Classification, Purpose, Enablers of Lean Dimensions at Automotive Manufacturing Industry: A Case Study

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Abstract

The purpose of this paper is to create a comprehensive list of lean tools that prioritizes and assigns the level of implementation of these tools based on manufacturing strategy objectives. This empirical research utilized data collected from 32 automotive Big Three (GM, Ford and Chrysler) facilities in United States. The surveys were completed through interviews with 164 senior managers at automotive facilities that implemented lean manufacturing since early 21st century. The aim was to investigate the type of lean tools implemented, the level of implementation, and the categorization of lean tools with respect to performance dimensions. Data was analyzed using SPSS software. Result indicates that lean manufacturing is more effective and efficient when companies follow a comprehensive implementation of dimensions. The results demonstrate that execution level of lean tools varies based on manufacturing strategy objectives. Driven by its depth and breadth on lean manufacturing, this paper is unique because is provide a guide for researchers and practitioners on lean implementation tools in manufacturing industry and their direct impact of specific operational performance metrics.

Keywords:
Lean Manufacturing; Automotive Industry; Operational Performance Metrics; Lean Management

1.Introduction

The new worldwide business market which emerged after the Second World War focused on satisfying customers' demands and interests by way of distributing creative and personalized products (Taj & Morosan, 2011). This market was led by changes in buyers' approaches and views where they became more cautious about purchasing high-quality products at affordable prices (Mishra, Pundir, & Ganapathy, 2014). Manufacturers were forced to adopt new production system after these alterations aroused. Thinking of new tools and techniques in substitution of mass production was an essential task for organizations to stay competitive in this challenging market (Taj & Morosan, 2011)and (Bhamu & Sangwan, 2014). They were forced to understand what people value as a product and attempt to manufacture the wants of consumers with a reduction in prices. For them to provide the best value for customers while maximizing profits in the customer-oriented and limited resources market, most corporations intended to implement Lean Management (LM) (Bhamu & Sangwan, 2014). Lean management is coined with the principle of using fewer resources as well as enhancing the value added activities plus eliminating wastes from the production process to derive the best efficient production system (Sharma, Dixit, & Qadri, 2015). Improving quality, decreasing lead time, and reducing cost are reported as the main and central goals of lean (Sanchez & Perez, 2001).

Lean Management was initially applied in Toyota, the Japanese Automotive company which was known as the core foundation of this concept (Bhamu & Sangwan, 2014), and (Piercy & Rich, 2015), (Sisson & Elshennawy, 2015); (Ljungblom, 2014). Toyota turned to lean when it recognized the struggle to meet customers' needs and at the same time maintain its competitive advantages taking into consideration the economic reality regarding shortage of available resources (Ghosh, 2012). After implementing lean production system, Toyota proved its capability of producing diverse items with fewer resources, errors and lead time in a continuously improving environment where all employees interfere in the manufacturing process. Also, Toyota registered high profits and critical growth for which today it is the top 2 in the automotive industry (Sisson & Elshennawy, 2015). When Toyota implemented lean, it was tracked to be the winner in the challenging market because it differentiated itself from other companies. It gained its competitive advantages as being the first company to use a new and innovative strategy in manufacturing. Toyota justified the success of implementing lean in its manufacturing strategy as being a strategic plan that results in competitive advantages. LM is a key successful element which provides privilege to boost quality, shrink costs, and decrease lead time. The lean concept was kept as a secret in Toyota and no other company could decipher the rudiments of lean until Toyota wrote the manuals in the Japanese language. After that, an extensive research was done to demonstrate the theory of Lean and its benefits.

John Krafcik was the pioneer to bring in lean idea in his article “Sloan Management Review” during 1988. However, (Womack, Jones, & Roos, 1990) were behind making this modern term popular after their book “The Machine That Changed the World” (Bhamu & Sangwan, 2014). (Shah & Ward, Defining and developing measures of lean production, 2007) propose lean as tools classified into four categories JIT, TQM, TPM, and HRM. Later research focused more on different aspect of lean for example (Piercy & Rich, 2015) explained the adoption of lean operational practices and independently the uptake of business practices related to sustainability and corporate social responsibility continues to grow, while (Wickramasinghe & Wickramasinghe, 2016)investigated the importance of the variable pay and job performance of shop floor workers and (Prajogo, Oke, & Olhager, 2016) illustrated more on supply chain in lean management. After the extended research throughout the years, there is no single and definite definition for LM since every author gives Lean a new definition/meaning. They stated that lean is a process (Womack, Jones, & Roos, 1990), production paradigm (Fullerton & Wempe, 2009), conceptual framework (Sanchez & Perez, 2001), a set of waste reduction technique (Sundar, Balaj, & Kumar, 2014), philosophy, rule-driven system and congregation of tools and techniques (Ghosh, 2012), generic term (Bhamu & Sangwan, 2014), and business philosophy (Sisson & Elshennawy, 2015). Lean was described over time by different terms, analyzed based on diverse aspects, and sorted into various groups/categories. Researchers are digging deeper into lean to reveal more information regarding this philosophy.

Different authors studied lean from numerous disciplines and perspectives. The results from certain manuscripts focused on sorting lean indications based on the wastes it diminishes and proficiency to reduce production problems (Pavnaskar, 2003). According to Sanchez and Perez (2001), manufacturing strategy proves and presents the explanation of lean tools where they associated lean dimensions with manufacturing strategy objectives. Also, (Ward & Duray, 2000), found out upon their analysis that lean indicators contribute positively to the strategic aims. Lean management was viewed by most authors as a part of manufacturing strategy sharing similar purposes.

Although lean was structured in various manners and definitions, it was agreed upon its significant role in delivering high-quality products while resulting in fewer wastes. In times of resources scarcity, managers are in need for more clarified illustrations for lean. Representing the automotive market, the increase in competition in this market pushes the Big Three Auto companies (General Motors, Ford, and Chrysler) to restructure and reconfigure their production process system using lean tools. It has been a core requirement for managers to propose detailed lean dimensions that enable the achievement of strategic goals leading to better performance. Senior managers at one company of the Big Three requested an investigation into the importance of the following issues, which helped set an outline for our study:

- The most utilized Lean tools at facilities
- The most important lean tools utilized at Manufacturing facilities
- The relationship between the level of implementation and performance metrics
- The relationship among Lean tools
- The interaction between Lean tools and performance metrics

The authors Lucato, Calarge, Loureiro,and Calado (2014), in a paper on performance evaluation of lean manufacturing implementation, pointed out four implementation level of lean tools to evaluate the usefulness of the tools to companies objectives. All lean tools cannot have the same degree of performance; each lean tool has a significant level corresponding to indicators/manufacturing strategy objectives (Ghosh, 2012). This study measured implementation level of lean tools within each indicator to verify the dissimilarity in lean tools adoption level.
It was noted that some specified lean tools are highly practiced and vital to accommodate more than one lean indicator (Pavnaskar, 2003). The analysis of data obtained from this research allowed the confirmation of the great significance of identified lean tools to various lean indicators.

- Companies observe great performance improvement if they follow a comprehensive implementation of lean fundamentals, i.e. implement all lean tools.
- Lean implementation level varies among indicators.

- Certain lean tools have established high level of implementation at more than one indicator.

This paper aims at studying all critical lean practices for managers to produce high quality products with lower costs. The data utilized in this paper shed light on the importance of each lean tool based on manufacturing strategy objectives. All information stated throughout this research was analyzed to determine the needed lean tools and their level of implementation to improve manufacturing.

2. Literature Review

In a world occupied with competitiveness, manufacturers recognize the importance of being lean to survive and prevent others from beating them in the market. Since past years, lean has been a key successful topic for researchers to present due to the significance of such issue. The bottom line of this subject stick to efficient production via eliminating wastes from manufacturing process which have to end in high-quality products delivered to customers at the shortest time (Womack, Jones, & Roos, 1990). Studying lean philosophy more and from different demeanor, scholars were able to execute lean as a set of tools grouped under varied categories. Shah and Ward (2003) ended up in their research by categorizing the 22 lean tools into four categories: JIT, TQM, TPM, and HRM. The thrive to become lean and benefit from waste reduction accompanied with the variety of products and focus on value added activities along with lesser lead time drove many scholars to go deeper in revising lean tools. The results of these examinations propose dissimilarity in lean tools and their categories among authors' work. Going back in history, it was established that companies' first efforts to employ the new innovative system "lean" were during 1990 (Taj & Morosan, 2011). While implementing lean during all these years, manufacturers were addressing the process to improve performance. According to the Global Manufacturing Outlook 2015 Report, all manufacturing sectors need to be innovative to grow and ensure high performance. They "empowered with the right technology, talent and capabilities to fight – and win – against the coming competition for growth". Moreover, companies have to estimate the compulsory competitive advantage and assign the strategy which facilitates the accomplishment of these improvements. Also, the Global Manufacturing Outlook illustrates that the initial transformation in their way to be innovative is the manufacturing business strategy.

2.1 The Linkage between competitive strategy and manufacturing strategy

The business manufacturing strategy is defined as map and preparations which dictate the process to satisfy customers, compete successfully, and achieve goals (Mishra, Pundir, & Ganapathy, 2014). Finding the appropriate strategy is the core task of managers. This assessment demands to create a direct and active link between strategy plan and the goals that can bring advantages for the company in a way that distinguish it from others. In this manner, managers will be looking for the steps that enhance and influence the needed competitive achievements. A strategic plan can be put in the frame of comprehensive view of the steps to implement in order to attain differentiating advantages (Ward & Duray, 2000). The foremost competitive goals of business are cost and differentiation. These two broad dimensions are the basis of competitive strategy (Ward & Duray, 2000). Then the strategic plan is crucial factors that lead to competitive strategy. Prior studies have put great effort trying to find how manufacturing strategy is linked to competitive strategy. Scholars after making their analysis marked a direct influence of competitive strategy on manufacturing plan (Dangayach & Deshmukh, 2001); (Ward & Duray, 2000). Also, it was pointed that managers that did not make a link between these two strategies end up with poor performance of the business (Ward & Duray, 2000). After these results, it can be noted that manufacturing strategy should be designed based on the dimensions of the competitive strategy. Manufacturers have to path through different steps to get to the aim. Finding the right steps and tools of the manufacturing strategy is not easy at all. The focus of these tools should end up with four dimensions to put manufacturing strategy into action which are quality, flexibility, delivery, and low cost (Ward & Duray, 2000). When thinking about quality, the company should assure that it is delivering the best quality with no defects and fewer errors to the customer. Flexibility is the ability of the company to reduce its costs, effortlessly adjust to amendments in the market for the reason of demanding new features of products, and shrink lead time. Speed to the market and deliver the product at time to customers undergo under the umbrella of delivery dimension. Low cost is accompanied by decreasing inventory and wastes and producing effectively. These 4 measurements can guide the steps desired to be implemented in the manufacturing strategy. But as illustrated above companies have to be innovative in order to grow according to Global Manufacturing Outlook 2015. Then the key area of focus should be on allocating and discovering the creative and new production system which embraces the tools that can show the way to the four dimensions. If companies go deeper into lean, they will find that it is a set of tools that creates a high responsiveness environment to customers' demands and interests along with minimizing costs and wastes throughout the supply chain (Hu, Mason, Williams, & Found, 2015). It is implemented by many businesses as a scheme for competitive advantages in the global market (Arif-Uz-Zaman & Ahsan, 2014). For proposing the most reliable scheme and ensuring the successful link between Lean management and manufacturing strategy, companies have to classify lean tools under manufacturing strategy objectives. This step was exemplified by authors in a variety of categories (See Appendix A). This research attempt to identify lean categories and lean tools according to practical application at automotive industry.

2.2 Lean Manufacturing and Operational Performance.

Companies can be successful and attain high business performance for a long time with the techniques of designing the strategy that goes with the goals. The current strategy they are implementing has to achieve the business objectives (Hu, Mason, Williams, & Found, 2015). Ward and Duray (2000) affirmed that manufacturing strategy should combine and manage the measurements of high business performance. Then it is understandable that lean management which influences manufacturing strategy have direct and critical impact on business performance. It was noted that lean diminishes the resources of inefficiency in the production process by focusing on the activities that improve value of the product ((Sanchez & Perez, 2001). By this way companies will be able to deliver high quality products for their customers on time (Chauhan, 2016). Also, scholars found that lean can end up in continuous improvement in the organization by setting problem – solution techniques (Secchi & Camuffo, 2016). Moreover, lean is a critical path for growth and a source of competitive advantage (Sisson & Elshennawy, 2015); (Prajogo, Oke, & Olhager, 2016). Wickramasinghe & Wickramasinghe (2016) announced that lean can lead to flexibility and at the same time develop the ability of the manufacturer to control any changes in the market to become more stable. In addition to that, it is explained companies benefit from lean tools implementation through increasing their financial savings (Lander & Liker, 2007). Lean tools seek perfection in products (Sundar, Balaj, & Kumar, 2014). Lean is philosophy of inter-related tools which requires changes of internal and external manufacturing processes with higher involvement of employees to direct all corporate members' efforts toward high performance results (Olivella, Cuatrecasas, & Gavilan, 2008); (Karim & Arif-Uz-Zaman, 2013); (Christer Karlsson, 1997). Lean management is integrated in the process of manufacturing strategy to get to business objectives.

3. Research Methodology

As lean philosophy became a vital ingredient toward gaining competitive advantages for many organizations, the major goal of this paper is rooted in the need to derive a full list of lean tools that are indicated as practices for attaining each strategic planning objective. This issue opened the path to look forward in searching further regarding lean tools for its critical part in devising lean implementation. As a first step, data was reviewed from numerous literatures prepared by different authors between the time period 1998 and 2016 where an initial list of lean practices from various papers is showed in appendix A. This step allows presenting the different important lean tools which were derived from different research papers written by different authors. Interviews with managers at the Big Three Companies of the automotive industry in North America during benchmarking visits between 2014 and 2016 were used to specify the lean tools they utilize in their facilities and how they categorize these tools based on their manufacturing strategy. The purpose of interviewing the managers was to find out a list of all lean tools; implemented in well standing companies; categorized under manufacturing strategy objectives (See Appendix A). The intent to make these results more reliable and viable for most corporations, a survey questionnaire was carried out in 2016 where the companies of interest were considered to be manufacturing companies characterized by implementing lean Management in North America. Simple random sampling was used for the survey in which the total sample size was 550. The research model is shown in Figure 1.

3.1 Measurement Scale

The Big Three were chosen because they are the three automotive companies that lead lean implementation. The questions asked in the interviews were developed and authenticated by senior managers at the Big Three who are specialized in lean philosophy; along with faculty members at University of Michigan and University of Toledo in addition to the author who is a consultant for the Big Three in lean and flexibility. The questions were about strategic planning frame work and what kind of support process, tools, and measurements are used in order to achieve organizational objectives. Regarding the survey, the inquiry was to rank the lean tools based on their importance within lean indicators that are revealed from Big Three managers. A seven point Likert scale was developed to measure the importance of each of the 49 lean tools to the 6 indicators lean category.

1. Least important. (5 to 15 percent);
2. Slightly Important. (16 to 29 percent);
3. Moderately Important.(30 to 43 percent);
4. Important. (44 to 57 percent);
5. Highly Important. (58 to 71 percent);
6. Very Important.(72 to 85 percent);
7. Extremely Important. (86 to 99 percent);

The numbers figured out from the survey were statistically analyzed using SPSS software to find implementation level importance of each lean tool to manufacturing strategy objectives.

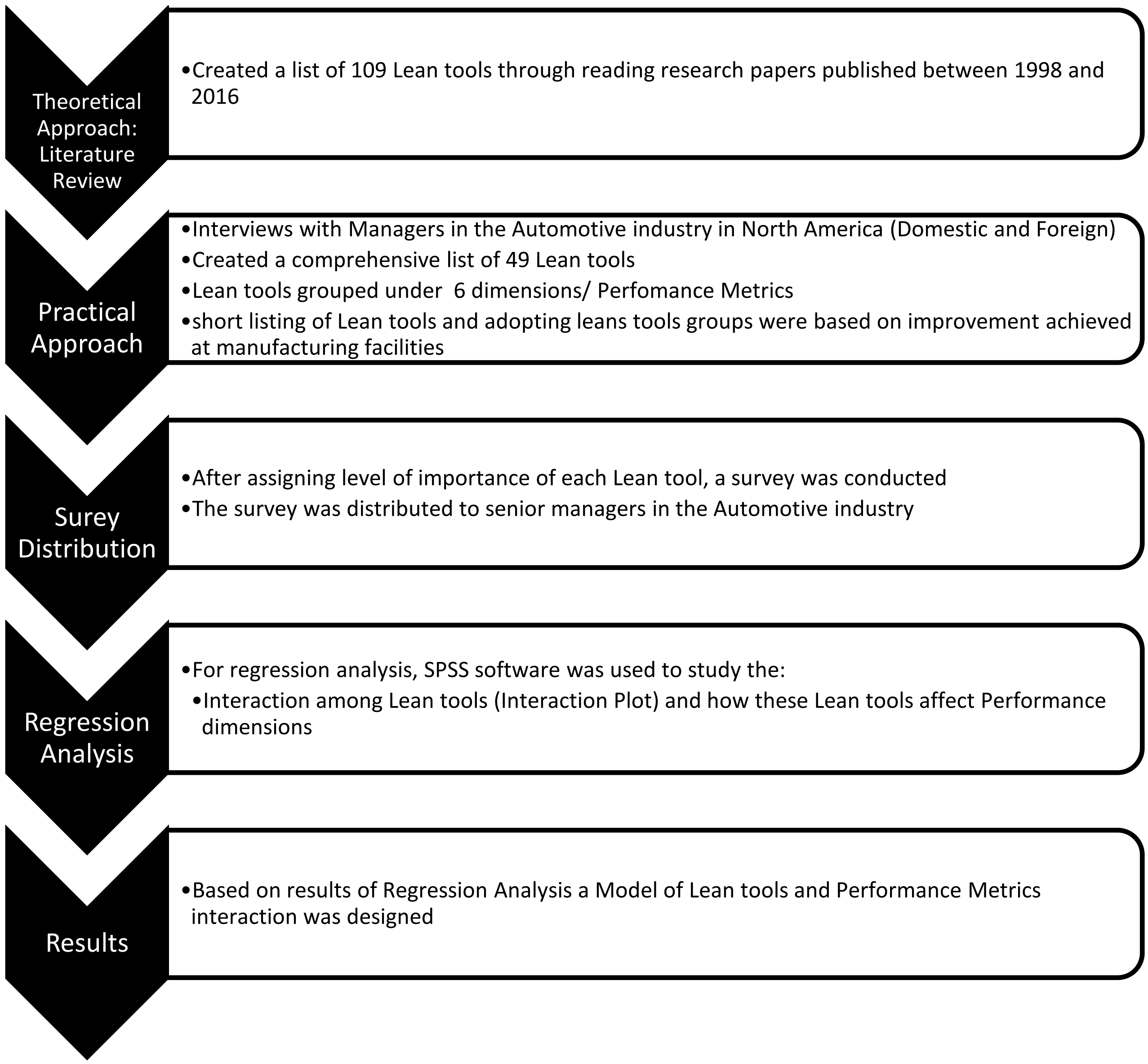

Figure 1. Research methodology

3.2 Validation

The questions asked in the interviews were developed and validated by senior managers at the Big Three who are specialized in lean philosophy; along with faculty members at University of Michigan and Toledo University in addition to the author who is a consultant for the Big Three in lean and flexibility. The results were derived by the author who is a consultant for the Big Three and an operational management professor with an extensive experience in lean.

3.3 Data collection and review

Data was collected from two of the Big Three manufacturing facilities in North America. Data collection covered 32 facilities out of which 12 are assembly facilities and 20 are power-train and components facilities. 84 percent of the surveys were conducted face-to-face and 16 percent were conducted through the phone. Seven senior managers from the Big Three companies were interviewed. Surveys were distributed to 202 managers. Managers were asked to:

1. Rank the importance of each lean tool
2. Indicate the implementation level. A total of 202 responded to the survey, out of which 164 were usable. These responses were entered in SPSS for data analysis.

Managers indicated improvement achieved since implementing lean; in addition, the also indicated the top 9 operational performance ranked by importance, as illustrated in Table 2 and Table 3.

4. Results

4.1 Descriptive statistics

The managers of the Big Three established a conceptual frame work for lean where they highlight 49 tools that value the purpose of manufacturing strategy. Additionally, the managers illustrate 6 indicators to arrange tools under them. By this way new lean metrics have been proposed to organize each lean dimension into a specific indicator, a step to match lean tools and indicators that have the same goal. The data revealed from interview is related to H1. The managers announce that they insist on comprehensive adaptation of lean tools to accomplish strategic goals.

Table 1. Descriptive statistics

Lean Dimensions / Tools	**Mean**	**SD**
Business Plan Development	5.37	0.73
Scheduling Process	4.91	1.02
Plan-Do-Check-Act (PDCA)	5.21	0.80
Problem Solving Techniques	5.33	0.95
Single Page Report	4.67	1.18
Concept of Communication	5.15	0.94
Kaizan (continuous improvement)	5.29	1.03
Small Team Theory	4.91	1.18
Communication Between Employees	5.13	1.04
Job Rotation	4.56	1.40
Multi-skilled Workers	5.20	1.17
Poka Yoke (Error Proofing)	4.54	1.35
Andon System	4.87	1.20
Zone Control	4.51	1.34
Direct Run Loss	4.64	1.35
Direct Run First Time Capability (FTC)	4.61	1.33
Process Quality Control	4.41	1.30
Process Control System	4.34	1.35
Process Failure Mode Effect Analysis	4.11	1.44
Total Quality Management (TQM)	4.83	1.35
Product Quality Standards	4.40	1.46
Fixed Line Stop	4.86	1.04
Buffer and WIP	4.62	1.17
Operator Assist Devices	4.84	1.08
TPM (Total Productive Maintenance)	5.37	1.16
Selectivity Bank	5.00	1.03
Quick Set Up	4.47	1.29
Pulse Tools	4.64	1.23
Common Torque and Fasteners	4.54	1.30
Automation/Robotics	5.05	0.91
Material Line Balancing	5.28	0.88
Material Management (Bulk & Small parts)	4.98	0.99
Pull Production (Bulk & Small Parts)	4.90	0.98
Continuous Flow	4.98	0.94
Returnable Container Process	4.18	1.37
Load Leveling	3.89	1.80
Part Categorization	3.62	1.74
Schedule Shipping and Receiving	3.78	1.69
Material Flow/Plan for Every Part	3.96	1.68
Just in Time (JIT) within workstations	5.09	1.24
Small Part Containerization	3.72	1.72
Line Side Presentation	4.15	1.55
Supplier Management	5.09	1.07
Enterprise Resource Planning-System	5.07	0.88
Material Requirement Planning-System	5.33	0.84
Production Planning and Monitoring System	5.23	0.92
Autonomation	5.32	0.84
Throughput Improvement	5.44	0.90
Standardized Work	5.62	0.84
Workplace Organization (5S)	5.58	0.91
Visual Control	5.47	0.88
Workstation Certification	5.18	0.96
Workload Balancing	5.09	1.00
Design for Manufacturing/Assembly (DFM/DFA	5.06	1.01
Lead Time Reduction	5.24	1.01
Over Speed Reduction (Gross to Net)	4.95	1.09
Job Boards	4.88	1.13
Value Stream Mapping	5.80	0.86
Note: n = 164		

For matching the tools with their indicators, a survey was distributed to rank the importance of each lean tool to all indicators. The responses were checked and reviewed for any missing data to assure accurate findings. Then correlation which is descriptive statistics was calculated to measure implementation level. The analysis was done based on a seven-point Likert scale ("1" being least important and "7" being extremely important). Managers evaluated the importance of each tool according to the Likert scale after which the individual ranking for each company was entered to SPSS software. Since the highest rank based on the scale for each tool is 7, the total score for each company will be 343 (49x7). This score was transformed to 100. The highest score for the firms was 92 and the lowest was 54. The results from SPSS show that lean tools level of implementation varies among indicators as emphasized in Table 1. Table 4, illustrates the multiple regression models of lean, and Table 5 categorizes lean tools under specific lean categories based on regression model results.

Table 2. Average operational improvements achieved (among 32 facilities)

Operation Performance Metrics	Improvement (%)
Management Procedure	15
Employee Involvement	28
Quality Assurance	14
Equipment Support	22
Materials Handling and Processing	20
Production Support	19
Safety	22
Morale	19
Environmental	15

Table 3. Ranking in order of importance (among 32 facilities)

Operation Performance Metrics	Rank
Management Procedure	1
Production Support	2
Quality Assurance	3
Employee Involvement	4
Equipment Support	5
Materials Handling and Processing	6
Safety	7
Morale	8
Environmental	9

4.2 Plant size, plant age, and number of years of lean existence

When it comes to plant size, all the Auto Assembly and Power train facilities of the Big Three were studied. The average number of employees at the facilities studied ranges between 2500 and 4000 employee.

Regarding the age of facilities, it was found that 60% of facilities were above 40 years old, 30% were between 40 and 20 years, and 10% were below 20 years.

In terms of lean existence, the percentages came out as follows: 34% of the facilities implemented lean philosophy since 1995, 19% since 2000, 25% since 2003, and 22% since 2005.

4.2 Lean tools' level of implementation and lean indicators

Regression analysis was executed to study the level of importance of 49 lean tools (dependent variables) and their level of implementation within each of the 6 indicators (independent variables) that are management procedure, employee involvement, quality assurance, equipment support, materials handling and processing, and production support. After reviewing the results, there was no negative correlation between tools and indicators. All lean tools are important for all indicators but not with the same significance. The data emphasized that lean tools have different level of implementation based on the manufacturing strategy objectives. Some of the tools were found to be significant at $p < 0 .01$ which have to be highly implemented with a high percentage between 86 and 100, and others are significant at *p<0.05 and p<0.1* that are essential to be implemented at lower levels. For example, Just in Time tool, its use was found to be a highly positive factor (*p<0.01*) for Materials Handling and Processing and have low level of implementation (*p<0.05*) for Quality Assurance. The regression results regarding Materials Handling and Processing indicates that 36 percent (R^2) of variation in outcome at $P<0.05$ while the analyzed representation for Quality Assurance explained39 percent (R^2) inconsistency in the outcome with an associated significance at $p<0.05$. This analysis was a critical step to categorize the tools into lean bundles/manufacturing strategy objectives. Each tool was put under the indicator after revealing the significance level of each tool to the indicators.

Table 4. Multiple regression models for key drivers of lean system

	Management Procedure	Employee Involvement	Quality Assurance	Equipment Support	Materials Handling and	Production Support
Business Plan Development	.442***	.312**	.469**	.203**	0.07**	.489**
Scheduling Process	.738***	0.284*	0.253*	.263***	.275**	.158**
Plan Do Check Act	.488***	.324**	0.213*	.263**	0.457*	.268**
Problem Solving Technique	.328***	.364**	0.53*	0.383*	0.158*	.311**
Single Page Report	.621***	0.354*	.214**	0.263*	.158***	.158***
Concept of Communication	.474***	0.241**	.530**	0.263*	.158**	.280**
Small Team Theory	.351**	.664***	.124**	0.576*	.721**	.277**
Communication Between Employees	.187**	.748***	.212**	.689**	.521**	0.332*
Job Rotation	.254**	.802***	.267**	.347**	0.837*	0.239**
Multiskilled Workers	0.25*	.744***	.354**	0.525**	.632**	.316**
Poke Yoke	.110**	0.156*	.781***	0.377*	0.07*	.449**
Andon System	0.145*	0.125*	.862***	0.066*	0.158*	0.645*
Zone Control	0.055*	0.156*	.625***	0.247*	0.489*	.349**
Direct Run Loss	0.185*	0.348**	.522***	.291**	0.234*	0.234*
Direct Run First Time Capability	0.25**	.177**	.530***	.328**	0.425*	.158**
Process Quality Control	0.231*	0.010*	.873***	.122**	0.239*	.293**
Process Control System	0.185*	.174**	.616***	0.097*	.234***	.234**
Process Failure Mode Effect Analysis	.231**	0.546*	.655***	0.243*	.293**	.293**
Product Quality Standards	0.086**	.243**	.728***	.495**	0.108*	0.108*
Fixed Line Stop	0.822*	.516**	.129**	.719***	0.745*	0.346*
Buffer and WIP	0.625*	0.354*	0.116**	.857***	.316**	0.316**
Operator Assist Devices	0.745*	.372**	0.124*	.714***	0.277*	.484**
Total Productive Maintenance	.745**	.372**	.124**	.624***	0.658*	.541**
Selectivity Bank	.825**	0.354*	0.119*	.657***	.316**	0.316*
Quick Set Up	.745**	0.372*	0.356*	.714***	0.345*	.388***
Pulse Tools	.745**	.372**	.124**	.854***	0.277*	.645**
Common Torque and Fasteners	.745**	0.372*	.255**	.714***	0.365*	.674**
Material Line Balancing	.175**	.744**	0.496*	0.253*	.610***	.277**
Material Management(Bulk & Small Parts)	0.088*	.620**	.372**	0.023*	.721***	.388**
Pull Production(Bulk & Small Parts)	.150**	.424***	.636**	.217**	.616***	.332**
Continuous Flow	0.074*	.417**	0.265*	.155**	.846***	.466**
Returnable Container Process	0.645*	0.444*	0.222*	.186**	.745***	.447**
Returnable Container Process	0.645*	0.444*	0.222*	.186**	.745***	.447**
Load Leveling	0.578*	0.48*	0.222*	.377**	.785***	.447***
Part Categorization	0.044*	0.248*	0.372**	0.768*	.721***	0.388*
Schedule Shipping and Receiving	0.044*	0.248*	.372**	.392**	.841***	0.456*
Material Flow/Plan For Every Part	.125**	.235**	.589**	.394**	.632***	0.316*
Just In Time (within workstations)	.482**	.467**	.475**	.438**	.610***	.277**
Small Part Containerization	0.044*	0.448*	0.425*	0.392*	.721***	.388**
Line Side Presentation	0.678*	0.425**	.258**	.575**	.693***	.346**
Throughput Improvement	0.066*	.371**	.186**	.172**	0.425*	.914***
Standardized Work	.131***	.186***	.186***	.448***	0.083*	.914***
Workplace Organization (5S)	0.066*	.371***	.186***	.172***	0.445*	.914***
Visual Control	0.066*	0.371*	.186**	.172**	0.465**	.844***
Workstation Certification	.158**	0.766*	0.456*	0.083*	.240**	0.844***
Workload Balancing	.158**	0.889*	0.35**	0.083*	.255**	0.745***
Design for Manufacturing/Assembly (DFM/DFA)	.158***	0.588*	0.688*	0.083*	.184**	.834***
Lead Time Reduction	.250**	.354**	0.177*	0.131*	.158**	.791***
Over Speed Reduction (Gross to Net)	0.047*	.267**	0.010*	.546**	.120**	.914***
Job Boards	0.177*	.333**	0.167**	0.186*	0.188*	.894***
R^2	0.47	0.41	0.39	0.43	0.36	0.49
Adj. R^2	0.42	0.38	0.27	0.38	0.32	0.48
F-Value	3.69***	4.21**	2.64**	3.44***	3.61**	4.88***

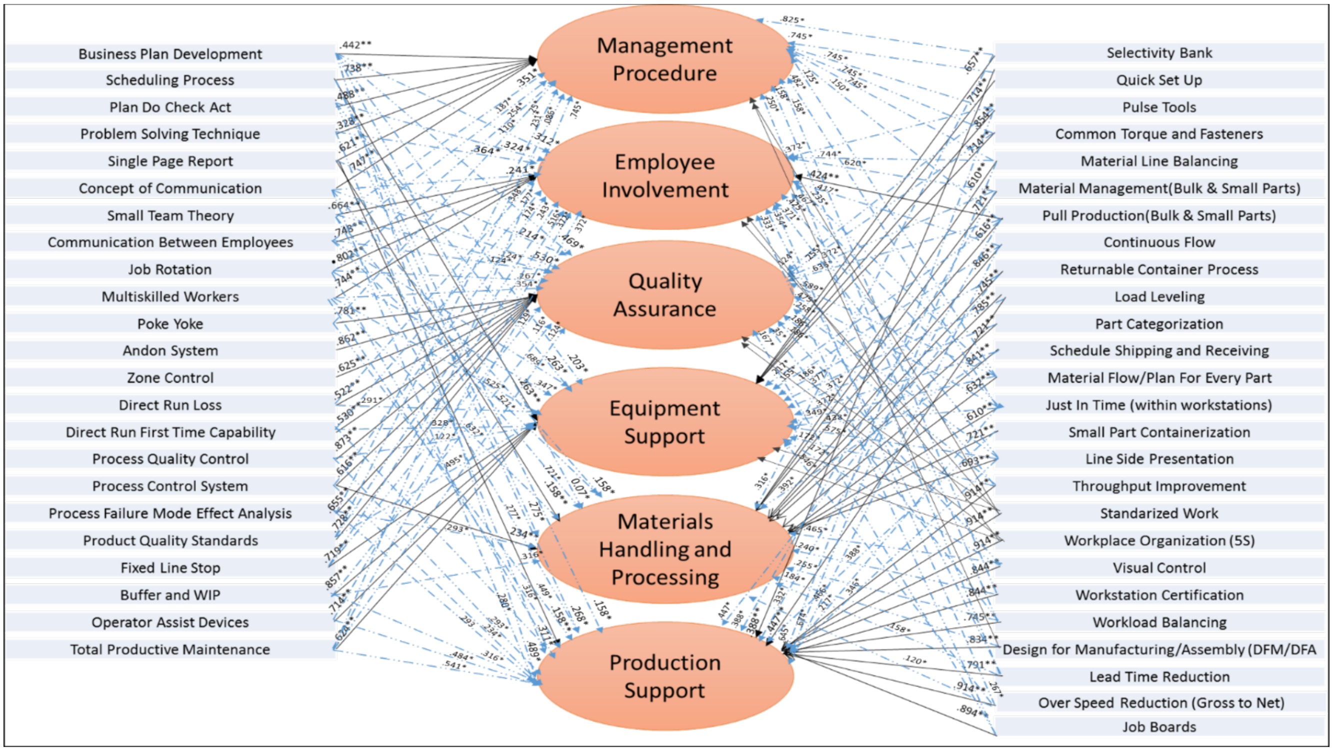

Figure 2. SPSS interaction output categories and tools

The results demonstrate that some specific lean tools are crucial to be highly implemented for various lean categories. For example, Single Page Report that is shown to be high significant for Management Procedure, was found to be implemented at high levels (*p<0.01*) for Materials Handling and Processing and Production Support indicators, as illustrated in Table 4 and Figure 2.

The outcomes derived from surveys and SPSS indicated that if a company demand high operational performance it should focus on comprehensive implementation of lean with higher focus on lean tools associated with category objective. Every company practicing lean must ensure introducing all lean tools in the production process. The outcomes of lean are improved when each facility knows the level of implementation of each tool. Companies cannot implement all tools at the same level, because this research results finds that not all lean tools are extremely important for all indicators. Level of tools implementation varies across lean indicators, so managers have to choose tools that are highly correlated with their manufacturing strategy objectives which are vital in defining lean indicators. The six operational metrics were marked as lean indicators by all managers, and it was observed that several lean tools are highly important for more than one indicator.

5. Discussion and conclusion

Literature on Lean Production shed lights on the value for companies created by many lean tools. Yet, many empirical studies focused on some lean tools without specifying the comprehensive list of these practices. Although, certain authors demonstrate a large number of lean applications, but fewer explain in an inclusive style the list of tools which manufacturers practice. In particular, Literature revised several tools without taking into consideration the level of importance of each tool to manufacturing strategy objectives. This paper research shows the lean tools that are important for a comprehensive implementation of lean in automotive companies. The results were derived after interviews with mangers who recommended all the lean tools they practice in the companies.

Table 5. Managers' feedback on lean categories

	Tool	Purpose
1) Management Procedure	Business Plan Development	Delivers business success creating discipline in development and execution
	Scheduling Process	Organize and document events (scheduling process)
	Plan-Do-Check-Act (PDCA)	Ensure success in attaining corporate goals and amtter planning tasks
	Problem Solving Techniques	Obtain problem root cause
	Single Page Report	Communicate and/or make a decision on a prposal or problem
	Concept of Communication	Exchange information at all levels of the organization in order to make informed business decisions
	Tool	**Purpose**
2) Employee Involvement	Small Team Theory	Employees in small groups function as owners of the production task and support each other to achieve common goals
	Communication Between Employees	Distribute information to operation levels and provide feedback
	Job Rotation	Foster job and skill improvement and growth for team members and facility job rotation flexibility
	Multi-skilled Workers	Support employees to achieve facility business and organizational goals
	Tool	**Purpose**
3) Quality Assurance	Poke Yoke	Prevent defects from occuring
	Andon System	Allow team members to get help in order to prevent a defect from leaving the work station
	Zone Control	Provide a standardized and systematic method to quality control within a production zone.
	Direct Run Loss	Reduce the number of offline vehicles (vehicles require fixing due to defects and/or quality problems
	Direct Run First Time Capability (FTC)	Evaluate the capability of building quality in the process and clarify the problem to be resolved
	Process Quality Control	Prevent defects from passing to the next process
	Process Control System	Prevent defects from occuring and passing to the next customer
	Process Failure Mode Effect Analysis	Recognize and evaluate the potential failure mode of a product or process and its effects
	Product Quality Standards	Provide criteria for process planning, product evaluation, and product acceptance
	Tool	**Purpose**
4) Equipment Support	Fixed Line Stop	Establish a point such that the process stops at each time a quality item requires fixing in station
	Buffer and WIP	Provide optimal buffer for each station. If a problem occurs, the buffer compensates for the station downtime and the assembly line does not lose production
	Operator Assist Devices	Provide devices that support and/or reduce employee fatigue and increase station efficiency (i.e. easy to use devices
	TPM (Total Productive Maintenance)	Minimize unscheduled machine downtime through maintaining and substaining manufacturing process that insures first time capability
	Selectivity Bank	Maintain vehicle sequence in order to meet Takt time and benefit a downtime process
	Quick Set Up	Eliminate non-value added work and increase thoughput by minimizing the time required to changeor set-up tools or machines
	Pulse Tools	Improve safety, increase quality, and reduce assembly time
	Common Torque and Fasteners	Reduce assembly cost, make process less robust, and reduce tools and maintenance cost
	Tool	**Purpose**
5) Material Handling and Processing	Material Line Balancing	Distribute workload as the same/leveled manner across all material handling employees/operators
	Material Management (Bulk & Small Parts)	Control inventroy levels and material flow of small and bulk part containers within a central material area
	Pull Production (Bulk & Small Parts)	Provide line operator with the right material, in the right quantity, at the right time, in the right place by implementing a standard small and bulk parts replenishment system
	Continuous Flow	Eliminate in plant storage and reduce material handling
	Returnable Container Process	Ensure the availability of sufficient amount of containers and pallets in the supply chain to meet production needs at vendors/suppliers for facility
	Load Leveling	1- Balance/level production build schedule 2- Maintain facility capability 3- Maintain efficiency of operator work cycle 4- Support supplier capabiltiy
	Part Categorization	Distinguish parts by their container size and density. Determine the planned flow process for each part
	Schedule Shaping and Receiving	Control material movement in and out of the facility by utilizing a scheduled and visual management process
	Material Flow/Plan for Every Part	Provide an action process that map out the lean material flow. Ensure that empty containers are delivered to the right location at the right time at a minimum cost
	Just In Time (JIT) within workstations	Provide materials just-in-time for production operator
	Small Part Containerization	Provide the production operator with small parts that are located as close as possible for production use
	Line Side Presentation	Reduce waste of motion and improve safety and/or ergonomics for the operator
	Tool	**Purpose**
6) Production Support	Throughput improvement	Meet customer requirement/demand in a cost effective way by focusing on increasing Jobs Per Hour (JPH)
	Standardized Work	Provide the best method in order to perform work in a safe and effective way with achieving the best quality level possible providing the standard for continuous improvement
	Workplace Organization (5S)	Minimize manufacturing and assembly waste by providing safe, neat, clean, efficient, and effective way to conduct work. Every part and tool is in the right place and proper location.
	Visual Control	Identify normal and abnormal conditions that exist at a glance using visual identification tools (i.e. light board, alarms, etc.)
	Workstation Certification	Certify that each production station is production ready. All tool/materials/training that support quality work are available
	Workload Balancing	Focus on insuring that all stations operate at the highest efficiency and utilization possible. Insure that all production workers have balanced amount of work, and non of the operations are above cycle time.
	Design for Manufacturing / Assemly (DFM/DFA)	Identify the simplest/easier design that works for the operation. Reduce and eliminate the possibility to install a product the wrong way.
	Lead Time Reduction	Reduce time required to produce a product from the time it enters the planet until it goes out of the plant production line for shipping
	Over Speed Reduction (Gross to Net)	Minimize the gap between production line rate and the customer demand rate
	Job Boards	Provide workstation boards that explains the operational requirements: work instructions, safety instructions, control plans, part listing, and tooling and machine instructions

Table 6. Correlation between latent variables (lean categories)

	Business Plan Development	Scheduling Process	Plan-Do-Check-Act (PDCA)	Problem Solving Techniques	Single Page Report	Concept of Communication	Kaizan (continuous improvement)	Small Team Theory	Communication Between Employees	Job Rotation	Multi-skilled Workers
Business Plan Development		0.91	0.93	0.95	0.89	0.9	0.57	0.54	0.61	0.62	0.64
Scheduling Process	0.912		0.97	0.94	0.94	0.9	0.58	0.46	0.62	0.57	0.44
Plan-Do-Check-Act (PDCA)	0.934	0.973		0.98	0.95	0.92	0.57	0.51	0.59	0.44	0.52
Problem Solving Techniques	0.946	0.943	0.975		0.94	0.92	0.64	0.55	0.44	0.51	0.53
Single Page Report	0.894	0.94	0.95	0.935		0.94	0.47	0.56	0.55	0.61	0.57
Concept of Communication	0.902	0.9	0.92	0.921	0.943		0.54	0.58	0.58	0.47	0.58
Kaizan (continuous improvement)	0.6	0.45	0.64	0.71	0.68	0.4		0.88	0.91	0.94	0.96
Small Team Theory	0.61	0.57	0.61	0.38	0.54	0.6	0.88		0.89	0.92	0.94
Communication Between Employees	0.71	0.62	0.58	0.54	0.52	0.51	0.91	0.89		0.92	0.92
Job Rotation	0.54	0.5	0.51	0.66	0.61	0.48	0.94	0.92	0.92		0.91
Multi-skilled Workers	0.48	0.4	0.62	0.54	0.57	0.61	0.96	0.94	0.92	0.91	

This paper offers the first contribution to the literature by investigating lean tools implementation level in the manufacturing strategy. It was widespread in lean followers the idea that lean tools have to be linked to manufacturing strategy objectives, but it was not known that each tool has specific importance for each indicator. What this paper reveals is that, managers have to designate their manufacturing goals and then specify the tools that are best fitting to fulfill the aims. Manufacturers in North America allocate each lean practice to manufacturing strategy goal after survey distribution. Ideally, implementation of Job Rotation enhances Employee involvement due to its role in improving workers skills and facilitating the team work growth. On the other hand, Zone Control tool served the objective about Quality Assurance. It is a significant positive factor which provides a standardized and systematic method to quality control within a production zone to assure good quality. As founded in this result, although Zone Control is an important tool for Quality Assurance, yet mangers have to implement it even when they aim to achieve different manufacturing goals. However, the implementation level for Zone Control must be about 90% of manufacturing process to achieve Quality Assurance and about 30% implemented in the Employee Involvement. All lean tools are inter-related to each other leading to better performance if they are implemented in a comprehensive manner. Studying the purpose of each tool validated the categorization of lean tools. The analysis shows that even though level of implementation differs between lean tools, 9 lean tools were characterized by cross functional i.e. these tools are highly significant for more than one indicator. Some lean tools are mentioned in more than one indicator as being a significant at $p<0.01$. These tools would serve the same similar uses to accomplish the needed purposes of various indicators. The most vital tool for lean production is Standardized Work recorded to be high significant for five indicators. This tool aims at providing the best method in order to perform work in a safe and effective way with achieving the best quality level possible providing the standard for continuous improvement.

This paper reveals that the most effective process and approach to implement lean is the examination of lean application at a strategic level to set up the production guide for choosing the right tools which enhance the delivery of the best value with fewer resources.

Organizations during the 21st century were pressured by high global competitiveness and forced to be innovative as a step for fulfilling the basic requirement for them to stay in the market. Companies were excavating to acknowledge themselves with an innovative method that can reduce cost, and produce high quality goods. The academic community have long proposed lean manufacturing as the most dynamic and typical manner for high positive operations performance. Lean manufacturing is an ideal approach that will improve quality, reduce cost, improve lead time, and reduce waste. Yet, its adoption in some companies resulted in stunning outcomes where they were not able to achieve superior operational performance. Due to lack of comprehensive lean tools and misunderstanding the terms of implementing lean, many organizations fell in the gap of disruptions in the manufacturing process designed by lean philosophy. Lean tools are considered the innovative process to accomplish the intended aims. The findings of this study design a scheme of lean tools classified based on manufacturing strategy in a systematic and logic way supported by what facilities practice regarding lean. The gained advantages of the findings of this research are centered in their possible competence to extend the definition of lean tools making tools selection easier and ending in competitive performance. Developing this scheme presents for managers lean in a comprehensible approach to shrink the percentage of misused tools and errors of implementation level of these tools. In explaining the benefits of this paper work, it is vital to demonstrate that this scheme enables managers to choose lean tools and point out the percentage of implementing the tools in their production process based on their manufacturing strategy goals. Master analysis of lean philosophy ended up concluding that there are 7 lean tools characterized by high level of implementation for different indicators i.e. that these tools are crucial for various firms goals. The 7 tools are Scheduling Process, Single Page Report, Process Control System, Quick Setup, Load Leveling, Pull Production, Workplace Organization, Design for Manufacturing, and Standardized Work. The tool Standardized Work can be considered the most crucial tool because it is highly implemented in five lean indicators. This tool is about setting rules guide for technical standards. It works on simplifying the management of varieties of products, and facilitates the delivery of product at time. Obviously, this classification scheme enriches managers with the most effective, enhanced and efficient method to decrease waste and build up the appropriate implementation of tools that address their goals and serve as solution for their problems. Obviously, this research justifies the comprehensive implementation of lean tools with dissimilar level of implementation based on their manufacturing strategy to establish high business performance.

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Biographies

Raed El-Khalil is an associate professor. He holds a Doctorate in Industrial and Manufacturing Engineering from Lawrence Technological University and has a rich background in numerous areas, including an MS in Engineering Management and Industrial and Manufacturing Engineering, as well as a BSc in Industrial Engineering, Manufacturing Engineering and Computer Science, both from the University of Michigan. In addition, he works as a consultant for several companies in the US like Chrysler, General Motors and Boeing, in the areas of operations management. His research focuses on subjects within the automotive industry such as improving body shop flexibility and robot spot welding efficiency.

Appendix A: Lean tools indicated by authors and year

Lean Tools	Feld, W.M	Sanchez, A.M., Perez, M.P	Berry et al.	Pavnaskar et al.	Doolen, T.L., Hacker, M.E	Botha,C.J	Shah, R., Ward, P	Aulakh, S.S.,Gill, J.S	Pettersen, J	Summers, D	Vinodh, S., Chintha, S.K	Angelis Bruno Fernandes	Nawanir et.al	Mishra et al.	Sharma et.al.	Sisson, J., Elshennawy,A	Alaskari et al.	Mahapatra et.al	Abdelhadi, A.	Prajogo et al.
	2001	2001	2002	2003	2005	2006	2007	2008	2009	2011	2011	2012	2013	2014	2015	2015	2016	2015	2016	2016
Kaizen	x		x	x		x	x	x	x	x	x			x	x	x	x	x		
VSM	x			x				x	x	x	x			x		x	x	x		
Kanban	x		x			x	x	x		x		x	x	x			x	x		
Flexible resources						x									x					
Cellular manufacturing				x	x	x	x	x	x		x		x				x	x	x	x
Planning strategies	x		x												x			x		
Bottleneck removal			x															x		
Cycle time reduction			x	x	x							x			x		x		x	
Manufacturing strategies			x													x		x		
Takt time	x							x	x					x			x	x	x	
Logistics								x							x		x			x
Lean criteria and goals								x			x		x			x	x	x	x	
Total cost	x			x	x												x	x	x	
Space utilization	x			x													x			
Travel distance	x	x												x						
Productivity	x			x													x	x	x	
Synchronization									x											
Concurrent engineering					x												x			
Information flow											x					x	x	x		x
Information transparency											x					x				
Flow optimization											x				x			x		
Waste elimination				x					x		x	x	x	x		x	x	x	x	
Pilot studies											x				x			x		
Workplace organization	x			x	x			x		x	x		x			x	x	x		
Line balancing	x									x							x			
Standardized work	x			x	x	x			x	x		x			x	x	x	x		x
Visual Management	x			x		x		x	x	x				x		x	x	x	x	
Focused production			x								x				x		x	x		
Lead time reduction	x	x							x								x		x	
Line stops	x																			
Graphical instructions	x	x																		
Spare capacity																				
WIP reduction		x		x													x	x	x	x
Process sharing															x		x			
Group technology											x		x							
Layout change	x								x						x		x	x		
CAD/CAM/CAE																				
Product/process simplif					x										x					
Error Proofing	x	x		x	x			x	x	x							x	x		
Statistical Process Control	x		x				x	x									x	x		
Standardized quality															x	x	x			
Quality measurement																		x		
Product checks																		x		
Autonomation						x			x			x				x				
TQM			x		x		x					x					x			x
Benchmarking			x												x					
Quality management prog			x																x	x
Quality yield	x																			
Andon									x									x		
Automation															x		x	x		
Problem solving technique											x					x	x	x		
TPM	x	x	x		x	x		x	x	x		x	x		x		x	x		
Set-up reduction	x	x	x		x	x	x	x	x	x	x	x	x		x		x	x		x
Preventive maintenance			x				x						x				x			
Safety programs			x														x			
Product design		x			x		x								x		x	x		
Part standardization					x															
DFMA					x													x		
Mushroom Concept																				
Phase overlapping																				
New technology											x							x		
Machine downtime		x															x	x		
Small machines																				
Value identification					x										x		x		x	
Small lot size		x			x		x		x	x	x		x							x
Schedule leveling	x				x	x				x								x		
JIT	x	x	x				x		x		x		x		x		x	x	x	x
Single piece flow	x			x		x	x	x									x			
Pull system			x		x	x	x		x		x		x	x	x		x	x		x
Mixed modeling	x					x														
Quantity assessment	x																x			
Inventory	x			x					x			x	x		x		x			x
Equipment layout							x										x	x		
Scrap & Rework		x															x			
Team concept	x	x							x		x	x	x		x	x		x	x	
Operational work rules	x	x																		
Worker involvement		x					x		x			x	x		x	x	x	x		
Training	x						x				x	x			x	x	x			
Cross-functional/ cross-training	x	x			x		x					x				x				
Pay incentives					x						x					x				
Worker authority, rules, and res	x	x			x						x	x				x		x		
Organization management		x					x	x			x				x	x		x		
Lean management deve	x	x									x				x	x	x	x		
Service enhanced agreements	x																			
Employee evaluation					x													x		
Group problem solving							x								x					
Workforce commitment							x											x		
Job enlargement and rotation		x									x	x						x		
Work time flexibility schedule							x													
Communication	x															x		x		
Employee morale											x									
Inventory replenishment		x	x																	
Customer participation	x		x				x											x		
Demand stabilization	x				x												x			
Sales network competence	x																			
Early information	x																			
Delivery performance				x	x										x					x
Services to entrance value					x															
Customer requirement analysis					x										x			x	x	x
Quality at the source						x	x				x		x				x			
Supplier networks		x				x						x	x			x	x	x		
Supplier annual cost reduction			x														x			x
Certified suppliers															x	x	x			x
Supplier evaluation			x		x										x		x			x
Customer-supplier alignment	x		x												x					
Supplier relation		x			x		x								x		x	x		x
Supplier involvement		x							x						x	x	x	x		x
Early information exchange		x			x															
Open orders																	x			
Supplier development											x		x		x		x	x		