Applying Lean Thinking to Improve Processes in the Trucking Industry

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Abstract

Manufacturing businesses that use complex production systems face major challenges in establishing an efficient procedure to maximize throughput. Such businesses would need a significant number of workers and process improvement resources to sustain expansion and offer high-quality products to their consumers. This can only be accomplished by implementing a chain of value-added activities built with the help of lean-based techniques capable of producing highly efficient processes. To that purpose, this research was done, and lean manufacturing-based value-added procedures were established on the shop floor. The study concentrated on conventional truck body manufacturing company called Delta-Waseca that have been dealing with concerns including low production rates, lengthy lead times, problems with material flow, nonlinear layout, delayed client deliveries, and poor quality. A methodology was developed that involved applying process improvement techniques to workstations with low efficiency. Utilizing a variety of methods, including time analysis, motion analysis, standard working procedures (SWP), value stream analysis, 5S, value layout, and bottleneck analysis, the research and implementation were carried out in key bottleneck regions. Production rates, quality, and customer service have all significantly improved because of the value-added process deployment. With the new procedure in place, the production rate grew to three trucks per day from the previous average of two trucks per day.

Keywords
Time analysis, Lean manufacturing, Process improvement, Value stream, implemented and sustained.

1. Introduction

Despite improvements in modern technology and marketing tactics, most businesses in the manufacturing industry fall short of client expectations. Long lead times and delayed deliveries are frequent problems in small manufacturing companies, which find it difficult to compete on both a global and a national scale. One of the main factors behind this is the lack of development in creating a culture of continuous improvement within the organization (Dahlgaard, 2006). This indicates that employees may lack proper lean thinking training or the management may not be comfortable with change as only a tiny fraction of businesses are able to maintain lean process improvement and promote a lean workplace culture.

The primary goal of lean improvement is to identify and transform non-value-added operations into value-added activities. The lean process examines the whole plant's functioning, from raw materials to customer delivery. A comprehensive approach was utilized in this research paper to better understand the process from upstream suppliers to downstream customers.

The research is conducted in Delta-Waseca, a medium-sized automobile (OEM) firm located in south-central Minnesota. The firm specializes in manufacturing truck trailer bodies ranging in length from 18 to 30 feet. Unfortunately, Delta-Waseca has been facing lengthy delivery periods, and the quality of their items has significantly declined. Customers are unsatisfied therefore, and specific workstations in the facility are taking longer to complete tasks. Delta-Waseca's supply chain is chaotic, and its interactions with suppliers are not efficient. They also have very few inbound material inspection processes in place, which adds to the confusion. After evaluating the problems at Delta-Waseca, lean approaches like time and motion analysis were studied to see whether they could be used to enhance the currently inefficient operations. A set of research questions was established to analyze the results and conclusions to assess the effectiveness of these strategies.

1.1 Objectives
1. How can major constraints be identified in the Delta-Waseca plant?
2. In what ways does implementing a series of connected value-adding activities assist in resolving identified process bottlenecks?
3. What techniques can be used to sustain the process improvement activities?
4. Do people really factor in process improvement process? If so, how can improving or creating lean culture be addressed?
5. What steps can be taken to establish a more adaptable supply chain relationship management system using lean principles within a manufacturing facility?

2. Literature Review
The Toyota Motor Corporation developed the lean manufacturing concept in the 1940s and 1950s. It is referred to as "Lean" or lean production. The primary principle of lean manufacturing is to continually enhance processes to reduce waste and boost productivity. This is accomplished by enabling employees to recognize and address issues on the assembly line using the Kaizen approach (Womack et al, 1990). Lean also emphasizes the necessity of quality control and employee engagement at all levels of the manufacturing process. Lean culture has gone beyond manufacturing and into other sectors, such as healthcare, finance, and government. To understand the complex elements of lean, it is necessary to first understand its five core concepts. The first principle is "Value," highlighting the significance of determining what is valuable to the client (Womack and Jones, 2010). The second concept, "Value Stream," is concerned with identifying and removing any non-value-adding operations from the process (Krafcik, 1988). The third principle, "Flow," emphasizes the importance of a continuous and seamless flow of work (Melton, 2005). The fourth concept, "Pull," emphasizes the need to create only when there is a demand (Schrotter, 2000). Finally, the fifth principle, "Perfection," promotes constant development and waste reduction at all levels of the company (Hicks, 2007). Approximately 80-90% of all actions in any manufacturing process are considered waste. Lean methods and practices are intended to eliminate non-value-added operations in order to increase efficiency, save costs, and improve customer satisfaction. To achieve the best possible results, a specific tool or combination of tools may be used depending on requirements (Hines and Taylor, 2000). Value analysis is a system consisting of a set of techniques arranged for identifying unnecessary costs before, during, and after the fact. Time value analysis is one of the most common techniques used in lean continuous improvement projects. Analyzing each subprocess will provide details on where improvement is possible and how value can be increased. Manufacturing companies must practice effective inventory management to maintain optimal working capital (Miles, 2015). The ABC analysis is also a useful tool for inventory management, as it categorizes goods into Class A, B, and C items based on their value. Designing layouts and warehousing systems for improved logistical support of manufacturing might benefit from this categorization (Arnold et al, 2001).

3. Methodology
3.1 Research Methodology
The current state of the production system at Delta Waseca is poorly maintained, with constant problems such as longer processing times, reworks, and quality issues. To address this situation, a systematic approach has been developed to analyze the entire plant and understand the effects of these symptoms. Once the analysis is conducted and constraints are understood, a methodology is developed to increase the production rate of the plant by optimizing the operational activities from raw material to the final product. The plan was developed by looking at the holistic view of the production process, considering the working capital of the company at a specific time, and supplier relations. In this section, we explain the methods used to achieve a higher production rate by implementing new processes into the existing production system, using a lean thinking approach. The main goal of this paper is to study and understand the entire holistic value stream and implement changes based on the five core principles of lean manufacturing. Since the methodology was devised based on the lean manufacturing principles, the process improvement tool is used to identify the bottlenecks in the current system. When the bottlenecks are identified and the process is analyzed, a new process is designed based on the available resources in relation to the financial situation of the company. Major emphasis is given to the input provided by the shop floor workers and their feedback on the current process. It is noted repeatedly that the most important pillar in lean thinking is the involvement of people.

3.2 Identifying the Value Chain
A systematic approach has been developed for identifying current bottlenecks within the plant. A value stream map has been created for the entire plant, and constraints have been identified by analyzing the value stream and assessing

new conditions. The entire team has analyzed the current state value stream map and identified potential constraints. Figure 1 shows the systematic methodology.

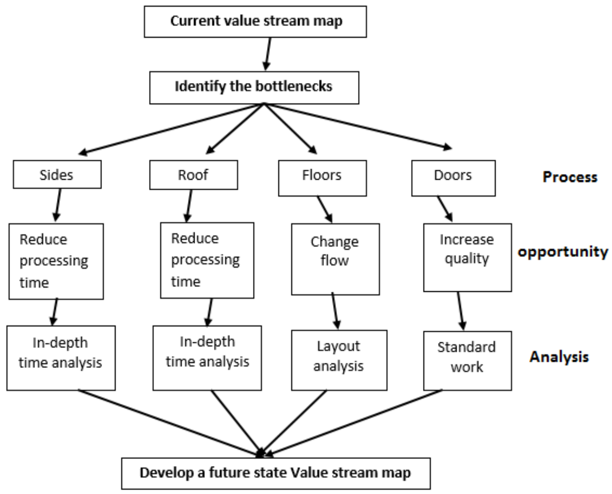

Figure 1. Methodology diagram

3.3 Data Collection Process

To look at possible opportunities for process improvement, data was gathered from each process. Time sheets were used to gather data for each distinct process, which was then used to pinpoint areas that the Kaizen team should look at for potential opportunities for process improvement. Each sub-process inside the target region is thoroughly time-analyzed, from material transit time through final assembly time. Each process' duration is measured using a stopwatch, and the results are recorded and utilized to identify bottlenecks. A sample time sheet is shown in Table 1, and the data analyses and findings are covered in more detail in the next section.

Table 1. – Time sheet

JOB TYPE	TYPE OF BODY	START DATE	START TIME	END DATE	END TIME	TOTAL TIME (Hr.)
UNDERCOAT	QXTSS-80-12'6"-96-	5/3/2016	11:30:00 AM	5/3/2016	1:30:00 PM	2.00
ASSEMBLE	QX-85-16-102-CURT	5/3/2016	6:45:00 AM	5/3/2016	12:00:00 PM	5.25
ASSEMBLE	QX-85-16-102-CURT	5/3/2016	6:45:00 AM	5/3/2016	2:00:00 PM	7.25
ASSEMBLE	QX-85-16-102-CURT	5/4/2016	6:00:00 AM	5/4/2016	11:00:00 AM	5.00
ASSEMBLE	QX-85-16-102-CURT	5/5/2016	6:00:00 AM	5/5/2016	11:30:00 AM	5.50
RADIUS	QX-85-16-102-CURT	5/4/2016	10:45:00 AM	5/4/2016	4:20:00 PM	5.58
ASSEMBLE	QXT-85-16-96	5/11/2016	6:02:00 AM	5/11/2016	11:26:00 AM	5.40
ASSEMBLE	QXT-85-16-96	5/11/2016	12:00:00 PM	5/11/2016	2:30:00 PM	2.50
ASSEMBLE	QXT-85-16-96	5/11/2016	12:00:00 PM	5/11/2016	2:30:00 PM	2.50
FLOOR	QXT-85-16-96	5/9/2016	3:50:00 PM	5/9/2016	4:15:00 PM	0.42
FLOOR	QXT-85-16-96	5/10/2016	6:00:00 AM	5/10/2016	7:30:00 AM	1.50
REARS	QXT-85-16-96	5/9/2016	8:00:00 AM	5/9/2016	11:00:00 AM	3.00
ROOFS	QXT-85-16-96	5/10/2016	6:01:00 AM	5/10/2016	9:30:00 AM	3.48
ROOFS	QXT-85-16-96	5/10/2016	1:09:00 PM	5/10/2016	4:20:00 PM	3.18
ASSEMBLE	QX-103-26-102	5/5/2016	9:35:00 AM	5/5/2016	4:20:00 PM	6.75
ASSEMBLE	QX-103-26-102	5/5/2016	12:00:00 PM	5/5/2016	3:30:00 PM	3.50
FLOOR	QX-103-26-102	5/4/2016	7:00:00 AM	5/4/2016	9:00:00 AM	2.00
RADIUS	QX-103-26-102	5/9/2016	2:10:00 PM	5/9/2016	4:20:00 PM	2.17
RADIUS	QX-103-26-102	5/10/2016	6:00:00 AM	5/10/2016	10:00:00 AM	4.00
ASSEMBLE	QX-103-26-102	5/9/2016	6:20:00 AM	5/9/2016	6:40:00 AM	0.33
ASSEMBLE	QX-103-26-102	5/9/2016	8:30:00 AM	5/9/2016	11:00:00 AM	2.50
ASSEMBLE	QX-103-26-102	5/9/2016	8:30:00 AM	5/9/2016	3:00:00 PM	6.50
FLOOR	QX-103-26-102	5/4/2016	3:30:00 PM	5/4/2016	4:20:00 PM	0.83
FLOOR	QX-103-26-102	5/5/2016	6:00:00 AM	5/5/2016	8:00:00 AM	2.00

3.4 Process Analysis

A methodology has been developed to analyze the current production system and implement a new system to increase efficiency. This section presents an analysis of the data and discusses the results obtained. The paper's scope is limited to the research questions presented in section 1. After conducting an initial analysis with current state value stream mapping, four critical processes have been identified to reduce processing time and increase trailer production. Attempts were made to solve each research question with a unique system design based on lean thinking and floor input. To understand the major constraints responsible for low production, a value stream analysis was conducted. The value stream map revealed that the critical processes for building a trailer are the sides, roof, and floor. The production line begins with the sides and roof process, and without them, there can be no assembly, resulting in no trailer. The working time calculated, excluding a 60-minute break, is 570 minutes. The continuous improvement team has identified these target areas for improvement.

$$\text{To achive additional unitfor each process, following condition must be satisfied}$$

$$(\mathbf{Ps}, \mathbf{Pr}, \mathbf{Pf}) \leq \mathbf{Tk.t} \qquad (\mathbf{condition})$$

$$\text{Ps} = \text{Process time for sides}, \text{Pr} = \text{Process time for roof},$$
$$\text{Pf} = \text{Process time for floors}, \text{Tk.t} = \text{Takt time}$$

3.4.1 Sides Process

Figure 2 illustrates the average timings for four attempts of the side's method. Each set currently takes more than 6 hours to finish using the sides' present procedure. Given that the entire working time every shift is just 570 minutes, the present system could not create more than one set of sides per day at this rate.

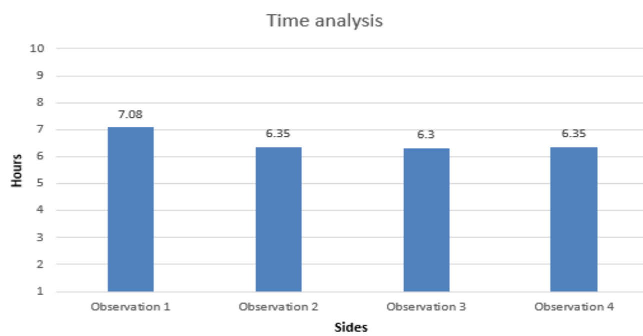

Figure 2. Time analysis for the side process

The processing time must be reduced for each side to increase production. A thorough time analysis was conducted for each sub-process, recording each step down to the second. The recorded timings revealed a tendency toward shorter processing times. It was discovered that marking, measuring, and drilling made up 35% of the entire process. To reduce processing time for each side by 35%, this procedure will be separated from the mainstream process. The client does not value this procedure, categorized as Type 2 waste, but it is necessary to turn the material into the finished item. With the process improvement target area determined, a new procedure was created using the available resources to reduce waste.

$$\text{Tk.t} = \frac{\text{Available working time}}{\text{Demand per day}}$$

Current demand is at 38 units per one month, which is 2 per day (given 19 working days per month)

$$\text{Tk.t} = 285 \text{ minutes per side unit}$$

Figure 3 illustrates that the time trend for drilling, marking, and measuring is the same for each recorded activity.

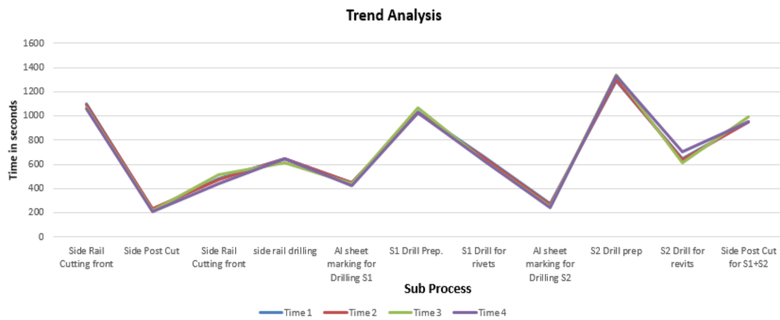

Figure 3. Trend analysis for side process

Removing the measuring and marking processes from the main process would decrease human interaction and, in turn, reduce the need for rework at the station. The amount of time that might possibly be cut from the primary process is shown in Figure 4. Based on the trend and an overall evaluation of the process, a new working procedure has been developed.

Figure 4. Value analysis graph

Dividing the process improvement opportunity time from the main process time would determine the cycle time for the side's process. The workers need to drill two sets for extrusion for sides with more than 600 holes. Prior to the drilling process, the worker needs to cut the extrusion to the appropriate length while walking to the material lot and station. Once the material is cut, measuring, marking for exact length, and drilling patterns are exposed to various human errors. The three main subprocesses, namely marking, measuring, and drilling, serve as constraints for the side process. Table 2 presents the time difference from the main processing time.

Table 2. Sub process for side process

Process	Time 1(Seconds)	Time 2(Seconds)	Time 3(Seconds)	Time 4(Seconds)
Cutting operation	2762	2754	2795	2660
Marking operation	718	718	694	672
Drilling operation	4276	4267	4274	4339
Total time(seconds)	7756	7739	7763	7671

Based on time analysis, a new process has been designed to eliminate cutting, marking, and drilling operations from the main process in the side workstation. Taking a holistic view of the process, the extrusion required to complete the sides is shipped from a supplier based in Michigan. However, due to lean times, the materials often miss the shipping deadline.

3.4.2 Roof Process

In the trailer industry roof is the part with thick sheet supported by aluminum extrusions. This process is similar to the side's process. Time analysis is conducted for roof process to understand the bottlenecks in detail as shown in Figure 5.

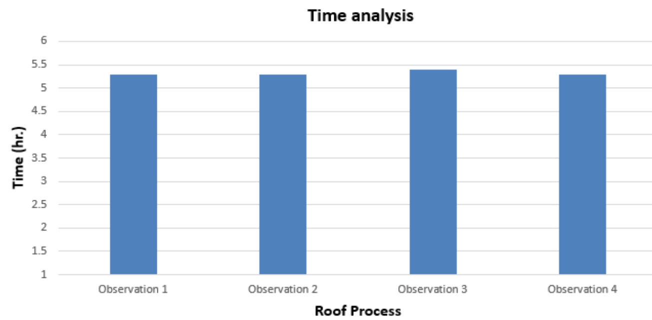

Figure 5. Time analysis for roof process

A total of four observations are recorded to understand if the process have any deviation than past process. In-depth time analysis is conducted by recording all the sub processes to the second and trend has been identified from the four observations.

$$\text{Tk.t} = \frac{\text{Available working time}}{\text{Demand per day}}$$

$$\text{Tk.tr} = 285 \text{ minutes per roof body}$$

Figure 6 displays the trend analysis for the roof improvement process.

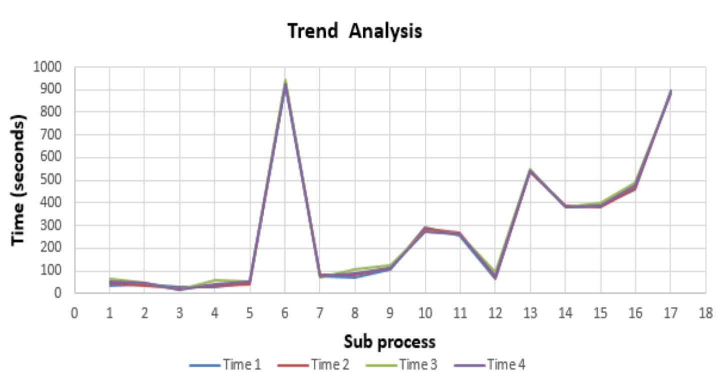

Figure 6. Trend analysis for roof process

It is observed that sub-processes 5 to 7 and 14 to 17 are time-consuming, and reducing their targeted time will lead to a reduction in the overall production time for the roof process. In order to increase the plant process time for additional roofs, the time taken should not exceed 4.4 hours per unit in the roof station. To eliminate non-value-added activities in the roof process, the same approach used for the sides is being followed. Removing cutting, drilling, and measuring operations from the main process will reduce the workload by 35%, ultimately resulting in a decrease in total processing time for the roof. Table 3 shows the sub process time for roof process.

Table 3. Sub process time for roof process

Sub Process	Time 1 (seconds)	Time 2 (seconds	Time 3 (seconds	Time 4 (seconds
Cutting operation	548	535	566	563
Measuring operation	2141	2208	2286	2222
Drilling operation	1901	1908	1933	1906
Travel time	30	24	15	18
Total time (Seconds)	4620	4675	4800	4709

3.4.3 Floor Process

The floor process consists of three stages: chassis structure, wood floor, and painting, all aimed at providing anti-corrosion properties. However, the material flow is problematic. The underbody is dragged and pushed to the paint booth before being returned. This requires at least four employees to move the 600-pound device each time. The Kaizen team identified another issue with the raw material unloading and transportation process for the Floors station. Unloading 30-foot-long wooden bars using a forklift poses safety concerns as they tilt during the process. Three workers take more than six hours to complete the unloading process. Figure 7 depicts the plant layout for floors, with black arrows indicating the material flow as the underbody goes to the paint booth and returns to the same location for assembly.

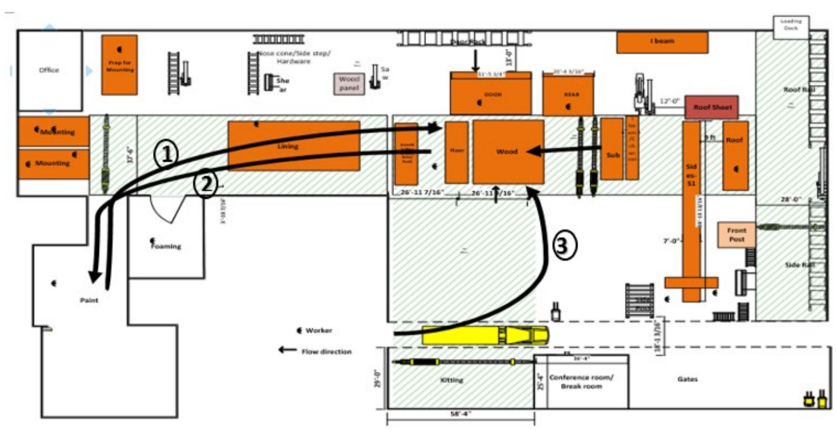

Figure 7. Plant layout for floor process

To understand the interactions between different materials and workstations, a matrix was created that identifies more than 600 parts and how they interact with each cutting station. Data has been collected on each part in the inventory system, and motion analysis has been conducted on each item to track the travel path from one workstation to another. Table 4 shows the total time required for material movement and unloading time for floors.

Material movement (from floor to undercoating)	Material movement (from undercoating to assembly)	People needed for matrial mvement	Unloading time for single kit	Unloading time for full load	People needed for unloading	Total wokers	Total time in minutes
7	7	4	15	390	3	7	404

Table 4. Non-value activity time for floor process

Table 5 indicates each state that the material has passed through at the following station for the required operations. Based on the travel path and the required station for the operation to convert the raw material into the final product, the layout is designed to move all the necessary material closer to the stations.

Parts	Floors + Subs	Linning	Mounting	D (ElliS band saw)	G(Betenbender)	H (Bender)	L (Ellis band saw	M(uni hydro)	V saw Dewalt	E samco cuttin	A (ellis band saw)	B (craftsman saw)	C (dewalt saw)	k Drill Press	
GUSSET-STAINLESS BRKT	x				x	x				x					4
TUBING-STEEL 1" X 1" 1/8" 20'	x						x	x							3
TUBING - STEEL 2X2X1/4X24'	x						x	x							3
TUBING - STEEL 2X2X11GA 20'	x						x	x							3
CONNECTOR - FRONT 109 AE-02-010-07005 106 3/8 (2.925) DIE SS0592/6063T-6												x	x		2
CONNECTOR - REAR 109 107 7/8 (7.389 DIE SS0053/6063T-							x					x			2
ANGLE STEEL 1X1X1/8X20'	x			x											2
ANGLE STEEL 2X2X1/8X20'	x			x											2
ANGLE STEEL 3X2X3/16X20'	x			x											2
ANGLE STEEL 1X3X10 GA FROM 4X10 MCNEILUS # SA-1X3 REAR 12/PER SHEET	x			x											2
CHANNEL STEEL 2X1X3/16 20'	x			x											2
CHANNEL STEEL 3X3.5X20'	x			x											2
CHANNEL STEEL 4X5.4X20'	x			x											2
CHANNEL STEEL 8X8.5X20'	x			x											2
TUBING - STEEL 2 X 4 X 24' 11	x			x											2
FRAME - TOP TKRD72	x			x											2
CROSSMEMBER 3 I-BEAM STD 94" CLIP/DO NOT WAX	x			x											2
CROSSMEMBER 4 I-BEAM 102 METAL #100" CLIP/DO NOT	x			x											2
CROSSMEMBER 4 I-BEAM STD METAL #94" CLIP/DO NOT WAX	x			x											2
CHANNEL STEEL 6X20'			x				x								2

Table 5. Material interaction matrix for floor process

3.4.4 Door Process

The production process of the units involves an interlinked process between the sides and door frames. Side frames and the entire frame, which includes the side door frame, are produced when customers request specific units. The door process can only begin after the completion of the side process, as the measurements for the door process are based on the actual side frame process. This causes a waiting time at the door workstation, resulting in jobs starting and ending late. An analysis of the door process reveals many reworks occurring due to the complicated working process at the door station. This is mainly because the workers lack proper training. The observation indicates that there is a challenge related to people rather than the process. Delta Waseca has a lot of tribal knowledge with the workers, being a treasure trove of information related to process and material. However, this knowledge has not been passed on to their successors due to a lack of proper documentation and transparency.

4. Results and Discussion

Lean techniques are used to analysis the process at each of four workstations. Each bottleneck has been studied and different techniques have been identified to eliminate the non-value process. The results are discussed further in this section. For each process individually.

4.1 Sides Process Results

Delta Waseca does not have CNC capabilities, but its sister company, Opus Mach, located only a few hours from the supplier, has state-of-the-art machining systems. To optimize production, the entire traffic from the supplier is diverted to Opus Mach, where all the materials needed to make the final side body are pre-drilled. The new side process times are illustrated in Table 6.

Table 6 – New process time results for side process

Observations (sides)	Old process (hr.)	New process (hr.)
Time 1	7.08	4.68
Time 2	6.35	3.95
Time 3	6.3	3.9
Time 4	6.35	3.95

A new process has been developed that demonstrates better lead time and superior quality. The majority of cutting is now performed using CNC programming, which eliminates the drilling process. Final processing time has been reduced from 390 minutes (6.30 hours) to 247 minutes (3.9 hours). The total working time is 9.5 hours, and it is now possible to produce two sides of a body within 8 hours in the side's workstation. A comparison with the old process for sides was made using value stream mapping to explain the new process, as shown in Figure 8. It was found that supplier lead time had a significant impact on throughput efficiency. By changing the supplier base and diverting traffic to machine centers in Detroit, the overall cycle time for the sides process was significantly reduced.

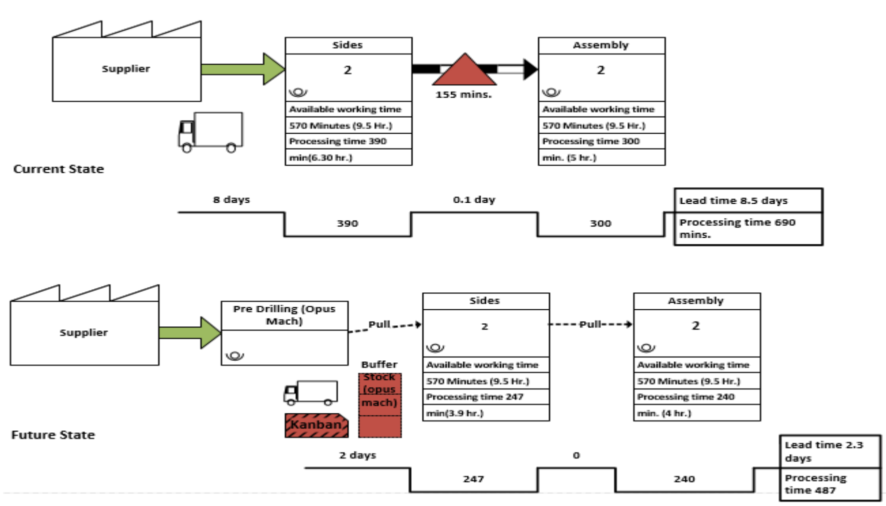

Figure 8 – Value stream map for side process

Based on the new analysis, the new takt time is calculated for the side's process. Considering the demand for two units per day for 19 working days in month.

$$\text{Tk.ts} = 285 \text{ minutes per unit}$$
$$\text{Ps} \leq \text{Tk.ts} \qquad \text{(Condition)}$$
$$\text{Note: ts is time for sides process}$$

P_s is abbreviation for side's process and condition should be satisfied to get additional units at station.
In the above equation, P_s should be less than the takt time in the workstation to achieve required pace time for demand.

$$\text{Ps} = 247.2 \text{ minutes per unit.} \quad (247.2 < 285) \text{ Condition is met for sides process}$$

The above results in the sides workstation are below required takt time to produce 2 units per day.
The new process time is 247 minutes per unit.

4.2 Roof Process Results

The roof process is almost identical to the sides process, as it involves the installation of extrusions and riveting. This process heavily relies on drilling and riveting. To streamline the process and differentiate it from the actual process, a similar approach to that of the sides process has been taken. The materials for the roof process are supplied from Michigan and are diverted to Opus Mach for pre-drilling of the extrusions. The newly implemented process has resulted in an average time savings of 78 minutes per unit in the roof station, as shown in Table 7.

Table 7 – New process time results for roof process

Observations	Old process (hr.)	New process (hr.)
Time 1	5.33	4.05
Time 2	5.34	4.05
Time 3	5.41	4.08
Time 4	5.36	4.06

When compared to the initial process duration of 5 hours and 30 minutes, the new technique has been shown to save around 1 hour and 30 minutes. The procedure can currently build two roofs at the station with a total working duration of 9.5 hours, with around 4 hours allowed for each unit. Figure 9 illustrates the roof process value stream map.

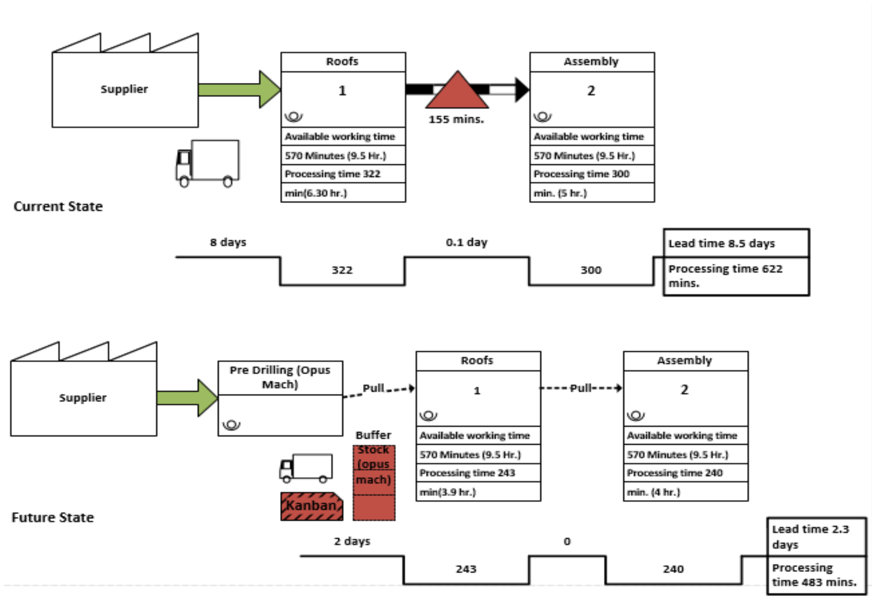

Figure 9. Value stream map for roof process

Based on the new analysis, the new takt time is calculated for roofs process. Considering the demand for two units per day for 19 working days in month.

$$\mathrm{Tk.tr} = 285 \text{ minutes per unit}$$
$$\mathrm{Pr} \leq \mathrm{Tk.tr} \qquad \text{(Condition)}$$
$$\text{Note: tr is time for roof process}$$

P_r is abbreviation for roof process and condition should be satisfied to produce addition unit at the workstation. In the above equation, P_r should be less than the takt time in the workstation to achieve required pace time for demand.

$$Pr = 243 \; minutes \; per \; unit. \quad (243 < 285) \; Condition \; is \; met \; for \; roof \; process$$

The new process time for roof station after improvements is 243 minutes per roof.

4.3 Floor Process Results

To address the constraints in the process, it is important to make changes to the material flow. In order to understand how materials are traveling and interacting between each workstation, a material interaction matrix was created. After analyzing the interactions, an optimal layout was designed that takes into consideration material flow and safety issues. Figure 10 illustrates the new layout for the floor process, with an optimized flow for both materials and transportation.

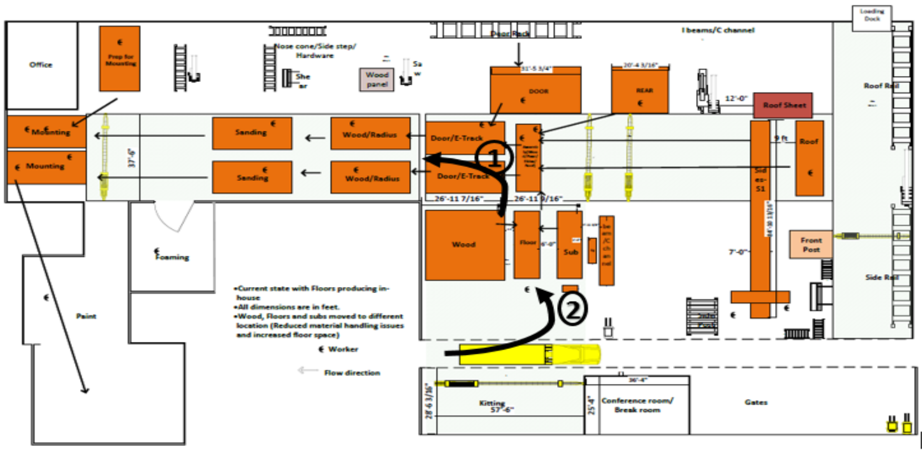

Figure 10. New layout for floor process

In the new layout, material flow is more linear than older flow. Black arrow with 1 shows how material flows after floors are put together. Arrow 2 shows raw material receiving flow for floors process.

$$Ft = 78\ minutes$$
$$Note: Ft\ is\ floor\ transit\ time\ from\ one\ station\ to\ other\ and\ material\ unloading\ time.$$

Table 8 shows the new results for the floor process.

Table 8 – New results for the floor process

Material movement (from floor to undercoating)	Material movement (from undercoating to assembly)	People needed for matrial mvement	Unloading time for single kit	Unloading time for full load	People needed for unloading	Total wokers	Total time in minutes
0	0	0	3	78	2	2	78

Figure 11 illustrates the value stream map of the floor process with the lead time and processing time including the current and future state.

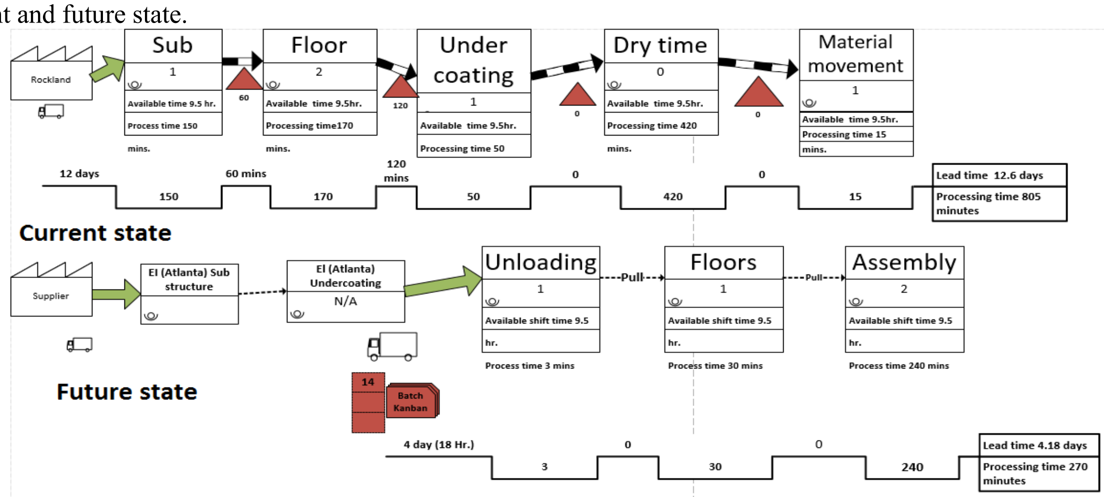

Figure 11. Floor process value stream map

$$\mathrm{Pf} = 270 \text{ minutes per unit}$$
$$\mathrm{Pf} < \mathrm{Tk.t} \text{ (takt time)}$$
$$\mathrm{Pf} = 270 \text{ minutes per unit.} \quad (270 < 285) \text{ Condition is met for floor process}$$

5. Conclusion
The study results were implemented on the production floor using lean thinking. Production floor workers played an important role by conducting kaizen events and extracting tribal knowledge, which helped the team identify bottlenecks in the process. As a result, processing time for sides, roof, and floors was reduced, meeting conditions to increase plant efficiency.

$$(Ps, Pr, Pf) < Takt\ time$$
$$Ps = Sides\ process\ time, \mathrm{Pr} = Roof\ process\ time, Pf = Floor\ process\ time$$
$$\therefore\ Condition\ is\ satisfied\ for\ all\ three\ major\ process$$

As the product is related to the automotive industry, each process improvement was conducted in compliance with Occupational Safety and Health Administration (OSHA), National Highway Traffic Safety Administration, Federal Motor Safety Administration, and International Organization for Standardization (ISO) standards. All design and process changes were subject to a standard verification process, and changes were recorded in engineering change notices prior to approval. Implementing process changes with lean thinking has helped the organization significantly, and the entire team's participation from the managerial level to the floor labor level has made the changes much easier. Small projects were targeted initially, and major process changes were carried out once the projects were successful and team members were more confident.
To sustain the lean culture, daily meetings are conducted to discuss the production process and scheduling for 20 to 30 minutes with the leads and workers. These meetings have led to leadership development for some floor workers who have started to lead projects in the absence of a supervisor or floor manager. All employees constantly strive to reduce lead time and increase product quality by bringing more change on the floor. Delta Waseca invests heavily in the lean process implementation along with the integration of new technologies to build superior quality products in the trucking industry.

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Dr Kuldeep Agarwal is a professor in the Department of Automotive and Manufacturing Engineering Technology at Minnesota State University Mankato. His research is in the areas of Additive manufacturing, metal forming, process improvements, and robotic welding. He is the graduate coordinator and works with local industries on lean, project manufacturing, and six sigma methodologies.

Naim Islam is a professional science master's student, pursuing engineering management under the Department of Industrial and Manufacturing Engineering at Minnesota State University, Mankato. He completed his bachelor's degree in communications engineering from International Islamic University, Malaysia. Upon completing graduation, he worked as an IT assistant in Sydney, Australia and as a performance marketer in Dubai, U.A.E. During his work experience, he has handled process improvement and waste reduction projects in different applications. He is actively involved and interested in various research topics including quality assurance, supply chain management, Lean manufacturing, Lean-Six-sigma applications, project management, new product development, design of experiments, data analysis and statistics. He has registered with IEOM as a student member to be actively involved and learn more from the industrial/manufacturing sector.