Use of RFID Technology in Lean Manufacturing: A Survey on Inventory Management

Abubaker Haddud*****
Faculty Manager and Honorary Lecturer
Operations and Supply Chain Management Online Master Pogramme
University of Liverpool
Liverpool, England

Huei Lee
Professor of CIS & SCM
Department of Computer Information Systems
Eastern Michigan University
Ypsilanti, MI 48197
Huei.Lee@emich.edu

*Corresponding Author: abubaker.haddud@my.ohecampus.com

ABSTRACT

This paper is aimed at providing an insight to help manufacturing managers determine implementation areas where RFID can have the greatest impact on inventory management in lean manufacturing settings. The study investigates the implementation of RFID technology in seven sectors of U.S. manufacturing industries. The study specifically focuses on how RFID can help identify, reduce, and eliminate the seven common types of waste identified by Taiichi Ohno. All questions are related to one of the following lean manufacturing wastes: overproduction, waiting time, inefficient transportation, inappropriate processing, unnecessary inventory, unnecessary motion, and rejects & defects. Data collected through the use of a survey. The respondents were asked to rate their level of agreement using the five-point Likert scale. Results show that the adoption of RFID technology can significantly reduce seven types of wastes except "inappropriate processing". It also indicates that RFID technology can significantly reduce 'defects' not by knowing finished goods/raw material expiry dates or implement suitable protocol, but by identifying non-conforming material and thus reducing the overall inventory.

Keywords: RFID technology, Lean manufacturing, Waste reduction, Inventory management.

Acknowledgements: The authors would like to thank the Society of Manufacturing Engineers (SME) for providing support and co-administrating the research survey.

INTRODUCTION

Many manufacturing companies are turning towards lean manufacturing to cut costs and increase profits. In implementing this philosophy, it is essential that lean benefits are measured in order to benchmark savings. Radio Frequency Identification (RFID) technology is suggested as a means to speed up this measurement process (Dunlop, 2007). Research that conjoins RFID technology and item-level inventory management on the shop floor is at a preliminary stage, only inferring benefits upon application (Saygin & Sarangapani, 2006; Saygin, Sarangapani, & Grasman, 2007). The application of RFID technology is widened into the process improvement field through its innovative implementation (Dunlop & Fitzgerald, 2007). Inventory continues to have important impact on companies across different manufacturing industries. It is important to identify where RFID technology can be implemented to help manage inventory more effectively and add more value.

The remainder of this paper is organized as five sections: In the first section, we present a brief literature review which includes background about RFID technology, lean manufacturing & waste reduction, and manufacturing inventory management. In the second section, we discuss research model which includes research question and hypothesis. In the third section, we describe research methodology which includes sampling and data collection, instrument design, and variable measurement. In the fourth section, results and discussions are presented. Finally, conclusions including summary and future work are given in the last section.

LITERATURE REVIEW

RFID Technology

Implementing RFID applications on a large scale started back in 2003, when Wal-Mart first announced that its suppliers would have to tag crates and pallets. At the time, Wal-Mart mandated that its top 100 suppliers would have to complete the move by January 2005 (Gaudin, 2008). Initially, Wal-Mart estimated the following savings: (a) $6.7 Billion in reduced labor costs (no bar-code scanning required), (b) $600 Million in out-of-stock supply chain cost reduction, (c) $575 Million in theft reduction, (d) $300 Million in improved tracking through warehousing and distribution centers, and (e) $180 Million in reduced inventory holding and carrying costs (Asif & Mandviwalla, 2005). The momentum of RFID is growing. RFID systems are being implemented throughout a surprisingly wide variety of industry sectors (Saygin, Sarangapani, & Grasman, 2007). This include aerospace, defense, consumer packed goods (CPG), healthcare, logistics, manufacturing, pharma, retails, and library. Fundamentally, RFID systems consist of three components: an electronic tag to identify each item, a tag reader, and a computer system (middleware) that translates and integrates data for enterprise applications (Stambaugh and Carpenter, 2009).

Lean Manufacturing and Waste Reduction

Russell (2009) stated that the term lean "refers to using less of everything during production – less labor, less manufacturing space, less equipment, less inventory, and less engineering inputs during development and processing – all of which results in fewer defects and more variety" (p. 721). Spencer and Plenert (2007) defined lean as a systematic approach to identifying and eliminating non-value-added activities through continuous improvement by flowing the product at the pull of the customer in pursuit of perfection (p. 34). To get lean, companies need to fully understand where they want to go and how they want to get there (Cohen, Hasan, Stonich, & Waco, 2009). Womack and Jones (1996) summarized lean thinking in five principles. To successfully adopt and continuously sustain lean philosophies, companies need to follow these five principles: (1) identify value; (2) map the value stream; (3) create flow; (4) establish pull; and (5) seek perfection. Taiichi Ohno initially identified seven types of wastes associated with manufacturing process. These are: (1) overproduction; (2) waiting (human or machine); (3) transportation; (4) over-processing; (5) inventory or work in process; (6) motion; (7) rework; and (8) un-utilized people (Adams, 2006).

Taiichi Ohno saw overproduction as the root of all manufacturing waste. Waiting waste also occurs when a worker waits for material to be delivered or for a line stoppage to be cleared, or when employees stand around waiting for a machine to process a part (Dennis, 2007). Over-processing waste is the extra effort that adds no value to the product from the customer's point of view (Alukal, 2003). Unnecessary transporting waste occurs when supplies, materials, WIP, and raw materials inventory are scattered across a plant (Rizzo, 2009). Unnecessary inventory refers to any supply in excess of a one-piece flow through the manufacturing process, whether it is raw materials, work in process or finished goods (Alukal, 2003). Examples of unnecessary motion include time spent searching for and retrieving tools and materials, poor process layout (Rizzo, 2009). The waste of defects includes the cost of time and raw materials spent manufacturing unacceptable product (Rizzo, 2009).

Manufacturing Inventory Management

Inventory has been defined as the stockpiles of raw materials, supplies, components, work in progress, and finished goods that appear at numerous points throughout the firm's production and logistics channels (Ballou, 2004). It is important to have the sufficient stock when needed – the stock should not be too much or too little. Effective inventory management is to have the necessary inventory items at the right time, at the right amount, and at the right place (Saygin, Sarangapani, & Grasman, 2007). Frazelle (2002) indicated that businesses can improve inventory management through one or more of these five approaches: improve forecast accuracy; reduce cycle times; lower purchase order/setup costs; improve inventory visibility; and lower inventory carrying costs. This study explores where RFID technology can be used to help improve inventory management.

The Five Key Lean Principles

To get lean, companies need to fully understand where they want to go and how they want to get there (Cohen, Hasan, Stonich, & Waco, 2009). Womack and Jones (1996) summarized lean thinking in five principles. To successfully adopt and continuously sustain lean philosophies, companies need to follow these five principles: (1) identify value, (2) map the value stream, (3) create flow, (4) establish pull, and (5) seek perfection.

Principle one: Identify value. The customer defines value in a lean thinking system. Product design objectives are identified though the definition of value. Value may include reliability, maintainability, availability, multiple functions, and attractive styling (Dettmer, 2001). "Value is expressed in terms of how the specific product meets the customer's needs, at a specific price, at a specific time" (Nave, 2002, p. 75).

Principle two: Map the value stream. After value is identified, activities that involve fulfilling value are identified. The sequence of these activities is called the value stream (Nave, 2002). In this step, the product is required to go through three critical management tasks: problem solving, information management, and physical information (Dettmer, 2001).

Principle three: Create flow. "Flow is the uninterrupted movement of product or service through the system to the customer" (Nave, 2002, p. 75). The objective of lean system is to make work valued by the customer move through the system quickly and smoothly (Dettmer, 2001).

Principle four: Establish pull. Womack and Jones (1996) defined Pull as "a manufacturing philosophy based on synchronizing production objectives and rates with actual customer demand, rather than on forecasts or arbitrary finished inventory levels" (Dettmer, 2001, p. 9). Through pull philosophy, the company should provide the product or service only when the customer needs it - not before, not after (Nave, 2002).

Principle five: Seek perfection. This is a constant effort attempting to: remove non-value adding activities, improve flow, and satisfy customer delivery needs (Nave, 2002). Womack and Jones (1996) stated that lean thinking has no end to the process of reducing effort, time space, cost, and mistakes, while offering products that continually approach exactly what customers want (Dettmer, 2001, p. 9).

RESEARCH MODEL

This study investigates the perceptions of the selected respondents about the impact of RFID technology implementation on manufacturing waste reduction when used in inventory management. The proposed research model is illustrated on Figure 1 on the next page.

The proposed research mode hypothesizes that the seven types of manufacturing waste (overproduction; waiting time; inefficient transportation; inappropriate processing; unnecessary inventory; unnecessary motion; and rework/defects) affected by RFID technology implementation.

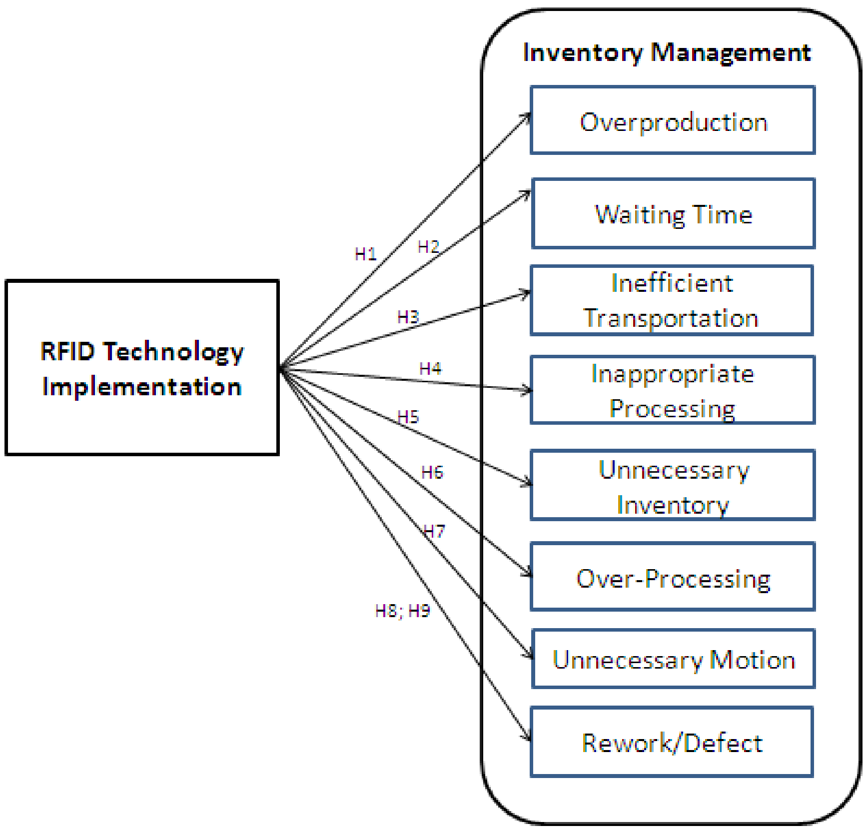
Research Question and Hypotheses

It is unclear how and where RFID technology can be implemented within manufacturing to help identify, reduce, and ultimately eliminate the seven types of waste defined by Taiichi Ohno in the Toyota production system. This research study focused on answering the following research question: Where does RFID technology have the potential of identifying, reducing, and eliminating the seven types of waste in lean manufacturing? To answer this research question, we have designed the following hypotheses:

H1: There is a significant relationship between overproduction waste reduction and the adoption of RFID technology in inventory management.

H2: There is a significant relationship between waiting time reduction and the adoption of RFID technology in inventory management.

Figure 1: Research Model



H3: There is a significant relationship between transportation inefficient reduction and the adoption of RFID technology in inventory management.
H4: There is a significant relationship between inappropriate processing waste reduction and the adoption of RFID technology by knowing which raw material is suitable for which processing.
H5: There is a significant relationship between unnecessary inventory waste reduction and the adoption of RFID technology in inventory management.
H6: There is a significant relationship between over-processing waste reduction and the adoption of RFID technology in inventory management.
H7: There is a significant relationship between unnecessary motion waste reduction and the adoption of RFID technology in inventory management.
H8: There is a significant relationship between defect waste reduction and the adoption of RFID technology by identifying non-conforming material in reducing the overall inventory requirement.
H9: There is a significant relationship between defect waste reduction and the adoption of RFID technology by knowing finished goods/raw material expiry dates and implement suitable protocols.

RESEARCH METHODOLOGY

Sampling and Data Collection

The population for this research included leaders working in the US manufacturing industry with knowledge of lean manufacturing and RFID technology. Those leaders have executive job titles that included management, president, owner, V.P, supervisor, senior, director, leader, executive, CEO, chief, chairman and industrial job titles that include (operations, production, plant, quality, and maintenance). In addition, job functions included were manufacturing production, corporate executive, manufacturing engineering, product design, quality management, and control engineering. This population includes industries classified by the North American Industry Classification System (NAICS), which include fabricated metal products, machinery manufacturing, computers and electronics, electrical equipment, transportation equipment, furniture and related products, and miscellaneous manufacturing. Finally, only plants with a size of 250 employees or more were considered for this research.

The research sample included those leaders who fit into the above stated population criteria and are currently active US members with the Society of Manufacturing Engineers (SME) and have self-reported that lean manufacturing is their technical interest when applying for the SME membership.

Instrument Design

For the purpose of this research, a survey was used to gather data and was administered electronically using the SurveyMonkey website. All questions were close-ended. 35 questions were based on a five-point Likert-type scale and five were related to demographic information. Questions were developed using two approaches: first, utilizing information from existent literature mainly from a study conducted on businesses within the European Union region (Brintrup, Roberts & Astle, 2008). Second, a panel of experts that consisted of three industry experts and three university scholars verified the selected questions. The validity of the final instrument was established through a review by this selected panel. The survey consists of five sections. The third section of the survey consists of nine questions to explore where the use of RFID technology may improve inventory management through the reduction of the seven common types of waste in lean manufacturing. These questions were designed to investigate if there is a significant relationship between lean manufacturing waste reduction and the adoption of RFID technologies in inventory management.

Variable Measurement

Independent variables. The seven common types of manufacturing waste have been used as independent variables in this study. These are: (overproduction, waiting time, transportation, over-processing, inventory, motion, and rework). Nine RFID technology potential implementations within inventory management at a lean manufacturing setting were investigated. Each item is related to one of the mentioned seven manufacturing wastes. All the questions were close-ended and used the five-point level of agreement Likert-type scale: (1) Strongly disagree, (2) Disagree, (3) Neutral, (4) Agree, (5) Strongly agree.

Table 1: The Investigated Items

	Items
1	The use of RFID technology helps reduce 'overproduction' by knowing how much of goods/materials are in stock.
2	The use of RFID technology helps reduce 'waiting time' by knowing where finished goods/materials are.
3	The use of RFID technology helps reduce 'inefficient transportation' by knowing where nearest finished goods/raw materials are.
4	The use of RFID technology helps reduce 'inappropriate processing' by knowing which raw material is suitable for which processing.
5	The use of RFID technology helps reduce 'unnecessary inventory' by improving inventory visibility.
6	The use of RFID technology helps reduce 'unnecessary inventory' by eliminating the need for material queuing, and assisting in the application of Just-in-Time methodology.
7	The use of RFID technology helps reduce 'unnecessary motion' by eliminating manual counts and human error.
8	The use of RFID technology helps reduce 'defects' by identifying non-conforming material and in turn reducing the overall inventory required.
9	The use of RFID technology helps reduce 'defects' by knowing finished goods/ raw material expiry dates and implement suitable protocols.

Dependent variable. This study intends to gain the perception of the selected participants of the impact of RFID technology adoption on lean manufacturing waste reduction in inventory management. Table 1 illustrates the investigated items.

RESULTS AND DISCUSSION

Scale Reliability

The reliability was evaluated using Cronbach's alpha coefficient in order to assess the internal consistency of the nine items utilizing the SPSS software. Cronbach’s alpha is based on the average inter-item correlation and it is the most generally accepted instruments internal consistency reliability test (DeVellis, 2003). Although 0.7 or higher is normally what considered to be an acceptable reliability coefficient, lower thresholds are sometimes used in the literature (Santos, 1999). The closer Cronbach’s alpha coefficient is to 1.0, the greater the internal consistency of the items in the scale (Gliem & Gliem, 2003).

Cronbach’s alpha reliability coefficient value of all 9 items (as one scale) was 0.871. Individual coefficient values for each items ranged from 0.846 to .866 – this is very acceptable.

Items Statistics

The scale mean was 31.49 and standard deviation was 5.86 with a variance of 34.42. The scale statistics are presented in Table 2 below. The items means ranged from 2.86 to 3.69 with an overall mean of 3.49. Items 4, 6, and 8 had means below the average. All items’ mean averages were above 3.00 except item 8 (2.86). This indicated that respondents tended to respond on the positive side of the five-point Likert-type scale. Corrected item-to-total correlation for item 9 was 0.718. Items 2, 3, 5, and 6 had corrected item-to-total correlations ranged from 0.603 to 0.672. Items 1, 4, 7, and 8 had an item-to-total correlation from 0.505 to 0.571. A rule-of-thumb is that these values should be at least 0.40 (Gliem & Gliem, 2003). Except items 4, 6, and 8, the remaining items had significant item skewness above +/- 0.7. These data indicated highly homogenous responses by respondents. Most responses were at the end of the Likert-type scale with a mode of 4.00 for items 1, 2, 3, 5, 6, 7, and 9. Items 4 and 8 had a mode of 3.00. All skewed items were negatively skewed. The 25th percentile was 3 for items 1, 2, 3, 4, 5, 6, 7, and 9. It was 2.00 for item 8. The 75th percentile of item 8 was 3.6 and the remaining items were 4.00.

As illustrated on Table 3, items central tendency measures using Mode. In addition, and to make the data results much easier to understand, a chi square test representing residual values for each of the five-point Likert-type scale categories is provided.

Chi-square test is comparing expected N to observed N. A decision about the expected values against which the actual frequencies are to be tested was made by setting all categories to equal value because this is the most common choice. These equal values are determined by dividing the total number of usable responses by the number of the used Likert-types scale. In this study, the usable responses were 77 and the used Likert scales were five. By dividing 77 by five the result was 15.4. The highest residual value

Table 2: Item Statistics for Inventory Management Scale

	Mean	Std. Dev.	Item Skewness	Item-to-total correlations
1. The use of RFID technology helps reduce 'overproduction' by knowing how much of goods/materials are in stock.	3.68	.926	-1.157	.536
2. The use of RFID technology helps reduce 'waiting time' by knowing where finished goods/materials are.	3.66	.931	-1.166	.654
3. The use of RFID technology helps reduce 'inefficient transportation' by knowing where nearest finished goods/raw materials are.	3.52	.944	-.824	.672
4. The use of RFID technology helps reduce 'inappropriate processing' by knowing which raw material is suitable for which processing.	3.34	.946	-.238	.571
5. The use of RFID technology helps reduce 'unnecessary inventory' by improving inventory visibility.	3.69	.833	-1.022	.632
6. The use of RFID technology helps reduce 'unnecessary inventory' by eliminating the need for material queuing, and assisting in the application of Just-in-Time methodology.	3.32	.970	-.490	.603
7. The use of RFID technology helps reduce 'unnecessary motion' by eliminating manual counts and human error.	3.85	.892	-.780	.564
8. The use of RFID technology helps reduce 'defects' by identifying non-conforming material and in turn reducing the overall inventory required.	2.86	.887	-.093	.505
9. The use of RFID technology helps reduce 'defects' by knowing finished goods/ raw material expiry dates and implement suitable protocols.	3.59	.998	-.727	.718

was the decisive factor when selecting under which of the five scales the majority of responses were.

The mode and residual values were calculated for each of the 9 items as presented in Table 2. Items 1, 2, 3, 5, 6, 7, and 9 had a mode of 4. This is equal level 4 (Agree) of the used Likert-type scale. Items 4 and 8 had a mode of 3. This is equal to level 3 (Neutral) of the used Likert-type scale. Items 4 and 8 were rejected based on this test.

Table 3: Items Statistics

		Chi Square Test – (Frequencies Residual Values)					
Item	Mode	SD	D	N	A	SA	Hypothesis
1	4	-11.6	-9.6	-1.6	28.4	-5.6	accept
2	4	-11.6	-8.6	-2.6	29.4	-6.6	accept
3	4	-11.6	-7.6	4.4	22.4	-7.6	accept
4	3	-12.6	-3.6	12.4	11.4	-7.6	reject
5	4	-12.4	-11.4	3.6	26.6	-6.4	accept
6	4	-11.6	-2.6	7.4	16.4	-9.6	accept
7	4	-13.6	-9.6	-.6	22.4	1.4	accept
8	3	-10.6	6.4	15.4	2.4	-13.6	reject
9	4	-11.6	-7.6	3.4	19.4	-3.6	accept

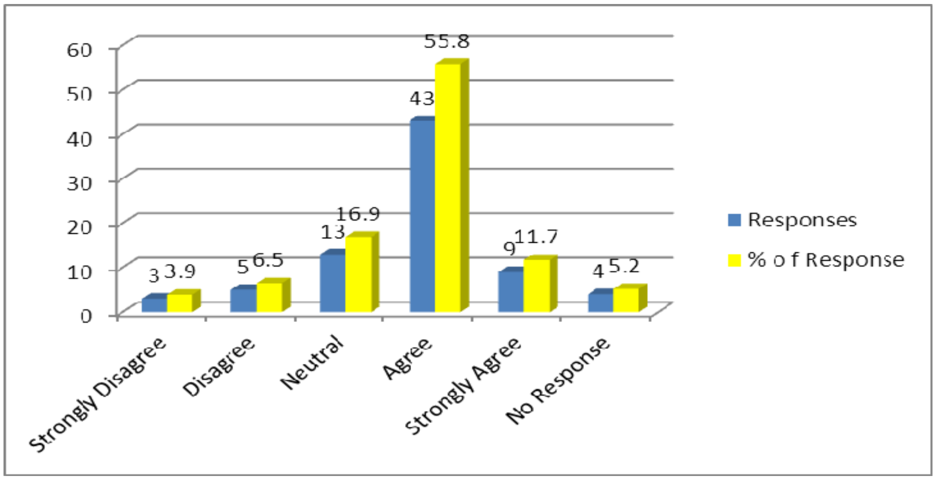
SD=Strongly Disagree; D=Disagree; N=Neutral; A=Agree; SA=Strongly Agree

The highest residual values for items 1, 2, 3, 5, 6, 7, and 9 were under (Agree) category. Whereas, the highest residual values for items 4 and 8 were under (Neutral) category. Thus, items 4 and 8 were rejected. Based on these results, the majority of respondents agreed that inventory management will improve through the adoption of RFID technology that reduces the following six lean manufacturing wastes; overproduction, waiting time, inefficient transportation, unnecessary inventory, unnecessary motion, and defects. Whereas respondents did not think the adoption of RFID technology helps reduce the waste of inappropriate processing in lean manufacturing settings.

RFID can be used to improve inventory management through: (a) eliminating manual counts and human error; (b) eliminating the need for material queuing, and assisting in the application of just-in-time methodology; (c) improving inventory visibility; (d) knowing finished goods/ raw material expiry dates and implement suitable protocols; (e) knowing where nearest finished goods/raw materials are; (f) knowing where finished goods (or materials) are; and (g) knowing how much of goods/materials are in stock. In conclusion, items 1, 2, 3, 5, 6, 7, and 9 were supported, whereas, items 4 and 8 were not supported.

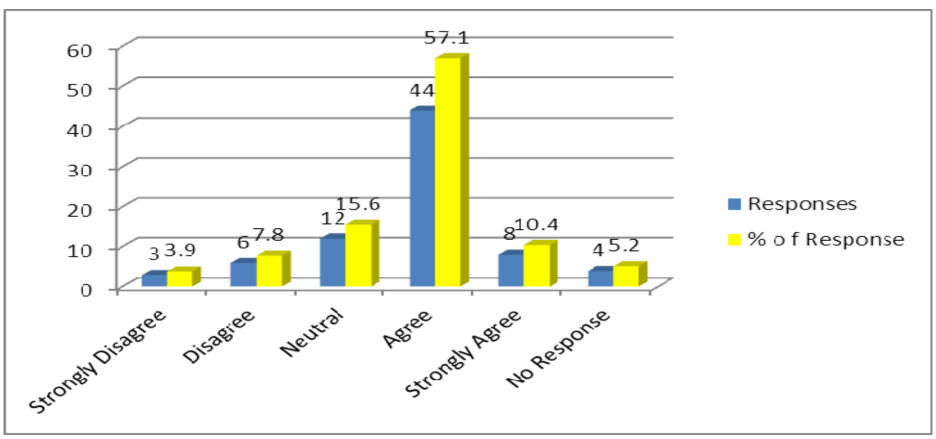
Figures 1 to 9 show the distribution of responses of each of the nine questions showing number of responses and percentages that strongly disagree, disagree, neutral, agree, and strongly agree.

Figure 1: Analysis of Responses to Overproduction



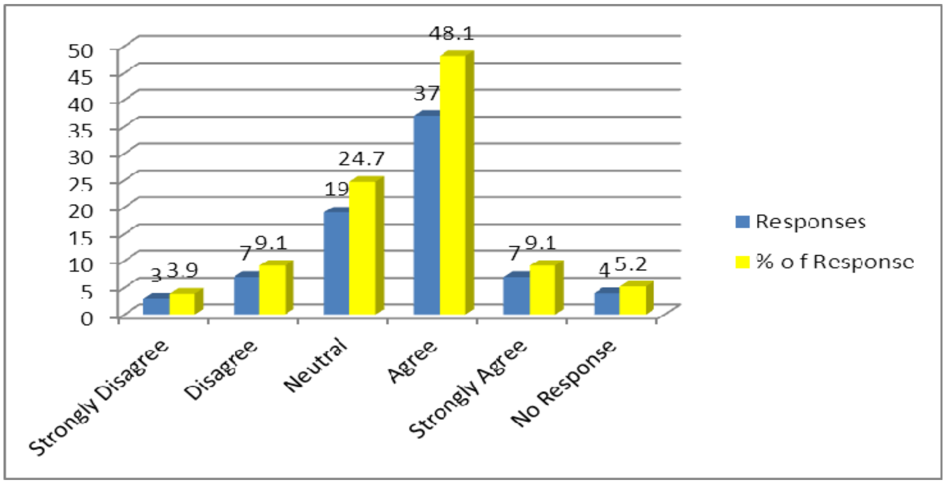
Question: The use of RFID technology helps reduce 'overproduction' by knowing how much of goods/materials are in stock. (N=77)

Figure 2: Analysis of Responses to Waiting Time



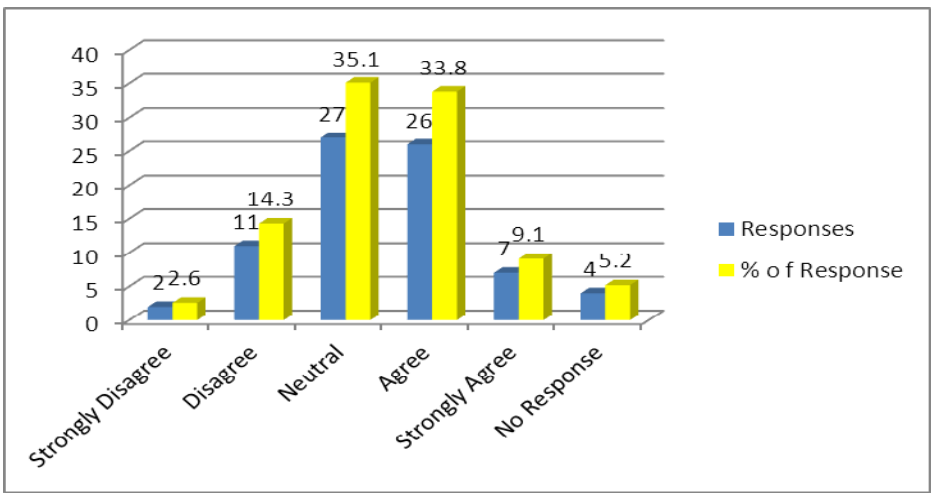
Question: The use of RFID technology helps reduce 'waiting time' by knowing where finished goods/materials are.

Figure 3: Analysis of Responses to Inefficient Transportation



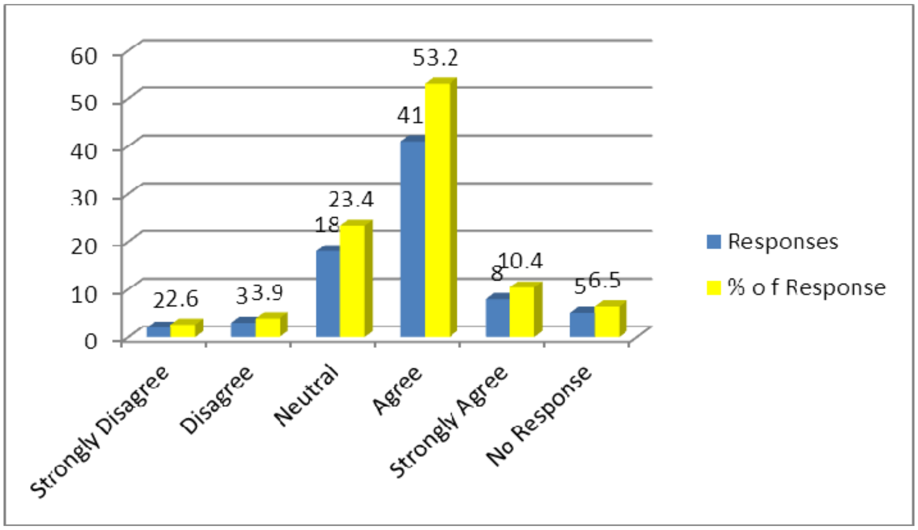
Question: The use of RFID technology helps reduce 'inefficient transportation' by knowing where nearest finished goods/raw materials are.

Figure 4: Analysis of Responses to Inappropriate Processing



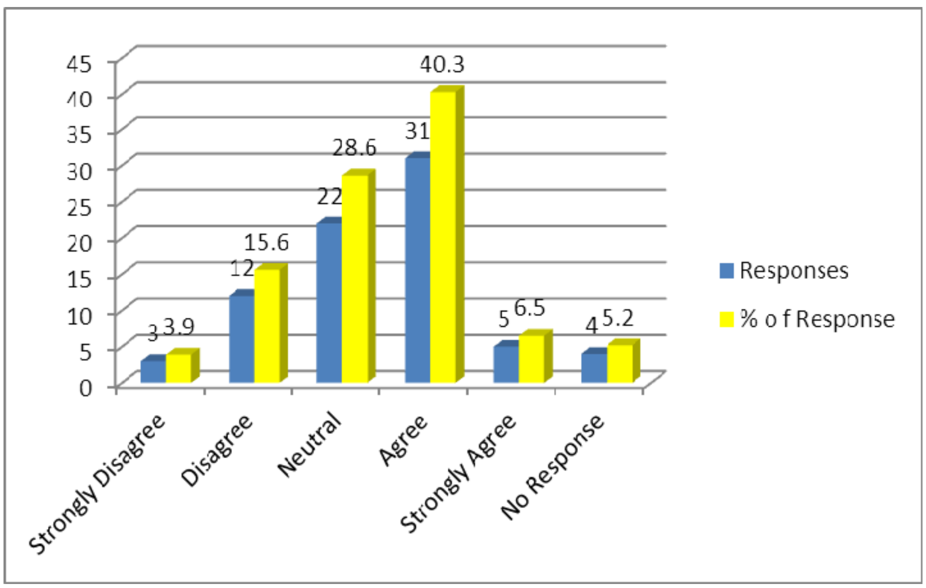
Question: The use of RFID technology helps reduce 'inappropriate processing' by knowing which raw material is suitable for which processing.

Figure 5: Analysis of Responses to Unnecessary Inventory – Improving Visibility



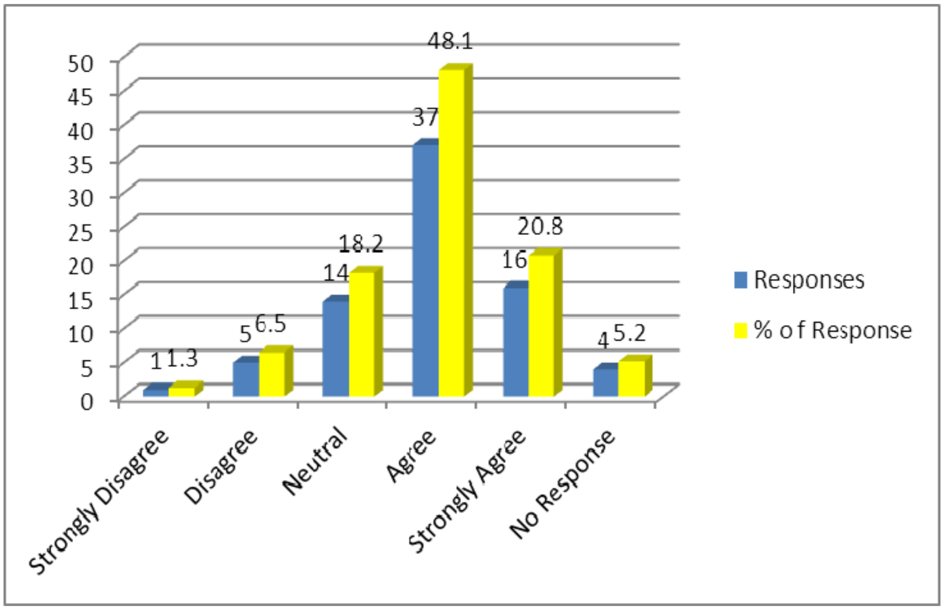
Question: The use of RFID technology helps reduce 'unnecessary inventory' by improving inventory visibility.

Figure 6: Analysis of Responses to Unnecessary Inventory – Eliminating Queuing



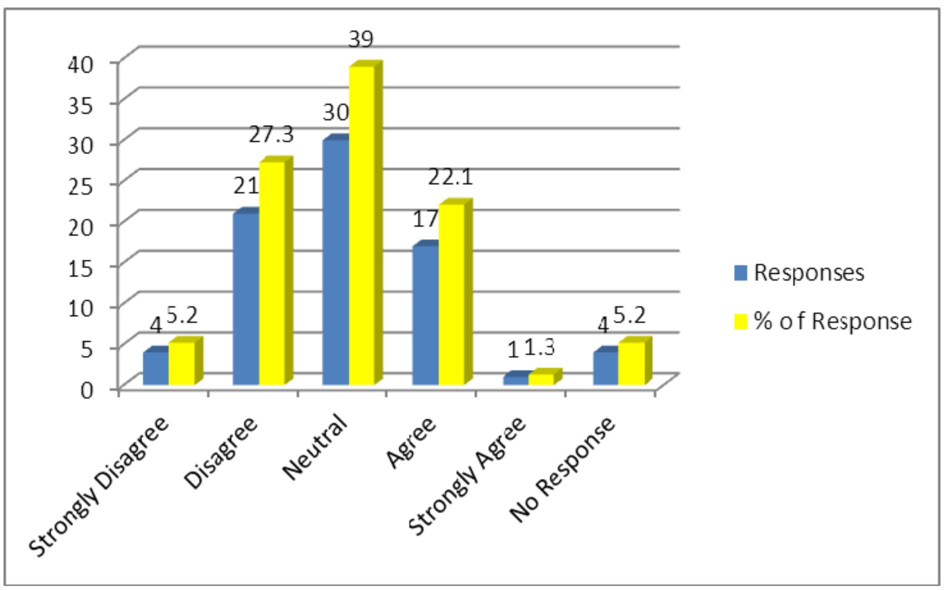
Question: The use of RFID technology helps reduce 'unnecessary inventory' by eliminating the need for material queuing, and assisting in the application of Just-in-Time methodology.

Figure 7: Analysis of Responses to Unnecessary Motion



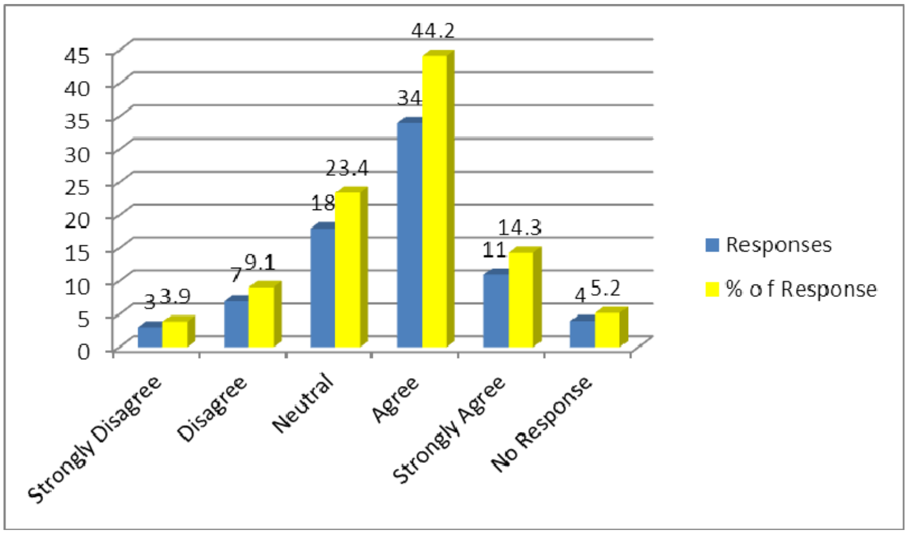
Question: The use of RFID technology helps reduce 'unnecessary motion' by eliminating manual counts and human error.

Figure 8: Analysis of Responses to Reduce Defects-Nonconforming



Question: The use of RFID technology helps reduce 'defects' by identifying non-conforming material and in turn reducing the overall inventory required.

Figure 9: Analysis of Responses to Reduce Defects – Expiry Dates



Question: The use of RFID technology helps reduce 'defects' by knowing finished goods/ raw material expiry dates and implement suitable protocols.

CONCLUSION AND IMPLICATION

The study attempts to study whether RFID can help identify, reduce, and eliminate the seven common types of waste identified by Taiichi Ohno. Based on the perception of the managers from several types of industries, the adoption of RFID technology can significantly reduce seven types of waste except "inappropriate processing". It may indicate that current RFID technology is not sophisticate enough to identify the inappropriate process. Furthermore, RFID technology can significantly reduce 'defects' not by knowing finished goods/raw material expiry dates or implement suitable protocol, but by identifying non-conforming material and thus reducing the overall inventory.

Practical Contribution

Lean manufacturing is one of important topics for manufacturing companies in recent years. Taiichi Ohno has identified seven types of waste in manufacturing in the Toyota production system. How to reduce the types of wastes using current technology is important to major manufacturing companies. As mentioned by Heim, Wentworth, and Peng (2009), "... managers today are facing difficulty decisions about whether to adopt RFID or wait until the technology matures further…," The major contribution of this study is to know what types of wastes the current RFID technology can reduce and thus achieve the goal of lean manufacturing. The results are obtained through a survey of managers from major manufacturing companies across seven different types of industries. It provides insight for the managers for adopting RFID technology. It also indicates what the RFID can contribute and what the RFID cannot.

Theoretical Contribution

Current literature does not provide the framework between RFID technology and waste reduction. This study contributes to academic literature by establishing a link between RFID and seven types of waste reduction mentioned by Taiici Ohno. Furthermore, the study conducted a survey from managers in seven different types of industries and indicated RFID is useful in reducing most of the waste in manufacturing.

Limitation and Future Studies

The limitation of the study has two. First, the sample size is about 250 from managers who are implementing RFID technology. The sample size is fine but larger sample can be done. Second, the data were collected through the subjective opinion of managers from manufacturing companies. To actually measure the relationship between adoption of RFID technology and reducing waste, a more objective scientific experiment can be setup for certain period (for example, one year of costing data between pre-adoption and post adoption).

REFERENCES

Adams. J. (2006). Stop wasting time, effort, money! *Supply House Times*, *48*(11), 26-27.

Asif, Z., & Mandviwalla, M. (2005): Integrating the supply chain with RFID: A technical and business analysis, *Communications of the AIS*, 15(24), 393-426. Retrieved April 8, 2010, from http://www.bauer.uh.edu/rfid/Spring2006/RFID_Tutorial.pdf

Alukal, G. (2003). Create a lean, mean machine. *Quality Progress*, *36*(4), 29-34.

Ballou, H. (2004). Business logistics/supply CHAIN management. planning, organizing and control the supply CHAIN management. 5th edition. Pearson – Prentice Hall. USA.

Brintrup, A., Roberts, P., & Astle, M. (2008). Report: Methodology for Manufacturing Process Analysis for RFID Implementation.

Burnell, J. (2006). What is RFID Middleware and Where is it Needed? RFID update.

Chuang, M. & Shaw, W. (2008). An empirical study of enterprise resource management systems implementation: From ERP to RFID, *Business Process Management Journal*, *14*(5), 675-693.

Cohen, S., Hasan, N., Stonich, M., & Waco, M. (2009, November). Achieving success with large-scale lean. *Supply Chain Management Review*, *13*(8), 42. Retrieved April 19, 2010, from ABI/INFORM Global. (Document ID: 1932449721).

Cusumano, M. (1994). The limits of lean. *Sloan Management Review*, *35*(4), 27–32.

Dennis, P. (2007). *Lean Production Simplified* (2nd ed.). University Park, IL: Productivity Press.

Dettmer, W. (2001). Beyond lean manufacturing: Combining lean and the theory of constraints for higher performance. Port Angeles, US. Retrieved April 19, 2010, from http://www.goalsys.com/books/documents/TOCandLeanPaper-rev.1.pdf

DeVellis, F. (2003). *Scale Development: Theory and Applications* (Second Edition ed.). Thousand Oaks: Sage Publications.

Dunlop, G., & Fitzgerald, K. (2007). Measuring lean benefits using radio frequency Identification (RFID) Technology. Retrieved October 15, 2009, from http://www.rfidinfo.jp/whitepaper/381.pdf

Fink, R., Gillett, J. & Grzeskiewicz, G. (2007). Will RFID change inventory assumptions? *Strategic Finance*, *89*(4), 34-39.

Frazelle, E. (2002). *Supply chain strategy: The logistics of supply chain management*. New York: McGraw-Hill.

Gaudin, S. (2008, April). Some suppliers gain from failed Wal-Mart RFID edict. *Computerworld*, *42*(18), 12-13. Retrieved March 12, 2010, from ABI/INFORM Global. (Document ID: 1475080861).

Gliem, J., & Gliem, R. (2003). Calculating, interpreting, and reporting Cronbach´s alpha coefficient for Likert-type Scale. Type scales. Presented at the Midwest research to practice conference in adult, continuing, and community education. The Ohio State University, Columbus, OH, October 8-10. Retrieved October 29, 2010, from https://scholarworks.iupui.edu/bitstream/handle/1805/344/Gliem+&+Gliem.pdf?sequence=1

Heim, G. R., Wentworth Jr., W. R., & Peng, X., (2009). The value to the customer of RFID in service applications. *Decision Sciences*, *40*(3), 477-512.

Huang, S. & Shieh, S. (2010). Authentication and secret search mechanisms for RFID-aware wireless sensor networks, *International Journal of Security and Networks*, *5*(1), 15-25.

Jordan, J., & Michel, F. (2001). *The Lean Company: Making the Right Choices*. Dearborn, MI: Society of Manufacturing Engineers.

Kilpatrick, J. (2003). Lean Principles. Utah Manufacturing Extension Partnership.

Levinson, M. (2009). Henry Ford’s proven lessons for American industry. *Industry Week*, *258*(7), 16-17.

Mcleod. A. (2009). Conceptual development of an introductory lean manufacturing course for freshmen and sophomore level students in industrial technology. *Technology Interface Journal*, *10*(1).

Nave, D. (2002). How to compare Six Sigma, Lean and the Theory of Constraints. *Quality Progress*. *35*(3), 73-78. Retrieved March 8, 2010, from http://www.asq1530.org/images/Compare_Lean_Six_Sigma_TOC.pdf

Rizzo, K. (2009). 8 Costly Issues. *American Printer*, *26*(5), 20-23.

Russell, L. (2009). Are lean organizations better prepared for disaster? Retrieved October 30, 2009, from http://www.swdsi.org/swdsi2009/Papers/9S11.pdf

Santos, J. R. A. (1999). Cronbach’s alpha: a tool for assessing the reliability of scales. *Journal of Extension*, *37* (2). Retrieved October 28, 2010, from http://www.joe.org/joe/1999april/tt3.html

Saygin, C. & Sarangapani, J. (2006). RFID on the Manufacturing Shop Floor: Applications and Challenges, invited session on RFID, Annual Industrial Engineering Research Conference (IERC).

Saygin, C., Sarangapani, J. & Grasman, S. E. (2007). A systems approach to viable RFID implementation in the supply chain. *Trends in Supply Chain Design and Management.* Springer: London, 3-27.

Schiele, J. (2009). Lean thinking, *Government Procurement*, *17(4)*, 10.

Spencer, D., & Plenert, G. (2007, November). Win in the flat world: Apply lean principles across the IT organization. Manufacturing Business Technology, *25*(11), 34. Retrieved April 17, 2010, from ABI/INFORM Global. (Document ID: 1382680561).

Stacks, C. & Ulmer, J. (2009). Applied lean thinking: General usage principles. *Technology Interface Journal*, *9*(2), 1-13.

Stambaugh, C. & Carpenter, F. (2009). RFID: Wireless innovations in inventory monitoring and accounting, *Strategic Finance*, *91*(6), 35-40.

Stier, K. W. (2003). Teaching lean manufacturing concepts through project-based learning and simulation. *Journal of Industry Technology*, *19*(4), 2-6.

The Total North American RFID market for manufacturing and logistics generated $74.8 million in 2005. (2006). *RFID Industry.* Retrieved from: http://www.rfid-industry.com/app/sc/mf/manufacturingrfid.htm

Wilcox, D (2008). Teaching your employees to recognize waste is the smart thing to do. *SuperVision*, *69*(2), 10-13.

Womack, J. & Jones, D. (1996). *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. NY: Simon and Schuster.

Abubaker Haddud works as a Faculty Manager for the Operations and Supply Chain Management Online Master's Programme at the University of Liverpool in England. He also works as a management consultant for the Ministry of Oil and Gas in Libya and a faculty for the Academy of Graduate Studies in Tripoli - Libya. Abubaker has several years of university teaching experience, within business and management domain at undergraduate and postgraduate. He has more than 10 years of industrial work experience working for private, public and governmental organizations. Dr. Haddud has a PhD in Engineering Management from Eastern Michigan University (USA) where he was a Fulbright Scholar. He also has an MBA with Distinction from Coventry University (UK), and a Bachelor's degree in Management from Tripoli, Libya. His teaching and research interests focus on lean thinking, strategic Operations Management and Supply Chain Operations Management.

Huei Lee is a professor of Computer Information Systems and Supply Chain Management at Eastern Michigan University. He currently serves as a member of the advisory committee for advisory board of Microsoft Dynamics Academic Alliance (DyNAA) and the editor-in-chief for *Journal of Integrated Enterprise Systems* (JIES). He was also the former president of the Association of Chinese Management Educators (ACME). He received his Ph.D. from Georgia State University. Dr. Lee received distinguished research awards from both the Southern Business Administration Association and the Academy of Information and Management Sciences. He also received Instructional Award from Microsoft DyNAA in 2013. He has published more than sixty refereed articles in academic journals or proceedings.