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Lean Manufacturing Tools In Job Shop, Batch Shop and Assembly Line Manufacturing Settings

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Dr. Daniela Todorova and Dr. John Dugger

Abstract

Lean manufacturing implementations have been very popular based on the promise of improving the economic advantage of manufacturing organizations while attaining better outcomes using less of everything.

This study addressed the differing challenges faced by those organizations undertaking a lean implementation in different manufacturing settings. The levels of applicability of sixteen lean tools were examined using an electronic survey generated through social media mechanisms of those in charge of manufacturing in three different manufacturing settings: a job shop, a batch shop, and an assembly line. One hundred eighty nine usable surveys were analyzed for the purposes of this research.

The results revealed that different lean tools are used at different levels in the three manufacturing settings, and the lean tools contributing most to the group differences between job shop and batch shop settings were *Heijunka* (HEIJ), *Just in Time* (JIT) and *Kaizen* (KAIZ).

Recommendations for each of the three types of manufacturing settings are provided.

Suggestions for future research: A replication of this study should utilize discriminant analysis combining job shop and batch shop as one group, and comparing the level of implementation of the lean tools with an assembly line setting. An effort that compares the level of implementation of the lean tools between an assembly line and continuous flow manufacturing setting is suggested as well.

Introduction

The implementation of the Lean approach in manufacturing settings has been very popular based on the promise of improving the economic advantage of the firm along with the promise of attaining better outcomes while using less of everything. Lean manufacturing is the other name of the Toyota Production System (TPS) (Chen et al., 2010). Reduction of delivery time, labor, capital and space are some examples of the lean benefits achieved through continuous improvement techniques (Taninecz, 2005; Katayama & Bennett, 1996). In the lean manufacturing companies, product is designed and distributed in less than half the time that other companies do (Sohal, 1996). Overall, the lean manufacturing has proven to be a very effective management system attaining better operational outcomes (Dibia & Onuh 2010).

Most of the lean success stories are from companies with production technology similar to Toyota's: only cosmetic customization, high volume production, repetitive manufacturing and stable or predictive demand (Lander & Liker, 2007), which are characteristics of an assembly line production. The unchanged lean formula is applicable to a small sector of manufacturers using an assembly line manufacturing setting, while for the rest, guidance is needed to adjust to different company's situations (Jina et al., 1997). Lean is universally applicable, but only after some adjustment for the characteristics of each industry or plant (Shingo, 1981).

For a successful lean implementation, it is important to know which lean tools are relevant to which environments (Corbett, 2007). Despite the fact that each lean implementation is unique, there is a likelihood that we can generate lean production development trajectories for different types of manufacturing settings (Lewis, 2000). Lean manufacturing is a well understood concept, but its applicability to low volume, high value, and complex products has not been well defined (James-Moore & Gibbons, 1997). This paper will investigate the optimal level of implementation of each of the identified sixteen lean tools for the job shop, batch shop and assembly line manufacturing settings.

Creating a lean success route is a challenging procedure because of the uniqueness of each individual lean implementation (Lewis, 2000). Lean research efforts have identified many reasons for the lean failure, but many questions remain. Consequently, if the appropriate alignment between the lean tools and the particular manufacturing settings is outlined, the companies will have a greater probability of success in implementing lean, sustaining the results, and improving organizational performance.

Problem Statement

The problem of the study was to determine the degree of applicability of different lean tools within a job shop, a batch shop, and an assembly line manufacturing setting.

Significance of this Study

Despite a wealth of natural and economic resources, US manufacturing companies are forced to constantly seek ways to reduce waste when competing with low-cost foreign suppliers (Fullerton & Watters, 2001; Flinchbaugh, 2005). However, based on the high level of competitiveness of the current market place, U.S. firms are looking for better ways of doing business (Fullerton & Watters, 2001; Flinchbaugh, 2005). To enhance competitiveness, some manufacturers have focused on two strategies: moving their production off-shore or implementing lean concepts (Chen et al., 2010).

The U.S. manufacturing landscape is transforming itself through the lean production paradigm (Fullerton & Wempe, 2009). The results have proven that lean manufacturing is the most successful tool employed by manufacturing companies (Green et al., 2010). Based on the increased global competition faced by most manufacturing organizations, almost every manufacturing industry is willing to implement lean (Pavnaskary et al., 2003; Vinodh & Chintha, 2011).

Principles of Lean

In *Lean Thinking*, Womack and Jones (1996) identified five lean principles essential for successful lean implementation and elimination of non-value added activities: (a) specify value, (b) identify the value stream, (c) flow, (d) pull, and (e) perfection. These lean principles are successfully improving performance in many industries, but they are universally applicable

only after some adaptation to specific characteristics (Poppendieck, 2002; Shingo, 1981). Lean tools are solving Toyota's problems, because they were designed by Toyota for Toyota, but for a specific organization's problems, specific tools must be designed or existing tools modified to increase the likelihood of success (Lander & Liker, 2007). The universality of lean applications depends on being adaptable to different business conditions (Cooney, 2002).

Types of Manufacturing Settings

Hayes and Wheelwright (1984) identified four different types of manufacturing settings: job shop, batch shop, assembly line and continuous flow. The Job shop mostly relies on the knowledge of workers, and is characterized by wide variability in the demand for specific jobs along with a constantly changing product mix with small to medium volume. Examples include machine tool shops, machining centers, or paint shops (Hayes and Wheelwright, 1984).

The batch shops usually have several key products, produced in batches with disconnected activities which require setup time for changeover between the products, such as injection-molding manufacturing (NetMBA, 2011). A batch shop is a standardized job shop with a stable line of products (Hayes and Wheelwright, 1984). Examples are bakeries, and the manufacture of pharmaceutical ingredients and sports shoes.

The assembly line is characterized by very few products, low flexibility, high volumes and a fixed sequence of activities (NetMBA, 2011), such as in an automobile assembly plant or a soft drink bottling plant. Other characteristics include sequenced workstations producing highly similar products with operators performing assembly tasks, and products moving from workstation to workstation (Hayes & Wheelwright, 1984; Eswaramoorthi et al., 2011).

Low volume production organizations such as job and batch shops need the implementation of lean manufacturing to increase profitability (Hogan, 2005). Labor saving, reduced customer lead time and inventory reduction are the results of converting a job shop to a just–in-time environment (Howard and Newman, 1993). Implementing JIT converts the job shop to a continuous manufacturing process (Faizul & Lamb, 1996). Implementing cellular manufacturing in a job shop or batch shop manufacturing settings is not an acceptable solution because of the diverse demand pattern (Zijm and Kals, 1995). Longer-term planning and production schedules not dependent on firm orders, and long terms plans made based on a sales forecasts are some of the characteristics of large batch and mass production (Woodward, 1965, p. 135).

As indicated earlier, most of the lean success stories are from companies with production technology similar to Toyota (Lander & Liker, 2007). In low volume-high variety production settings, lean implementations have not been as successful, because each job is different and production approaches cannot be standardized (Pepper & Spedding, 2010).

Lean Tools

A literature review has yielded the sixteen lean tools found in Table 1. These tools were used for the purposes of this study.

TABLE (1): Lean Tools		
Lean Tools	**Definition**	**Literature**
Just in Time (JIT)	When an actual order is placed, the right item is produced at right time, in right quantity	Dennis, 2007
Continuous Flow (CONTFL)	The product flow, at rate one piece at a time from one process to another without WIP inventory between the processes.	Liker, 2004
Heijunka (HEIJ)	The workload and production is leveled over defined period in order to achieve constant flow of mixed parts and to minimize the peaks and valleys in the workload.	Furmans, 2005
Quick Set Up (QSETUP)	Reduced amount of time for change over from running one product to another.	Kilpatrick, 2003
Jidoka (JID)	Quality is built into the process through people and machine detecting abnormal conditions, preventing defective parts of passing to the next process and determining and eliminating the root cause.	Dennis, 2007; Haak, 2006; Liker, 2004;
Poke Yoke (PYOKE)	Low cost, error proofing device with high reliability is designed for specific work place conditions.	Melton, 2005; Dennis, 2007
Andon (AND)	Device allowing everyone working on the production line to stop the production if defect is detected	Kasul and Motwani, 1997
Standardized Work (STANDW)	The best practices are standardized and used as a base for improvement	Dennis, 2007; Liker, 2004;
5 S system (FIVES)	The extent to which the workplace is organized and standardized.	Dennis, 2007;
Total Productive Maintenance (TPM)	The extent to which everyone on the shop floor is involved in preventive basic maintenance work.	Kilpatrick,2003;
Visual Management (VISM)	The extent to which value added information is displayed to everyone.	Hogan, 2009; Melton, 2005;
Kaizen (KAIZ)	Employees contribute to the company's development through suggestions aiming elimination of all kinds of wastes.	Dennis, 2007;
Teams (TEAM)	Team members with supplementary skills work together to achieve common goals.	Sanchez and Perez, 2001;
Workers Involvement (WINV)	The extent to which employees are motivated to participate in continuous improvement and problem-solving activities.	Bodek, 2010;
Value Stream Mapping (VSM)	The extent to which the current process is mapped to make the improvement opportunities obvious.	Dennis, 2007;
Muda (MUDA)	The extent to which the process is not value added.	Womack and Jones, 1996

Theoretical Framework

"Contingency theories are a class of behavioral theory that contends that there is no one best way of organizing/leading and that an organizational/leadership style that is effective in some situations may not be successful in others" (Fiedler, 1964, p. 151). An organization is performing well when the context and structure somehow align together (Drazin & Ven, 1985). Because the success of a lean implementation is contingent on the organization's environment or context, the lean practices must be customized to align with a particular organization's environment (Browning & Heath, 2009). A best lean implementation approach that is applicable to all organizations does not exist, because the moderating factor of contextual variables have to be taken into account (Browning & Heath, 2009).

Purpose of the Study

The purpose of this study was to examine the differences in the level of utilization of the lean tools as defined by Liker (2004), Dennis (2007), and Womack and Jones (1996) in three of the different manufacturing settings identified by Hayes and Wheelwright (1984): job shop, batch shop, and assembly line. For a successful lean implementation, it is very important to know which of the lean tools are applicable to a specific environment (Corbett, 2007). Based on contingency theory and in the universality of lean principles that are dependent on different contextual factors, this study hypothesized the following.

> *H1 (Null): There would be no significant difference between the degrees of utilization of each lean tool in a batch shop when compared to an assembly line manufacturing setting.*
>
> *H2 (Null): There would be no significant difference between the degrees of utilization of each lean tool in a job shop when compared to an assembly line manufacturing setting.*
>
> *H3 (Null): There would be no significant difference between the degrees of utilization of each lean tool in a job shop when compared to a batch shop manufacturing setting.*

Methodology

This study utilized a descriptive research approach to gather the perceptions or those manufacturing professionals knowledgeable about lean principles and about different manufacturing settings. An electronic survey and social network connections were used as well.

Population and Sample

The population for this study included manufacturing leaders, managers or engineers with lean manufacturing knowledge and experience who were working for US manufacturing companies that were at some stage of lean implementation. The potential sample included members of the Lean Enterprise Institute (LEI) or members of Continuous Improvement, Six Sigma, and Lean LinkedIn groups.

Instrument Development

An instrument (see Appendix A) was developed to examine the level of utilization of each of the lean tools in the job shop, batch shop and assembly line manufacturing settings. This study utilized portions of the empirically validated measurement instruments for measuring

the companies' lean implementations proposed by Shah and Ward (2007), operational items for *Just in Time* (JIT), *Continuous Flow* (CONTFL), *Total Productive Maintenance* (TPM), *Workers Involvement* (WINV), and *Quick Set Up* (QSETUP). According Shah and Ward (2007), an empirically tested operational measure is "reliable and meets established criteria for assessing validity" (p. 28). A Likert-type scale was selected to reflect the purpose of this instrument. When using a Likert-type scale, the respondents make an evaluation of the statement based on magnitude (Leedy & Ormrod, 2005). The anchors selected for the Likert-type scale were: 1-strongly disagree, 2-disagree, 3-neutral, 4-agree, and 5-strongly agree.

The instrument was used to determine the level of implementation of each of the sixteen lean tools identified by earlier authors.   Q-sort pilot testing was performed to establish content validity and convergent validity as well as to assess survey an items' readability (Moore & Benbasat, 1991). Reliability was established since all Cronbach alpha coefficients were greater than 0.74 (Davis, 1996). Threats to content validity were initially addressed through a comprehensive literature review (Davis, 1996). Internal consistency or reliability was confirmed through a composite reliability greater than 0.70 (Hair et al. 2011). Convergent validity was established by CR values that were greater than the AVE values, AVE values greater than 0.5 (Hair et al., 2011) and Q-sort pilot testing (Moore & Benbasat, 1991).

Data Collection and Analysis
Surveys were distributed to two groups of professionals with knowledge of lean practices: 300 members of the Lean Enterprise Institute and 700 members of the Continuous Improvement, Six Sigma, and Lean Group in LinkedIn. Table 2 summarizes the response rate.

TABLE (2): Response Rate Summary			
	Surveys	Surveys Completed	Response Rate in Percent
Lean Enterprise Institute	300	59	**19.6**
Continuous Improvement, Six Sigma Group	700	241	**34.4**
Total	1000	300	**30.0**

After reviewing the 300 completed surveys, 119 of them were removed because the respondents were based in companies outside of the US or the manufacturing setting was continuous flow, the companies had not started the lean transformation, or there were several missing values. Overall, 189 survey responses were used for the data analysis. Job shop manufacturing settings were used in 29.1 percent (55) of the companies; batch shop-manufacturing settings were used in 37 percent (70) of the companies, and assembly line manufacturing settings were used in 33.8 percent (64) of the companies.

The data analysis began by generating descriptive statistics for each variable and subsequently a multiple range test was performed to test each hypothesis followed by a discriminant analysis. "Discriminant analysis is the appropriate statistical technique for testing the hypothesis that the group means of a set of independent variables for two or more groups are equal" (Hair et al., 2009, p. 236). The discriminant analysis predicts the likelihood that an entity will belong to a specific group based on a few independent variables and delivers a variable that discriminate value between the different groups (Hair et al., 2009).

Results and discussion

The central tendency measures revealed that *Heijunka* (HEIJ), *Quick Set Up* (QSETUP), *Jidoka* (JID) and *Standardized Work* (STANDW) had means scores below 3 and are less applicable to job shop, a batch shop, and an assembly line manufacturing settings, while the rest of the lean tools—*Just in Time* (JIT), *Continuous Flow* (CONTFL), *Poke Yoke* (PYOKE), *Andon* (AND), *5 S's* (FIVES), *Total Productive Maintenance* (TPM), *Visual Management* (VISM), *Kaizen* (KAIZ), *Teams* (TEAM), *Workers Involvement* (WINV), *Value Stream Mapping* (VSM) and *Muda Elimination* (MUDA) are more applicable to all three manufacturing settings.

	Job Shop(55)			Batch Shop (70)			Assembly Line (64)		
	Mean	Skew	Kurto	Mean	Skew	Kurto	Mean	Skew	Kurto
JIT	3.06	-.180	-.472	2.97	-.057	-.210	3.57	-.251	-.622
CONTFL	3.52	-.391	-.525	3.7095	-.350	-.289	3.84	-.883	.627
HEDJ	2.26	.424	-.272	2.51	.321	-.684	3.16	-.173	-.554
QSETUP	2.60	.748	1.235	2.42	.388	.048	2.30	1.152	1.802
JID	2.33	.086	-0.999	2.60	.021	-.795	3.25	-.218	-.323
PYOKE	2.90	-.137	-.388	3.17	-.407	.871	3.73	-.384	.310
ANDON	3.09	-.492	-.128	3.21	-.317	.111	3.71	-.771	.416
STANDW	2.41	.565	.167	2.26	1.291	2.360	1.89	.120	.252
FIVES	3.66	-.524	.275	3.90	-.348	.034	4.00	-1.202	2.249
TPM	3.47	-.333	-.184	3.54	-.458	-.340	3.64	-.833	.492
VISM	3.69	-.775	.520	3.80	-.854	1.01	4.15	-.359	-.426
KAIZ	3.49	-.942	.578	3.75	-.403	.313	3.96	-.585	.585
TEAM	3.58	-.888	.917	3.69	-.521	.405	3.93	-.917	1.002
WINV	3.50	-.564	-.035	3.51	-.094	-.624	3.75	-.678	.177
VSM	3.58	-.508	-.664	3.67	-.072	-.047	3.84	-.529	-.123
MUDA	3.35	-.494	-.897	3.62	-.716	-.026	3.72	-.731	.210

TABLE (3): Central Tendency of the Utilization of the Lean Tools

The means of the level of utilization of the sixteen lean tools were calculated for the different groups and were plotted in a spider diagram.

FIGURE (1): Spider plot of means for the three manufacturing settings
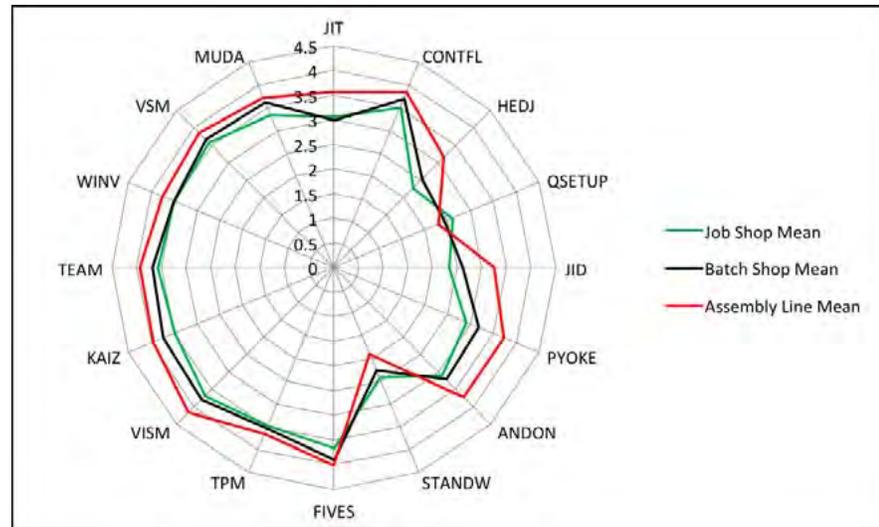
As seen in Figure 1, there was a visible difference between the degree of utilization of the sixteen lean tools in a job shop, a batch shop, and assembly line manufacturing settings.

The data distribution is slightly skewed, as seen in Table 3, which is expected when using the ordinal Likert scale (Norman, 2010). On the other hand, Schwab (n/a) suggested that for data analysis, accepted normality is defined by a skewness and kurtosis value between -1 and 1. The descriptive statistics revealed that most items were within the range of accepted normality since skewness and kurtosis scores ranged between -1 and 1. *Quick Set Up* (QSETUP) had kurtosis scores greater than 1 for job shop and skewness and kurtosis greater than 1 for assembly line and were transformed to an acceptable normality with a logarithmic transformation. *Standardized Work* (STANDW) had skewness and kurtosis scores greater than 1 for batch shop and were transformed to an acceptable normality with a logarithmic transformation. The Five S's has skewness less than -1 and kurtosis more than 1 and was transformed with a logarithmic transformation.

Post hoc comparison tests are an appropriate technique for identifying the means that differ from each other (Lunenburg and Irby, 2008). One of those tests is the Duncan's multiple range test, which was performed to determine if there were statistically significant differences between the means of utilization of the lean tools in the different groups when paired two by two: job shop and batch shop, batch shop and assembly line and job shop and assembly line manufacturing settings. As recommended by Hair et al. (2009), the minimum sample size per category is twenty observations. The job shop category has the smallest sample size with 55 responses, which is greater than 20, so the requirement for an adequate sample size was satisfied.

TABLE (4): Differences in Means between Job Shop, Batch Shop, and Assembly Line (Multiple Range Test)			
	H1	**H2**	**H3**
	Batch shop- Assembly line	**Job shop- Assembly line**	**Job shop- Batch Shop**
Just in Time (JIT)	-0.594***	-0.503**	0.091
Continuous Flow (CONTFL)	-0.139	-0.328	-0.188
Heijunka (HEIJ)	-0.642***	-0.895***	-0.252
Quick Set Up (QSETUP)	0.058	0.118	0.06
Jidoka (JID)	-0.650***	-0.916***	-0.266
Poke- Yoke (PYOKE)	-0.568***	-0.836***	-0.268
Andon (AND)	-0.499**	-0.621**	-0.122
Standardized Work (STANDW)	0.172**	0.224**	0.051
5S's (FIVES)	-0.132	-0.373	-0.240
Total Productive Maintenance (TPM)	-0.103	-0.173	-0.070
Visual Management (VISM)	-0.350**	-0.459**	-0.109
Kaizen (KAIZ)	-0.210	-0.470**	-0.259
Teams (TEAM)	-0.241	-0.350*	-0.109
Workers Involvement (WINV)	-0.232	-0.244	-0.011
Value Stream Management (VSM)	-0.177	-0.261	-0.084
Muda Elimination (MUDA)	-0.094	-0.372	-0.270

$**p< 0.000, **p< 0.01, *p< 0.05$

Consequently, the H1 (Null): "There would be no significant difference between the degrees of utilization of each lean tool in a batch shop when compared to an assembly line manufacturing setting" was rejected for *Just in Time* (JIT), *Heijunka* (HEIJ), *Jidoka* (JID), *Poke-Yoke* (PYOKE), *Andon* (AND), *Standardized Work* (STANDW) and *Visual Management* (VISM). This finding indicates that there were significantly different means of utilization between the two groups for these seven Lean tools.

The H2 (Null): "There would be no significant difference between the degrees of utilization of each lean tool in a job shop when compared to an assembly line manufacturing setting" was rejected for *Just in Time* (JIT), *Heijunka* (HEIJ), *Jidoka* (JID), *Poke-Yoke* (PYOKE), *Andon* (AND), *Standardized Work* (STANDW), *Visual Management* (VISM), *Kaizen* (KAIZ) and *Teams* (TEAM).

The reason for the different levels of implementation is that Just in Time theory differs from JIT practice, which is not applicable to all of the manufacturing processes used in different industries (Beard and Butler, 2000). The Heijunka implementation is very challenging in a high variety production setting, and that explains the different levels of utilization in the various manufacturing settings (Huttmeir et al., 2009). Designing error-proofing devises for a product that will run only one time is not justified, so Jidoka and Poke are implemented at different levels in job shop and assembly line settings. Andon is a cord or a button that stops the production line if defect is detected, consequently if there is no production line, maybe there is no need for Andon. Standardized work, Visual Management, Kaizen and Teams should be investigated further, because the concepts seems to be applicable in all three manufacturing settings.

The H3 (Null) "There would be no significant difference between the degrees of utilization of each lean tool in a job shop when compared to a batch shop manufacturing setting" was not rejected, which is not surprising because Hayes and Wheelwright (1984) described the batch shop as a standardized job shop with a stable line of products.

To understand the differences between the three groups of manufacturing settings regarding the utilization of different Lean tools, especially between the job shop and batch shop, a discriminant analysis was performed. When the dependent variable is categorical, the independent variables are continuous, and if "the researcher is interested in the prediction and explanation of the relationships that affect the category in which an object is located", discriminant analysis is the most appropriate technique (Hair at al., 2009, p. 231). In the stepwise method of discriminant analysis, at each step the distance between the two closest groups is taken into account (SPSS, 2012). The two closest groups with no significant difference between them are job shop and batch shop groups. When performing discriminant analysis, Hair et al. (2009) recommended following steps.

Step 1: Evaluate group differences on a multivariate profile

Tests of the Equality of Group Means were administered to understand if there is a significant difference between the three groups. A statistically significant difference was found to exist between the means of the level of utilization for each of the Lean tools in the Table 5.

TABLE (5): Tools where a Significant Difference was Found		
Just in Time (JIT; p=0.000)	*Jidoka* (JID; p=0.000)	*Poke-Yoke* (PYOKE; p=0.000)
Kaizen (KAIZ; p= 0.008)	*Andon* (AND; p=0.001)	*Visual Management* (VISM; p=0.003)
Heijunka (HEIJ; p= 0.000)	*Standardized Work* (STANDW; p=0.000)	*Teams* (TEAM; p= 0.043)

Step 2: Research design and sample size

Hair et al. (2009) recommend using a ratio of the overall sample size to the number of predictor variables, with value of 20. The overall sample size in this study is 189 observations. The independent variables that differ across at least two of the groups are nine. Since the ratio of observation to predictor variables 189/9=21 is larger than the suggested ratio value of 20 and each category has at least 20 observations, this analysis is appropriate (Hair et al. 2009).

Step 3: Assumptions of discriminant analysis

The first assumption of normality of the independent variables necessary for this analysis is satisfied (Hair et al., 2009) The second assumption is "Unknown, but equal dispersion and covariance structure for the groups as defined by the dependent variable" (Hair et al. 2009, p. 251). Box's M test tests the equal dispersion question. Equal dispersion and covariance structure is indicated a non-significant probability level (Hair et al. 2009). The Box's M test resulted in a score of 11.38 and F of 1.87, and significance of 0.08, which is greater than 0.05, indicating that the dispersion and population covariance matrices are not significantly different.

The discriminant analysis derives a discriminant function which is a linear combination of the independent variables that discriminate between the different groups (Hair et al. 2009). The discriminant analysis revealed that predictors of whether a specific company will be in either job shop, batch shop or assembly line categories are Poke Yoke (PYOKE; D^2=0.08) as the best predictor and *Heijunka* (HEIJ; D^2=0.11). To get the best possible prediction, those two variables

describing the differences between job shop and batch shop were included in the model. The Wilks' Lambda was statistically significant (p< 0.000), which means that the two predictors add predictive power to the discriminant functions. A discriminant analysis estimates one less discriminant function than there are groups (Hair et al., 2009). The predictive equations for both functions are:
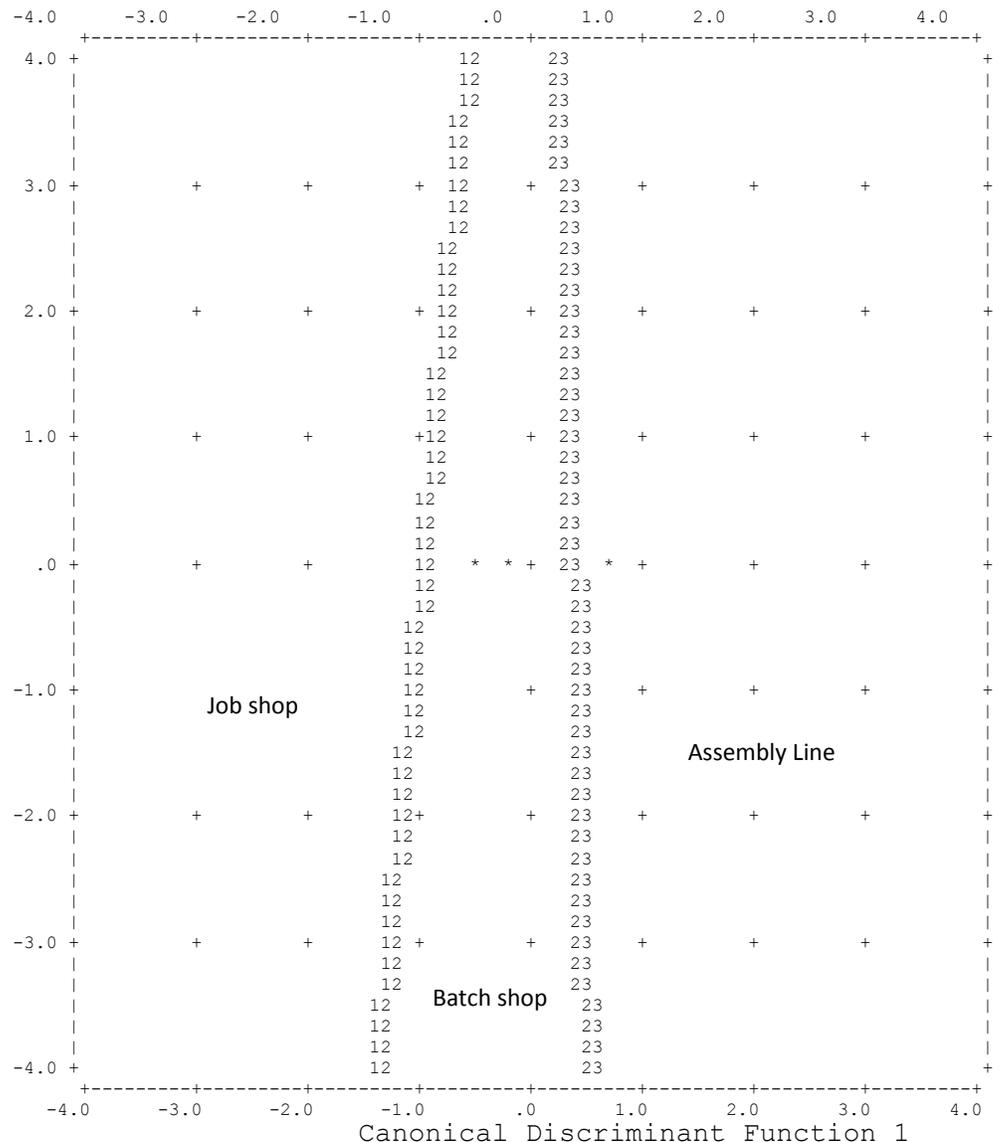
DF1=0.593*HEDJ+0.625*PYOKE
DF2= 0.887*HEDJ-0.864*PYOKE (Cook, 2010)

An acceptable cross-validated classification accuracy rate should be at least 25 percent higher than the proportional by chance accuracy rate (Schwab, n/a). Schwab (n/a) suggested calculating the proportional by chance accuracy rate by squaring and summing the proportion of cases in each group from the table of prior probabilities for groups: $(0.291^2+0.370^2+0.339^2 =0.3359)$. The cross-validated accuracy rate computed by SPSS was 54.5 percent, which was greater than the proportional by chance accuracy criteria of 42 percent (1.25 x 33.59 = 42%). The criterion for classification accuracy was satisfied.

FIGURE (2): Territorial Map for the Three Types of Manufacturing Settings

Canonical Discriminant - Function 2

```
      -4.0       -3.0       -2.0       -1.0        .0       1.0        2.0        3.0        4.0
      +---------+---------+---------+---------+---------+---------+---------+---------+---------+
  4.0 +                                      12      23                                        +
      |                                      12      23                                        |
      |                                      12      23                                        |
      |                                      12      23                                        |
      |                                      12      23                                        |
      |                                      12      23                                        |
  3.0 +         +         +         +  12    +  23    +         +         +         +           +
      |                                      12      23                                        |
      |                                      12      23                                        |
      |                                      12      23                                        |
      |                                      12      23                                        |
      |                                      12      23                                        |
  2.0 +         +         +         + 12     +  23    +         +         +         +           +
      |                                      12      23                                        |
      |                                      12      23                                        |
      |                                      12      23                                        |
      |                                      12      23                                        |
      |                                      12      23                                        |
  1.0 +         +         +         +12      +  23    +         +         +         +           +
      |                                      12      23                                        |
      |                                      12      23                                        |
      |                                      12      23                                        |
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      |                                      12      23                                        |
   .0 +         +         +         12 *  * + 23   *  +         +         +         +           +
      |                                      12      23                                        |
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      |                                      12      23                                        |
      |                                      12      23                                        |
      |                                      12      23                                        |
 -1.0 +                                      12      +  23    +         +         +         +  +
      |                Job shop              12      23                                        |
      |                                      12      23                                        |
      |                                      12      23         Assembly Line                  |
      |                                      12      23                                        |
      |                                      12      23                                        |
 -2.0 +         +         +         12+     +  23    +         +         +         +           +
      |                                      12      23                                        |
      |                                      12      23                                        |
      |                                      12      23                                        |
      |                                      12      23                                        |
      |                                      12      23                                        |
 -3.0 +         +         +         12 +     +  23    +         +         +         +           +
      |                                      12      23                                        |
      |                                      12      23                                        |
      |                               12    Batch shop 23                                      |
      |                                      12      23                                        |
      |                                      12      23                                        |
 -4.0 +                                      12      23                                        +
      +---------+---------+---------+---------+---------+---------+---------+---------+---------+
      -4.0       -3.0       -2.0       -1.0        .0       1.0        2.0        3.0        4.0
                            Canonical Discriminant Function 1
```

LEAN MANUFACTURING TOOLS IN JOB SHOP, BATCH SHOP AND ASSEMBLY LINE MANUFACTURING SETTINGS

Symbols used in territorial map
  1   1 Job shop
  2   2 Batch shop
  3   3 Assembly line
  *   Indicates a group centroid

The discriminant analysis identified two discriminant functions between the three groups under investigation, taking into account the differences between the closest groups: a job shop and a batch shop. The discriminant functions revealed a significant relationship exists between the three groups—a job shop, a batch shop, and an assembly line—and the lean tools contributing most to the group separation are *Poke Yoke* (PYOKE) and *Heijunka* (HEIJ).

Suggestions for Manufacturers

Consistent with Corbett (2007), this study confirmed that there is a variable level of utilization of selected lean tools within the different categories of manufacturing settings. In addition, it provided valuable insights, which may guide practitioners in a successful implementation of Lean tools in their job shop, batch shop, or assembly line manufacturing operations. Most of the lean success stories are from companies with an assembly line manufacturing setting (Lander & Liker, 2007). *Visual Management* (VISM) is the lean tool most frequently implemented in all three manufacturing settings.

TABLE (6): Lean Tools with Significant Differences			
Lean Tools	Job Shop, N=55 Rating (Mean)	Batch Shop, N=70 Rating (Mean)	Assembly Line, N=64 Rating (Mean)
VISM	1 (3.69)	1 (3.8)	1 (4.15)
TEAM	2 (3.58)	3 (3.69)	3 (3.93)
KAIZ	3 (3.49)	2 (3.75)	2 (3.96)
ANDON	4 (3.10)	4 (3.22)	5 (3.72)
JIT	5 (3.07)	6 (2.98)	6 (3.57)
PYOKE	6 (2.90)	5 (3.17)	4 (3.74)
STANDW	7 (2.42)	9 (2.26)	9 (1.90)
JID	8 (2.33)	7 (2.6)	7 (3.25)
HEDJ	9 (2.27)	8 (2.52)	8 (3.16)

Job shops may want to pay more attention to the following Lean tools: *Visual Management, Teams, Kazen, Andon,* and *Just in Time*. Batch shops may want to place extra effort in exploring *Visual Management, Kaizen, Teams, Andon* and *Poke Yoke*. Assembly line settings may want to pay special attention to *Visual Management, Kaizen, Teams, Poke yoke, Andon, Just in time, Jidoka*, and *Heijunka*.

Based on the perceptions of the respondents, *Poke Yoke* and *Heijunka* were the lean tools which provided the greatest levels of discrimination between all three manufacturing settings based on the discriminant analysis. *Kaizen* is implemented most frequently in an assembly line setting, followed by a batch shop setting and a job shop setting. *Just in Time* is implemented at the highest level in an assembly line setting, followed by a job shop setting and batch shop setting. *Heijunka* is implemented at the highest level in an assembly line setting, followed by a batch shop setting and a job shop setting.

Limitations and Suggestions for Future Research

There are several limitations inherent in this research study. The population of this study included lean managers in U.S. companies, and the results may differ if the population was not limited to the US. The next limitation is that this study examined the level of utilization of the lean tools based on the perception of the respondents. Therefore, the personal biases of the respondents cannot be controlled. In addition, when using an online survey, there is a possibility of sampling bias issues (Selm & Jankowski, 2006).

Based on the results of this study, researchers would be wise to consider combining the job and batch shops and compare this combined group with assembly line settings and/or perhaps continuous manufacturing settings. Such efforts could provide further guidance regarding the implementation of Lean tools and principles in manufacturing settings.

The question of why *Standardized Work* (SWORK) is perceived as not being highly utilized in assembly line settings is worth exploring since a greater understanding of this phenomenon may provide a deeper understanding of manufacturing challenges and success criteria.

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Appendix A: Survey Instrument

JIT (Just in Time)	1. Production at stations is "pulled" by the current demand of the next station. 2. We use Kanban signals for production control. 3. We produce exactly as much pieces as needed.	FIVES (5 S's)	1.We organize our work place with marked positions for each tool 2.We have cleaning responsibility assigned to the team members 3.We keep our work place organized.
CONTF (Continuous Flow)	1. Products are classified into groups with similar processing requirements 2. Products are classified into groups with similar routing requirements 3. Equipment is grouped to produce a continuous flow of families of products	TPM (Total Productive Maintenance)	1.We dedicate a portion of everyday to planned equipment maintenance related activities 2.We maintain all our equipment regularly 3.We maintain excellent records of all equipment maintenance related activities
HEIJ (Heijunka)	1. Our production volume is distributed evenly over time. 2. We do not have peaks and valley in our production schedule. 3. Our production mix is distributed evenly over time.	VISM (Visual Management)	1.We use visual board to display value added information 2.We use visual indicators, signs and controllers 3.We use simple signals providing immediate understanding of situation
QSETUP (Quick Set Up)	1. Our employees practice setups to reduce the time required 2. We are working to lower setup times in our plant 3. We have low set up times of equipment in our plant	KAIZ (Kaizen)	1.Our employees participate in rapid improvement events. 2.Our employees' suggestions are generally implemented. 3.Our employees work to eliminate waste in an ongoing fashion
JID (Jidoka)	1. We detect process deviations with automated technology 2. We detect quality deviations with automated technology. 3. Most inspections are done by automated technology.	TEAM (Teams)	1.Most of our shop-floor employees are working in multifunctional teams 2.Our shop-floor team members are cross-trained 3.Our shop-floor employees change tasks within the team
PYOKE (Poke-Yoke)	1. We have poke-yoke devices designed for our work place conditions. 2. We use simple, inexpensive error-proofing devices. 3. Our poke-yoke devices are used 100% of the time.	WINV (Workers Involvement)	1.Our shop-floor employees are key to problem solving . 2.Our shop-floor employees drive suggestion programs 3.Our shop-floor employees lead product/ process improvement efforts
AND (Andon)	1.Everyone working on the production floor is able to stop the production line if a defect is detected. 2.We have a device (cord or button) to stop the production line if defect is detected. 3.Our employees stop the production line if defect is detected	VSM (Value Steam Mapping)	1.We use value stream mapping to eliminate muda. 2.We use VSM to improve our business processes. 3.We use VSM to improve our production flow.
STANDW (Standardized Work)	1.Our work processes are standardized. 2.We use our standards as a basis for improvement. 3.We change our work process standards as needed for improvement.	MUDA (Muda)	1.Our workers identify non value added activities. 2.We are working to minimize non value added activities. 3.Everybody participates in eliminating non value added activities.