.3 %	75.5 %	31.5 %

Note. Information taken from 2012 annual reports published in Yahoo Finance.com. Inventory, accounts receivable, and accounts payable data in millions of USD.
[a] Inventory, current assets, and sales data in millions of EUR, 1 euro equals 1.37 USD (Yahoo Finance, October 20, 2013).

Evaluating the working capital of the same seven firms shown in Table 1 shows a range of working capital of 40,520,000 USD for Toyota to a negative 9,892,000 USD for

General Motors, as shown in Table 2. General Motors managers will need to raise money to pay suppliers for acquired material in inventory. Also seen from the chart, Daimler managers will need to sell some inventory in a short time to pay their suppliers, as accounts payable exceeds accounts receivable. In situations when payables exceed available cash, companies must raise or borrow money to remain viable.

Raising capital and borrowing money incur additional costs, adding to the payables (Lifland, 2010). Managing the optimal level of working capital is a complex problem and depends on (a) the company's strategy, (b) the financial situation of the firm, (c) the firm's place in the market, and (d) the company's industry.

In addition to the industry the company is participating in, other external factors influence the amount of working capital companies have on hand. In a study of working capital carried by companies in the Baltic States (Lithuania, Latvia, and Estonia), several factors influenced the working capital over a period from 2005–2010 (Arbidane & Volkova, 2012). As the national economy grew, so did the amount of working capital. Inventory increased so as not to miss sales growth, and payment terms became more flexible, leading to increased receivables.

When the global economy began to falter at the end of 2008, working capital started to fall in companies that were able to respond to the change. Arbidane and Volkova (2012) found that in cases in which companies did not respond appropriately to the change in the economy, inventories aged as the shortage of cash slowed sales and the shortage of cash pushed buyers to borrow money from suppliers. Those companies unable to respond to the change struggled for survival. The governments' response to economic change through monetary policy, government spending, and tax policy may also play a factor in corporate working capital levels, with businesses increasing or decreasing working capital levels based on what will help optimize profits and maintain viability.

The results of a similar study that evaluated U.S. companies by comparing working capital before and after the global recession (2007 to 2010), Duggal and Budden (2012) showed an increase in firms retaining more cash and short-term investments, contrary to the findings in the Baltic States. The researchers indicated that the effect of working capital in some industries, including consumer staples, health care, telecommunications companies, and consumer discretionary companies, such as McDonalds and Dollar Tree, was minimal. In these industries, the days of inventory stayed flat or decreased. Other industries increased inventories, which may mean that they responded slowly to the change in the purchasing habits of their customers.

In a study evaluating working capital as a percent of sales, Ek (2011) determined that a relationship exists with respect to industry type. Automobile manufacturers and automobile parts suppliers are on the high end with a ratio of 24%, followed by personal and household goods suppliers at 21%, with travel and leisure and telecommunications at the lower end at 5%. As seen in Table 2, a fair amount of variation in inventory exists even in similar industries. General Motors and Daimler may need financial assistance, as accounts payable exceeds accounts receivable. Determining whether others have the correct quantity on hand is difficult based on the information in the table.

Bartram (2013) listed several methods to improve working capital, including (a) use key performance indicators across the company to manage performance, (b) consider alternative funding to reduce financing expenses, (c) pay suppliers on time to avoid late payment charges, (d) pay suppliers early to take advantage of discounts, (e) generate detailed reports to keep close track of expenses, (f) manage inventory to keep supplies moving, (g) eliminate inventory that is not moving, (h) closely manage customer payment times, and (i) take advantage of electronic procurement using e-auctions to bid competitively. Using the definition of cash cycle time introduced earlier, reducing cash cycle time and improving cash flow requires (a) reducing the receivable turnover by collecting from customers sooner, (b) increasing inventory turnover by reducing the amount of inventory,(c) increasing the accounts payable days by extending the payments to suppliers, or (d) any combination of the three. These actions will reduce the cash cycle for a single company in the value chain. To reduce the cycle time of the entire value chain requires the firms to work together.

Akgün and Gürünlü (2010) evaluated a four-tier value chain including raw material supplier, manufacturer, distributor, and retailer with the hypothesis that to optimize profit in the entire value chain, all members in the value chain need to work together versus optimizing individual organizations or process steps. In this scenario, the days of accounts receivable at the first step in the process is also the days of accounts payable for the second step. This situation applies to each subsequent stage. Requiring faster payment from customers will not shorten the cash conversion cycle time except at the final selling point, the retailer. Suboptimizing also occurs when extending payments to suppliers. Any of the individual firms in the value chain extending payment terms will shorten their cash conversion cycle, but add to the days of accounts receivable to the company in the previous step, nullifying any benefit to the entire value chain. An organization that removes inventory from their processes improves the cash conversion cycle of an individual firm as well as shortening the cash conversion cycle of the entire value chain. The whole value-chain cash cycle improves as long as removing inventory in one process step does not make another step in the process add inventory to compensate.

In a survey by Grant Thornton LLP (2010) regarding supply chain improvements, 90% of the respondents reported taking steps to optimize working capital. The actions reported most often were taking price concessions from suppliers (55%), extending payment terms to suppliers (43%), granting price concessions to customers (43%), and extending payment terms to customers (29%). Some improved relationships with partners by sharing forecasts (33%), and establishing supply chain-wide inventory management strategies (33%) (Grant Thornton LLP, 2010). Many of the actions reported in this survey may have helped an individual firm at the expense of suppliers and did not improve the value chain efficiency.

Losbichler and Mahmoodi (2012) shared similar information regarding the opportunity for improving working capital through shortening the cash conversion cycle. For example, if IBM reduced their cash-to-cash cycle by 1 day in 2010, IBM would increase their cash flow by 1.578 billion USD. The benefits of reducing inventory count as double savings as in addition to reducing cash tied up in inventory, operating costs are reduced including (a) storage costs, (b) cost of insurance, (c) cost of moving materials,

(d) loss due to damage, and (e) loss due to obsolescence, estimated to be 10% of the value of the inventory. The authors indicated few companies successfully sustained improvement in cash cycle time. The results of the study conducted by Losbichler and Mahmoodi agreed with findings from a study conducted by Mitra and Bhardway (2010), which found many companies struggle to improve working capital. Cisco wrote off 2 billion USD of inventory in 2001 because of poor sales forecasts. Mitra and Bhardway identified Walmart's success in reducing and sustaining improved cash flow has reduced its cash conversion cycle from 90 days in 1971 to less than 10 days in 2011.

Mitra and Bhardway (2010) suggested four factors prevent companies from improving cash-to-cash cycle. The first factor is management shifting focus based on the place in the business cycle. Emphasis is on working capital management during a downturn in the business cycle as companies seek to finance programs internally based on the increased cost of capital. The next factor is the use of measurements and incentives that do not support proper working capital management. Metrics focusing on short-term profitability may do so at the expense of improving cash flow. One example of focusing on short-term profits measures unit costs of individual items. One factor to determine unit costs includes depreciation of capital equipment. Running more units keeps the cost per unit down. Focus on reducing unit cost may encourage behavior to produce amounts exceeding demand resulting in excess inventory.

The next factor preventing cash-to-cash cycle improvement is not having a designated owner of the inventory or several groups share responsibility. One example is accountability of raw materials. The product developers select the raw materials for a new product design. Working with suppliers, the sourcing agent determines economic order quantities. The supply chain analyst orders raw materials based on a forecast provided by the sales department. Each of the individuals determining the amount of raw material to order has different criteria for deciding how much to purchase that may result in suboptimal levels. The final factor, a lack of understanding of the influence of working capital management on the cash-to-cash cycle prevents improvement. Each of the individuals determining the amount of material to order may have conflicting metrics. If the finance group owns the management of working capital, the other groups may not understand how their decisions increase or decrease working capital and cash flow for the corporation.

Optimizing inventory in the value chain and in individual firms has a positive effect on the company's profitability and long-term sustainability. Many companies have focused on reducing cash conversion cycle time and improving cash flow because of the economic opportunities provided. Although some corporations have successfully implemented changes to improve the cash position of the company, many others have struggled. Following is an overview of the evolution of manufacturing operations and the effect the evolution in practices has had on working capital management.

Evolution of the Manufacturing Processes Affecting Inventory

Inventory was not an issue in the early days of manufacturing as skilled craftspeople built products one piece at a time. Customers ordered product to their specifications making production expensive, and lengthy. An example of early production is the first automobile in England (Womack, Jones, & Roos, 1990). In 1894, the Honorable Evelyn Henry Ellis decided to purchase a car. Ellis traveled to France authorizing the establishment of Panard et Lavassor to build a car. Panard et Lavassor produced a few hundred automobiles each year. The automobile consisted of a few fundamental components. Ellis was able to define a vehicle to suit his needs. Manufacturing the necessary components took place in local shops. Panard et Lavassor assembled components into the final product. Fitting parts required artisans to file and trim parts to assemble into the final product. Although drawings existed for the parts, measuring devices varied, tolerances of the machines in each shop varied, and metal parts required heat-treating that hardened parts making them fit for use. The heat-treating process distorted parts requiring additional work to make parts fit. Ellis returned to drive his vehicle for testing, and modification of parts continued until he agreed to accept the purchase.

Eli Whitney won a contract from the U.S. Government for muskets in late 1890 (Cooper, 2003; Woodbury, 1960). Whitney struggled with mass production because the heat-treating process warped parts and required manual rework before assembly (Woods, 2009). McCormick and Singer also attempted mass production using interchangeable parts in the early production of farm equipment and sewing machines but were unsuccessful for the same reason (Paxton, 2011). A heat-treating process developed by Fredrick Taylor and J. Maunsell White III hardened steels used to cut parts after the treatment (Paxton, 2011). The development of hardened steels along with feed rate and speed calculations for machine tools (the creation of the slide rule) led to an economical means of creating interchangeable parts,. Mass production allowed manufacturers to produce large volumes of parts economically to a geographically broad base of customers. Instead of waiting for orders to begin producing parts as artisans did, mass production relied on forecasts to pre-build parts and finished goods. Finished products filled store shelves, and while consumers could continue to order products to their specifications, many people purchased finished goods directly from the sales floor.

Henry Ford was an early adapter in taking advantage of interchangeable parts (Ford & Crowther, 1988). Henry Ford and Colonel Albert Pope developed manufacturing practices, such as quality control, specialization of duties, vertical integration, and the moving assembly line (Ford & Crowther, 1988; Norcliffe, 1997). Henry Ford also added standard work, and the assembly line to his production process allowing an increase in production of 1,700 Model T automobiles in 1903 to 66,640, in 1912 (Ford & Crowther, 1988). The assembly line signified the beginning of the mass production era in manufacturing. Benefits included lower cost and faster response, allowing buyers to purchase an automobile and drive it away on the same day. Inventory was part of the mass production process as production occurred based on an estimate of demand, not actual orders. Manufacturers produced product based on expected demand creating inventory until customers purchased items.

Another essential factor in the development of mass production was the ability to transport interchangeable parts, collect, and relay information regarding those parts from manufacturer to manufacturer economically (Helper & Sako, 2010). Advancements in communication and transportation allowed producers to provide products to customers economically. Since Ford's development of automobile production lines, many manufacturers relied on the economies of scale achievable through mass production operations.

Around the same time, industrial companies were changing their organizational structures. In a review of 200 larger companies from 1980 through 1990, Chandler (1990) identified several structure changes in successful and unsuccessful organizations. Standard Oil Company managers combined similar companies to create economies of scale and develop cost advantages. German chemical companies Bayer, BASF, and Hoechst, expanded capabilities by increasing the scope of processes and product offerings to reduce costs. The theory behind these actions was to spread an increasing number of units over fixed costs thereby reducing the total fixed cost per unit. The fixed cost per unit measures the total fixed cost divided by the total number of units produced. Chandler indicated the success of these operations was the continuous flow of materials through equipment maintaining low fixed costs. Because fixed costs do not change or change slowly with depreciation, the best mathematical decision with this equation was to increase the number of units produced.

Increasing the scale and scope increased the number of units, driving down unit costs. Creating inventory is a likely outcome of this logic when capacity exceeds demand. A viable solution when capacity exceeds demand, is increasing the scope and manufacturing different products with similar processes. A potential outcome of increasing the number of products produced on the same equipment is an increase in machine setups resulting in changeovers leading to economic manufacturing quantity calculations to determine the appropriate batch size. Because the formula uses an estimate of annual demand and not actual demand, the economic order quantity formula is likely to create either inventory or service issues.

Economies of scale may provide benefits to individuals, industries, and countries. Catalan (2011) studied the development of the automobile industry in three countries, Argentina, South Korea, and Spain, all desiring to improve the state of their economy after World War II. The governments of these countries worked closely with manufacturers to develop their country's automobile manufacturing industry. The governments of these countries virtually eliminated imports and some local manufacturers to ensure a constant demand for the remaining companies. Each of the countries benefited from economies of scale initially. Later, industrial policy changes for Argentina and Spain included increasing imports, leading to overproduction, severely hampering economies of scale and significantly reducing the viability of the local producers. South Korea was more conservative than Argentina and Spain, and the three largest local manufacturers, Hyundai, Daewoo, and Kia continued to thrive, taking advantage of economies of scale.

Helper and Sako (2010) expanded on Chandler's work evaluating the economies of scale and scope in the modern supply chain. To maintain the flow through fixed cost equipment requires a constant supply of inputs. The authors indicated Chandler's premise is improvements in communication and transportation allowed corporations to develop vertical integration. Chandler (1990) recognized organizations developed vertical integration through purchasing suppliers or developing their source of supply. DuPont and Ford extended vertical integration purchasing mines to provide raw materials for their operations (Ford & Crowther, 1988). Helper and Sako suggested continued improvements in communication and transportation allowed companies to integrate vertically without owning supply operations. An important aspect of vertical integration is ensuring the supplier has the proper incentive to provide materials when needed, at an appropriate cost. Vertical integration leads to creating value chains also called supply chains, involving other companies. These changes in operation have created the term *supply-chain management* and the next phase of manufacturing.

Supply Chain Management

The definition of supply chain management is far reaching. In a qualitative review of more than 1000 articles, Stock, Boyer, and Harmon (2010) identified 166 unique definitions for the term *supply-chain management.* The analysis found three reoccurring themes, (a) activities, (b) benefits, and (c) constituents of components. Activities included movement of materials, information, and money. Benefits included value, efficiencies, and satisfied customers. Constituents are the players involved in the entire process including (a) procurement, (b) operations, and (c) distribution (Carter, Rogers, & Choi, 2015). The supply chain included the processes and entities responsible for harvesting and converting materials into a product purchased by a customer and the flow of cash in the reverse direction. The term *supply chain* and *value chain* defined by Porter (1998) are synonymous.

In an integrated supply chain, the constituents work together for the benefit of the total supply chain and each participating entity. Daugherty (2011) described integrated supply chain relationships as a continuum with wholly owned operations on one end, versus one-time spot buying between a customer and supplier on the other end with various levels of relationships between them. Daugherty defined partnerships and alliances as meaningful links in integrated supply chains. In a partnership, parties work together on a long-term basis to the mutual benefit of both. In a partnership, both companies share information and risk. Alliances are the next level of relationship in which firms mutually take advantage of the strengths of the other. Alliances provide a long-term commitment to cooperate for the future success of both companies. In an alliance, companies work together to develop products and services while sharing proprietary information.

In a survey ranking the top 25 global supply chains, a primary characteristic of leaders is relationships developed through the supply chain including partnerships with customers and suppliers (Hofman & Aronow, 2012; Hofman, Aronow, & Nilles, 2013). Benefits should include increased profitability through operational, service, and innovation improvements. In a review of Chinese firms, Flynn, Huo, and Zhao (2010) found collaboration improved the flow of information, products, services, and cash between suppliers and customers. The researchers also found firms participating in collaboration improved flow within the company.

In another example of collaboration, Sahoo (2010) studied farmers in India regarding the advantages of developing relationships with suppliers and customers in the form of corporate distributors. In the past, farmers pushed their products into the marketplace regardless of demand creating an inefficient operation. In collaboration, the farmers formed alliances with banks, seed providers, and distributors, which improved the flow of information and goods. Sahoo reported that collaboration removed non-value added participants, reduced risk of demand, thereby reducing the cost to fund operations. Collaboration improved information from the customer, increasing the match between supply and demand, reducing the likelihood of waste. Sahoo found that firms collaborating with suppliers and customers led to reduced inventory throughout the supply chain.

Reasons for Inventory

Inventory is a valuable asset for most businesses because it uses limited resources. Manufacturing leaders consider inventory a luxury, a necessity, or a waste of resources, depending on perspective. Willems (2012) defined types of inventory based on its purpose as follows:

1. Anticipatory inventory is material purchased or manufactured based on expected demand.
2. Cycle inventory is a material created or purchased to fill the void caused by a batch process, caused by infrequent deliveries or a manufacturing process, which make the material cycle infrequently.
3. Early arrival inventory is material delivered before requested.
4. Marketing inventory is the finished product displayed on store shelves.
5. Obsolete inventory is material made or purchased and not needed.
6. Pipeline inventory is material in transit from place to place in the supply chain. Pipeline inventory includes material moving from the raw material supplier to the manufacturer, from the manufacturer to the distribution center

and from the distribution center to the retailer. An important note - the material is moving.

7. Pre-build inventory is material made or manufactured because of known instantaneous demand exceeding instantaneous capacity. This situation is common in seasonal type businesses.
8. Promotional inventory is a material made for specific finished goods in a short-term sale.
9. Strategic inventory is material purchased or manufactured because of a favorable condition.
10. Finally, safety inventory is a material made to compensate for variability throughout the value chain, for instance, variability in production or uncertain demand.

According to Willems (2012), safety inventory is usually the largest amount of controllable material. Reducing safety stock requires reducing variability throughout the system. He et al. (2011) completed a study supporting the hypothesis that reducing variability in lead-time had a larger effect on inventory reduction than reducing the mean of the lead-time. There are several areas of variability in supply chains. Singh (2010) developed equations for perfect and imperfect quality supply chains demonstrating total inventory cost increased with imperfect or inconsistent quality. Unpredictable demand variability may be another cause for safety inventory. Sabath and Sherman (2013) discussed the importance of understanding variability of customers' requirements. In many cases, the most unpredictable customer requires additional inventory to cover the uncertainty at the expense of the steadier, more predictable customers.

Pipeline inventory mentioned by Willems (2012) is inventory between steps in processes internally, and inventory between supply chain partners. Pipeline inventory may also present an opportunity for inventory optimization. Internally, operations in the same facility and the same company should be able to optimize material flow and resultant inventory. That is not always the case. Bakker et al. (2012) analyzed four businesses and discovered two significant reasons for suboptimal material flow internally, fire-fighting and functional-silo mentality. In the study (a) poor value stream design, (b) inconsistent strategy, (c) independent systems, and (d) high levels of uncertainty and variability in processes contributed to firefighting. Functional-silo mentality is when each department in a company focuses on improvement of the department regardless of the effect on the organization. Causes of functional-silo mentality included (a) structure differences, (b) different goals and incentives, (c) different cultures, (d) lack of integrated systems, and (e) geography differences.

In a Supply Chain Executive Brief survey (2011), functional-silo mentality ranked as the third highest barrier (45.9% of respondents believe it was the greatest obstacle) to effective inventory management. Differences in functional groups caused internal pipelines to carry more inventory than is necessary to meet business goals. In the case of pipeline inventory in a value chain involving multiple companies, information flow between partners is critical. Pipeline inventory compensates for uncertainty of demand leading to uncoordinated production throughout the system. The results of the Supply Chain Executive Brief survey ranked inability to optimize the system holistically (55.9%)

and demand volatility (45.9%) as the top two barriers to effective inventory management.

Several methods are available to manage information and material flow in value chains. Datta and Christopher (2011) analyzed four methods to control information and material flow. Centralized control, decentralized control or a combination of the two defined the four methods. Centralized control refers to one company making decisions for the entire value chain. Decentralized control occurs when each company in the value chain makes decisions. The first method occurs when control of both information and material flow is by one entity in the value chain. This method may lead to restricted information flow and over-reaction to minor changes in the supply and demand, but has demonstrated reduced material flow cost. Decentralized controlled decision-making and centrally controlled material flow improved information flow and service, but is slow to react to system upsets.

Decentralized decision-making and material flow improves information flow and improves value chain metrics for make to stock items, but leads to a bullwhip effect when changes in demand occur. The bullwhip effect is a term describing a small change in demand resulting in increased demand swings in each company as the effect moves up the supply chain (Heim, Peng, & Jayanthi, 2014). The bullwhip effect may cause excessive production and extra inventory. An extreme example of the bullwhip effect occurred with a new product in a relatively new company responding to a perceived increase in demand resulting in an inventory overrun with the product becoming obsolete, bankrupting the company (Marion & Sipahi, 2010). The final form of control, decentralized decision-making with centrally coordinated material flow resulted in increased information flow and led to improved value chain metrics.

Ranganatham (2011) defined inventory slightly differently than Willems as (a) normal inventory, required for production flow; (b) safety inventory, to cover unexpected demand; (c) profit making inventory, finished goods stock; and (d) flabby inventory held because of inefficient operations. Classifying inventory based on its place in the manufacturing process as (a) raw materials, that are inputs to a manufacturer's operation; (b) work-in-process or *WIP*, that is a material that has begun processing, but not ready for shipment to customers; and (c) finished goods, that is the material sold to customers, is also typical. Ranganatham (2011) surveyed several small-scale enterprises in India and found companies based minimum raw material inventories on (a) lead-time, (b) lead-time plus safety stock, or (c) consumption over a fixed period. The same companies based maximum raw material inventories on (a) future production plans, (b) the useful life of the material, (c) projected price changes, or (d) the amount of storage space available. In the case of raw materials, there needed to be enough inventories to compensate for delivery times. Increasing the frequency of deliveries decreased the amount of material inventoried.

Sana and Chaudhuri (2013) defined several factors when developing an economic manufacturing quantity. Those factors have some effect on the amount of safety stock inventory recommended for achieving optimal economic operations. Factors considered in the development of the equation are (a) machine failure frequency and duration, (b) preventative maintenance frequency and duration, (c) good part yield, (d) cost to rework parts not meeting requirements, (e) the cost of running out of the product, and (f) the set up cost to change the machine from one part to the next. More frequent disruptions and longer downtime increased the inventory carried as safety stock. Safety stock can be in the form of raw materials, WIP, or finished goods.

Another factor influencing levels of inventory is available capacity versus the consumer demand and market fluctuation. Li and Meissner (2011) evaluated the effects of investment in capacity versus the costs of production and inventory carrying costs. Too little capacity and the possibility of missed sales and long customer wait times exist. Too much capacity wastes resources, restricting other investments. Cost accounting methods and individual incentives may cause overproduction and excess inventory. Under the fully burdened cost accounting method, the product and the inventory both absorb variable and fixed costs (Meade, Kumar, & White, 2010). Fixed costs exist even when there is no production and include depreciation of plant and equipment and salaries of office people. Variable costs are the costs incurred when manufacturing products including the materials going into the product and the workers operating the equipment. The concern in the fully burdened cost accounting method is individuals may overproduce to reduce the cost of individual units creating excess inventory. In financial statements, inventory is an asset. Reducing inventory decreases assets and will show a decrease in profits short term. A rapid reduction in inventory will show a larger reduction in profits short term, which may cause alarm and discourage inventory reduction (Meade et al., 2010).

In a study of North American automobile companies (Ford Motor Company, General Motors, and Chrysler) from 2005 to 2006, Brüggen et al. (2011) observed managerial incentives used excess capacity to improve unit costs by over producing products. For each 1% of extra capacity, there was a corresponding 0.49% increase in excess production resulting in excess inventory. In this case, spreading fixed depreciation over more units lowered the unit cost. While spreading depreciation over more units appears to be a smart decision in the short-term, purchasing raw materials and using labor to create the extra units requires additional cash outlay. Stank, Dittman, and Autry (2011) indicated a lack of strategy and focus on short-term results are significant barriers to lasting improvement in material optimization measurements. Over producing to reduce the unit cost may lead to managers to discount the inventory in order to sell it. Longer term, this behavior teaches consumers to wait for discounted goods before making purchases. Gupta, Pevzner, and Seethamraju (2010) completed a similar study of firms with relatively high fixed costs and reported similar results. The authors presented the influence inventory levels had on the stock market analysts, as well. In some cases, investors consider a buildup of inventory as a prediction for future sales and a favorable investment. In other instances, if a firm has falling sales and increasing inventories, analysts considered inventory a liability.

The Statement of Financial Accounting Standards, Number 151 (2004), required organizations to report extra capacity, also called idle capacity, on financial statements as a line item affecting cash flows for the reporting entity. Bettinghaus, DeBruine and Sopariwala (2012) reported General Motors North America operations to have over 32 billion USD of idle capacity in the period from 2002 – 2008. Typically, capacity decisions affected finished goods. Increased demand fluctuation requires increased capacity or inventory. The researchers also found that significant variability in supply, in production processes, and in demand, required a higher level of safety stock inventory (Bettinghaus, DeBruine, & Sopariwala, 2012).

The development of economic manufacturing quantities and economic order quantities required defining several cost factors. As cost factors change, updating the factors and recalculating lot sizes is essential to maintain optimal quantities. Huang, Cheng, Kao, and Goyal (2011) developed a mathematical model determining economic manufacturing quantities, which included 14 independent variables. The reduction of one of the 14 variables, the setup cost, reduced the economic order quantity. Reducing the economic manufacturing quantity reduces the amount of safety stock and inventory carrying costs and the total manufacturing cost. The model developed in this research may contribute to reducing inventory and total costs by justifying investments in reducing the setup cost.

Analyzing distribution systems provided another perspective with respect to finished goods inventory. De Leeuw et al. (2011) analyzed the finished products carried by dealers in the automotive industry. Because each dealer seeks to optimize their profit, the distribution systems behave the same as decentralized control with each dealer controlling their inventory level. Through the study, the authors found significant differences in finished goods inventory between dealers. Dealer inventory ranged between 23 and 89 days with an average inventory level of 66 days (de Leeuw et al., 2011). The average level has not changed since the early days of mass production. The lack of change is particularly relevant knowing that most automobile manufacturers have instituted improvement programs such as JIT, lean manufacturing, and the Toyota Production System.

As identified by several authors, several reasons exist to maintain inventory and most manufacturing operations require a certain level of inventory to operate efficiently (Bakker et al., 2012; Brüggen et al., 2011; de Leeuw et al., 2011; He et al.,2011; Ranganatham, 2011; Sana & Chaudhuri, 2013; Willems, 2012). Because inventories typically account for 50% of current assets in manufacturing operations, optimizing inventory is extremely beneficial to the success of the business (Ranganatham, 2011). As most inventory reporting is in terms of financial value, understanding the methods of valuing inventory is important. Three methods exist to determine the value of inventory according to the Generally Accepted Accounting Principles (GAAP).

Harris (2011) defined commonly used methods as Last in First out (LIFO), First in First out, (FIFO), and the weighted average. Each method returns a different value for the same inventory. The LIFO method values inventory based on the first purchase price of the period. The FIFO method values inventory at the acquisition price of the last inventory purchased, and the weighted average method bases the inventory value on the average for purchases throughout the year. Harris (2011) demonstrated the differences in the methods, the effect on the cost of goods sold, and the tax burden with an example shown in Table 3. In each case, the number of units sold and the number in inventory are identical.

Accountants using the FIFO method use the most recent purchase price as the basis for the inventory valuation. Accountants employing the LIFO method utilize the first purchase price as the basis for the inventory valuation. In this example, the first purchase was 100 units at a cost of $10.00; the second purchase of 100 units cost $10.20 each; the third purchase of 100 units cost $10.40 each, and the final purchase of 100 units cost $10.60 each. In this example, because the purchase price increased throughout the year, the value of inventory is highest in the FIFO measurement and lowest in the LIFO measurement.

Table 3

Inventory Based on Accounting Method

	FIFO	LIFO	Weighted average
Beginning inventory	$0	$0	$0
Purchases	$4,120	$4,120	$4,120
Sales units	400	400	400
Remaining inventory	20	20	20
Ending inventory $	20 x $10.60[a]=$212	20 x $10.00[b]=$200	20 x $10.30[c]=$206
Cost of goods sold	$3,908	$3,920	$3,914

Note. a = last purchase price (most expensive); b = first purchase price (least expensive); c = average purchase price which is equivalent to $4,120/400 units. Table reprinted with permission from "Should Last In First Out Inventory Valuation Methods be Eliminated?" by P. Harris, 2011, *Global Journal of Business Research, 5*(4), p. 63.

Inventory value works the opposite way when the purchase price drops throughout the period such as times of deflation. The accounting method affects the value of inventory, cost of goods sold, and profit reported. Because inventory, cost of goods sold, and profits are part of financial statements and various financial ratios, understanding the method of inventory accounting is necessary for correctly interpreting financial results.

The accounting method effect varies based on the amount of inventory a company carries and the age of the inventory. For instance, the value of Exxon Mobil Corporation's inventory valuation is 21.3 billion USD less using the LIFO method versus the FIFO method (Krishnan & Lin, 2012). The basis for this estimate is the price of oil reserves in 1939 at the time the company formed. Again, the lower inventory value increases the cost of goods sold lowering the profits and the income taxes paid. In Exxon Mobil's case, the resulting lower profit leads to a tax savings of approximately 9 billion USD (Fosbre, Fosbre, Kraft, & Stockton, 2010). According to Jeffers, Wei, and Askew (2010), about 36% of U.S. companies use the LIFO accounting method including several petroleum companies. Use of the LIFO method of inventory valuation is under discussion as the Securities and Exchange Commission considers adopting International Financial Reporting Standards (Krishnan & Lin, 2012).

Mobil Exxon's LIFO accounting method only includes raw materials because raw materials are relatively easy inventory to calculate using purchase price. Other inventory items included in the entire inventory calculation are the work-in-process (WIP) and finished goods. WIP and finished goods valuations may be more complicated as each requires a determination of the amount of value added at each process step. Accountants include several costs to produce goods, considered direct costs, and costs to support production, considered indirect costs to determine inventory values for WIP and finished goods. Direct costs should be relatively straightforward to calculate, as the design of the product will determine the type and amount of materials used to make the product, and the labor costs to produce parts. Determination of indirect costs requires decisions on what costs are included and how to allocate the costs.

Terzioglu (2012) defined four types of indirect costs as (a) logistics, (b) balancing, (c) quality, and (d) change. Logistics costs included spending to receive and transport materials throughout the production facility and ship to the distribution point. Balancing costs determined what to make and when to make it. Quality costs ensured the product meets customer expectations, and change costs are costs incurred because of modifications to the process and equipment. Allocating indirect costs to a product determines the value of both the WIP and the finished goods inventories. These inventory values determine the cost of the product, which also determines the profit margin. In Terzioglu's research, allocating indirect costs based on the percent of direct labor in each part was the most common method of allocation. Terzioglu identified fourteen other allocation methods and several companies that did not allocate indirect costs. Terzioglu found the intent of the allocation method chosen by top-level management was to influence the compensation and behavior of managers to make the best decisions for corporate resources. Selecting the appropriate accounting method and corresponding compensation plans should provide optimal results. Likewise, inappropriate accounting methods and compensation plans would lead to suboptimal results.

Another aspect to consider when valuing inventory is whether the value diminishes as it ages. According to Wampler and Holt (2013), at some point, inventory value declines with age and financial reports need to reflect the decreasing value. GAAP requires inventory valuation at the lower of cost to produce or market value in which market value is the cost to purchase a replacement for the inventory. Determining the value of aging inventory is a consideration when reporting total inventory in financial statements. The higher the amount of old inventories on hand, the more the discretion of the organization to determine the inventory measurement (Wampler & Holt, 2013). Gemayel, Stasny, Tackett, and Wolfe (2012) completed a study comparing auditing methods used to evaluate inventory data because inventory is a commonly manipulated account. Harris (2011) noted the LIFO accounting method does not support JIT inventory methods. Harris also notes firms using LIFO are more likely to purchase extra inventory at the year-end resulting in decreased profits and reduced taxes.

The reason for this discussion about inventory value is to demonstrate various methods exist for determining inventory value within organizations. As Terzioglu (2012) reported, individual compensation plans may influence the levels of inventory reported as well as corporate strategies to minimize taxes. The value of inventory is a significant measure as it affects financial statements and financial ratios used to determine a firm's performance. This research is not to determine which inventory accounting method is best, as one method may not be ideal for every company, but to identify differences between methods. Some companies may display unusually high inventory values based on the cost of the raw material. A company using gold as a raw material will probably show a greater value of inventory on its financial statements than a corporation using paper as a raw material. Because of the differences used to determining inventory value, understanding the measurement is necessary for calculating optimal inventory levels.

Optimal levels of inventory should ensure on-time delivery to consumers at a predictable profit margin while preventing loss of sales (Nyabwanga & Ojera, 2012).

Too little inventory to meet customer demand may result in future sales loss. Too much inventory results in (a) higher product costs caused by increased storage, (b) increased movement of materials, (c) increased insurance, (d) increased overhead to account for valuing inventory, and (e) increased inventory obsolescence. Several tools and philosophies exist to assist decision makers in optimization of inventory.

Inventory Optimization Tools

Mass production and the moving assembly line. Many of the current manufacturing philosophies find roots in Henry Ford's automobile operation dating back to 1913 with the first moving assembly line. In 1926, Ford was able to produce an automobile beginning with raw iron ore to a finished, drive ready, automobile in just 81 hours (Ford & Crowther, 1988). Henry Ford identified several philosophies that made this production rate possible. Ford had the advantage, or disadvantage of experiencing failure when he helped organize the Detroit Automobile Company in 1899 which went bankrupt 1-1/2 years later. This experience played a role in forming new manufacturing operations. One of Ford's core principles was, *do not waste any resources.* Before the concerns of sustainability, Ford considered materials and labor delivering materials to the manufacturing process as valuable resources worth conserving.

From the moving assembly line came the standardization of methods, and interchangeable parts and processes creating the parts to assemble an automobile. Henry Ford applied this principle of standardization to incoming parts requiring suppliers to ship parts that meet every specification with minimal variability. In most cases, Ford supplied materials to upstream operations, so he controlled the quality of the input materials shipped to the assembly plant. In cases in which an outside vendor supplied parts, Ford shared his philosophies and practical information to help them deliver on his expectations in a profitable manner. Ford realized the importance of keeping his suppliers viable.

Ford required operations kept clean and organized, copied by the Toyota Production System now called 5S. Sand quarries and rock-crushing operations required cleaning as dust could be extremely damaging to equipment. Ford's moveable assembly line is the forerunner of one-piece flow concept. As the automobile market grew, Ford developed regional assembly operations to minimize shipping costs and provide wages for local workers so they could afford the automobiles they were assembling. This regional assembly process was economical and standardization ensured the parts worked at each location matching the same quality requirements.

Ford also understood the consumer. The example of the Model T and the Lincoln illustrated this. Engineers designed, built, and sold the Model T at a reasonable price, so most people were able to afford it. The same individuals designed, built, and sold the Lincoln for a different market with more financial resources. Both vehicles followed exacting standards, each vehicle satisfying its' customers. Ford made a point to emphasize a high level of quality conformance, as a requirement for a profitable product in both automobiles, even though, the market and the specifications were different. A summary of Ford's contributions to manufacturing operations still relevant include (a) cleanliness and organization of work areas; (b) collaboration with suppliers; (c) total quality control; (d) one-piece flow; (e) JIT deliveries; (f) understanding and catering to customer needs and wants; (g) standardized, interchangeable parts; (h) standard processes and operations; (i) conservation of resources; and (j) design for manufacture. Eiji Toyoda and Taiichi Ohno observed these manufacturing practices and copied Ford's original concepts, first with JIT deliveries, and further advanced concepts defining the Toyota Production System and lean manufacturing.

Just in time (JIT) manufacturing. Toyoda and Ohno received credit for developing JIT manufacturing principles at Toyota Motor Company (Wantuck, 1988). Because of limitations of land and raw material resources Toyoda and Ohno made modifications to Ford's concepts fitting their situation. Wantuck (1998) identified several changes and additions including (a) quality at the source, (b) stop and fix, (c) employee involvement, (d) the kanban card system, and (e) single minute exchange of dies.

Quality at the source describes fixing root causes of quality issues. To make this a reality, Toyoda introduced *Jidoka*-stopping the line any time a quality issue or defect arises until corrected. Stopping a production line is a significant disruption and ensured the problem received immediate attention. These practices also led to employee involvement identifying quality issues and encouraging operators to help resolve issues. With the assistance of W.E.Demming and Kaoru Ishikawa, quality circles started training workers to identify quality defects and resolve issues (Wantuck, 1988). Observation of supermarkets in America spurred Ohno's idea of the kanban card system. Ohno observed the systematic, visual organization of supermarkets and applied the attributes to manufacturing operations including (a) limited shelf space for each item, (b) each customer found items with little or no help taking what they wanted, and (c) a stock person tracked inventory and replenished items as needed (Wantuck, 1988). A change in operations resulted in manufacturing small lot sizes, producing every part every day, which led to optimized materials in the supermarket warehouse. Adding the concept of single minute exchange of dies for forming sheet metal body parts supported small lot sizes allowing Toyota to manufacture every part, every day, based on customer demand.

In a study of JIT philosophy, White, Ojha, and Kuo (2010) identify four practices: (a) conformance to quality, (b) delivery reliability, (c) volume flexibility, and (d) lowest cost, consisting of ten elements. Conformance to quality related practices have elements of quality circles and total quality control. Delivery reliability has elements of (a) group technology, (b) total productive maintenance, (c) uniform workload, and (d) focused factory. Volume flexibility has elements of reduced set-up times and multifunctional employees. The final method of the lowest cost has elements of kanban and JIT purchases. As part of the data collection process in the study, 1035 surveys received from members of the Association for Manufacturing Excellence confirmed implementing all four practices in the correct order provides the greatest improvement in reducing non-value-added tasks.

The Toyota production system. Womack et al. (1990) described how Taiichi Ohno applied JIT concepts to the Toyota manufacturing operations, resulting in the Toyota Production System (TPS), also referred to as lean production. One innovation included the idea of making parts only when needed. TPS required quick changeovers on the presses making the metal pieces for the body of the car. The need for quick changeovers led to the concept of single minute exchange of dies (SMED) performed by machine operators and not maintenance employees. Ohno also designed the kanban system for delivery of parts. In this system, the size of the container holds only the required amount for a given period. When all containers are full, the supplying operation stops making parts until an empty container returns from the assembly operation.

Another innovative idea from the TPS is the relationship with suppliers. Toyota engineers design automobiles and manufacturing operators assemble them. Toyota outsources many of the components in the assembly of their automobiles. The suppliers produce parts and decide on the majority of the component design. Toyota engineers provide part specifications, and the manufacturer designs the part to make it effective and economical. Tier 1 suppliers provide components directly to Toyota assembly lines. Tier 2 suppliers provide materials to tier 1 suppliers: tier 3 suppliers provide materials to tier 2 suppliers, and so on, continuing through many levels of suppliers. One advantage of this system is the designers employed by the suppliers are experts in designing and manufacturing the part for which they are responsible. As a result, the designs are robust and inexpensive. The primary roles of the Toyota organization in this arrangement is to coordinate tier 1 suppliers ensuring the designs fit together and ensuring the materials arrive when and where needed. While there may be inventory at each supply location as well as at the assembly plants, incentive exists to optimize inventory at each site by the use of a kanban system. These practices, including (a) single minute exchange of dies, (b) collaboration with suppliers, (c) just in time deliveries, and (d) kanban, support material flow through the manufacturing process, leading to optimal inventory levels throughout the supply chain (Womack et al., 1990).

The two central themes of the TPS are JIT and respect for people (Ohno, 1988). As the JIT philosophy evolved at Toyota, the focus turned to the elimination of waste in every aspect of the manufacturing process (Thun, Drüke, & Grübner, 2010). The TPS seven forms of waste includes (a) overproduction, (b) waiting, (c) transporting, (d) over-processing, (e) inventories, (f) motion, and (g) defects. Some organizations view not using an employee's full potential as an eighth form of waste. Respecting people addresses wasting an employees' potential mainly by involving production operators in the process of improving product quality through quality circles. The TPS Kaizen (continuous improvement) teams included employees focused on reducing all forms of waste. Thun, Drüke, & Grübner (2010) analyzed data from 188 manufacturing plants involved in the High Performance Manufacturing research project correlated positive manufacturing results based on the extent of TPS implementation.

The TPS practices (independent variables) included as part of the study were the use of (a) kanban, (b) shop floor layout, (c) machine setup, (d) preventive and productive maintenance, (e) machine control through statistical process control, (f) operator training, and (g) workers performing multi-tasks. The outcomes (dependent variables) measured were (a) cost of manufacturing, (b) product conformance, (c) on time delivery, (d) delivery speed, (e) flexibility to change product mix, (f) volume flexibility, (g) inventory turnover, and (h) product cycle time. The data from the 188 manufacturing plants supports the theory that the more thorough and comprehensive the implementation of TPS practices, the larger the amount of improvement. Conversely, failure to achieve high levels of improvement in manufacturing operations was a result of shallow and partial implementation of TPS principles.

Lean manufacturing. John Krafcik, an American engineer working in the Toyota/General Motors joint venture called New United Motor Manufacturing Incorporated (NUMMI) first used the term, *lean production*, in 1988 (Womack et al., 1990). As part of his employment, Krafcik trained in Toyota City and participated in the Toyota Production System. Krafcik observed the Toyota Production System required fewer resources than traditional manufacturing operations needed, making Toyota more profitable (Womack et al., 1990). Lean manufacturing is a term describing efforts to reduce waste in American manufacturing companies and companies across the globe.

As lean manufacturing gained notoriety, companies have implemented various forms of lean manufacturing. General Motors called their implementation, the Global Manufacturing System (GMS). Brondo and Baba (2010) observed the GMS implementation in a longitudinal, exploratory case study beginning in 2003 through 2005, evaluating the effectiveness and progress at the Lansing Grand River Assembly plant that assembled Cadillac automobiles. Several measurements showed significant improvement in the first years as perfect attendance of production workers increased from 23% in 2002 to 91% in 2004, and the Cadillac received J.D. Powers number one ranking for North American Luxury cars in 2003. In the third year of implementation, perfect attendance dropped off to 65%, and the J.D. Powers ranking fell to number 12. Brondo and Baba attributed the drop-off in performance to a breakdown in participation in improvement activities from the production workers.

As assembly lines began to function better through elimination of waste, less time was available for breaks for operators. The solution employed by GMS was to have shift supervisors fill in when production workers went to break. The work became physically demanding with no recovery opportunity. New workers brought into the operation from other General Motors manufacturing plants without the GMS brought their culture with them disrupting the initial changes. The plants began to push rather than pull materials to drive down unit costs producing more materials than necessary. Brondo and Baba (2010) posited the GMS implementation took place on the shop floor without changes in leadership behavior.

In a similar study, an automobile factory in Brazil implemented lean manufacturing principles and enjoyed longer lasting results (Vieira et al., 2012). In this instance, relevant measurements included ergonomic injuries of production operators. Ergonomic injury tracking drove improvement in working conditions for workers as well as productivity improvements. Measurements over a four-year period from 2007 to 2010 showed improvement in attendance, accident incident rate, vehicles requiring rework, and production performance. Vieira, Balbinotti, Varasquin, and Gontijo (2012) concluded concern for the production workers, identified by Ohno as a fundamental principle, seems to have influenced sustained performance.

A supporting study evaluated implementing Total Quality Management (TQM), JIT practices, and Human Resource Management (HRM) as part of lean manufacturing (Furlan, Vinelli, & Dal Pont, 2011). The study included 266 manufacturing plants from nine countries analyzing the synergy between TQM and JIT supported by HRM. TQM practices included (a) Poka-Yoka, (b) operating standards, (c) statistical process control, (d) visual display of information, and (e) housekeeping. JIT practices included (a) lot size reduction, (b) cycle time reduction, (c) quick changeovers, and (d) process reengineering. The HRM practices included (a) decentralized authority, (b) multi-functional training, and (c) broad-based communication. The findings of the study supported the hypothesis that adding JIT after implementing TQM provided higher performance than JIT alone or adding TQM after JIT implementation. In addition, HRM practices enhanced and enabled the implementation of both TQM and JIT. Other tools added to lean manufacturing principles enhanced business results including (a) value stream mapping, (b) one-piece flow, (c) vendor-managed inventory, (d) third-party logistics providers, (e) customer relationship management, and (f) various information technology programs. Following is a brief review of these tools and their relationship to lean manufacturing and the associated potential benefit.

Value stream mapping. A value stream map is a visual representation of process steps from the beginning of a production process to the final destination (Chen & Meng, 2010). The map shows the flow of material and information step to step. The measurements for each process step in a typical value stream map include (a) processing time, (b) lead-time, (c) setup time, (d) distance traveled, and (e) inventory measured in dollars and days. A value stream map points out the number of processing steps at all locations in the value chain (see Appendix A). The more steps in the process, the longer the lead-time and the more places for inventory storage (Mefford, 2011). Value stream mapping aids individuals improving processes to identify opportunities. Chen and Meng

(2010) investigated several Chinese companies implementing lean manufacturing tools-some with success and others without success. The belief is that some of the unsuccessful companies have adapted tool use without tying tool implementation to the business results. The other conclusion is that organizations not mapping value streams are unable to see each form of waste. The value stream mapping tool can help identify tasks as value-added or incidental-not adding value to the customer. Chen and Meng recommended using a future-state value stream map to identify improvements in the process.

Lu, Yang, & Wang (2011) suggested using the value stream mapping tool as a basis to establish an improved manufacturing process. The authors identified a systematic approach to developing the improvement process as follows:

1. create the current state value stream map,
2. evaluate the current process to calculate takt time, defined as the available production time per day divided by the customer demand in parts per day, to create a pull system,
3. create a simulation model identifying supply variability, which includes raw material availability, equipment downtime, process time, yield, and setup times,
4. create a simulation model that will calculate the amount of material or inventory for each process step, resulting in a future state map.

The differences between the current state map and the future state map identify gaps in desired performance of the value chain. Improvement projects close the gap and the future state becomes the new current state. At this point, the whole process repeats. Lu et al. (2011) suggested using a simulation model to calculate an estimate of the improvement in supply variability that should reduce cost and inventory and improve customer service. Fifty-four percent of U.S. manufacturing executives report no visibility beyond the first tier of suppliers in their value chains (Economist Intelligence Unit survey, 2012). Lack of visibility may result in unexpected upsets in the value chain creating uncertainty in the intended outcome. Lack of visibility of material flow between value chain partners makes it difficult to optimize inventory and provide predictable service (Kärkkäinen, Ala-Risku, Främling, Collin, & Holmström, 2010). The value stream map in this instance is the starting point for the improvement model identifying potential wastes in the system. Lean tools supported the development activities determined in the value stream map.

The value stream map has several applications as it creates a visual depiction of the entire process, not just manufacturing processes. In a research paper regarding the value stream mapping process, Popescu and Dascălu (2011) used a value stream map to identify the status of quality parameters at each step in the fulfillment process and explain information flow existing between (a) suppliers, (b) internal processes, (c) distributors, and (d) end customers. The value stream map provides a visual representation of the value added activities, the level of control at each value added step, and feedback and response loops throughout the system. The creation of a value stream map provides a means to prioritize improvement activities, determine who should lead them, determine the people involved, determine target levels, and provide a feedback mechanism determining success. Several examples using value stream maps to improve processes in industry follow.

The value stream mapping concept works equally well within service organizations as demonstrated in the healthcare sector in a study by Acharyulu and Shekhar (2012). The authors created a value stream map defining the value added process steps as (a) marketing and sales, awareness and referrals; (b) inbound logistics, patient registration and assessment; (c) operations, diagnosis and treatment; (d) outbound logistics, discharge; and (e) service, follow-up care and treatment. The value stream map for health care service assisted hospitals in meeting the goals of (a) product availability, (b) minimizing storage space, (c) increasing patient care space, (d) reducing material handling time, (e) reducing costs, and (f) minimizing inventory. India spends approximately 5.2% of India's' gross domestic product on healthcare. The objective of the value stream map in this application is supporting health care cost reduction in India.

In another study conducted in India, Sahoo (2010) applied the value chain framework to assist farmers increase bargaining power by providing a means to market their products. The value stream framework aided manufacturers in India to develop the wine industry on a countrywide basis (Patnaik & Sahoo, 2009). On a global basis, Kannegiesser, Gunther, van Beck, Grunow, & Habla (2009), analyzed the chemical commodities industry using Porter's framework to optimize profits through coordination of functions and decision-making. Italian regional districts expanded profitability and exports by understanding and building global links using the value chain framework (Chiarvesio, Di Maria, & Micelli, 2010).

Advances in technology have helped to improve communication among organizations in value chains (Gilaninia et al., 2011). Improved communication increases the potential for improved processes and products. In another study, the value chain map identified a person in several firms to receive input and output information from the other companies in the value chain (Hemmatfar et al., 2010; Tallon, 2012). One output of a process is an understanding of the essential quality variables whether an actual product, report, or service. Popescu and Dascalu (2011) applied the value chain framework to develop a quality management system for a product improving fit for use and reducing costs. Managers used the value chain map tracing raw materials back to harvesting from the earth to understand the effect of their harvest on the environment and the local economy (Closs, Speir, & Meacham, 2010; Lund-Thomsen & Nadvi, 2010). Leaders of companies using the value chain framework work closely with wildlife foundations to improve the environment while continuing to provide jobs and products (Senge, Smith, Kruschwitz, Laur, & Schley, 2008). The value chain mapping concept of linking activities together to provide a service has reached human resources and talent management as well (McCarthy, 2009).

As previously mentioned, value stream mapping may help to identify information flow between process steps internal and external to an organization. Tallon (2012) evaluated the role information technology (IT) played in improving information flow in value streams to improve customer satisfaction in a profitable manner. In Tallon's research, information sharing internally and externally developed (a) alignment throughout the process, (b) reduced delivery uncertainty, and (c) increased understanding of requirements and expectations. The information sharing resulted in purposeful communication and spillover effects, providing opportunities for organizations to solve problems with support from organizations not directly connected with a process step. Tallon found organizations with visibility to all partners in the value chain made the entire value chain stronger and more responsive as they shared knowledge and expertise. The value stream mapping tool provides a foundation for improvement.

Material flow tools. Vertical integration, customer understanding, JIT, the Toyota production system, lean manufacturing, and value stream mapping are tools supporting improvement of the entire value added process. Included in this section are tools focusing on improving material flows. Using a case study in a Volvo assembly plant, Ellis, Meller, Wilck, Parikh, and Marchand (2010) mapped existing material flow patterns with the intent to optimize material handling costs. A map consisted of lines drawn between multiple trailers feeding multiple docks to various storage locations feeding multiple assembly lines represented material flow. Each of the stopping locations, trailers, docks, storage, and assembly lines represented a node with the material handling equipment aisles representing paths creating a network map. The map provided a means for visualizing (a) constraints in each process step, (b) travel time and distance between nodes, (c) capacity at each node, (d) quantity needed at each node, and (e) daily demand for each part at each node. Using the map helped employees determine the form of the carrier and storage for each part, as well as the delivery schedule. Microsoft Excel software in conjunction with the simulated annealing procedure determined the shortest distance traveled to meet daily production requirements. The focus of this case study was material handling optimization. Employees used the tool to provide information regarding the amount of material needed to satisfy the daily flow of materials in the assembly operation. The analysis was for a single assembly plant, manufacturing heavy equipment trucks for hauling loads on highways. Employees used the map of the material flows to improve material flow throughout the facility.

Auer (2013) used the same material flow analysis to describe the chemical production industry in Germany. Byproducts produced along with primary products make chemical processing complex, and the output of one chemical process may be an input to several other chemical producing companies. Auer’s case study of the process producing methylchlorosilanes and related byproducts demonstrated the use of the value stream mapping process on an individual process, optimizing the income of the methylchlorosilane and three byproducts. An advantage in the chemical process industry relating to inventory is storage tanks limit the amount of input and output materials in the process making it difficult to over-produce. The discussion included as part of the study demonstrated the extensive use of value stream mapping from a large picture perspective, a national industry, down to a single processing step. Following the example of a manufacturing process producing multiple outputs, the value chain mapping tool is also useful to define material flow for recycling and waste streams (Kovačić & Bogata, 2011). Kovačić & Bogata (2011) developed a model that determined the net present value of material flows including recycling. Again, people using the value chain mapping tool visualized material flows inferring the value of recycling activities and waste material created during manufacturing, and after consumption of the product. Visualizing flow using a value chain map aids in measuring both speed and quantity of materials.

Additional tools to reduce inventories. One-piece flow is a concept in which a single part moves through each manufacturing operation by itself until fully produced, rather than as part of a batch (Satoglu et al., 2010). In the manufacturing process with ten steps, there would be ten parts in production, one at each step. Advantages of one-piece flow include (a) reduced cycle time resulting in shorter lead times and quicker response to customers, (b) lower work-in-process inventory resulting in less capital tied up in working capital, and (c) improved quality, verifying requirements after each step, so no defective product passes to the next step. In the research by Satoglu et al.(2010), the five factors required to support one-piece flow include (a) defining takt time, (b) U-shaped manufacturing cells, (c) pull production, (d) standard work, and (e) jidoka. Even with these factors implemented, one-piece flow is difficult to achieve as each process step needs to have equal processing and setup time.

Another concept to improve manufacturing operations is agile manufacturing (Amir, 2011). Agile manufacturing merges the concepts of forecasting and pull systems into the same transaction. In agile manufacturing, the initial manufacturing operations use a forecast until reaching a decoupling point, at which time the remaining activities produce product based on actual customer demand. Implementation of agile manufacturing varies based on the decoupling point in the process. In a buy-to-order implementation, forecasting is at the raw material level and decoupling occurs in the first step of the manufacturing process, pulling materials based on actual orders. Buy-to-order production uses the least amount of work-in-process material.

The next level of agile manufacturing is make-to-order that decouples in the early stages of processing pulling through most of the manufacturing process steps based on orders. Inventory exists in the process steps before decoupling. The next level of agile manufacturing is assemble-to-order products decoupled at the point of production and purchasing components used to assemble the product. Work-in-process exists in all steps of assembly. The next level, make-to-stock, decouples at the distribution center with inventory existing in raw materials, manufactured parts, assembly, and includes finished goods not yet sold. Each step relies on the forecast until the retailer pulls product to place on store shelves. The final process is ship-to-stock. Forecasted volumes drive purchasing and manufacturing decisions and include the retailer. Ship-to-stock requires the highest level of inventory. Amir's (2011) model identified that the more process steps dependent on the forecast, the higher the uncertainty of demand, the higher level of inventory required. Deciding the type of order fulfillment process has an effect on the amount of unsold material and inventory in the value chain.

Vendor managed inventory is a tool implemented between a customer and supplier that transfers the responsibility for material replenishment to the supplier. Bookbinder, Gümüs, and Jewkes (2010) analyzed the potential cost implications of this tool. In general, the customer costs of ordering supplies and storing them are (a) cost to place an order, (b) cost of transportation, (c) costs of receiving, (d) cost of capital to pay the purchase price, and (e) cost to store the item. The costs to the supplier include (a) setup cost to change operations to produce the customers' part, (b) cost to release the shipment, and (c) storage costs while waiting for shipping. The total cost for the system is the sum of both customer and supplier costs.

Bookbinder et al. (2010) assessed the possible outcomes for each party and the total system cost. Depending on the relationship, total costs may increase, decrease, or remain the same. In the case in which the supplier is responsible for managing the inventory, the customer incurs no cost. In the case in which cost of order processing is the same or less with vendor-managed inventory, the customer realizes a reduction in total cost. In some instances, because the vendor plans the order size, the vendor may optimize the batch size and benefit as well, reducing the total cost. Bookbinder et al. indicated the potential for the vendor and the client to be worse off occurs when demand from the customer is uncertain requiring increased setups (increased cost to the vendor) and more frequent shipments (increased cost to the buyer). In the best scenario, the customer and supplier develop a relationship in which sharing information reduces the total cost in the supply chain and both parties benefit.

Kauremaa et al. (2009) evaluated five successful vendor managed inventory (VMI) relationships. Initially, the study included seventeen cases, but twelve did not have a successful implementation, were too new in a VMI relationship, or lacked data to determine success. Successful cases were those adding value to one or both parties and both parties were open to the vendor managed inventory concept. In the five cases included in the study, three patterns of relationship emerged: (a) basic, (b) cooperative, and (c) synchronized. In basic VMI, both parties agree to transfer the responsibility for replenishment to the supplier, and the supplier receives access to required information. Basic VMI relationship provides potential advantages for the buyer.

In cooperative VMI, the two parties share information and resources to create efficiency for both. In synchronized VMI, the supplier has access to downstream information including finished goods demand and incorporates the information into decision-making, potentially providing efficiencies for both the supplier and customer. Based on the evaluation of the five case studies, Kauremaa et al. (2009) concluded four items limit the value of vendor managed inventory, (a) customized products limit the consumer dependency on the supplier, (b) buyer expertise in purchasing limit the extent of reducing replenishment costs, (c) delivery quantity from the vendor may limit the potential inventory reduction, and (d) a small share of business limits the potential benefits to the supplier. The authors defined limits to successfully implementing vendor managed inventory and did not include unsuccessful implementations that may further the understanding of why VMI implementations fail.

Fawcett, Waller, and Fawcett (2010) defined advances in VMI including collaborative inventory with three examples. In one example, Dell managers used several tactics to maintain low levels of inventory (5.18 days), and negative days cash to cash cycle (-5.97 days), meaning customers paid for purchases before suppliers received payment. Dell's managers used build to order products and offered incentives to customers to buy products requiring lower levels of work-in-process inventory. Suppliers stored and owned materials until needed.

Toyota's managers collaborated with suppliers treating them as business partners. Toyota's designers worked with suppliers designing products meeting requirements as well as designing for manufacturability in supplier's operations. Boeing's managers copied this practice in the design and manufacturing of the 787 *Dreamliner* with much less success (Fawcett et al., 2010). Wal-Mart's managers employed an information system to suppliers providing real-time inventory levels across the entire Wal-Mart distribution and store network in the third example. This information system allowed the sale of approximately 33% of products before paying for them.

In the cases mentioned above, the Toyota practice benefited suppliers and Toyota. In the practice used by Dell's managers, customers pay for goods before receiving them: suppliers own the material until the last moment benefiting Dell operations only. Wal-Mart's managers allowed suppliers to view inventory levels in real time and required suppliers to respond to demand benefiting Wal-Mart operations and somewhat for suppliers. Fawcett et al. (2010) noted collaboration can fail if (a) partners do not share information, (b) one partner takes advantage of the other by pushing out payment terms or devising ways to deduct from paying in full, or (c) forcing one partner to take all the risk or carry the entire inventory. In a healthy situation, taking advantage of supplier expertise allows the purchasing organization to focus on its core business (Laosirihongthong, Tan, & Kannan, 2010).

Toyota's model included both production *and* inventory integration. Prasetyo, Luong, and Lee (2010) defined integrated vendor-buyer relationships as benefiting vendor and buyer and others in the value chain. Prasetyo et al. reviewed two components of vendor, supplier relationships, Economic Lot and Delivery-Scheduling Problem (ELDSP), and Joint Economic Lot Sizing Problem (JELSP). ELDSP considered raw material at the vendor site (the vendors finished goods) and incoming raw materials at the buyers' location. Optimizing the lot size of materials provided benefits to both vendor and purchaser. The JELSP accounted for work-in-process and final product of the manufacturer as well as the final product at the distribution point. Optimizing the materials in the JELSP benefited the manufacturer and distributor. For this integrated relationship to be successful, both parties must benefit. In this form of relationship, the possibility exists one party has a superior advantage and may make an agreement one-sided. If the relationship is not benefiting each party, the relationship is unlikely to continue. Prasetyo et al. posited competition between companies has changed to competition between supply chains. Minimizing the total cost of delivering the product is essential to every partner in the supply chain.

Integrating information technology enhances supply chain collaboration among firms in a product value chain. Chang and Graham (2012) completed a qualitative case study including six firms analyzing success factors in supply chain collaboration and electronic commerce. Key success factors identified included (a) developing an understanding of industry conditions and customer needs; (b) flexibility to adapt to changing environments including customer, supplier, and industry trends; (c) managing change within the supply chain partnership; (d) trust with supply chain partners including sharing sensitive, proprietary information providing valuable information to partners; and (e) enhancing customer satisfaction through receiving immediate feedback from customers. These success factors depend on accurate, up to date information that information technology can provide. A benefit of supply chains with integrated information is the correct amount of proper inventories is in the right place at just the right time. Information technology integrated between firms within a supply chain is a significant investment for stakeholders. Along with financial investment, developing relationships with supply chain partners may enhance potential benefits for all parties involved.

Schloetzer (2012) found partners with comprehensive information sharing are more likely to have increased financial performance, sales growth, and profitability. Often, partnerships require specialized tools and software to do business creating a barrier for others attempting to enter a partnership, increasing the chances of renewing contracts with existing partners. The specialized tools and software also create a barrier to leaving the partnership. Schloetzer also noted, the larger the difference in firm equity, the less chance for mutual benefit. Gilaninia et al. (2011) found accurate and timely information led to improved supplier responsiveness and improved supplier efficiency. These two factors resulted in improved supplier performance. The opposite also proved to be true: inaccurate, untimely information led to reduced supply chain responsiveness, reduced efficiency, and poorer performance.

Third-party logistics is another practice involving collaboration and integration between firms in the same supply chain. In third-party logistics, firms work with providers specializing in warehousing and transportation services. This practice served the same purpose as other collaboration and integration activities, removing costs from a value chain. In one example cited by Jayaram and Tan (2010), a firm reduced pipeline inventory from 53 days to seven days following implementation of third-party logistics. Not all third-party logistics relationships are successful. Jayaram and Tan surveyed senior purchasing, supply, and operations managers from U.S. firms of varying sizes. The study included 250 firms involved in third-party logistics and 150 companies not participating in third-party logistics. Jayaram and Tan did not find data supporting a difference between firms with or without third-party logistics. Evidence supported firms using selection criteria and continued evaluation of the criteria achieved improved performance. In a similar study Partida (2012) surveyed supply chain professionals from 52 shipping firms involved in third-party logistics that showed inventory carrying costs and service levels improved with companies using a third-party logistics provider.

Barriers to Optimizing Inventory

A thorough search of literature identified several items that contributed to the creation of inventory that included (a) the cost accounting system, (b) cost accounting method, (c) incentives to reduce unit costs, (d) the risk of running out of stock, (e) lack of visibility (f) collaboration with value chain partners, and (g) the ten reasons listed by Willems (2012). In a survey conducted by Chief Supply Chain Officer Insights (2011), barriers to effective inventory management included (a) inability to optimize the entire network-55.9%, (b) demand volatility-45.9%, (c) functional silos-45.8%, (d) lack of technology integration-45.2%, and (e) misaligned metrics-44.6%. Described next are tools used to eliminate and optimize inventory. Information on why these well-intended tools fail in some cases, do not live up to expected results or in some instances, made operations worse follows.

Hicks and Matthews (2010) completed a literature review of failed improvement implementations identifying several reasons for failure. All reasons fell under leadership responsibility and included (a) lack of commitment from the organization including lack of training and resource support, (b) lack of management involvement and direction, (c) lack of leadership communication of improvement activities and benefits, (d) leadership's reactive approach to implementation, and (e) not allowing enough time to understand the development activity or the effect of changes in the organization. Using the wrong tools or using the right tools incorrectly resulted in failure. Lack of communication regarding improvement plans increased an organization's resistance to change.

Additional reasons for failed implementations included incomplete implementation of change through loss of interest by the leadership group or lack of clear understanding of the total program and multiple initiatives with conflicting goals. In a qualitative case study of failed improvement programs, Vicencio-Ortiz and Kolarik (2012) found leaders of continuous improvement programs in operations struggled to deliver expected results because of lack of formal tools or methods to assess potential influences on interrelated processes during the design and implementation phase of the program. The recommendation by the authors was to create a cross-functional team including people from functional areas involved as members of the team.

In a case study exploring the failure of sustainable lean manufacturing implementation in one company, Turesky and Connell (2010) found possible causes included top management commitment to change is not visible or frequent, and top management does not demonstrate a clear commitment through their behaviors by providing needed resources, or regular, ongoing communication. If the workforce perceives lack of commitment from top management, commitment to change is unlikely.

The authors suggest communication should be open and move up and down through the hierarchy of the site. Communication enables clear understanding of common goals. Turesky and Connell posited a lack of ongoing training is another significant factor to not being able to sustain change. Training an organization in new behaviors and new tools enhances the chances of success and employee buy-in of the change. Project selection is critical and the project needs to benefit those involved. Last, frequent sharing of relevant measurements of the implemented changes creates individual ownership of both the project and the results. The research took place in one facility of an organization making a concerted effort to implement lean manufacturing over an eight-year period. Two engineers, one shift supervisor, and three hourly production employees took part in the survey for their insight after the failed implementation.

Čiarnienė and Vienažindienė (2013) found similar results researching literature finding two primary barriers to sustainable lean implementation as people related barriers, and organizational related obstacles. People related barriers included (a) focus on tools instead of a focus on people, (b) resistance to change, (c) lack of understanding of lean principles and techniques by both leadership and employees, (d) poor communication including use of jargon, and (e) selecting inappropriate team members. Focus on tools instead of people is a mistake corporations make limiting the success of lean implementations (The Shingo Prize for Operational Excellence, 2012). Organizational obstacles included (a) lack of resources, (b) not incorporating lean into the business strategy, (c) not sharing results, (d) hierarchy getting in the way of collaboration, and (e) functional silos preventing teams from compatible goals and working as a team.

Research Method and Design

As Yin (2013) prescribed, research explaining answers to *why* and *how* questions fit the case study method. Bounded studies, with no control placed on variables, studied in real time are appropriate attributes of case study method. As reported by Zivkovic (2012), business researchers frequently use the case study method. An identified strength of the case study method is the freedom to use any relevant source of information pertaining to the case. Using multiple sources of information strengthen the researchers' findings. Multiple sources of information provide a broad range of viewpoints on the object or process under study. Multiple perspectives on researched topics allow researchers to discover new meanings and approaches (Baig & Akhtar, 2011). As in the multi-case study conducted by Zivkovic, many businesses related case studies defined the unit of research to be an organization. Chang and Graham (2012) used a case study method defining six companies representing six different cases in their research on supply chain collaboration. Vicencio-Ortiz and Kolarik (2012) used a case study method describing three companies representing three cases evaluating improvement projects. Van der Krogt, Geraghty, Salman, and Little (2009) used a case study design representing two cases as separate companies. Wolf (2011) identified four companies to represent four cases in a study of sustainable supply chains. Using a company is a common research unit defining boundaries for a case study.

In this study, a single value chain founded on Porter's (1998) value chain model originally presented in 1985, established the research unit. An advantage of the value chain as the research unit was value chain modeling defined the process steps, process locations, measurements at each process step, and the people responsible for creating and measuring the outcomes at each step. The value chain model is conducive to creating visuals to identify and organize sources of information adding to the depth and detail of the research. Porter's model also identified entities indirectly supporting the value chain, which provided additional sources of interpretation and information. Baig and Akhtar (2011) used a value chain within a single company as the boundaries in their research analyzing the value of using supply chain management tools. Several researchers used a value chain map as the case unit to study the effect of lean manufacturing tools (Chen, Li & Shady, 2010; Chowdary & George, 2011; Ellis et al., 2010; Gurumurthy & Kodali, 2011; Lu et al., 2011). Using case study design for value chains within companies is a common practice for business research. The extensive use of the value chain model for research in previous studies provided the rationale for using the value chain model in this study.

Transition and Summary

Section 1 included a description of the background to this research project identifying an opportunity to improve operations and profitability by optimizing inventory levels in manufacturing. Previous authors have focused much of their research on surveying and interviewing top management and supply chain experts to gain an understanding of reasons for inventory creation and maintaining excessive levels of inventory (Čiarnienė and Vienažindienė 2013; Hicks & Matthews, 2010; Turesky & Connell, 2010; Vicencio-Ortiz & Kolarik, 2012). Several researchers provided information on reasons for inventory, methods to optimize inventory and results of organizations implementing improvement processes. An important factor in understanding the opportunity and results is the variations managers' use in the valuation of inventory and definition of optimal levels.

Included in Section 2 is a description of the research method and design. Porter's (1998) value chain model provided the basis for the conceptual framework. The design included (a) a description of an existing product value chain, (b) the method identifying interview participants, (c) the method for collecting and summarizing the information, and (d) a systematic procedure for the entire research. Included in Section 3 is a (a) summary of the findings, (b) applications to professional practice, (c) implications to social change, and (d) recommendations for action and further study.

Section 2: The Project

This section of the study describes the research method and design used to answer the research question and the rationale supporting the selection of both the research method and the research design. The research design defined the selection criteria for potential participants and the interview questions. The design description included the process of (a) collecting, (b) recording, (c) documenting, (d) analyzing the information, and (e) ensuring ethical research. Last, included in this section is information demonstrating the reliability, credibility, and transferability of the study.

Purpose Statement

The purpose of this qualitative case study was to explore strategies managers use to optimize and control inventory levels in manufacturing processes. The manufacturing process in the study involved a single, common household product in the Midwestern region of the United States. Inventory is an important asset accounted for in financial statements and was the focus of this study. Acquiring inventory uses a firm's valuable resources. Misuse of any organization's resources makes it difficult for an organization to remain viable. Several documented methods and philosophies exist explaining how to optimize inventory levels in business, including (a) JIT (Wantuck, 1989), (b) the Toyota Production System (Ohno, 1988), and (c) lean manufacturing systems (Womack et al., 1990). Leaders in many organizations have implemented these philosophies with varying levels of success. This study investigated the strategies managers use to influence the success of optimizing inventory levels from the perspective of the manager of the person deciding how much material to purchase or manufacture.

Porter's (1988) value chain model provided a framework for this research. The value chain model defined the functions needed in an organization and the role they play in delivering the product to customers. The value chain model was the basis for selecting participants in the study, as participant selection was by area of responsibility. The model provided a means for identifying functions directly influencing inventory levels, as well as those having an indirect effect. The findings from this study may provide useful information for optimizing inventory levels in manufacturing operations. Optimizing inventory levels minimizes the misuse of resources. On a local level, optimal use of resources provides a better chance of business success. Business success increases the likelihood of continued employment and job creation. Business success results in profits, providing tax dollars for community investment. Optimal use of resources minimizes manufacturing costs, providing products to consumers at reasonable prices. On a larger scale, optimal use of resources improves the sustainability of the environment. In a broader sense, the results of this study may contribute to the improvement of an organization's *triple bottom line*, which includes (a) environmental, (b) economic, and (c) social performance and practices (Hollos, Blome, & Foerstal, 2012).

Role of the Researcher

The role of the researcher in a qualitative study is to capture and document the experiences and interpretations of events from participants (Frels & Onwuegbuzie, 2012). The researcher needs to approach the study with an unbiased, open mind regarding the participants, the subject matter, and the data to create a usable, valid interpretation of the results of the study. The creation of the value stream map defined the product flow used in a framework for the study beginning at the assembly stage (see Appendix B). The assembly stage was the starting point for the research, predicated on access to information and participants. Manufacture of the product happened at my place of employment, and while employed by the same company, potential participants reported through a different organization. A letter of cooperation from an officer of the company granted access to production information, including (a) inventory levels, (b) access to managers defining and implementing strategies, (c) individuals ordering materials, and (d) persons with influence over their decisions (see Appendix C).

The data collection process included (a) interviewing participants using a semistructured format, (b) reviewing system and software rules and constraints, and (c) collecting inventory data at each process step. Interviewing was either face to face or over the phone. Inventory data included the preceding 12 months of on-hand inventory in terms of days of use, the standard deviation of the average, and the age of the oldest load of material at the time of data collection.

Participants

The value chain map determined potential participants (see Appendix B). Because the process under study was internal to one manufacturing company, various company employees comprised the potential interview participants. The participants work in four different geographic locations across North America. Each internal process step may contribute up to six potential participants, including managers and supervisors of (a) purchasing agents, (b) supply chain analysts, (c) operations and production, and (d) engineers. This group of potential participants supports the product value chain directly and may number as many as 40 people. Several departments' members indirectly related to the product value chain contributed to the body of knowledge as well. Departments included (a) the corporate supply chain organization, with over 100 members; (b) the corporate purchasing organization, with over 100 members; and (c) the corporate lean manufacturing organization, with over 30 members.

Diverse groups process information and solve problems differently, providing broader perspectives for developing and implementing solutions (Foster, Wallin, & Ogden, 2011). Diversity in areas of responsibility and leadership levels increased the variety of answers to interview questions. While the total potential population consisted of more than 300 personnel, the sample size for this study was 20 managers and direct reports in the supply chain. To ensure that findings and conclusions agreed with the answers provided to the questions, each interviewee acknowledged correct information through member checking. *Member checking* is the practice of providing respondents the opportunity to check the interpretation the researcher gleaned from the interview (Carlson, 2010). The corporate vice president responsible for lean manufacturing operations provided a letter of permission to undertake a study (see Appendix C). All participants signed a letter granting permission to use their responses as part of the data (see Appendix D).

I employed purposeful sampling, focusing on key individuals within the selected value chain. Purposeful sampling provides abundant information as participants respond to questions in their words (Suri, 2011). Purposeful sampling through interviewing provided a human aspect to inventory generation versus inventory data only (Roy, Zvonkovic, Goldberg, Sharp, & LaRossa, 2015). The interviewees provided names and access to the next level in the value chain and names of other people influencing their decisions. Adding interview candidates in this manner reflected my use of snowball or chain sampling (Suri, 2011). Processes existed to ensure that participants' responses and data collected remain protected and confidential. Interviews took place in a private office or on a personal phone line. Telephone interviews were necessary in 16 cases in which geography or scheduling was an issue. In all instances, recording was with a Samson Meteor Mic microphone in conjunction with Audacity software on my personal password-protected computer, which recorded questions asked and each participant's response. Coding and safely storing participants' identities during and after the completion of the study ensured confidentiality. Information regarding process materials included general terms such as *mixing powder* or *liquid coating* to describe the material for each process step in the value stream map, so that inferences concerning the company and product would not be possible. Storage of information including consent forms is on a personal password-protected computer and in a personal file cabinet. I will burn paperwork and erase electronically stored information 5 years after the completion of the study.

Research Method and Design

Method

Three methods for conducting research are (a) quantitative, (b) qualitative, and (c) mixed, which is a combination of quantitative and qualitative (Zivkovic, 2012). Selecting the appropriate research method depends on the answers to three questions;

namely (a) what is the form of the research question, (b) are the events controlled, and (c) are the issues historic or current (Yin, 2013)? Quantitative analysis is appropriate when defining relationships between variables and events. A study using quantitative research begins with a theory or hypothesis that certain variables or events affect other variables or events. Quantitative research may involve multiple paths to establish relationships. Exploring the relationship of a condition or measurement with respect to the outcome, and determining whether an effect on a resulting condition or value exists, describes one path. An example of a quantitative research design is a comparison of assessment test scores determining whether test scores predict the job performance of the test taker (Papadopoulos, 2012). Papadopoulos (2012) determined whether evidence existed that an applicant with a high test score had better job performance than an applicant with a lower test score.

Quantitative analysis is also appropriate when the researcher controls one or several variables, seeking to establish a relationship between the controlled variable and the dependent variable or resultant. A study in which the researcher randomly assigns and controls different levels of independent variables and measures the outcome of the dependent variable is another example of quantitative research (Jivani, Patel, & Jivani, 2012). In quantitative research, the questions answered are whether the variables or events relate to one another and, if related, what the effect or size of the relationship between the variables or events is. In quantitative research, independent and dependent variables and events require measuring, coding, or possibly both. The result of quantitative analysis is typically a mathematical formula defining the estimated relationship, or a statement signifying that there is no evidence that a relationship exists. In this research study, there was no testing of theories or hypotheses. Through this research, I identified strategies that managers implemented for controlling and optimizing inventory levels.

Another method of conducting research is mixed methods research, which employs both qualitative and quantitative methods. Mixed method research provides advantages of both methods, enhancing the validity of the results (Kipo, 2013). Mixed methods studies follow one of two approaches. The first approach is sequential, using one research method first, followed by the other. An example of this approach is conducting interviews with a group of experts to ascertain ways to measure an item-qualitative, and measuring and testing the information to determine the validity of the measurement system-quantitative (Papakiriakopoulos & Pramatari, 2010). The other approach, mixed methods research, combines both qualitative and quantitative methods in collecting and testing data from interviews, surveys, and analysis tools (Bendavid, Boeck, & Philippe, 2010). In this study, I explored strategies affecting inventory levels using qualitative research. If this research continued by testing strategies identified to determine whether a relationship existed between strategies, independent variables, and inventory efficiency, the dependent variable, this research would become a mixed methods study. Relationship testing was not part of this research design, and the mixed methods design was not appropriate for this study.

Qualitative researchers explore how and why questions through observations and interviews of people involved in the research topic (Hooper, 2011; Roy et al., 2015;

Foley & Timonen, 2015). Conditions for a qualitative study include three factors: (a) observation does not include control of variables, events, or participants; (b) questioning is not restrictive, allowing the participants to express personal opinions of how and why the phenomenon is occurring or in existence; and (c) observation of events, people, and variables occurs in the natural setting. This research met all three of the criteria, which was the basis for selecting the qualitative method. Observation of the system occurred without attempting control of variables or participants involved in the research, meeting the first criterion. The interview questions were open-ended to allow participants to express answers in their words, meeting the second criterion. The setting for the study was in the natural environment of the manufacturing process, and information and observations were part of the existing system, meeting the final criterion for the qualitative research method. Qualitative researchers may use various designs, one of which is the case study, used for this research. The following question was the basis for this study: What strategies do production managers need for efficient inventory control? A qualitative study was relevant to this research question, as the participants answered open-ended interview questions based on their experience and perception of the situation.

Research Design

A qualitative, exploratory case study design was appropriate to answer the research question concerning strategies for controlling and optimizing inventory by reviewing one value chain in detail. The design met the criteria for qualitative, exploratory, case study research as defined by Yin (2013), as (a) questions were how and why, (b) I did not control events as the researcher, and (c) the study pertained to real-life events. I explored the strategies managers use to determine how and why levels of inventories exist as they do. How and why questions are exploratory, allowing participants to explain answers in their words rather than limiting them to a number of choices. Beverland and Lindgreen (2010) also recommended that a case study have boundaries. A single value chain including inputs, process steps, and outputs established the boundaries of the study. This research involved collecting information rich in content from managers designing and implementing strategies to manage inventory and individuals responsible for using the purchase orders and manufacturing orders at each step in the value chain process.

A case study of a single product value chain is appropriate to explore strategies answering what, why, and how research questions (Wolf, 2011). A case study allows the researcher to explore all aspects of the system, process, or phenomenon (Zivkovic, 2012). The case study design is open to reviewing multiple sources of information, including interviews across levels in an organization and related documentation and numerical data. Wang, Quesada-Pineda, Kline, and Buehlmann (2011) used a value stream map in a case study to explore a current-state furniture-upholstery process and make suggestions for improvement. The design of the furniture upholstery study was similar to the design of this study.

I considered several other research designs and rejected them for various reasons. Grounded theory analysis did not fit because it has no boundaries related to time, place, or unit of analysis (Foley & Timonen, 2015). Ethnographic researchers focus on behaviors, beliefs, and norms. In ethnographic design, observation is the primary data collection tool (Brondo & Baba, 2010). An ethnographic research design was not appropriate, as observation of the entire system was impractical and ethnography would not have enabled the consideration of factors outside of cultural behaviors. A phenomenological research design was not an acceptable choice because no event or phenomenon occurred that affected supply chain analysts (Ishaque, John, Tarig, & Qaisrani, 2012). The final design considered was narrative research. Narrative research was not an appropriate fit to answer this research question because it consists of story-telling experiences of individuals and organizations in everyday life (Adorisio, 2011).

Population and Sampling

A valid sampling plan requires (a) selecting the appropriate population from which to choose participants, (b) selecting the proper sample size, (c) selecting the appropriate sampling method, and (d) selecting the appropriate method of determining participants (Robinson, 2014). The potential population for this case included all people influencing the development, design, deployment, and implementation of strategies for optimizing and controlling inventories in the company manufacturing a product in the selected value chain (see Appendix B). This potential population consisted of approximately 100 people. The appropriate population also included people indirectly involved in *influencing* the levels of inventory in the value chain. The people influencing inventory decision makers included (a) the corporate supply chain organization, (b) the corporate purchasing managers, (c) the corporate human resources managers influencing hiring practices and employee compensation, and (d) the Lean Six-Sigma analysts. This potential group of participants consisted of approximately 200 people, resulting in a total eligible population of more than 300 persons. Interviewing 20 individuals from this population with the use of member checking led to data saturation.

In the qualitative research method, interviewing continues until there are no new concepts and information is redundant (Francis et al., 2010; Marshall, Cardon, Poddar, & Fontenot, 2013). Several factors helped determine the appropriate sample size for a study including (a) the homogeneity of the population, (b) multiple samples within the study, (c) the number of selection criteria, and (d) resources and time available (Mason, 2010). Theme saturation occurs when no new themes emerge. In a review of 179 case studies, Mason found the number of the interviews ranged from 1 to 95 with a mean of 36 and a standard deviation of 21.1. Theme saturation occurred in this study with 20 interviews covering each function and process step.

Purposeful sampling strategy helped to define participants who can provide insight in answering the research question (Suri, 2011). Purposeful sampling was an appropriate strategy for the data collection process in this study. The process for selecting participants began by asking managers and supervisors directly involved in managing the internal manufacturing steps as identified in the value chain map. Interviewing people directly responsible for managing the tools, people, and systems creating inventory provided rich information as they are responsible for purchase orders and manufacturing orders to the shop floor, and setting levels of safety stock at each distribution point.

The interviewees included in this study are responsible for strategies managing inventory levels between process steps in the value chain. As part of their responsibility, the interviewees determine (a) the rewards, (b) consequences, and (c) compensation for the performance and behaviors of people placing actual orders. Included in the interview pool were supervisors and managers in (a) corporate logistics, (b) warehousing, (c) supply chain, and (d) lean management groups. Interviewing occurred in random order predicated on individuals' schedules.

Findings from this study may aid managers responsible for manufacturing operations improve material flow by reducing suboptimal levels of inventory. Improving strategies for optimizing inventory may decrease resources needed to purchase, manufacture, move, and store materials. The interview questions were open-ended, encouraging participants to express ideas in their own words. Participants were eager to answer questions and discussed their perspectives because of the potential gains from the study, and fit with corporate priorities. To ensure confidentiality and a comfortable environment, the participant selected the location for the interview. Because of geography and schedules, there were four face to face interviews with 16 occurring via the telephone. The four face to face interviews occurred in a private office. The 16 telephone interviews used a speakerphone in a closed office and the participants' private line.

Ethical Research

A senior officer of the company granted permission to conduct this study (see Appendix C). The consent included permission to (a) interview employees associated with the value chain under study, (b) capture inventory data, (c) economic purchase order, and (d) economic manufacturing order quantities. Each participant received an individual letter of consent granting use of information collected during the interview (see Appendix D). The consent letter included a place for the employee's signature granting the interview and the use of the information collected during the interview. Participants had the option to withdraw from the interview process before beginning the interview or following the interview. There were no consequences for non-participation, and no one chose to option out. A review of 12 months of inventory data triangulated the information collected from the interviews supporting the validity of the study's findings and conclusions.

Coding participant names and storing them on a personal computer hard drive with a backup on a flash drive for 5 years with password-protected files assured confidentiality and protected the identity of the participants. To ensure sustained confidentiality after 5 years, I will erase recorded interviews and shred written information. Interviewees received no incentives. The Walden IRB approval number is 11-24-14-0352019.

Data Collection

Instruments

In this study, I was the data collection instrument, contacting each participant by telephone explaining the purpose of the study and the data collection process. The tool for collecting information was a one on one interview asking the 11 questions presented in the interview question section. The participant received an explanation of how the process would occur using the recording device, the translation process, and follow-up member checking. To ensure accuracy, reliability, and validity, I recorded interviews using a Samson Meteor Mic microphone in conjunction with Audacity recording software on a personal laptop computer. The Samson Meteor Mic microphone and Audacity software tools are standard, tested tools. The information gathering process included collecting data from the corporate manufacturing reporting system to determine inventory levels for each input, work-in-process, and finished-product at each process step. This information strengthened the results of the study through triangulation. Policy information and job descriptions were available on line in the corporate database. I employed recorded interviews, the manufacturing reporting system, and corporate databases accessed through a computer as the data resources for this study.

Research protocol. The following systematic instructions describe the research protocol for this study.

1. Identify the value chain for study
2. Obtain a letter of cooperation from authority in the organization in the study
3. Create the value chain map
4. Identify the functions affecting the area of study
5. Identify reports, policies, and tools affecting the area of study
6. Identify employees with functions affecting the area of study (potential participants)
7. Contact potential participants and arrange interviews
8. Have participants sign a consent form
9. Interview participants asking interview questions in section 1 and record interviews (Audacity software in this study)

10. Document interview event into journal (Microsoft Excel software)
11. Gather inventory data (the number of loads over the past 12 months and average use) for each material in the value chain using the manufacturing operations database reports
12. Transcribe interviews word for word into a document (Dragon Naturally Speaking and Microsoft Word software)
13. Review transcribed information with interviewee verifying accuracy (member checking)
14. Match interview documents and inventory control strategy with inventory data
15. Analyze interview information, inventory data, policies, and tool parameters using Microsoft Word and Excel software
16. Code the transcripts by job title and strategy
17. Search for common themes, concepts, phrases and words
18. Develop conclusions
19. Document results
20. Safely store data
21. Destroy data after 5 years

Data Collection Technique

The data collection process followed the research protocol's steps 7 through 14. Data collection through interviewing began with step 7 in the research protocol including (a) scheduling interviews with a phone call, (b) explaining the study, (c) explaining rationale for performing the study, and (d) the individuals' role in the study. The corporate directory listed phone numbers of potential participants. The value chain map identified interview participants based on the process steps in the map. Part of the discussion during the phone call covered the need for a signed consent form, and measures taken to (a) protect identities, (b) answers, and (c) data collected regarding the process and results. Participants received a follow-up email with a meeting invitation to a private office or a call to a private phone line ensuring confidentiality and a comfortable environment. As part of the email, I provided participants a copy of the letter of approval signed by the senior officer of the company and a letter of consent for their perusal. Participants accepted the meeting invitation or proposed an alternate time.

Before the interviews began, the participants provided a signed letter of consent. All interviewees received an explanation of (a) the use of information collected, (b) assurance of protection of their identity, and (c) answers to any questions regarding the study. In the case of telephone interviews, respondents received the consent form ahead of the interview and consented to allow use of the interview data before beginning interviewing. Interviewees returned the signed cpnsent form through internal corporate mail. In all cases, I used a Samson Meteor Mic microphone in conjunction with Audacity recording software on a personal laptop computer to record interviews. Following the completion of the interviews, I transcribed the recordings by repeating the interviews into a microphone connected to a computer with Dragon Naturally Speaking software and edited as needed to ensure accurate transcription. The open-ended questions listed in the Data Analysis Heading encouraged participants to express responses in their terms. Steps 1 – 11 defined in the Research Protocol procedure of the Data Collection - Instruments section described the data collection process. Figure 3 is a visual representation of the data collection and analysis process.

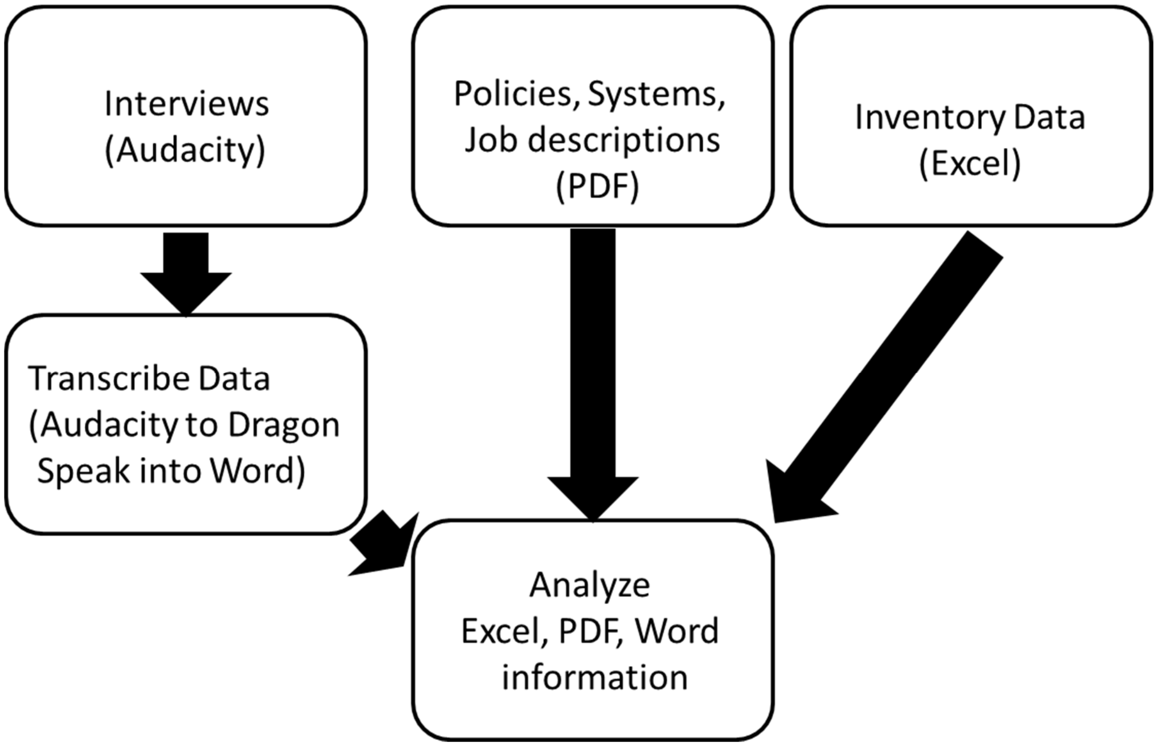

Figure 3. Data collection and analysis.

Pilot studies are common in complex research projects to (a) test data collection processes, (b) check equipment associated with the study, and (c) provide information on intervention and control methods. A pilot study was not necessary for this research project as (a) the structure is clear, (b) there is a definition of the potential pool of participants, (c) testing of equipment was not required as no equipment was used, and (d) no intervention or control methods were included as part of the study.

Data Organization Techniques

A record of each interview includes (a) the job title, (b) the organization the person represents, (c) the date, (d) start and end times, (e) location, (f) the setting, and (g) notes using the journal shown in Table 4's interview spreadsheet template (Microsoft Excel software). Each interview received a code number. Each participant reviewed

Table 4

Interview Journal

Code #	Job Title	Organization	Date	Time	Location	Setting	Notes

a summary of the interview information through member checking to ensure the summary reflected the participants' answers. To organize the data, (a) storage of the value stream map; (b) transcribed Word documents; (c) Excel files with inventory information, formulas, and job descriptions; and (d) corporate data files, are in electronic files on both a personal computer and a flash drive. Organization of files was by source and topic.

Data triangulation strengthens the results of the study. In this case, collection of inventory data from the corporate database provided a measure of inventory for each strategy. Comparing participants' responses regarding strategies with corresponding inventory measures increased the validity of the findings of the study. Each purchased or manufactured item has a unique number. Purchasing or producing an item the first time requires identifying both the purchasing agent responsible for negotiating the terms of the contract and the supply chain analyst responsible for managing the item. Each item requires several parameters as part of the database record called an item master. The parameters include (a) economic order quantity, (b) minimum order quantity, (c) average monthly use, (d) reporting unit, (e) billing unit, (f) dimensions, (g) shelf life, (h) lead time in days, (i) safety stock quantity, (j) inventory value, (k) storage location, (l) load type, (n) minimum and maximum on-hand quantities, and (o) weight per unit. These data are part of the record included in inventory data.

The electronic filing system included in Microsoft Windows 7 Professional operating system provided the means to organize (a) journal spreadsheet information, (b) policies and procedures, (c) job descriptions, and (d) other pertinent information for this study. Storing all files including (a) audio recordings, (b) interview transcriptions, (c) the journal spreadsheet, and (d) other related documents on a personal computer hard drive with backup on a flash drive for 5 years with password-protected files assured organized information. To ensure sustained confidentiality, after 5 years, I will erase recorded interviews and shred written information.

Data Analysis

Using qualitative data analysis provides researchers the means to evaluate various forms of information regarding the topic, convert the information into knowledge, and knowledge into wisdom resulting in new ideas (Chenail, 2012a). Qualitative data analysis uses various methods such as (a) the framework approach (Smith & Firth, 2011), (b) reading line-by-line (Chenail, 2012b), (c) pattern matching, (d) explanation building, (e) time-series analysis, (f) logic models, and (g) cross-case synthesis (Yin, 2013). These methods are useful analyzing qualitative data separately or in combination with one another. Transcribing audio data into a document format is helpful when using these methods. In this study, Dragon Naturally Speaking speech recognition software was a tool used to transcribe Audacity audio recording software into Microsoft Word software documents. Audacity audio recording software was readily available and easy to use. Dragon Naturally Speaking software is inexpensive and easy to use. The data collection, organization, and analysis software are relatively common, proven research tools. To support analysis of the information, I reviewed the transcribed documents along with (a) documented policies regarding performance recognition and rewards, (b) operating procedures and calculations determining purchasing contracts and manufacturing order size, (c) job descriptions, (d) mission and vision statements of organizations, amd (e) inventory data.

Originally, I planned to analyze all data using NVivo 10 software as the software is designed for qualitative analysis and can accept multiple forms of input including videos, pictures, social media, and documents. A free 30 trial subscription was available to become familiar with the software. Reviewing two NVivo 10 tutorials on Youtube led to the understanding input data required unique reformatting to enable analysis. The interview responses were already in Word documents that documents required no reformatting and were easily manipulated to sort the answers by questions and find common themes. The data in this study afforded rapid placement in Word documents and Excel spreadsheets and did not require the capabilities NVivo 10 offered. Inventory data was sorted by the identified strategies and entered into an Excel spreadsheet. The material control database was the source of the inventory data and the daily inventory graphs. Originally, the plan was to sort the inventory data by supply chain analyst and supervisor. After reviewing the interview data, the daily inventory graphs and observing the process flow through the production operation, it seemed logical to sort inventory data by strategy versus supply chain analyst. Sorting by the strategies discovered through the interviews provided insight into successful strategies that sorting by analyst did not.

Interview participants included managers, supervisors and their direct reports in the following roles: (a) purchasing agents, (b) supply chain analysts, (c) production operation leaders, (d) product and process engineers, (e) division manufacturing operations managers, (f) logistics analysts, (g) warehouse management, and (h) lean manufacturing managers defined by the value chain model. The following list contains the standard interview questions for all participants.

1. Is the value chain operating at an optimum inventory level?
2. How do you measure inventory efficiency in this value chain?
3. Describe the process and criteria for selecting a supplier and manufacturing location.
4. What role does inventory play in your purchasing and manufacture ordering decisions?
5. What parameters determine the amount of material ordered and manufactured?
6. What tools and systems do you use when deciding to place orders?
7. How is just-in-time (JIT) and lean philosophies included in your decision-making?
8. Who owns the inventory in the manufacturing process?

9. What, if any, inventory-level criteria are you measured on for your annual performance review?
10. What is the most challenging task to managing input and output inventory in your value chain?
11. What suggestions do you have for improving the material flow in your value chain?

Analysis of the inventory data determined (a) the range of units over the previous 12 months, (b) age of the oldest load, (c) the number of loads, and (d) material dollar value. While these measures determined storage requirements and cash used to fund operations, they may be misleading in exploring inventory levels. For example, an expensive material may show a high inventory value and represent a few days of required material while an inexpensive material may show a lower dollar value of material, yet represent months of a supply requirement. The same may be true for a bulky product requiring several load spaces, yet only a few days of supply, versus a small product requiring few spaces but representing months of supply.

The analysis of the collected information revealed the strategies managers use to (a) determine inventory levels, (b) determine causes of accumulated inventory, (c) identify steps in the process with excessive inventory, and (d) determine the positions with the most influence in the creation of excessive inventory. This analysis supported answering the research question: What strategies do production managers need for efficient inventory control? Porter’s (1998) Value Chain framework provided a visual representation of the production system. In a manufacturing operation, the value chain framework provided (a) insight into the locations of inventory, (b) people in the value chain organization responsible for decisions creating inventory, and (c) support people and policies affecting the decision makers. The information collected from each process step related directly to the visual representation of the process under study in the value stream map shown in Appendix B. Selecting participants via the value stream map showed the relationship between job titles. Open-ended questions asked of the managers, supervisors, decision makers, and influencers provided perspective on the choices made each day that created inventory. Coding the information by job title and strategy was a direct outcome of employing the value chain framework. In the data analysis process, tying the responses to the job titles in the framework and identified strategies increased understanding of the various perspectives and the effect the interactions had on inventory levels.

Reliability and Validity

Reliability

The fundamental criteria for evaluating the quality of a research project are (a) reliability, (b) construct validity, (c) internal validity, and (d) external validity (Gibbert, Ruigrok, & Wicki, 2008; Yin, 2013). These tests are common in empirical studies and may not be appropriate for every design type (Newton & Shaw, 2013; Street & Ward, 2012). Lincoln and Guba (1985) defined the following criteria specifically for qualitative research as: (a) confirmability, (b) credibility, (c) transferability, and (d) dependability. The criteria listed above parallel each other in that reliability is similar to dependability; construct validity is similar to confirmability; internal validity is akin to credibility; and external validity is similar to transferability (Goffin, Raja, Claes, Szwejczewski, & Martinez, 2011).

The dependability or reliability of a study refers to the repeatability of the study (Oluwatayo, 2012). Creating a dependable study requires an easily followed, defined systematic procedure, leading to repeatable results. A dependable study minimizes personal bias so another researcher following the same procedure would reach similar conclusions. A characteristic of a research project that is dependable includes a defined study protocol and a comprehensive study database (Gibbert & Ruigrok, 2010). The study protocol defined the steps from the beginning of the study question with explicit procedures for collecting, storing and analyzing information resulting in conclusions and a written report. The research protocol for this study is in the Data Collection – Instruments Heading of this paper.

A dependable study includes (a) a full explanation of the study, (b) a definition of the framework to determine potential data sources, (c) a review of current literature re-enforcing the question, (d) a description of the data collection and coding method including a spreadsheet, and (e) a review of data organization techniques and analysis (Vicencio-Ortiz & Kolarik, 2012). The clearer the research protocol, the more likely another researcher would be able to repeat the study and find similar conclusions. The first two sections of this research addressed these items with additional information tying the results to the research question in Section 1. Gibbert and Ruigrok (2010) recommended tape recording and transcribing interviews word for word to minimize personal bias and personal interpretation. I recorded interviews, transcribed them, and reviewed the results with each participant before analyzing the data for this research project.

Validity

As the reliability represents precision and repeatability, validity represents accuracy. In other words, validity verifies the study provides an accurate assessment of the real-life occurrence with respect to the research question (Oluwatayo, 2012). Criteria for judging qualitative research design validity include (a) confirmability, (b) transferability, and (c) credibility (Goffin et al., 2011; Lincoln & Guba, 1985). Assuring confirmability requires demonstrating the relationship between study parameters, the research question, and the research findings (Goffin et al., 2011). The design of a study with confirmability meets criteria to address the research question correctly. Confirmability relates to the data collection sources and the means of obtaining information. Suggestions to increase study confirmability are (a) using multiple sources of information, (b) triangulating data sources, and (c) describing the steps taken to collect the data. In this study, I used multiple sources of information including (a) interviewing people associated with managing inventory levels; (b) interviewing people working under the direct supervision of managers responsible for inventory levels; (c) policies, procedures, personnel expectations, and job descriptions, related to managing inventory; and (d) inventory data collected from the preceding 12 months for each component comprising the final product.

Triangulating data compares information, verifying consistency. In this study, if an interview participant stated the tools used to measure inventory is a factor in the level of inventory, an analysis of the measurement tool may verify the statement lending credence to the comment. Participants mentioned several measurement methods used to track inventory located in the corporate production database. The database is real time with updates after each transaction, sampled monthly for accuracy. Participants expressed confidence in the measurements. Interviewing groups of people with different perspectives and responsibilities regarding inventory levels added strength of confirmation to the results. Collecting information from multiple sources provided a means to verify the integrity of the information for assuring the validity of the results. Documenting the interview results, corresponding policies and procedures, and inventory levels in the journal spreadsheet in Table 4 provided an organized, repeatable method for triangulating information in this study.

Another suggestion to assure validity is to have the researcher perform each of the interviews personally and thoroughly transcribe the interviews ensuring the use of interviewees' words in the study (Gibbert & Ruigrok, 2010; Gläser & Laudel, 2013; Smith & Firth, 2011). Another tool ensuring the participants' transcripts reflect their perspective was through member checking in which I asked each participant to review the information collected after transcribing the interview (Carlson, 2010). I conducted all interviews, transcriptions and follow up member checking, reviewing a summary of the transcribed interview with each participant permitting clarifications and edits. An examination of the summary by the participants ensured the transcripts, concepts, and intentions of the answers were correct. The interview responses provided information on strategies influencing inventory levels. Comparing the numerical data with the interview responses enhanced the strength of the study. I triangulated final transcriptions, inventory data, software parameters, policies, job descriptions, expectations, and personal performance goals strengthening the confirmability of this study.

Gibbert and Ruigrok (2013) defined transferability as the ability to transfer the results of a study in a broader setting. The domain of this study is a single value chain in one manufacturing company. The assessment of transferability compares the relevance of results from this study regarding strategies affecting inventory levels applied to other value chains within other manufacturing organizations. One method to increase transferability is defining the setting accurately and clearly, so other researchers can judge if the findings may apply to similar settings. Using Porter's (1998) value chain model for this study provided an accurate, precise framework, and a means of assessing the applicability of the study to other value chains. Several other researchers use Porter's value chain model as demonstrated in the literature review section (Baig & Akhtar, 2011; Chen et al., 2010; Chowdary & George, 2011; Ellis et al., 2010; Gurumurthy & Kodali, 2011; Lu et al., 2011). The Research Protocol in the Data Collection – Instruments heading provides other researchers with a framework for judging the findings and recommendations for transfer to other settings. Another method to increase transferability is to use a *thick* description of the context of the study (Lincoln & Guba, 1985; Schwandt, 2007). A study with a thick description includes detailed information such as (a) settings, (b) participants, (c) data collection procedures, and (d) analysis procedure and tools (Carlson, 2010). Clear descriptions of the context were possible through the value chain model. Finally, triangulating the information collected from sources that supported common themes improved the likelihood of generalizing the results to other settings. In this study, I provided clear instructions on steps to conduct the study, triangulated the information for verifying the validity of common themes, and described differences in themes in summarizing the results.

The final tool to verify the validity of a study is credibility. Credibility is parallel to the internal validity test used in quantitative research (Lincoln & Guba, 1985). Credibility refers to ensuring the results of the research represent the sentiments of the interviewees (Goffin et al., 2011). Techniques used to increase study credibility include (a) triangulation of data, (b) reviewing data for common themes, and(c) member checking (Lincoln & Guba, 1985). I asked the same 11 open-ended questions of several people from two distinct groups providing 20 answers to each question. One group consisted of managers and supervisors managing inventory levels, material flow systems, and people. The other group consisted of people reporting to the manager group, using the material flow systems creating inventory. The two groups provided different perspectives on the strategies controlling inventory levels. Following the interviews, participants received summaries of their interview responses to ensure the summary represented the participants' answers to the interview questions. Additional sources of information for validating interview data included (a) job descriptions; (b) ordering policies for both outside supplied materials, work-in-process materials, and finished goods; and (c) inventory level data within the value chain. A review of all collected information provided answers to the research question.

Transition and Summary

Section 2 included a detailed explanation for defining and exploring the strategies affecting purchasing and manufacturing decisions in the process of creating the product defined in the researched value chain. Included was a detailed protocol for creating a transferable process for use by other researchers in different settings with the rationale supporting the design, and an explanation of how the design led to credible findings and verifiable conclusions. Porter's value chain model (1998) provided a method to identify individuals affecting the manufacturing process and resulting inventory levels. The premise for this research was many operations have excessive levels of inventory in the process of managing their business (Bartram, 2013; Basu & Wang, 2011; Fawcett et al., 2010). Maintaining optimal levels of inventory allows material to flow smoothly through a production system, fulfilling customer orders using resources efficiently. Section 3 includes details of the (a) the findings, (b) application to practice, (c) implications for social change, and (d) recommendations for actions and further study.

Section 3: Application to Professional Practice and Implications for Change

The purpose of this qualitative case study was to explore strategies that manufacturing managers use to optimize and control inventory levels in a manufacturing operation. I employed one-on-one interviews with managers and those who support them. The results of this study provided an answer to the research question: What strategies do production managers need for efficient inventory control? A value chain map provided the framework for defining process steps, identifying inventory locations, and identifying managers and others responsible for ordering raw materials and entering manufacturing orders determining levels of finished-goods inventory in distribution centers. Included in this section are findings from interviews and observations, as well as policies, tools, and systems that participants use. I collected inventory data associated with each process step in the value chain map to triangulate information, increasing the validity of the results. A review of the results includes translation into applications for practical use, a discussion of implications for social change, recommendations for action, and opportunities for future studies. Last, this section includes personal reflections and a summary of the study.

Overview of Study

An opportunity to improve business operations and sustainability exists in the form of improved working capital, as evidenced by U.S. businesses owning 1.7 billion USD in inventory at the end of 2013. The majority of the articles in the review of current literature contained descriptions and evaluations of tools to improve inventory levels. Tools included JIT manufacturing, mass production, inventory parameter management, the Toyota Production System, and lean manufacturing. Other researchers evaluated formulas and mathematical models for optimizing inventory levels (Dogru, Reiman, & Wang, 2010; Li & Meissner, 2011; Sana & Chaudhuri, 2013). A few of the researchers analyzed successes and failures of various tool implementations (Brondo & Babi, 2010; Brüggen, Krishnan, & Sedatole, 2011). None of the researchers referenced included discussions with individuals creating strategies, systems, and tools that create inventory. Included as part of this study are interviews with participants defining and implementing strategies, systems, and tools to gain additional perspective on the control of inventory levels in manufacturing operations. The purpose of this study was to close the gap between tools defined in the literature review and successful strategies by obtaining the perspective of those individuals responsible for inventory creation. Interviews, observations, and data address the research question: What strategies do production managers need for efficient inventory control?

I chose the qualitative method and a case study using a value chain map as a framework. The value chain framework defined the boundaries of a single value chain. The value chain map for this case study was a manufacturing process with 25 different raw materials and seven assembly processes with 12 inventory locations. Depicting this value chain provided (a) a process with several people involved; (b) multiple manufacturing locations; (c) people separated geographically; (d) multiple process steps; (e) multiple control systems, with each manufacturing location having distinct systems; and (f) multiple managers controlling inventory levels using various strategies. The product manufactured through the value chain is a common household product sold through major retailers and smaller specialty stores using a make to stock product fulfillment strategy. The product has been in existence for several years and the manufacturing processes have had many years of improvement activities. In interviews, participants identified three strategies with roots in JIT philosophy: (a) kanban, (b) vendor-managed inventory, and (c) process step integration. Also identified was the use of the economic order quantity (EOQ) strategy, also referred to as *minimum order quantity*. The EOQ strategy has lowest total cost as its basis. All potential interviewees whose participation I solicited agreed to participate in both the initial interview and follow-up member checking. Participants requested the opportunity to review the complete study.

Presentation of the Findings

Several data sources provided insight into the research question. Four strategies became evident through the interviewing process, which consisted of four hierarchical levels including one director, 15 managers, two supply chain analysts, and two process engineers. Achieving data saturation was possible through 20 interviews followed by a review of the interpreted results with each of the 20 interviewees. Participants included a director and managers supporting the identified value chain, managers providing support services including international locations, and those providing strategies at the corporate level. The engineers and analysts who participated were directly involved in supporting the value chain represented in Appendix B. A review of training manuals, training classes, parameters in formula calculations, and inventory data provided triangulation of the findings, validating the results.

The conceptual framework and value chain map visually represented the manufacturing process, providing insights into inventory levels within the process. In reviewing the value chain map (see Appendix B), it is evident a certain amount of inventory exists between each step of the process. In the process under study, there is potential for inventory in 12 locations consisting of 25 raw materials and seven subassemblies (work-in-process or WIP). The analysis of the information resulted in defining one overarching philosophy, JIT. Based on the information and data, four strategies were evident, dependent on the location in the value chain. A review of the four strategies, the logic defining them and the effectiveness of each strategy follows, beginning with the initial steps in the value chain.

Strategy 1: Economic Order Quantity

The strategy managers used to control most vendor-supplied materials and some WIP inventories was the economic order quantity strategy. Each of the interview participants mentioned economic order quantity as a primary strategy in deciding how much to order and manufacture for internal processes. Some interviewees indicated that they expected suppliers to calculate the economic order quantity to provide the lowest cost per unit. Many of the participants who mentioned that suppliers managed inventory based on a minimum order quantity referred to the practice as part of the economic order quantity strategy. Based on the supplier restricting the size of the order through a minimum order size, the vendor was controlling the inventory level for the item. The economic quantity calculation in this manufacturing operation used a formula containing 13 independent variables. The 13 variables were (a) inventory carrying costs, (b) process step equipment loading, (c) process step downtime, (d) historical demand, (e) standard deviation of historical demand, (f) production rate, (g) time required to change the process equipment to a new product, (h) batch size, (i) cost necessary to change the process equipment to a new product, (j) cost of the material, (k) required customer service level, (l) average lead time, and (m) standard deviation of lead time. Eighteen external suppliers and three internal suppliers implemented this strategy. The logic of the strategy involved balancing costs between the supplying process step and the next process step. In the case of an external supplier, the supply costs are the unit cost of the item, which in most cases decreases as the order quantity increases. Costs at the receiving process step included (a) inventory carrying costs, (b) storage costs, (c) costs to move loads, (d) tracking costs, and (e) material loss from handling damage. When selecting a vendor, the list of potential suppliers only included providers able to meet specifications with adequate capacity. Many of the materials ordered using this strategy were specialty items, and quality and part fit were the main criteria for supplier selection. While inventory-carrying costs were part of the equation, most participants stated that unit cost was the final deciding factor in selecting a supplier.

A measurement of inventory policy effectiveness that I used to draw comparisons among the various strategies entailed counting the days of material on hand and the oldest load. Appendix E has a table with inventory data based on material control strategy. Reviewing all materials using the economic order quantity, the average number of days of stock was 128.9, with a standard deviation of 239.5 days. The oldest load of the 21 items was 702 days. Another value chain on site also used this material. The oldest item not shared was 337 days. An example of the daily inventory of one item using the economic order quantity strategy is in Appendix F. The item representing the economic order quantity strategy graphed in Appendix F averages approximately 44 days of material on hand, with the last several data points averaging approximately 75 days of inventory on hand. Of the four strategies cited by the participants, economic order quantity was the least effective based on these measurements although it was the most widely used. A note regarding this supply strategy is that the 13 parameters must be current to provide an up-to-date economic order quantity. In the value chain under study, the 13 parameters for calculating the economic order quantity received quarterly updates. Effective use of the economic order quantity strategy requires balancing unit cost with JIT deliveries, as JIT is not inherent in the calculation.

Strategy 2: Kanban

The kanban strategy is an inventory control strategy in which there are a limited number of appropriately sized containers. When all kanban containers are full, the manufacturing process filling containers stops producing, and deliveries discontinue until an empty container signals the producer to begin refilling. The size and number of containers compared to the use determine the level of inventory. The value chain under study had eight materials using the kanban strategy. Several of the participants defined and discussed the use of kanban as an effective inventory control strategy. Participants mentioning the kanban strategy believed that the strategy did not fit all applications and was more difficult to set up and sustain than the economic order quantity strategy. One interview response described a kanban system setup with a supplier in which a camera focused on the kanban slots notifying the supplier when to replenish materials. Based on the inventory data, materials managed using the kanban strategy had an average of 42.9 days of inventory on hand, with a standard deviation of 53.0 days.

An example of the daily inventory of one item using the kanban strategy is in Appendix F. In this case, the strategy produced results with an average of approximately 17 days of material on hand. The oldest load was 144 days, which was unusually old. This oldest load was still in storage because it had a quality issue. The graph shows that this material had reached zero inventory two times in the past 12 months, indicative of when the production equipment was manufacturing another product or when there had been equipment reliability issues. At the time of the study, the latest data points reflected inventory dropping to less than 1 week as confidence in the process allowed managers to reduce safety stock. In this value chain, the kanban strategy related to lower inventory levels than the economic order quantity strategy.

Strategy 3: Vendor-Managed Inventory

Vendor-managed inventory is a supply strategy in which the supplier tracks use and inventory to keep the customer from running out of material while at the same time optimizing the supplier's operation. Less than half of the participants mentioned vendor-managed inventory as an effective strategy, possibly because the strategy was not as common. The value chain under study had one material using vendor-managed inventory. In this case, the supplier was in the same geographical location and delivered supplies for several value chains daily. Requirements to implement this strategy include a consistent process with little demand variability, predictable demand, and frequent deliveries. The customer provided a monthly demand plan, updated every 3 days, and a consumption plan locked in for 3 days, updated daily. The monthly plan was an approximation allowing the supplier to purchase appropriate supplies. The relationship between the supplier and customer was collaborative, developing over several years. The customer and supplier had quality and productivity improvement projects each year benefiting both. Renegotiation occurred annually because of the improvements.

During the study, the vendor-managed inventory strategy was producing results averaging approximately 6 days of material on hand, shown in Appendix F, with the oldest load at 13 days. The graph shows that this material had reached zero inventory several times in the past 12 months, indicative of when the production equipment was manufacturing another product. In cases where inventory grew, the customer's production equipment was not running because of equipment downtime or quality issues. A comment from a manager in the warehouse operation conflicted with some of the benefits previously mentioned. At times, the supplier delivered pallets with only one item on them, and they were stored in the warehouse taking an entire pallet slot with only one carton of material. The supplier providing vendor-managed inventory had more pallet slots allocated to its materials than any other supplier did. As suggested in the literature review, both entities must benefit for the vendor-managed inventory strategy to be successful (Bookbinder, Gümüs, & Jewkes, 2010). A vendor-managed inventory strategy may not fit all situations, as evidenced by the number of loads in the warehouse.

Strategy 4: Process Step Integration or One-Piece Flow

The strategy of integrating process steps occurs by transporting the output of one process step into the input of the next process step. None of the participants mentioned this strategy in their responses. This strategy was evident in observing materials flowing through the manufacturing process. In this case, there are two inputs conveyed directly to the assembly process step. The length of the conveying mechanism and the part size control the level of inventory. Sensors placed strategically on the conveying mechanisms monitor the output of process equipment in the previous step. For instance, if the assembly process stops, inventory backs up on the conveying mechanism until a sensor detects the material blocking it, which triggers the equipment in the last process to slow down or stop. When the conveying mechanism is moving material again, the unblocked sensor triggers the equipment in the previous process step to speed up or restart. Implementation of this strategy requires the process equipment to be in proximity geographically. The process feeding the integrated equipment must be capable of stopping and starting reliably without any effect on product quality, and each of the relevant process steps must have a high level of reliability.

Use of this strategy provided efficient inventory results, approaching one-piece flow at the output of the assembly process, even though the process steps feeding the assembly process were not manufacturing one piece at a time. One-piece flow is a manufacturing strategy in which an item is processed and checked at each step before moving to the next process step (Satoglu, Durmusoglu, & Ertay, 2010). One-piece flow has one piece in the process at each manufacturing step, with no inventory between steps.

While this process step does not have one-piece flow, integration provides similar results. An example of the daily inventory graph of material controlled using an integrated strategy is in Appendix F, the last graph. The line shows the level of 1 day of inventory. By comparison, the graph demonstrating the economic order quantity strategy has a line showing 1 month of inventory, while the graphs showing the kanban and vendor-managed inventory control strategies have a line showing 1 week of inventory. The scale for the “Y” axis represent days on hand based on the consumption rate of the material. On the integrated chart, there are several days with zero inventories, and the highest level of inventory represents approximately 4 days of demand. In this value chain, an integrated strategy provides an efficient level of control.

Interview Results

Each participant responded to all 11 questions. On average, the interviews lasted 15 minutes and 29 seconds, with the longest interview slightly over 31 minutes and the shortest interview slightly over 7 minutes. While most participants believed that inventory in the value chain was at an appropriate level, they also believed that an opportunity existed for improvement. One conclusion from this research is that the location of the process steps influenced inventory levels in the value chain. Ideally, all process steps would be in proximity and on the same site. Integration of process steps would be difficult if they were not in the same location. The geographic location also influences decisions regarding frequency of deliveries and quantity of the material delivered. Deliveries could be more frequent with smaller lot sizes if the supplier is nearby. When the supplier is not nearby, using a local storage facility to overcome geography is a possibility. Another factor for improving the value chain is reducing the number of process steps required to manufacture the item. Fewer process steps lead to fewer places materials accumulate, resulting in less inventory. Participants stated variability in the process, followed by product proliferation and inventory being a *secondary metric* as additional factors creating excessive inventory. Removing variability in the lead times of supplies and the output of process steps and increasing the accuracy of the demand forecast would remove some safety stock inventory, increasing the rate of material flow.

All interviewees mentioned inventory turns as the key measure of inventory efficiency. The calculation of inventory turns is the cost of goods sold for a period divided by the average inventory during the same period. The average inventory is equal to the beginning inventory added to the ending inventory divided by two. Prioritizing the inventory turns measurement may encourage behavior to reduce inventory at the end of the period versus encouraging practices to remove reasons for excess inventory. Participants' also defined inventory efficiency tracking included (a) the dollar value of inventory not used in the past 180 days, and material with more than 12 months of demand based on a forecast; (b) cycle time; and (c) service to customers. These measurements are indicators of inventory efficiency and highlight opportunity to understand and eliminate the cause of the old inventory. In some cases, these measurements may drive the behavior of depreciating inventory value or scrapping old materials while the intention of the measurement is eliminating the cause of the aged material. Inconsistencies existed regarding inventory ownership and individual performance measurements. Seven participants had ownership for inventory and annual inventory performance metrics. Seven participants did not have ownership for inventory or annual inventory performance metrics. Four participants had no ownership for inventory but had inventory performance metrics on their annual appraisal, and finally, two participants had ownership for inventory but no metrics on their annual appraisals. Participants in manufacturing sites claimed ownership in most instances, and all had inventory metrics on annual appraisals.

Participants' suggestions to improve material flow included (a) defining and using appropriate measures, (b) pulling materials through the value chain versus pushing, (c) stopping production when reaching optimum inventory levels, and (d) challenging the status quo with respect to material flow. One suggestion to improve measuring inventory efficiency was using Little's law, which shows the amount of material in the queue in front of each process step (Roach, 2011). The mathematical formula for Little's law is the average inventory equals throughput multiplied by flow time. Practically, Little's law defines the average amount of material or inventory defined in units of time in front of a process step. The use of average inventory in Little's law equation limits accounting for inventory fluctuations. Several participants recommended a measurement determining cycle time from the beginning to the end of a production run as a reasonable measurement of material flow and inventory effectiveness. Participants recommended the value chain mapping tool to represent cycle-time visually. Another suggestion for measuring inventory efficiency related to the method the U.S. Census Bureau News (2015) uses, defined as the ratio of inventory to sales. Participants recommended analyzing inventory measurements over a longer time span and including the entire value chain so as not to suboptimize individual process steps. Participants suggested using value stream mapping as a tool to begin the process of understanding, evaluation, and improvement.

Applications to Professional Practice

The philosophy of JIT delivery is at the core of three of the four effective strategies discovered in the study. The primary driver behind the economic order quantity strategy is minimizing total cost and not optimizing inventory. As discovered through the interviewing, inventory measurements are frequently a secondary metric. Balancing cost and material flow are important considerations when employing the economic order quantity strategy. The primary driver behind kanban, vendor managed inventory, and integration strategies are to keep the material moving as each time the material stops, inventory results. Applying JIT philosophy to material flow in a process increases the speed from raw material purchases to collection of funds from the customer, described earlier as the cash conversion cycle. Having less inventory in a process requires less cash required to purchase materials, requires fewer places to store materials, and less staff and equipment to move materials, making it less expensive to run an operation increasing profitability (Gupta & Iyengar, 2014).

Increasing the speed of material flow should also lead to decreasing the cash conversion cycle. The closer to zero the cash conversion cycle, the quicker cash returns to the organization. In some cases, the cash conversion cycle is less than zero meaning an organization with negative days cash conversion cycle uses their customers funds to pay their suppliers (Cagle, Campbell, & Jones, 2013). A consideration when reducing inventory: a reduction in inventory will decrease the level of working capital. Working capital is the sum of inventory dollars plus accounts receivable minus accounts payable and is an indicator of the liquidity of an organization and the ability to pay for daily operations.

Table 5

Working Capital Restated With Inventory Reduced 50%

	Ford	GM	Toyota	Daimler[a]	Honda	Deere	Cat
Inventory	7,362	14,714	18,219	17,720	12,906	5,170	15,547
Inventory restated	3,681	7,357	9,110	8,860	6,453	2,585	7,774
Accounts receivable	82,338	23,868	87,831	7,543	26,367	31,426	20,499
Accounts payable	68,715	48,474	47,311	8,832	16,976	9,288	15,309
Total working capital	20,985	-9,892	58,739	16,431	22,297	27,308	20,737
Working capital restated	17,304	-17,249	49,630	7,571	15,844	24,732	12,964
Working capital/sales	15.6 %	-6.5 %	25.1 %	14.4 %	21.3 %	75.5 %	31.5 %
Working capital/sales restated	12.9%	-11.3%	21.2%	6.6%	15.1%	68.4%	19.7%

Note. Information taken from 2012 annual reports published in Yahoo Finance.com. Inventory, accounts receivable, and accounts payable data in millions of USD.
[a] Inventory, current assets, and sales data in millions of EUR, 1 euro equals 1.37 USD (Yahoo Finance, October 20, 2013).

Elimination of inventory through improved efficiencies reduces working capital in the short term. A restatement of Table 2, shown in Table 5, reflects an inventory reduction of 50% demonstrating the effect on working capital. As is shown in Table 5, reducing inventory alone also reduces total working capital that financial managers may interpret as reduced liquidity. At some point, accounts payable will decrease, as fewer materials need purchasing, raising working capital to some extent. Reducing inventory should also reduce the cash conversion cycle unless a significant amount of older inventory is on hand. In an ideal situation, all inventory cycles quickly, resulting in little old inventory. Researchers concluded reducing average age of inventory and increasing inventory turnover increases profitability (Alipour, 2011; Bagchi, Chakrabarti, & Roy, 2012; Malik & Bukhari, 2014; Napompech, 2012; Raheman, Afza, Qayyum, & Bodla, 2010; Sharma & Kumar, 2011; Vural, Sokmen, & Cetenak, 2012). Balancing liquidity and profitability are necessary to an organization's viability. Effectively managing inventory is a significant factor in achieving both liquidity and profitability.

Implications for Social Change

Controlling inventory in manufacturing organizations at optimal levels has direct and indirect effects on individuals, businesses, communities, and cultures. Using the *Triple Bottom Line* measurement is an appropriate tool to analyze the influence of too much inventory in the value chain. The triple bottom line measurement contains three broad areas including (a) economic, (b) environmental, and (c) social effects (Mintz, 2011). The intersection of these three areas is a measure of sustainable manufacturing (Ocampo & Estanislao-Clark, 2014). The following describes how optimal inventory affects each of these areas thereby affecting social change.

From an economic perspective, inventory is one of three assets considered as working capital and monies for keeping an operation solvent on a daily basis. The other assets are accounts receivable and accounts payable. Working capital is at an optimal level when operations performance is optimal (Baños-Caballero, García-Teruel, Martínez-Solano, 2014). Not having enough working capital leads to lost business, and too much working capital leads to dependence on external financing. Kieschnick, LaPlante, & Moussawi (2011) posited that the appropriate level of inventory as part of working capital with respect to firm value depends on the perspective of the reviewer. A reviewer may view a high level of inventory as a good sign of future sales or view a high level of inventory as a sign of over production. Optimal inventory levels provide the highest level of firm value.

The appropriate level of inventory is enough to minimize sales loss and not so much to waste resources. All inventories expend resources to create, purchase, store, and move. Costs to create inventory include (a) purchasing, transporting, and storing raw materials; (b) wages and benefit of employees to move and operate equipment; (c) costs to purchase equipment; (d) utilities to run equipment; (e) maintenance costs to keep equipment running; and (f) costs of facilities to manufacture products. Storage costs include (a) facilities in which to store materials; (b) pallets, racking, boxes to store product; and (c) equipment to move materials. Creating too much inventory in the value chain requires expenditures to support these resources. The economic effect of expending these resources may deplete an organization's cash resources leading to borrowing cash to continue operations and in the worst case, result in bankruptcy (Pimplapure & Kulkarni, 2011). When managers in a firm struggle with insolvency and are unable to pay suppliers and employees, individuals and communities are affected.

Likewise, when a firm is in a growth period, communities benefit through increased tax revenue. Individuals may grow as well through the creation of jobs and opportunities. As noted earlier, mismanagement of inventories is included in the top ten reasons leading to bankruptcy (U.S. Small Business Administration, 2013). Strategies supporting managers optimizing inventories contribute to (a) sustainable businesses, (b) minimizing firm failure, (c) providing continued employment, and (d) job growth. Increased tax revenue from successful individuals and businesses positively influences society just as reducing social services because of increased employment positively influence society. Businesses also provide leaders and volunteers to community organizations contributing to improved quality of life.

From an environmental perspective, strategies supporting optimal inventories minimize waste of resources. Resources include materials as part of the product manufactured and the resources used in the manufacturing process such as water, electricity, and fuels. Disposal of process by-products and possibly excess inventories is also an environmental concern. An example is the issue leaders in Beijing face with water quantity and quality as production scaled up (Zeng, Liua, & Savenije, 2013). Greenhouse gas emissions have become a global concern in both the production and use of manufactured products (Harris & Symons, 2013). Overproduction of goods uses valuable resources before needed and possibly never needed. Excess inventory might require relocation of the materials using additional energy and fuels. Efficient use of inventory results in less waste going to landfills and other methods of disposal, relating directly to sustainability of natural resources (Wolf, 2011). Overproduction of materials contributes to overuse of resources and higher levels of emissions.

Implementing strategies to optimize inventory requires questioning why current levels of inventory exist and addressing reasons for having excess inventory. In some cases, individuals accept the levels of inventory inherited when they began the job. In other instances, individuals ask why the inventory levels are where they are, and then accept the answer as being sufficient. Manufacturing managers may influence suppliers and customers in the value chain asking questions regarding efficient inventory control affecting organizations up and down the value chain. As a result, improvement strategies throughout one value chain may influence other organizations in related value chains. Strategies to create optimal inventory may also establish a culture of continuous improvement and individuals who can lead continuous improvement in their personal and professional lives.

Recommendations for Action

The purpose for this study was to determine strategies supporting optimal inventory levels in the manufacturing process of a single value chain. The findings from this study demonstrate the JIT philosophy is the root of several strategies effectively controlling inventory levels. Interestingly, the standard measurements for evaluating inventory effectiveness do not relate to time. Managers using standard measurements count (a) loads, (b) the dollar value of inventory and, (c) inventory turns comparing inventory to sales and costs. From a financial point of view, these metrics may be adequate. From an operational management perspective, a measurement relating to time is worthy of consideration.

A consideration in financial measurements regarding inventory is the inventory value calculation may vary from company to company, making comparisons difficult. Many financial leaders compare sales dollars to inventory dollars to determine inventory efficiency. While sales should be relatively straightforward to define from company to company, the variability in calculating the value of inventory dollars has a direct relation to inventory efficiency. Employees with financial reporting responsibilities typically report inventory at the end of the month, quarter, or annually. End of period reporting with a single number based on the last day of the period does not accurately reflect inventory levels and tends to lead to underreporting (Rudi et al., 2009). Periodic review of inventory value in most companies reflects actual costs as the value of the material increases through processing. The value of inventory depends on many factors including (a) timing of the measurement, (b) the measurement system used, and potentially (c) incentives for people doing the measuring. The cost of goods sold calculation may vary from company to company. The discussion is not to discount the value of the financial measurements, only that perhaps a better measurement for operational managers would relate to time. Information from this study indicates using age of materials as a measure and cycle time of the value chain may help operational managers determine inventory efficiency.

The age of inventory based on the purchase date or manufacture date is a reasonable measurement to evaluate inventory efficiency. Age of inventory is not a calculated measurement and is consistent across value chains and corporations. The age of each load of inventory would define how early a load arrived before needed. Ideally, as the term JIT describes, the delivery of a supply occurs when the material is ready for processing, and the age of a load is minutes or hours. JIT may not be practical in every case because of the variability in (a) supply delivery, (b) quality of the input and output, (c) process, and (d) demand. A descriptive measure of inventory age would include a measure of the mean and the standard deviation of all loads. From an operational perspective, inventory age provides an indicator of inventory efficiency while also highlighting opportunities for improvement.

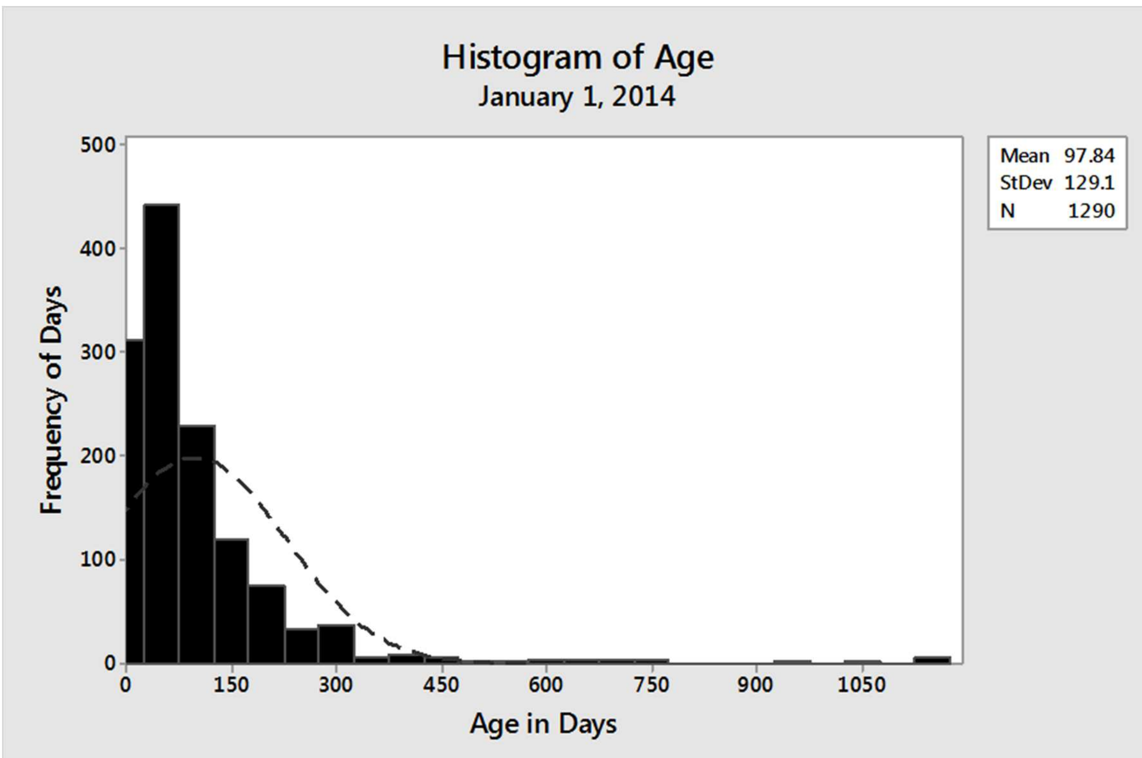

Figure 4. Example of inventory measurement by age in days.

Figure 4 is a graphic representation of the age distribution of inventory at a specific point in time in a value chain that has an opportunity to improve material flow. Some loads are older than 3 years. In financial measurements, inventory over 3 years old may be discounted and no longer visible to managers. The advantage of an operational manager using this type of measurement is old loads may highlight an opportunity to improve the flow of materials. Using JIT philosophy and the strategies emanating from this study provide operational managers tools to improve material flow, inventory efficiency and value chain productivity.

Each of the interviewees and the senior vice-president requested a copy of this completed study. The interviewees and the senior vice-president plan to share the results of this study with others who influence inventory levels within their organizations. This study is also available to future researchers through UMI/ProQuest CSA.

Recommendations for Further Study

My objective for this study was to determine strategies for managing inventory levels in a mature value chain. The results of the research identified use of the JIT philosophy through three strategies as well as economic order quantity strategy to control inventory and manage material flow. I employed Porter's (1998) value chain map as the framework defining the manufacturing and material flow process and identify the functions supporting the process. The value chain map and the identification of four separate strategies provided a foundation for several potential studies.

One potential future study would be to compare the age of multiple value chains to one another to determine if value chain maturity correlates to inventory efficiency. A possible hypothesis would be a more mature value chain has more efficient inventory use than a more recent value chain. The merit of this potential study is determining what strategies to implement to decrease the time it takes a newer value chain to achieve inventory efficiency. Another potential study would be to compare strategies versus the type of inventory: (a) raw material, (b) work-in-process, and (c) finished goods. A researcher could seek to develop a comparison of various value chains using multiple control strategies to provide direction to optimize inventories based on the location in the value chain. The value chain mapping tool aids viewing processes back to suppliers and their suppliers and forward to distributors and end users. With an extended map, studies similar to those above may extend efficiencies to additional organizations. Extending studies to suppliers may improve relationships benefiting all participants in the value chain.

The foundational information within this study could support improving existing value chains' efficiencies, and thereby increase the life of associated products. Managers and developers designing value chains may find the results of this study informative while making production decisions. Decisions such as (a) make to order versus make to stock, (b) the number of internal process steps versus external supply, (c) the timing and size of deliveries and manufacturing orders, (d) the location of the operation and (e) supplier selection, have an influence on the efficiency of the value chain, the success of the product, and the success of the organization.

Reflections

Interviews with managers in positions influencing inventory levels through implemented strategies were the primary source of information determining the findings, conclusions, and recommendations from this study. In the original planning, there was little consideration given to observation of the supply chain process. My original belief was that it would be impractical to observe the process as so much of the decisions creating inventory was in and through computers. Creation of the value chain map required walking through each step of the process. On the first tour of the value chain, little notice was made of what was taking place and observation was not a consideration as a source of information. A subsequent walk to the production floor after completing the interviewing revealed the manufacturing of the product was also a material flow process, which helped to crystallize the strategies for this value chain. Observing the work on the manufacturing floor also known as, *gemba* is a lean manufacturing practice to help people understand reality (Yamada, 2014). Implementers of lean manufacturing practices acknowledge observing an operation first-hand is a valuable training tool that takes time to become proficient and develop an understanding of what is happening (Ahmed, 2014).

The first walk was to see the manufacturing process steps in the value chain creating the product. Following interviewing and a review of the inventory data, I recognized the material flow as a process. The interviewing process facilitated identifying philosophies and tool usage. However, in some cases the strategies to control inventory were not evident. The consideration of value chain flow as a sequence of process steps provided meaning to both the interview responses and associated inventory data. Observation provided clarity and information demonstrating the power of using all data available to providing meaningful research.

Summary and Study Conclusions

The purpose for this qualitative case study was to explore strategies managers use to optimize and control inventory levels in manufacturing processes. A value chain model provided a visual representation of the manufacturing process producing the product. Creating the model required multiple observations to understand all aspects of the production process. The value chain model proved a valuable framework to assist in understanding the relationships between various process steps. Mapping the differences in rates, reliability, and yields of processing steps provided information needed to identify an appropriate strategy to manage inventory effectively. Regular updating of the map is an opportunity to demonstrate changes in the value chain and provide feedback determining strategies' actual effectiveness. Expanding the value chain map upstream and downstream of the internal process steps would identify additional opportunities for improving effectiveness for suppliers and distributors creating more value for all participants.

The results of this study indicate several strategies can be effective in optimizing material flow in a value chain. A significant finding is one strategy may not fit all situations. Location of suppliers has an influence on the level of inventory in the value chain. A local supplier may offer more frequent and smaller deliveries with the ideal situation of daily deliveries providing daily requirements for the consuming process step. As relationships with suppliers develop, or process yields improve, inventory control strategies may change improving process flow. In nearly every case, some inventory exists between each process step. When possible, a strategy to eliminate or integrate process steps can reduce the number of places inventory accumulates thereby reducing total inventory.

Another critical factor in optimizing inventory is ensuring accurate measurement. Several measures of inventory exist and are a requirement for financial entities to ensure reporting is comparative among organizations. Differences in measuring inventory exist dependent on the choice of LIFO, FIFO or mixed reporting. Differences may also exist depending on how the value of inventory changes as it ages. Organizations with work-in-process inventory may value inventory using fully burdened calculations or variable costs. These choices lead to inconsistent inventory valuations. Little's law provided useful information in that the formula provides a representation of the number of days of material in front of a process step. Little's formula depends on a forecast of expected use, which may not represent real demand and may not be correct. Using financial measures of inventory only does not offer sufficient information to managers to improve manufacturing operations. For the operations manager intending to improve the effectiveness of a value chain, the JIT philosophy for material flow can be beneficial. Measuring the time between arrival and consumption of material provides information that is not subject to interpretation or manipulation. Managers have several material flow strategies available for optimizing and controlling inventory (Baig & Akhtar, 2011; Bookbinder, Gümüs, & Jewkes, 2010; Chen, Li, & Shady, 2010). Using appropriate tools and measurements with the appropriate strategy provides the information needed for optimizing and controlling inventory.

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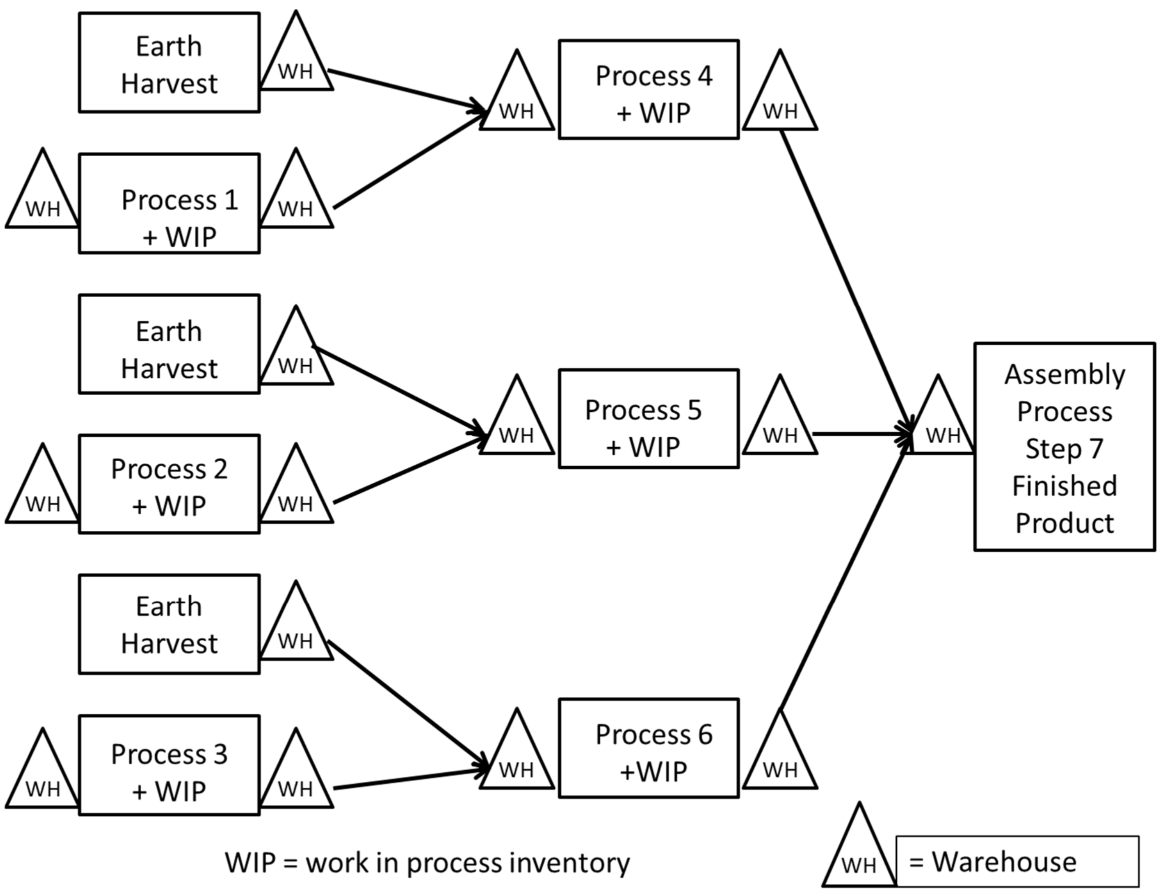
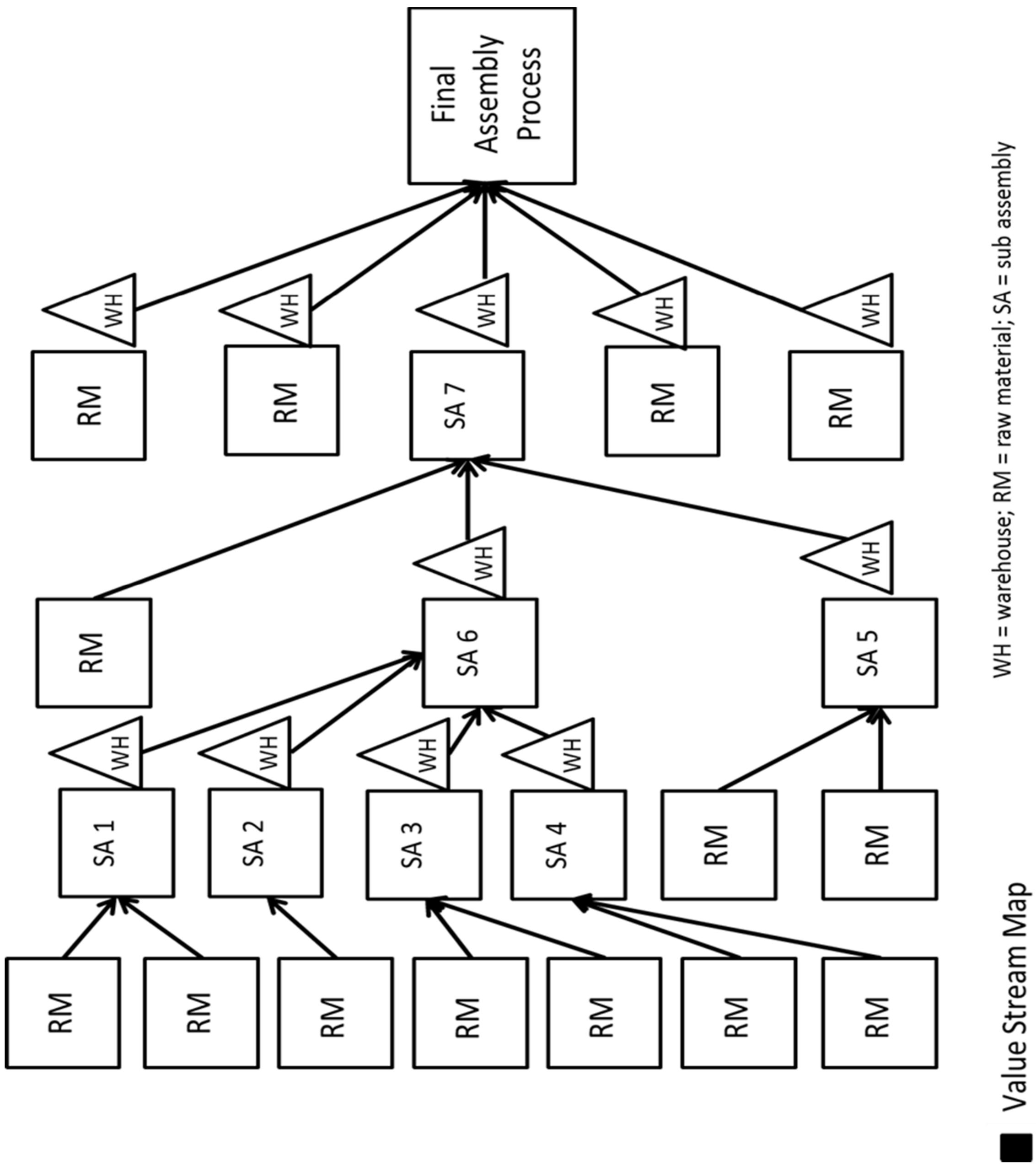
Appendix A: Example of a Value Stream Map



Appendix B: Value Stream Map of Product Under Study



Appendix C: Company Letter of Cooperation

Letter of Cooperation from a Research Partner

Jerome
November 14, 2014

Dear Scott Lemke,

Based on my review of your research proposal, I give permission for you to conduct the study entitled Inventory Optimization in Manufacturing Operations within . As part of this study, I authorize you to interview managers, supervisors, and supply chain analysts within the value stream as well as managers in the sourcing and lean six sigma organizations. Individuals' participation will be voluntary and at their own discretion and no names will be revealed. I also grant permission to review inventory data from the same value stream with the understanding all data will be disguised so no product construction, trade secrets or intellectual property will be revealed.

I understand as part of the study company phones and offices may be used for the purpose of interviewing. We reserve the right to withdraw from the study at any time if our circumstances change.

I confirm that I am authorized to approve research in this setting and that this plan complies with the organization's policies.

I understand that the data collected will remain in your possession, entirely confidential and may not be provided to anyone outside of the student's supervising faculty/staff without permission from the Walden University IRB and myself.

Sincerely,

Jerome

Appendix D: Individual Letter of Consent

CONSENT FORM

You are invited to take part in a research study of strategies influencing inventory in manufacturing processes. Scott Lemke, a Walden doctoral candidate, is inviting individuals involved either in decisions regarding inventory directly or indirectly to be in the study. You may already know the researcher as a production manager, but this study is separate from that role. This form is part of a process called "informed consent" to allow you to understand this study before deciding whether to take part.

Background Information:

The purpose of this study is to understand the strategies affecting suboptimal inventory levels in manufacturing operations and determine how modifying strategies may increase inventory optimization.

Procedures:

If you agree to be in this study, you will be asked to:

- Be interviewed by the researcher either face-to-face or through a phone call. Face-to-face interviews will be conducted in a location of your choice.
- Interviewing consists of 11 questions.
- Interviews will be digitally recorded, and recordings will be transcribed.

- The initial findings and results will be reviewed with you seeking your opinion on them.
- The transcriptions will become part of a database retaining interview transcriptions to determine common strategies and influences.
- At no time will your name be revealed to anyone besides the interviewer. The only information made public is your experiences and thoughts regarding inventory creation.
- The time to complete the interview is approximately 30 minutes.
- You are welcome to review the research findings upon completion and acceptance of the design, methods, and validity of the study.

Here are some sample questions:

1. How do you measure inventory efficiency in this value chain?
2. Describe the process and criteria for selecting a supplier and manufacturing location.

Voluntary Nature of the Study:

This study is voluntary. Everyone will respect your decision of whether you choose to be in the study. No one at [redacted] will treat you differently if you decide not to be in the study. If you decide to join the study, you can still change your mind later. You may stop at any time. You were selected to participate in this study because of your influence on inventory efficiency at [redacted] and specifically the [redacted] supply chain.

Risks and Benefits of Participating in the Study:

Participating in this study would not pose a threat to your employment or career.

The benefit of the study may help to understand how to reduce inventory levels in manufacturing operations without negatively affecting customers yet minimizing cash tied up in inventory.

Privacy:

Any information you provide is confidential. The researcher will not use your personal information for any purposes outside of this research project. The researcher will not include your name or anything else that could identify you in the study reports. Data will be kept secure in storage on my personal password-protected computer in my home. Data will be kept for a period of at least 5 years as required by the university.

Contacts and Questions:

You may ask any questions you have at any time, you may contact the researcher via phone at [redacted] or email at scott.lemke@waldenu.edu. If you want to talk privately about your rights as a participant, you can call Dr. Leilani Endicott. She is the Walden University representative who can discuss this with you. Her phone number is 1-800-925-3368, extension 3121210, or via email at irb@waldenu.edu. Walden University's approval number for this study is **IRB will enter approval number here,** and it expires on **IRB will enter the expiration date.** The researcher will give you a copy of this form to keep.

Statement of Consent:

I have read the above information, and I understand the study well enough to make a decision about my involvement. By signing below, I understand that I agree to the terms described above.

Printed Name of Participant ______________________

Date of consent ______________________

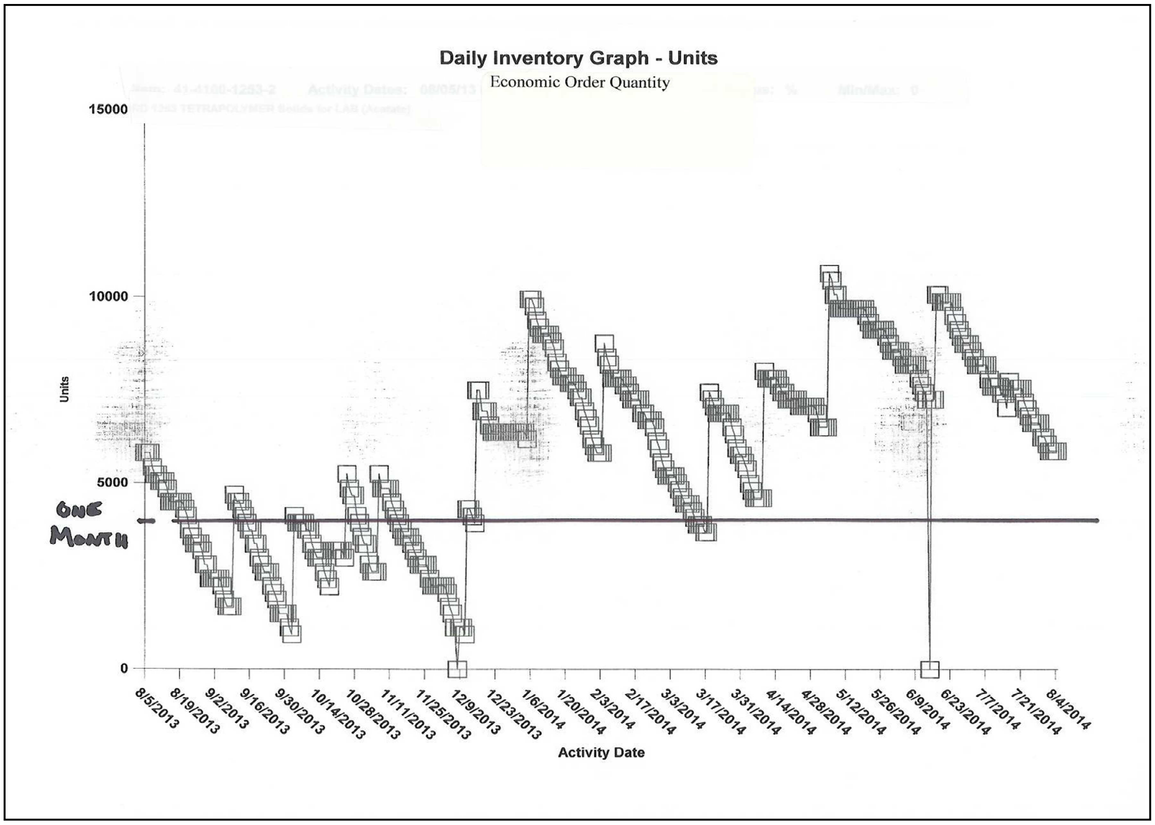
Participant's Signature ______________________

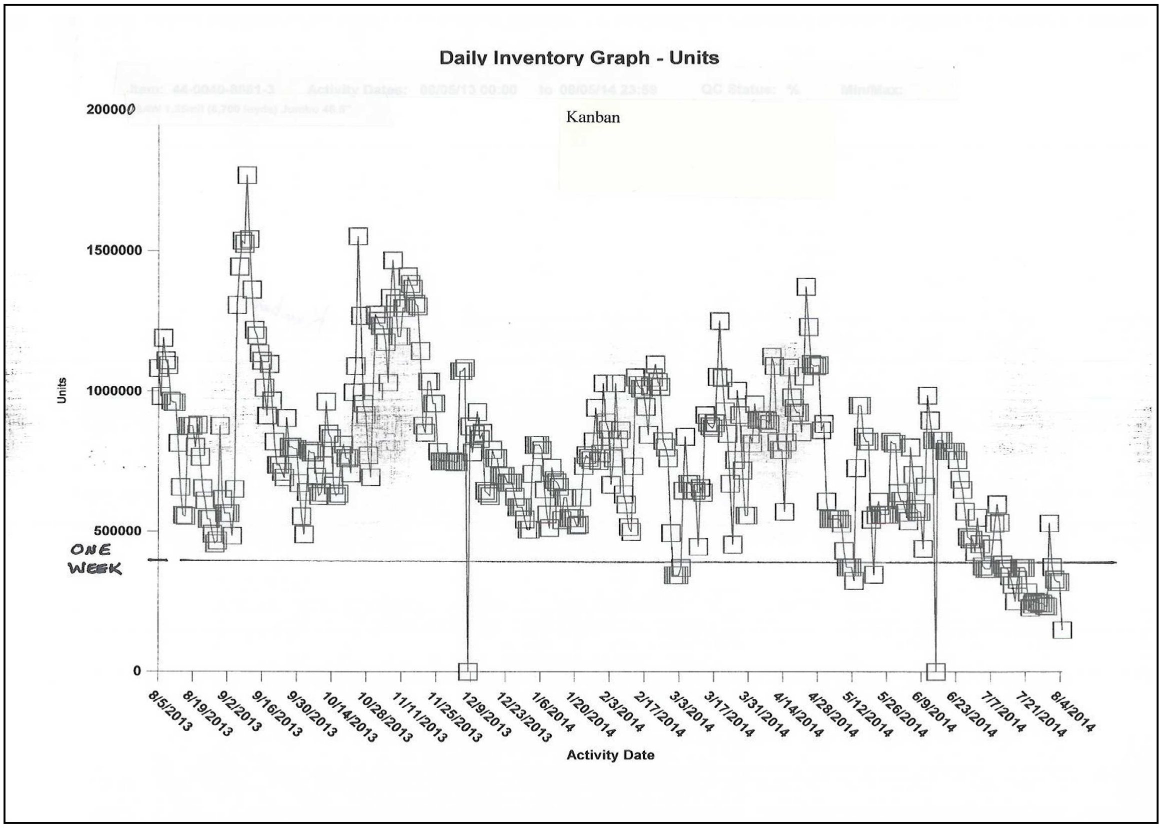
Researcher's Signature ______________________

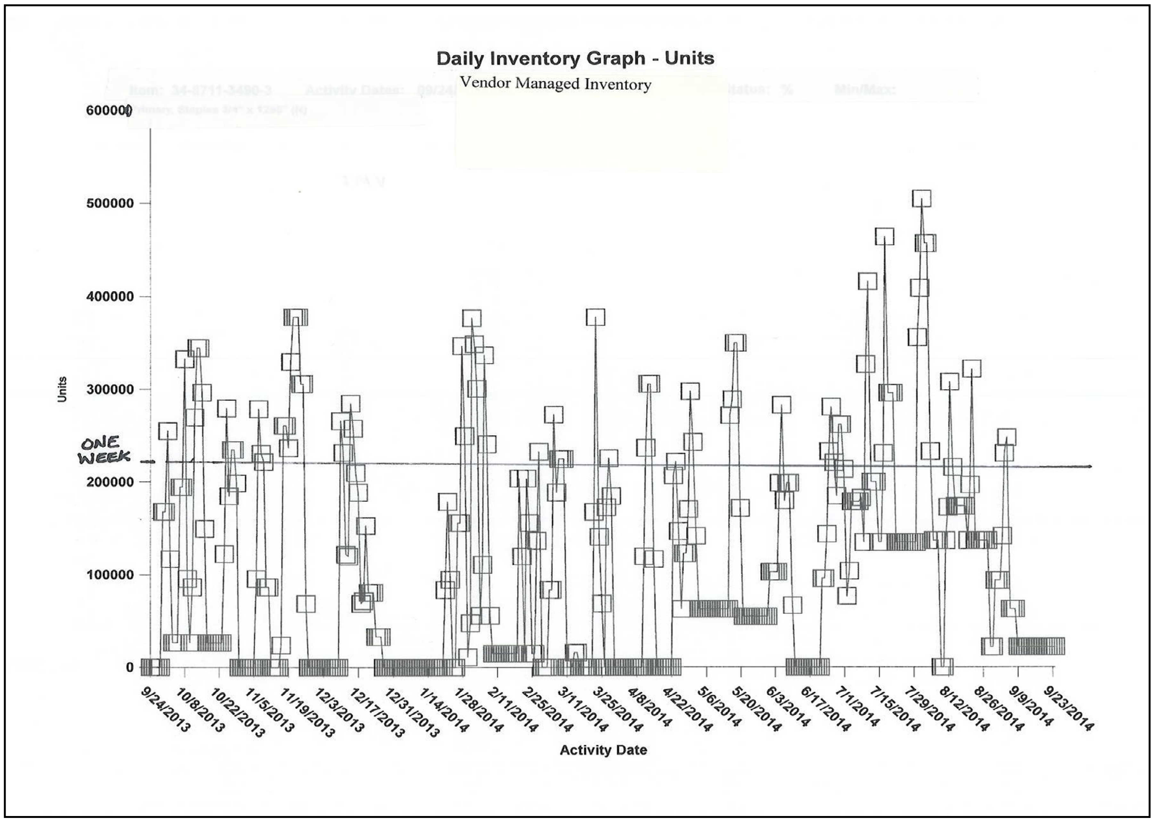
Appendix E: Inventory Data

Code	Strategy	Low Range	High Range	Monthly Usage	Days on Hand	Oldest Load
A	EOQ	0	3,100	9,517	9.8	194
B	EOQ	0	800	2,103	11.4	5
C	EOQ	0	7,250	9,288	23.4	702
D	EOQ	0	70,000	61,733	34.0	11
E	EOQ	0	3,000	2,414	37.3	13
F	EOQ	0	5,600	4,000	42.0	18
G	EOQ	0	345	210	49.3	43
H	EOQ	0	230,000	132,141	52.2	22
I	EOQ	0	2,000	886	67.8	19
J	EOQ	0	6,100	2,691	68.0	63
K	EOQ	0	12,000	5,235	68.8	42
L	EOQ	0	1,100,000	428,248	77.1	81
M	EOQ	0	2,500	954	78.6	36
N	EOQ	0	45,000	14,058	96.0	55
O	EOQ	0	11,000	3,199	103.2	257
P	EOQ	0	3,300	482	205.6	94
Q	EOQ	0	78,000	3,749	624.2	203
R	EOQ	0	7,000	209	1,003.3	337
EE	EOQ	0	280,000	918,000	9.2	35
FF	EOQ	0	935,485	1,326,444	21.2	144
Code	Strategy	Low Range	High Range	Monthly Usage	Days on Hand	Oldest Load
GG	EOQ	0	1,000,000	1,205,267	24.9	14
U	Kanban	0	95,000	286,746	9.9	5
V	Kanban	0	78,000	113,072	20.7	0
W	Kanban	0	62,000	23,300	79.8	167
X	Kanban	0	76,000	14,407	158.3	70
Y	Kanban	0	250,000	849,840	8.8	5
Z	Kanban	0	8,250	30,740	8.1	192
AA	Kanban	0	12,500	34,656	10.8	55
BB	Kanban	0	180,000	115,598	46.7	18
CC	VMI	0	550,000	945,667	17.4	13
S	Integrated	0	1	3,333	0.0	
T	Integrated	0	5,000,000	28,542,465	5.3	39

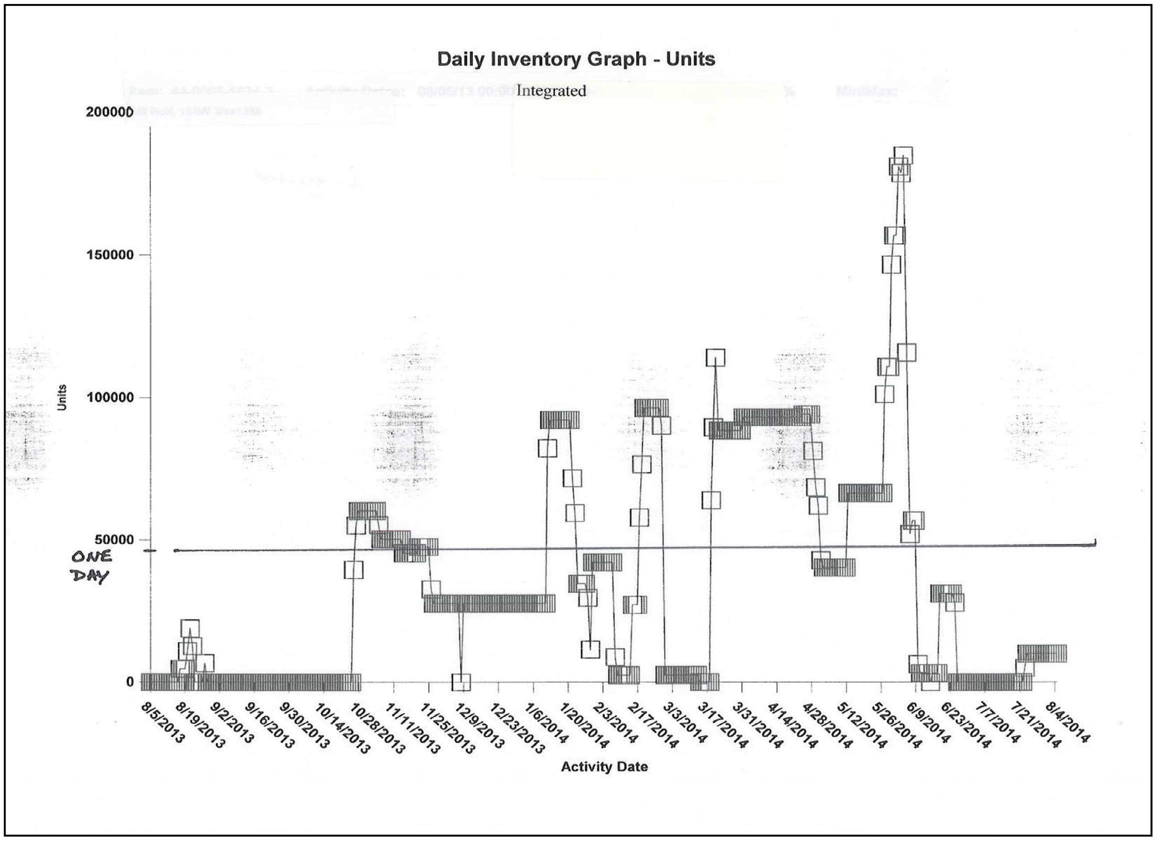
Appendix F: Daily Inventory Graphs




Daily Inventory Graph - Units
Kanban
2000000
1500000
1000000
500000
0
Units
ONE WEEK
8/5/2013
8/19/2013
9/2/2013
9/16/2013
9/30/2013
10/14/2013
10/28/2013
11/11/2013
11/25/2013
12/9/2013
12/23/2013
1/6/2014
1/20/2014
2/3/2014
2/17/2014
3/3/2014
3/17/2014
3/31/2014
4/14/2014
4/28/2014
5/12/2014
5/26/2014
6/9/2014
6/23/2014
7/7/2014
7/21/2014
8/4/2014
Activity Date



Daily Inventory Graph - Units
Vendor Managed Inventory
Units
600000
500000
400000
300000
200000
100000
0
ONE WEEK
9/24/2013
10/8/2013
10/22/2013
11/5/2013
11/19/2013
12/3/2013
12/17/2013
12/31/2013
1/14/2014
1/28/2014
2/11/2014
2/25/2014
3/11/2014
3/25/2014
4/8/2014
4/22/2014
5/6/2014
5/20/2014
6/3/2014
6/17/2014
7/1/2014
7/15/2014
7/29/2014
8/12/2014
8/26/2014
9/9/2014
9/23/2014
Activity Date



Daily Inventory Graph - Units
Integrated
Units
200000
150000
100000
50000
0
ONE DAY
8/5/2013
8/19/2013
9/2/2013
9/16/2013
9/30/2013
10/14/2013
10/28/2013
11/11/2013
11/25/2013
12/9/2013
12/23/2013
1/6/2014
1/20/2014
2/3/2014
2/17/2014
3/3/2014
3/17/2014
3/31/2014
4/14/2014
4/28/2014
5/12/2014
5/26/2014
6/9/2014
6/23/2014
7/7/2014
7/21/2014
8/4/2014
Activity Date

Appendix G: Permission to Reprint Emails

Permission from Michael Porter:

Sure. Please just cite the book

Good luck

MEP

From: Scott [mailto:scottelk@broadband-mn.com]
Sent: Wednesday, January 08, 2014 10:43 PM
To: Porter, Michael
Subject: Permission to Use Schematic

Professor Porter,

I am Scott Lemke, a doctoral candidate enrolled at Walden University. I am completing my dissertation on inventory reduction through a single value chain.

As part of my research, I would like to use your value chain framework that I found in Management Methods (http://www.valuebasedmanagement.net/methods_porter_value_chain.html).

This framework combined with the value stream map tool provide a solid basis for my study. I also found a very good schematic of your value chain framework on page 37 of your book,

Competitive Advantage Creating and Sustaining Superior Performance, 1998. The schematic provides an excellent visual for explaining the framework. As the book is copyrighted,

I am asking your permission to include in my paper.

Thank you for your consideration,

Best regards,

Scott Lemke

Permission from Peter Harris:

Absolutely.

Let me know if I can help you out in any other way.

Good luck,
Peter

-----Original Message-----
From: Scott <scottelk@broadband-mn.com>
To: pharris <pharris@nyit.edu>; nyitpharris <nyitpharris@aol.com>
Sent: Mon, Dec 23, 2013 3:59 pm
Subject: Permission to use example

Professor Harris,

I am Scott Lemke, a doctoral candidate enrolled at Walden University. I am completing my dissertation on inventory reduction and came across your article titled, "Should Last In First Out Inventory Valuation Methods Be Eliminated?". I appreciate your explanation on the various methods of valuing inventory and have referenced your work in the dissertation I am writing. Your straight-forward example in Appendix 1 is very clear and I would like to use it in my paper with your permission. If you are agreeable to allowing me to publish in my paper, would you please reply granting your permission. Thank you for your consideration.

Regards,

Scott Lemke