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STUDY OF IMPLEMENTATION OF VALUE STREAM MAPPING AND LEAN TOOLS TO ACHIEVE LEAN

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Abstract: This study has been undertaken to investigate how the companies achieved Lean. The paper provides a better understanding of how the tools were chosen and implemented to particular problems offering great awareness to the knowledge. The problems faced in different issues are described and the value stream mapping implemented to solve the issue or to find the underlying cause of the problem is clearly revealed. The improvements and the solutions given by the tools are also illustrated.

***Index Terms* - Six Sigma, Kanban, Lean tools, Value stream mapping, Lean.**

I. Identified Organization

1. Ford Production System Manufacturing Division, Ford Lio Motor Company, Chung-Li, Taiwan

2. Bombardier Aerospace Learjet- Assembly Division

II. Background and Problem Definition

The conventional way of thinking in the west was that mass production was the only way to minimize the manufacturing cost. Despite the fact that Japan�S automakers have low costs with small volumes and shorter lead times. In addition, Toyota products have got a reputation for being fuel-efficient and durable. Ford wonders how Toyota had consistently achieved continuous improvement through continuous elimination of waste whereas other competitors couldn‘t learn the art of implementing lean effectively even after years of implementation. However, if the implementation of the Toyota Production System (TPS) is the key to Toyota‘s success, why couldn't the competitors make their way towards success despite adopting similar principles? It seems that Toyota Production System (TPS) has got some special ingredients within its system.

2.1 Description of Value Stream Mapping (VSM) applied to the Problem

Ford implemented four steps of problem solving process that shows how lean supply chain affects the product quality and cost. VSM not only identifies the Value Added (VA) and Non- Value Added activities (NVA) activities but also tells the status of their lead time in supply chain from the unloading of the raw materials to the shipment of the final product. Therefore the lean VSM shows shorter lead time, higher quality and lower cost. So they thought of implementing VSM which is considered to be the best practice in supply chain management that TPS has proved.

- **Onsite study-** The first step is to conduct an onsite study of all the processes considering even the 5Ms- Man, Machine, Material, Method and Message (Information)
- **Value Added and Non-Value Added Activities -** Followed by the sorting of Value Added (VA) and Non-Value Added (NVA) activities
- **Current State Map** - Then draw the Current State Map (CSM) with the collected information, which will be the visual improvement tool in setting up target
- **Wastes** - Next is to identify the wastes (7 wastes) and the bottlenecks from CSM
- **Target -** Set up challenging target with measurable indicators
- **Ideas** - Brainstorming and bringing out continuous improved ideas to attain the target
- **Future State Map –** Then with the evolving ideas to achieve target draw the Future State Map (FSM)
- **Gap analysis -** Finally through gap analysis between CSM and FSM find the problems and the counter measures to implement them, evaluate and follow-up the problems.

The FSM implemented will become the CSM and the cycle goes on for continuous improvement.

2.2 As a result of applying VSM they found

- **Too much Non-Value Added activities (NVA)**- 69% potential opportunity for improvement existed as there was too much of Non-Value Added activities (NVA) to pick up parts by walking which had a total value of only 31%
- **Low First Time Through (FTT)**- 5% defect rate at the piston assembly station
- **Low Overall Equipment Effectiveness (OEE)** – 73% in the Head assembly station due to aged equipment and longer set-up time

2.3 Choice of Tools

In lean manufacturing, so often companies fail because they do not understand all facets of lean. Therefore, it is very important to understand lean before implementing it. Likewise, it is very essential to understand and know the underlying problem of the situation before selecting a tool. Selecting the right –lean tool plays a major role to manage outcome and expectations.

PROBLEM	TOOL SELECTION	REASON
Too much Non-Value Added activities (pick up time and walking)	Pull system concept Just In Time (JIT) and Kanban	To built up sequential parts feeding To reduce NVA
Low First Time Through parts in assembly indicating the low quality of the parts	Error Proofing (Poka- Yoke) devices and visual aids (Andons) for critical processes	To promote the quality of first time through
Low Overall equipment Effectiveness of the equipments leading to frequent breakdowns and repairs	Total Productive Maintenance (TPM) Quick changeover tool	To reduce machine breakdown To reduce set-up time

2.4 Solution provided by the Tools

- **Change the supply pattern of the parts:** In order to avoid the Non-Value Added activities (NVA) where the operators walk or wait to pick up parts frequently, identify the working space for kitting and sequential feeding which feeds the kits and the necessary parts to the main line through a separate conveyor to the stations such as Head/Belt assembly, Starter/Intake assembly and Generator assembly where there was a manpower shortage to pick up parts.
- **Re-design of sequential rack:** Redesigning the sequential rack for common use forming the one-piece flow making it easily accessible for all the operators from different working lines that makes the walking distance negligible saving time and cost
- **Re-balance of manpower:** identify the surplus manpower from Non-Value-Added activities (NVA) reduction to do kitting and sequential feeding rebalancing the workforce instead of non-value-added activities
- **Set up Just in Time (JIT) Kanban:** So that the supplier directly supplies generators to the working line just in time as needed by the working line through Kanban which has the same coding system. Applying JIT reduces the inventories which had occupied most of the space leading to the shortage of working space to design the feeding operations
- **Set up Error Proofing (Poka-Yoke) and visual aids (Andons):** Error proofing devices can be any electrical, mechanical, procedural, visual, human or any other form that prevents incorrect execution of a process step and monitors continuously the errors(processing, missing, measurement, improper, operation, setup) to promote First Time Through (FTT). Andons bring these errors to the notice of the officials with the use of the colours where red and green are often used. Green- normal operations, red-abnormal action, immediate attention required.
- **Set up Total Productive Maintenance (TPM):** Practice frequently TPM and apply quick changeover to improve performance for ageing equipment to improve OEE.

2.5 Improvements Made

The impact of VSM is clearly summarized in the table.

Measurable indices (%)	Before Lean (%)	After Lean (%)	% Improved
OEE	75	85	10
FTT	94	96	2
Total working time	60.94	54.54	6.40
VA	18.96	19.54	0.58
NVA	41.98	35	6.98
Value ratio	31	36	5

Source: **H.M.Wee,Simon Wu,** (*2009) Chung-Li, Taiwan. Lean supply chain and its effect on product cost and quality: a case study on Ford Motor Company.*

- The OEE improved by 10%, thereby productivity increased, cost fell and output quality improved.
- The FTT improved by 2%, quality is improved, re-run rate fell, so cost and lead times fell
- Total working time has reduced means the reduction in labour costs
- Value added time increased means the assembly quality has improved
- Non-value added time reduced resulting in reduced costs
- Value ratio increase meant the production line improvement and became leaner because of lower cost, higher quality and shorter lead time

The result clearly shows how lean tool applied in VSM affects the product quality and cost.

2.6 Summary and Reflection

- VSM use pull system and one-piece flow concepts and identifies the wastes and the bottlenecks using suitable indicators and eliminates them with the usage of appropriate tools and techniques.
- Ford was able to reduce the Non-Value Added activities of the operators walking or waiting to pick up parts by introducing pull concept that built up sequential parts feeding, Just In Time and Kanban which reduced the inventories giving space for the feeding system resulting in the shorter lead time.
- Build-in quality is achieved by the error-proofing devices which led to the maximum First time through of the products.
- The ageing of the equipment and its breakdown had been controlled by continuous practice of Total Productive Maintenance and Quick Changeover of the equipment.
- VSM plays an important and major role in Lean. Implementing lean must be a continuous process and should only aim at long-term strategies to achieve or experience 100% lean. Cultural change is a long-term philosophy to achieve success. **"There is no 50% or 90% lean, it is either 0% or 100%".**

III. Background and Problem Definition

The phenomenon increase in demand in the aircraft industry has pushed the manufacturers to look for new concepts to stay in business amidst strong competition. To improve the performance of a process and ensure on-time delivery there are numerous different approaches available nowadays. Lean offers a unique method by using its concept of Value Stream Mapping (VSM) which helps to identify possible improvement areas on a production line. In addition, using its Six-Sigma tool DMAIC (define, measure, analyse, improve, control) offers a unique approach that is widely used in industries to improve the process and thereby reduce the number of defects. Although Six Sigma is a lean technique, most companies use Six Sigma as a separate strategy besides Lean. This is because companies do not understand completely the philosophy of lean. The Lean Six Sigma was tested in the assembly of the upper main entry door of a business jet model 40/45, where they had a problem with **late delivery and frequent occurrence of non-conformance in the final assembly line**.

3.1 Description of Value Stream Mapping (VSM) applied to the Problem

Value Stream Mapping was developed to prove that there were lead-time and non-conformance related issues with the door delivery shop. And also to identify the blocks in the flow of the assembly line. VSM was conducted on **the movement of the door and the door assembly line**.

- The door shop has two different lines, a line for the Upper door and another line for the Lower door
- The Upper door has to go through 4 posititor to be ready for installation, and they move at a specified move time that is associated with the move time of the final assembly line of the aircraft
- Positions 1, 2, and 4 are at the door shop and position 3 is at the foam shop where sealing and foaming are carried out
- For the smooth flow of the assembly line and also for the door to be completed as per schedule, all parts should be readily available

- All the parts for the door assembly are provided as kits by the Material Control Agents (Stock Room)
- Kit contains parts that are either made in-house or purchased from a vendor. So, when the purchased parts are short in supply, it is the procurement department to whom it is notified for the appropriate action to be taken and they are the ones held responsible for the block
- The final assembly line of the aircraft has 6 positions with a move time of 4 days, therefore a completed upper and lower door should be ready for the final assembly line every four days
- As scheduled, doors should be installed in position 3 of the final assembly line

3.2 The deviations from the VSM are;

- **Late delivery increasing the Lead time -** The upper door is delivered at position 5 of the final assembly instead of position 3 which mean that the doors are ready in 8 days rather than 4 days as scheduled
- **Rework due to non-conformance -** Even after the late availability of the door for installation, there were occurrences of non-conformance on the upper door which requires at least 8-10 hours of rework

3.3 Choice of Tools

A systematic lean tool – "Six-Sigma (DMAIC)" is used here for process improvement and redesign.

- **Define** - defines and quantifies the lead-time related issues from Value Stream Mapping
- **Measure** – measures the shortage parts, an intermediate phase where the problem is redefined and likely the root cause is identified
- **Analyse** – process and data are analysed using Pareto charts and the higher impact of the problem is identified
- **Improve** - identifies the corrective actions to reduce the shortage issues
- **Control** – improvements implemented are maintained and sustained with suitable measures

Key Performance Indicators (KPI) – Brainstorming, Cause and effect diagram, Pareto chart, Defect Concentration Charts

3.4 Solution provided by the Tools

3.4.1 Lead-Time Reduction

- **Define:** From the Value Stream Mapping it was defined that the kits were waiting in between positions spending at least 16 days more than the actual 12 days because of the missing parts/parts shortage
- **Measure:** A measure of the missing parts was carried out and found to be 13 parts missing from each kit on the average of 20 kits
- **Analyse:** Using three different measures namely the number of parts missing in the kit, parts that were missing repeatedly and the make of the park, the list of the parts was sorted out and a Pareto chart was plotted. It was found that 90% of the missing parts were from outside vendors, therefore the vendor's name was retrieved from the database and out of the 8 parts that were considered for the corrective action which was missing for at least 50% of the time, the same vendors supplied 4 parts
- **Improve:** To take corrective actions Material logistics agent team from Work Material &Planning (WMP) department was formed demanded the vendors that the failing the parts supply would be replaced, and eventually it was replaced. The shortage data was again collected after 3 moves which showed on the average of only three parts missing from each kit, but they did not affect the assembly line as they were filled before the door reaching the position 2 or position 4. It was noted that the lead-time has gone down to 10 days from 26 days. These 10 days were due to staging time taken by the stockroom
- **Control:** Consolidated Applications System (CAS) was used by the Work Material & Planning (WMP) department to monitor and control the corrective actions of the lead-time. By monitoring, they would be able to demand whenever their supply lead- time crosses the required production lead-time.

3.4.2 Non-Conformance Reduction

- **Define:** The repeating issue defined here was the deviation in the contour of the upper door that had lead to the rework
- **Measure:** The first step in the measure phase is;
  DCC: Defect Concentration Charts were used to identify the area where the defect occurs repeatedly. From DCC, it was found that the defective area was in the upper front door edge
  Cause and Effective Diagram: Possible causes were identified by considering the Man, Components and Methods. Undertrained employees and inconsistent manning were suspected to be the costs but were ruled out. Then the standardisation of the work was questioned which also proved to be in standard working. Tools used to assemble the doors were checked for calibration and maintenance, but they were all ruled out. Then the final was the inspection the contour that was checked for accuracy and found within specification
- **Analyse:** The contour of the door made was checked with the engineering drawing to match it and they were also found to be within the tolerance level. Finally, to find the cause, the repeated issue that was reported were collected, which was the force requirement in operating the door handle mechanism. It was analysed that the force required to handle the door exceeded the designed limit of 35lbs. then the door locking mechanism was studied in detail and a design fault was found in the door lock mechanism
- **Improve:** A design improvement was then introduced. The bell crank pin sliding into the bush at a straight angle was identified to be the root cause of the problem. As the bush was not aligned with the bush, more force was applied, changing the contour of the door. The centre bell crank assembly was moved up by 0.190 along with the other geometry
- **Control:** The design change implemented were followed for the future productions so that there wouldn't be non-conformance related to the force requirements

3.5 Improvements Made

- The lead-time was reduced from 26 days to 10 days
- Brainstorming, engineering knowledge, cross functional teaming to detect the problem: Non-conformance was reduced by 30%
- Reduction of rework time by 3 hours per aircraft
- Cost savings close to $6000
- The impact of VSM is clearly summarized in the table.

3.6 Summary and Reflection

- Opportunities needed for the improvement were identified by high-level value stream mapping by using DMAIC which is a finite sequence of steps that was followed to improve the process
- Part shortage was found to be the reason for high lead time therefore by implementing DMAIC. The lead time was reduced from 26 days to 10 days
- The DMAIC methodology was used and a design fault was found which had led to the non-conformance
- Non-conformance was reduced by applying DMAIC as a system approach with the engineering knowledge, along with the KPI‘s without which the problem could have been misinterpreted
- It will add value to form cross-functional team from the departments that are affected by the problem to reduce the effort in identifying the root causes
- The continuous use of this systematic approach would enhance more opportunities for improvement which could save time and cost
- Even a small mistake in the process or design would lead to a non-recurring cost

IV. CONCLUSION

Value Stream Mapping (VSM), one of the important principles of Lean has been applied to problems to identify the value-added and non-value-added activities to find the root causes. Also, to map the current state versus the future state to arrive at a clear idea of the opportunities and gaps in the situations faced. Accordingly, the appropriate tools of Lean has been identified, mapped and used to achieve corrective measures. DMAIC is an approach of Six Sigma- a data driven approach, one of the powerful tools of Lean has been used to reduce the number of defects. VSM is a very essential technique to attain Lean success.

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