Applying Lean Assessment Tools at a Maryland Manufacturing Company

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Abstract

Manufacturing companies are implementing and adapting to a number of strategic practices to enhance quality and improve productivity to remain competitive and reduce costs. The use of Lean practices has proven to achieve these objectives. The purpose of this research is to evaluate and perform an assessment of the current status of a local manufacturing organization, Middle River Aircraft Systems (MRAS), located in Baltimore, MD. An assessment tool is used to evaluate MRAS's current Lean manufacturing state in terms of actual manufacturing practice related to inventory cycles, production processes, maintenance procedures and operations, facility layout, quality control, and other key metrics used to improve manufacturing facilities.

1. Introduction

Middle River Aircraft Systems (MRAS), a subsidiary of General Electric Co., was founded in 1929 by aviation pioneer, Glen L. Martin. Its headquarters is located in Eastern Baltimore County, Maryland. MRAS designs, manufactures, and services aero structures and nacelle systems for commercial, military aircraft, and government markets. It is also a supplier of jet engine thrust reversers as well as a digital line of CNC-machined parts [4]. Some of its customers include GE, Boeing, Pratt & Whitney, and Lockheed Martin.

Over the last four years, MRAS has seen considerable growth in revenues, with business increasing 74%. The organization continues to expand its workforce to meet increasing customer demand, hiring over 300 new employees since 2004. The one million square foot facility contains manufacturing, laboratory, and engineering facilities designed specifically for the development and production of aerospace systems [4].

According to MRAS, the organization is constantly finding ways to improve its programs and processes. The company remains committed to designing and building aerostructures for today's needs and tomorrow's vision, while maintaining its reputation for providing customers with products and services that exceed quality requirements [4].

2. Objectives

The purpose of this research is to evaluate and perform an assessment study of a current manufacturing process within the Middle River Aircraft Systems organization to achieve Lean goals. This study involves the evaluation of inventory cycles, production processes, maintenance procedures and operations, facility layout, quality control, and other key metrics using a Lean assessment tool.

3. Literature review

Lean Manufacturing is a methodology that is prevalent in our society today when it comes to achieving highly effective improvements in a company's operations. In companies such as Lockheed Martin, Raytheon, Boeing, Dell, and Wal-Mart, that have Lean programs in their organizations, study shows that the implementation of this methodology has yielded excellent results [1][5]. Major benefits of the application of Lean in a process include the reduction of cost, elimination of waste, improvement in production quality, and increase in profit.

3.1 History of Lean Manufacturing

The first signs of Lean Manufacturing date back to 1799 when Eli Whitney developed the idea of interchangeable parts for his inventions [6][7]. Credit also goes to Henry Ford, who also made a huge contribution to Lean Manufacturing. In 1910, Henry Ford developed the first moving assembly line when he produced the Model T automobile [7]. He recognized the importance of cycle time and continuous flow. His assembly line incorporated machines, people, and tooling in a way that could manufacture a product more efficiently by eliminating waste. Another person that also had an impact on Lean Manufacturing was Taichi Ohno. In 1949, Ohno developed what was known as the Toyota Production System, which was an improvement on Henry Ford's assembly line invention. He developed the idea that instead of just one product being mass produced, many products could be manufactured at the same time, but with short setup times and in small sets [7].

Lean is a set of tools that identifies and eliminates waste, improves product quality, reduces project cost and production time. Some popular Lean tools include Five S (sort, shine, set, standardize and sustain), Value-stream mapping (VSM), Just-in-time (JIT), Poka-yoke, Kaizen, Kanban, etc.

4. Lean assessment procedure

The research approach used in this study is similar to that used by Shahram Taj (2005) in his paper "Applying lean assessment tools in Chinese hi-tech industries". Taj, with the help of some of his students conducted a lean assessment study on 65 manufacturing plants in China. Using the same assessment tool that was used in this study, he evaluated the manufacturing plants in nine key areas of manufacturing: inventory, team approach, processes, maintenance, layout/handling, suppliers, setups, quality and scheduling and control.

The research methodology used in this study is grouped into four stages: The selection of a Lean assessment tool, a preliminary visit out to the facility, execution of the assessment, and analysis of the results from the assessment.

4.1 Selection of a Lean Assessment Tool

The first stage of this research project was to select a Lean assessment tool to use in the evaluation of the current level of Lean at MRAS. Different assessment tools were compared and contrasted to meet specific requirements. The decision criteria were created based on the usability of the assessment tool, metric, familiarity with MRAS, detail, and affordability. These factors were used as a benchmark for the selection process.

The Lean assessment tool selected for this study was Strategos Lean assessment tool developed by Quarterman Lee at Strategos Inc. Several popular assessment tools were considered, but it came down to the following options:

- Strategos Lean assessment tool developed by Quarterman Lee at Strategos Inc.
- Lockheed Martin Lean assessment tool developed by Lockheed Martin Corp.
- Shingo Prize Model developed by Shigeo Shingo
- Throughput Lean assessment tool developed by Throughput Solutions

Table 1. Lean Assessment Tool (LAT) Decision Criteria

	Decision Criteria				
LAT	Usability	Metric	Familiarity	Detail	Affordability
Strategos	X	X	X	X	X
LM	X	X		X	X
Shingo Prize				X	X
Throughput	X		X		X

As shown in Table 1, the decision criteria used in the selection of a Lean assessment tool for the study were in terms of:

Usability: One of the factors considered in the selection of the assessment tool used in this study was ease of use. It was observed that for a first-time user, the easiest to understand and use was Strategos Lean assessment tool.

Computer-based metric: Another criterion that was considered for the Lean assessment tool selection process was the ability of the tool to generate metrics as needed, as well as be computer-based.

Familiarity with MRAS: MRAS, being a practitioner of the Lean methodology, is familiar with some of these assessment tools. It was best to use a tool that the company was not familiar with.

Detail: It was necessary to use an assessment tool that measures essential areas of manufacturing such as inventory, processes, maintenance, quality of product, etc.

Affordability: An assessment tool that was cost-effective was preferred for this study.

Strategos Lean Assessment Tool

The Strategos Lean assessment tool (SLAT) developed by Quarterman Lee at Strategos Inc. uses an Excel template to record data from an assessment study and scores the results. It evaluates nine keys areas of manufacturing namely: inventory, team approach, processes, maintenance, layout & material handling, suppliers, setup, quality and production control & scheduling. The final output from the assessment tool is a "radar chart" that visually displays the company's current Lean status and the gap from its specific LSS targets [8]. Each manufacturing area comprises of about three to six questions and the questions in each area attempt to focus on the key performances in the organization.

Inventory**:** In a Lean environment, the inventory turn ratio is either close to or better than the industry average [8]. Questions in this section aim to measure the rate at which inventory in the organization is sold and replaced over a period.

Team Approach*:* Participative organizations work best with LSS concepts. In a participative organization, the input of the employees is as valuable as that of management. Both come together to achieve company goals. In this section, SLAT measures the organizational culture; the working conditions and relationship between management and its employees in the company.

Processes*:* In this section, SLAT aims to measure the Leanness in the organization's production processes. In a Lean workplace that makes multiple products, each product or product group has dedicated equipment, sized to the needs of that particular product or group. This is to avoid problems in changeover, scheduling, handling and quality.

Maintenance*:* The fourth section, maintenance, evaluates the manufacturing system maintenance procedures, equipment downtime and uptime and the severity of preventive maintenance in the organization. In Lean Manufacturing, preventive maintenance is highly emphasized upon, since losing any equipment due to unexpected downtime in a cell would result to stopping the operation in that cell which is a cost. [9]

Layout & Material Handling*:* The questions in this section evaluate the space allocated to inventory, type of plant layout, and material movement around the facility. A poor factory layout and the resultant material handling can create difficulty and significant waste in a production process. Layout also reflects the effectiveness of other factors such as purchasing and the company's scheduling policy [8].

Suppliers*:* In a Lean organization, its supply chain uses dependable supplier(s) in long-term relationships; supplier(s) that can be trusted to deliver high quality parts at a competitive price and also on a time [8]. SLAT assesses the type of relationship the organization has with its supplier(s). More than one supplier for a single part often indicate a lack of trust that is probably based on poor past performance.

Setup*:* In this section, the questions assess the average time it takes for major equipment to be set up for use, the effort that has been taken by management to reduce setup times and also if setup performance is tracked and evaluated by management.

Quality*:* High quality is a requirement for any manufacturer [8]. The way it is achieved has a large effect on productivity and overall effectiveness. This section of the assessment emphasizes Statistical Process Control (SPC). SPC is an optimization philosophy concerned with continuous process improvements, using a collection of statistical tools for data and process analysis [10].

Scheduling & Production Control: Scheduling & production control systems often create many problems. They sometimes reflect the problems created by other policies and decisions made by management. The best production control & scheduling systems for Lean Manufacturing are simple and give very fast response to changes in demand. Examples include Kanban and Broadcast scheduling. In Kanban scheduling, a small stock of every part sits in a dedicated location with a fixed space allocation, and gets replenished once a certain quantity is used. In Broadcast Scheduling, a final assembly operation builds directly to schedule. The schedule is simultaneously "broadcast" to upstream sub-assembly and supply operations [8]. In this section, the questions evaluate the organization's scheduling process, and also measures on-time delivery performance.

5.2 Preliminary visit out to the facility

The next stage after the selection of a Lean assessment tool was a preliminary visit to the plant. One of the purposes of this visit was to get a Visual Stream Map of the organization's manufacturing process. Figure 1 shows the current manufacturing process of the Pratt & Whitney program. During this visit, I was introduced to the manager of the Pratt & Whitney program who gave me a tour of the plant. I also got a chance to introduce myself to some of the employees on the shop floor. MRAS is a unionized organization, therefore, it was necessary to inform some of the employees of my intentions so they would not feel threatened when I came back to carry out the assessment. The second of purpose of this visit was to select a section of the plant to assess. Due to time constraints, it was not possible to assess the whole plant.

MRAS manufactures thrust reversers for Pratt & Whitney, an aircraft engine manufacturing company. The program comprises of four processes: bonding, small parts, assembly and shipping process. From my observation during the tour, I found the assembly process of the Pratt & Whitney program the most in need of improvement. This factor led to my decision to assess it.

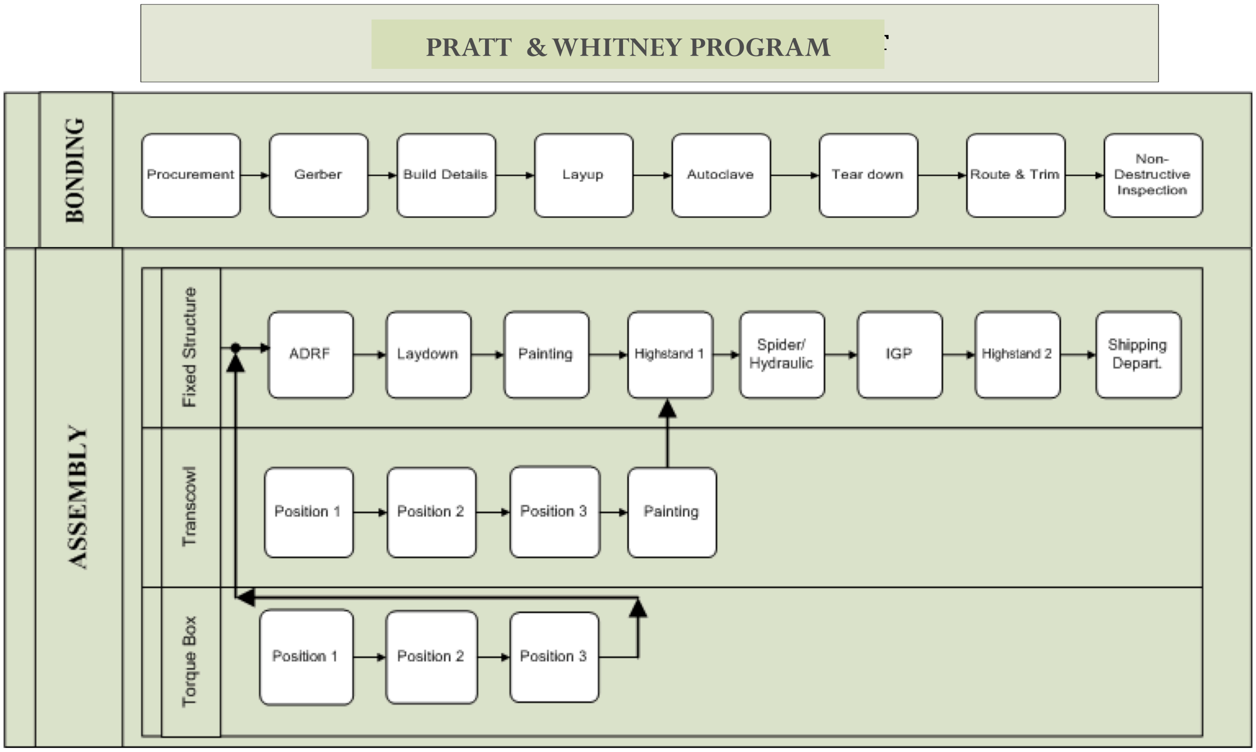

Figure 1. Pratt & Whitney Assembly Line Process

5.3 Execution of assessment

After the preliminary visit, the next stage of this research project was to perform the assessment. The assessment was completed in two days. During the assessment, various questions relating to the key areas of manufacturing were asked to the manager, as well as participating employees. They were very cooperative and provided me with the necessary information I needed for the assessment. I also went on the shop floor and interviewed a couple of the employees to get their input on how they felt about working in the organization. On the shop floor, observations were made and necessary data were gathered and recorded into the Excel spreadsheet.

5. Assessment Results

The answers from the assessment questions were recorded into the Excel spreadsheet which generated a score worksheet and a lean profile chart. Based on each response provided, a score between zero and four is given. The scores are totaled for each of the nine sections and the results are then displayed in a score worksheet. A lean profile chart is also created from these results, which shows the current status of the plant and the gap from their specific lean targets.

Table 2 shows the score worksheet that was generated from the assessment. The first column is the nine sections in the assessment. The second column is the section points, the total score for each section. The third column is the number of questions in each section. The fourth column, section AVG, is calculated by dividing the section points (second column) by the number of questions in that section (third column). The fifth column, section percentages, is calculated by dividing the section average by four, which is the maximum possible score. The sixth column, "strategic impact factor" (SIF) is an important factor that is set by the user. This reflects the relative importance of a particular section in relation to the others. A user can use different SIFs based on his or her preference. Total of all the sections should equal 100 percent. The last column, the section target, is calculated by dividing the strategic impact factor column by the maximum number in that column.

The SIF I gave for each section varied, with quality being the highest at 15 percent and the lowest being maintenance and layout, each, having a 9 percent weight. As a result of this, the section targets for each of the sections varied as well.

As can be seen in the score worksheet, layout scored the highest with 90 percent, and the lowest scores were 8 percent, 17 percent and 31 percent in inventory, setup and quality respectively. This is relative to their section targets. These three sections had the most gaps from their targets.

Table 2. LSS Assessment Score Worksheet

SECTION	SECTION POINTS	# OF QUEST.	SECTION AVG	SECTION %	STRATEIC IMPACT FACTOR	SECT. TARGET
1.0 Inventory	1	3	0.33	8%	12.0%	80.0%
2.0 Teams	11	6	1.83	46%	10.0%	66.7%
3.0 Process	7	6	1.17	29%	11.0%	73.3%
4.0 Maintenance	16	5	3.20	80%	9.0%	60.0%
5.0 Layout	18	5	3.60	90%	9.0%	60.0%
6.0 Supplier	15	5	3.00	75%	10.0%	66.7%
7.0 Setup	2	3	0.67	17%	11.0%	73.3%
8.0 Quality	5	4	1.25	31%	15.0%	100.0%
9.0 Scheduling	7	3	2.33	58%	13.0%	86.7%
				SUM:	**100%**	
				MAX:	**15.0%**	

A radar-like chart called a lean profile chart is generated based on the results from the score worksheet. Figure 3 shows the lean profile chart generated from this LSS assessment score worksheet. The chart shows the current state of the assembly line process in the nine key areas of manufacturing and the gap from their target.

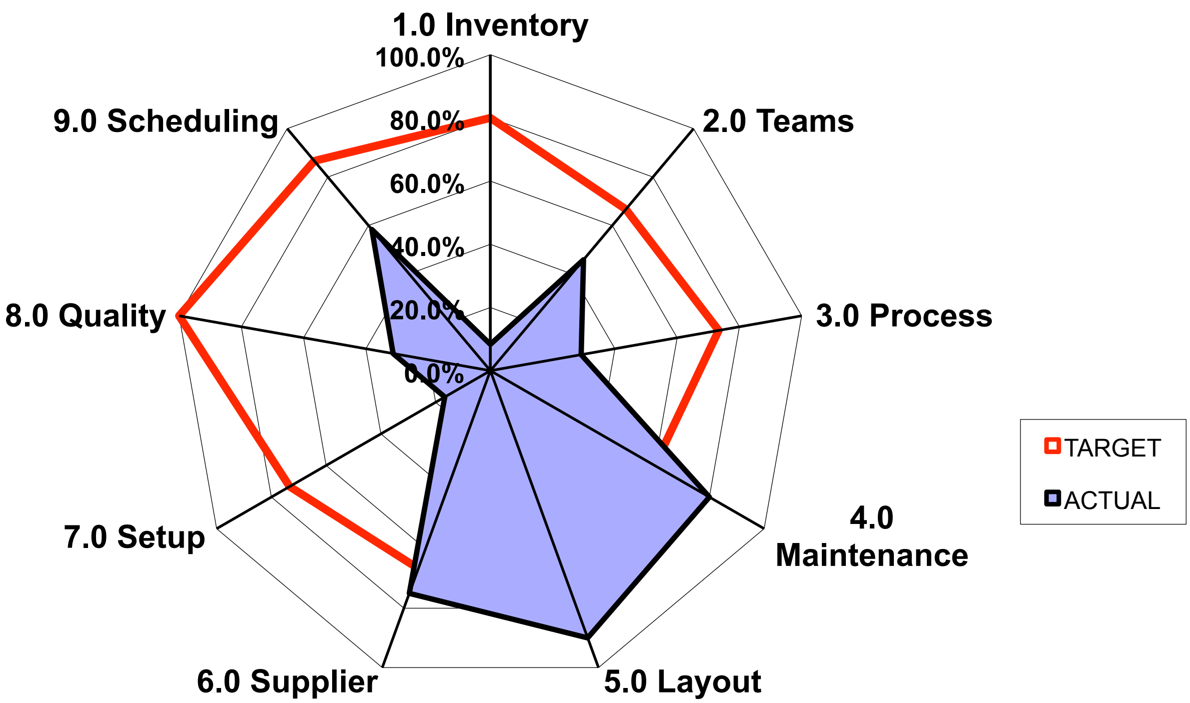

Figure 3. LSS Assessment Lean Profile Chart

6. **Analysis**

As seen in the score worksheet and lean profile chart, inventory scored the lowest. Further analysis was performed to identify the cause of MRAS' high inventory in order to recommend improvement measures to the organization's management.

6.1 Inventory

The inventory area assesses the actual inventory level and examines management's knowledge about inventory level and turnovers. As seen in Table 3, the first question identifies the percentage of middle and upper managers who are able to state from memory the turnover rate and purpose of work-in-process (WIP), finished goods and raw materials. Only 50 percent of the managers were able to state the turnover rate from memory. The two other questions relate to the company's annual inventory turnover compared to industry standard.

Table 3. Aerospace Industry Average Turnover Rate

	25th Percentile	Median	75th Percentile	90th Percentile	Mean
Aerospace	3.0	4.5	10.0	15.2	7.6

WHAT THE NUMBERS MEAN
25th percentile means 25 percent of the respondents have 3 or fewer inventory turns
75th percentile means 75 percent of the respondents have 10 or fewer inventory turns
Median the middle observation (50% with fewer than 4.5 turns, and 50% with more than 4.5)
Mean is the average calculated by adding all the reported number of turns and then dividing by the number of observations

Table 3 shows the average inventory turnover rate for the aerospace manufacturing industry, courtesy of IndustryWeek (a leading publication among manufacturers). The inventory turnover rate for the Pratt & Whitney program is 3 thrust reversers per year. When compared to the industry average of 7.6, yields a 0.39 ratio. This is considerably low. In a Lean environment, the inventory turnover rate is either close to or better than the industry average [8]. Table 4 shows the questions and responses given for the inventory section.

Table 4. Inventory Section Questions

1.0	Inventory	Response	X
1.1	For the categories of Finished Goods, Work-In-Process (WIP) and Purchased/Raw Materials, what portion of middle and upper managers can state from memory the current turnover and the purpose of each type?	0%-6%	
		7%-55%	X
		56%-80%	
		81%-93%	
		94%-100%	
1.2	What is the overall inventory turnover, including Finished Goods, WIP and Purchased/Raw material?	0-3	X
		4-6	
		7-12	
		13-24	
		25+	
1.3	What is the ratio of Inventory Turnover to the industry average?	<=1.0	X
		1.1-2.0	
		2.1-4.0	
		4.1-8.0	
		8.1+	

7. Recommendations

Low inventory turnover ratio often implies poor sales. The best way to reduce inventory is to, first, identify the cause, thereafter, measures can be taken to minimize, if not completely eliminate it. Some causes of excessive inventory (courtesy of Strategos Inc.) include: inflexible equipment, functional layouts, high defect rate (poor quality), and inappropriate scheduling. Table 6 shows the effects of these causes and some improvement measures that can be taken to control or eliminate them.

Causes	Effects	Remedies
Inflexible Equipment	-Long, expensive setups -Large batches -Inappropriate floor layout	- Setup Reduction (SMED) measures - Smaller scale equipment
Functional Layouts	-Excessive material handling -Work-in-process (WIP) queues -Disconnects/interruptions -Poor product quality	- Cellular Layouts
High Defect Rate	-Unhappy customers -High scrap and rework costs -Unpredictable schedules -Inaccurate inventory records	-Six Sigma & Total Quality Management (TQM) -Workcells -Work teams & Quality teams -Cycle counting & Error reduction
Inappropriate Scheduling	-Complex systems -Inaccurate inventory records -Large queues -Long lead times	-Kanban Scheduling -Broadcast Scheduling -Workcells

8. Conclusion

Lean Six Sigma is an industry practice improvement process that is known to lower inventory, improve company culture, eliminate waste in a process, decrease defect rate, and help strengthen customer relationship. The competitiveness in the manufacturing industry is forcing manufacturers to produce high-quality products at a reduced cost. This Lean assessment study on the Pratt & Whitney assembly line process at Middle Aircraft Systems identified manufacturing areas that need improvement. It showed the gap from their lean target. In order to remain competitive, improvement measures need to be taken by management to bring inventory, setup, and quality up to their targets.

9. References

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