# Design of a Lean MRO Business Process for EPCOR

“How to decrease process variability
and reduce the lead time”

**Wouter W. A. Beelaerts van Blokland**
Aerospace Management and Operations
Faculty of Aerospace Engineering
Delft University of Technology
Kluyverweg 1, 2629 HS Delft
The Netherlands
w.beelaerts@lr.tudelft.nl

**Albert de Waard**
Aerospace Management and Operations
Faculty of Aerospace Engineering
Delft University of Technology
Kluyverweg 1, 2629 HS Delft
The Netherlands
albertdewaard@gmail.com

**Ricky Curran**
Aerospace Management and Operations
Faculty of Aerospace Engineering
Delft University of Technology
r.curran@tudelft.nl

**Abstract**

*Lean Manufacturing originally derived from the Toyota Production system (TPS) has been developed and researched starting in the fifties of the last century within the automotive industry. In the meanwhile other sectors of industry like the aerospace industry have shown interest in this methodology to improve production processes. This research is projected on the Aviation MRO processes of the company EPOCR B.V. in the Netherlands which stands for European Pneumatic Component Overhaul and Repair.*

*Core of the management problem within EPCOR is the variability of the input of valves to the repair processes which causes unpredictability of the output leading to unsatisfactory low customer service level of 35%. Within the process there is hidden a lot of waste which should be identified to redesign the repair processes. Waste can be identified as producing value before there is demand to value, holding more inventory than absolutely necessary and delays that interrupt the flow.*
*The current business processes of valves repair is very inefficient and has to be redesigned according to the lean theory to improve customer satisfaction.*
*After redesigning the processes by applying lea theory and lean Six Sigma the performance could be improved significantly.*

## Introduction

This research paper is focused on the principles of Lean Six Sigma in a “real life” environment. The company in question is EPCOR B.V. in the Netherlands. EPCOR stands for European Pneumatic Component Overhaul & Repair and as the name states EPCOR’s business relates to the maintenance, repair and overhaul of aircraft components, most of which are pneumatic. Management was interested in the research because of the felt need to increase EPCOR's performance. At the time of the start of the research in early March 2007, customer service level (CSL) was at 35% and the average turn around time (TAT) was 28 days while 15 days is promised to the customer. So what could be the possible causes for the sub-optimal performance?

Due to the nature of the business there are some aspects that EPCOR cannot fully control. Firstly, the customer sends units to the shop *when* they want and *how many* they want. This means the input is not stable; it fluctuates. Secondly, there is a parts problem. In 25% of the cases the unit being repaired /overhauled has to go on parts hold. This in combination with a rudimentary planning system has contributed to some unsatisfactory results. The process inside EPCOR was not very efficient. By plotting the customer delivery graph (which is actual TAT – promised TAT) as depicted in Figure 1. these inefficiencies became clear.

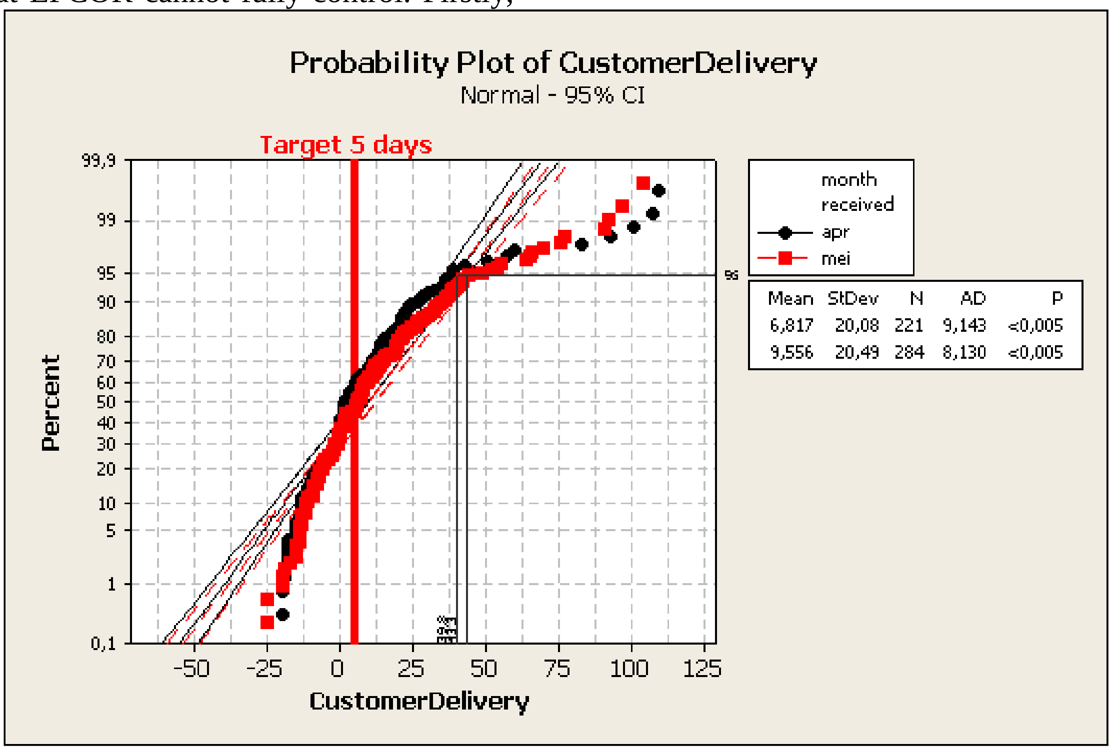


Figure 1: Customer Delivery Variation

The curve in Figure 1 is not a straight line rather it veers off towards the end. This means that the curve is not a normal distribution. Lean Six Sigma says that when a graph is skewed, as is the case there must be a lot of internal waste. Waste refers to the production of value before there is demand, holding more inventory than absolutely necessary and delays that interrupt the flow. In other words the current valve repair process is very inefficient. This leads to the formulation of the research question: *"How to decrease process variability and reduce lead time"*. This implies straightening the TAT line and thus making the TAT more predictable and therefore reducing the variation, making the process more stable. Straightening the line implies removing the waste, which in turn will also make the flow visible and easier to plan. Future steps should then be directed towards shifting the TAT-line towards the left.

## Research method

The method used to design and implement a lean business process was based on lean tools as the business process problem "input variability" identified was of a lean nature. The main tool used to define and analyze the current situation was value stream mapping. Furthermore, aspects needed to create a lean six sigma company were also looked into such as creating input rules, setting priorities.

The theory to be used to approach the research question is Lean Six Sigma. Lean Six Sigma is a familiar concept within the automotive industry derived from the Toyota Production System.

Lean Six Sigma combines two concepts:

1. <u>Lean:</u> The goal of lean is to increase process speed. This is done by systematically eliminating waste from all aspects of the organization's operations. Waste is viewed as any use or loss of resources that does not lead directly to creating the product or service a customer wants when they want it [Lean Manufacturing and the Environment 2003]. Taiichi Ohno [Toytota Production System 1978] categorized seven types of waste that cover all the means by which a manufacturing company waste or lose: overproduction, idle time (time when no value is added to product), inventory, transport (unnecessary moving or handling), bad quality (defective units), over-processing (work carried out on product that adds no value) and motion (movement of equipment or people that add no value to product).

   There are five main lean [Womack 1998]: Focus on steps that create value from the customer perspective

   1. Specify value from a customer perspective.
   2. The value stream: identify all the steps in the process
   3. Create flow in the process: remove the waste identified in the value stream
   4. Use the customer pull approach
   5. Strive for perfection

2. <u>Six sigma:</u> The goal of Six Sigma is to bring a process under statistical control. It is quality based and measures a system based on the number of defects. A defect is defined as: 'A measurable characteristic of the process or its output that is not within the acceptable customer limits'. 'Sigma' (the Greek letter $\sigma$) is a statistical term used in statistics to represent standard deviation and statistically 'six sigma' means that there are 3.4 defects per million opportunities. Often results are presented in a 'bell curve', in statistical terms it is known as a standard normal distribution (see Figure2 )

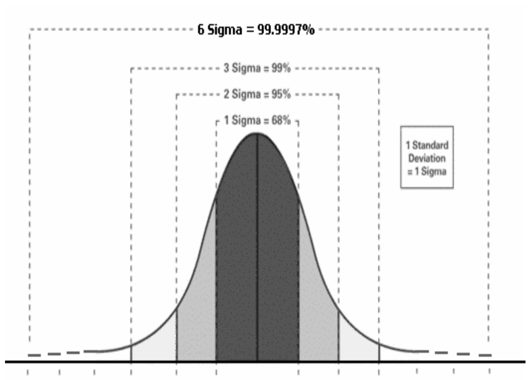


Figure 2: Bell Curve

The problem at EPCOR is related to variability and lead time and therefore the applied research method is related to the lean theory and Six Sigma. For example if the TAT is not a normal distribution the lean approach must be used as Six Sigma tools can only be applied if the data is normally distributed. The lean approach should result in data that is normally distributed so that subsequently the Six Sigma tools can be used to further improve the situation. DMAIC; define, measure, analyze, improve and control are the detailed research steps to be taken to stabilise and lean the processes.

### Measure

In the measure phase one collects data for the project. The objective of the measure phase is to understand the process that produces the defect. This means understanding what the flow of the process is, who is involved and what the entitlement of the process is.
There are several tools that are used in this phase. Firstly, the SIPOC diagram (Supplier, Input, Process, Output, Customer), which illustrates the departments that are involved and identifies the owner of the process in question. Secondly, value stream mapping is a great way to visually represent the process that is under investigation.

### Analyze

The analyze phase continues where the measure phase ends. The data that have been collected must now be analyzed. The aim is to identify the best improvement opportunities when taking the Six Sigma path. In lean circumstances the waste areas must be identified in the current state and the impact of each waste must be determined. In essence the main goal of the analyze phase is to gather enough knowledge that will ensure that no time is wasted during the improve phase. Therefore, the links between the input and output variables must be determined during the analyze phase.

### Improve

The improve phase ‘improves’ the aspects that were deemed to be a problem in the analyze phase. The causes are now known. These causes must now be eliminated or counteracted. The methods to do so must be laid down. Thus in the improve phase a solution must be found and implemented to solve the problems as identified in the measure and analyze phases.

### Control

The control phase is probably the hardest phase, as it requires a lot of discipline. Its goal is simple: gains that were made must be maintained. People must not fall back into old habits. Moreover, the process must be continuously monitored to see if something happens that must be resolved. One of the most common tools to achieve this is statistical process control (SPC). SPC can be divided into three steps:

- Create a control chart
- Isolate and remove special causes of variation
- Institute procedures for immediate detection and correction of future problems

Throughout the DMAIC improvement process there are several factors that are of utmost importance. Firstly, the management team must stand behind the project. They must be convinced of the importance and possible positive effects for both the customer and the company. If the management does not back the project there is no point in continuing. Secondly, the people directly involved in the process that is being changed must be incorporated in the DMAIC. It will ensure that the resistance to change becomes less. If people are involved they are motivated to make the project a success. The resistance factor must not be underestimated. It is a main major factor when it comes to influencing the success of a project. People often associate change with negativity. It is thus very important to get all parties concerned with the change to support it and see the value in it.

## Measure and Analyze: Current Sate

### Value Stream mapping

The technique used to define and illustrate the current state was value stream mapping. Firstly, as there are many different types of valves entering the shop and not all can be followed one of them must be chosen that is the most representative. The High Pressure Shut-off Valve is a valve that undergoes all the process steps currently at EPCOR so it was chosen. Next the path of the valve as it goes through the shop was followed starting at the end and finishing at the beginning. This visual representation was supplemented by data about each process step and waiting time. The data were collected from the ERP (Enterprise Resource Planning) system, actual timing and personal experience. The resulting current state is the basis for reducing variability by reducing all kinds of waste.

### General Analysis of Current State

The current state was now analyzed Firstly, the supplier of the goods and the end customer are the same in this process. This is a unique situation and gives EPCOR perfect insight into the customer's demand. It also had downfalls as was discussed earlier. The customer batches the input and supply is not consistent.
Secondly, it can be noted that the units are pushed into the repair/overhaul process. It doesn't matter whether the capacity is there or not: every unit that the client delivers immediately goes into the shop environment. This leads to valves having to wait in many different locations. The unit even has to wait after every process. This means that the flow is continuously disrupted and each delay costs time and money.
Thirdly, the valve is handled by as many as 8-10 different people during one stay at EPCOR. As a result, information about a specific valve is lost through the process.

Information being lost can be split up into two categories:

- Specific details of a valve can be lost/altered when the valve moves from mechanic to mechanic.
- Parts are ordered incorrectly => since a mechanic doesn't do assembly right after disassembly he never realizes that he has ordered an incorrect part => it also agitates the assembly mechanic as he has to correct the mistake, which disrupts his flow.

Moreover, the more people to handle a unit, the more views there are and given that the repair/overhaul industry is to a certain extent dependant on a mechanic's view of the situation these differences of views can cause more delays.
Finally, looking at the delays more closely the waiting time that springs to mind is on average the 15-day period between disassembly and assembly. This delay is caused by many smaller delays. With the lead-time of 15 days guaranteed to the customer, this delay is unacceptable. More importantly no value is actually added to the valve in this 15-day period. Instead the valve is kept waiting due to many factors which can be globally categorized into three categories:

1. Handlings/movements that the valve goes through
2. Waiting times before and after these handlings/movements
3. Material/part shortages

It is also during this period that the valve is unnecessarily handled by five to six different individuals.

On the basis of the above it was decided that the area between disassembly and assembly was going to be the focus of further analysis and improvement. The waiting times in this area were looked at more closely and where possible eliminated or decoupled from the actual flow of the valve. The full detailed analysis cannot be given but two examples will be covered below.

**Example 1**: A unit gets put on the hold rack after disassembly because the customer must approve the repair price before the valve can continue. This results in a waiting time of at least 3 days for the valve. However, the repair price is accepted 98% of the time. This means that the risk of continuing with out the customer approval is very small. Thus this waiting time can be eliminated for the valve.

**Example 2:** After the mechanic is done with disassembly the approved mechanic checks the mechanic's work. Currently, this means the mechanic now has to clear all the parts, put the parts in plastic bags and put these in a box and bring it to the approved mechanic. This clearly disrupts the flow. From now on in order to create flow the approved mechanic must come to the mechanic. The valve has the main priority and people must come to the valve. This does not only apply to the approved mechanic but to many other situations as well.

The detailed analysis of the 'current state' eventually led to the development of the 'future state'.

## Improve: Future State

The major innovation in the process is that mechanics will assemble a valve immediately after disassembly. This is done to create flow in the process as the longest waiting time is in between disassembly and assembly. Moreover, if a mechanic assembles the valve he has disassembled the actual time he spends working on a valve will also be considerably lower for several reasons. Firstly, the time needed to clean up a valve after disassembly and to sort out a valve for assembly has been eliminated, because a mechanic no longer has to clear up the valve after disassembly. Secondly the individual differences are eliminated which will result in less changes taking place later on in the process. Lastly, any materials that have been picked incorrectly will immediately be known instead of five days later. This change, assembly straight after disassembly, does however have some implications as the steps that used to be in between assembly and disassembly have to be eliminated/shifted or changed. As a result the whole flow starting by the valve entering EPCOR has changed. All the other main changes will now be highlighted below.

## Improvements

The first improvement that has taken place is that immediately after the unit enters EPCOR a check is done to see if 'all' the parts needed to repair the unit are present. If not, material planning immediately gets a sign and they can order the parts needed and the unit will not enter the shop. Moreover, the supervisor who is now in charge of the production planning will get a sign once a unit is complete or not. In this way he knows what units he must put through the shop process. The actual nature of the sign can be via a computer program a phone call or an e-mail. The next step is a very important one as it changes the flow from push to pull. A unit will only enter the shop if it is complete and there is a mechanic available to work on the unit. Once selected, the unit goes through the pre-test. The procedures and waiting times associated with the pre-test have not changed. After the pre-test the unit is placed in the free slot available to it on the rack in front of the cell (supermarket effect, the 'pre-test loop'). This means a mechanic will pick up the unit within two days. Once the mechanic starts with disassembly he can carry on with assembly straight away without any waiting times as stated before. This means that when the mechanic has completed disassembly and he is in a position to determine what parts he needs to replace, the pickers get a ‘sign’ to pick that particular work-order. Subsequently, 30 minutes later they bring the picked parts to the mechanic who can now continue with assembly. During these 30 minutes the various checks done by the approved mechanic have taken place and the units have been given a status. The unit will only be taken out of the flow if the status given to it is ‘beyond economical repair’. After assembly the approved mechanic not only performs the necessary checks but he also does the technical and administrative checks. Hereafter he delivers the unit for final test by putting it in the designated rack, which is ordered according to delivery date. The process for the final test has not changed.

## Results

The new state was introduced and monitored for three months at present (September 2007). Recall the customer delivery graph in the introduction

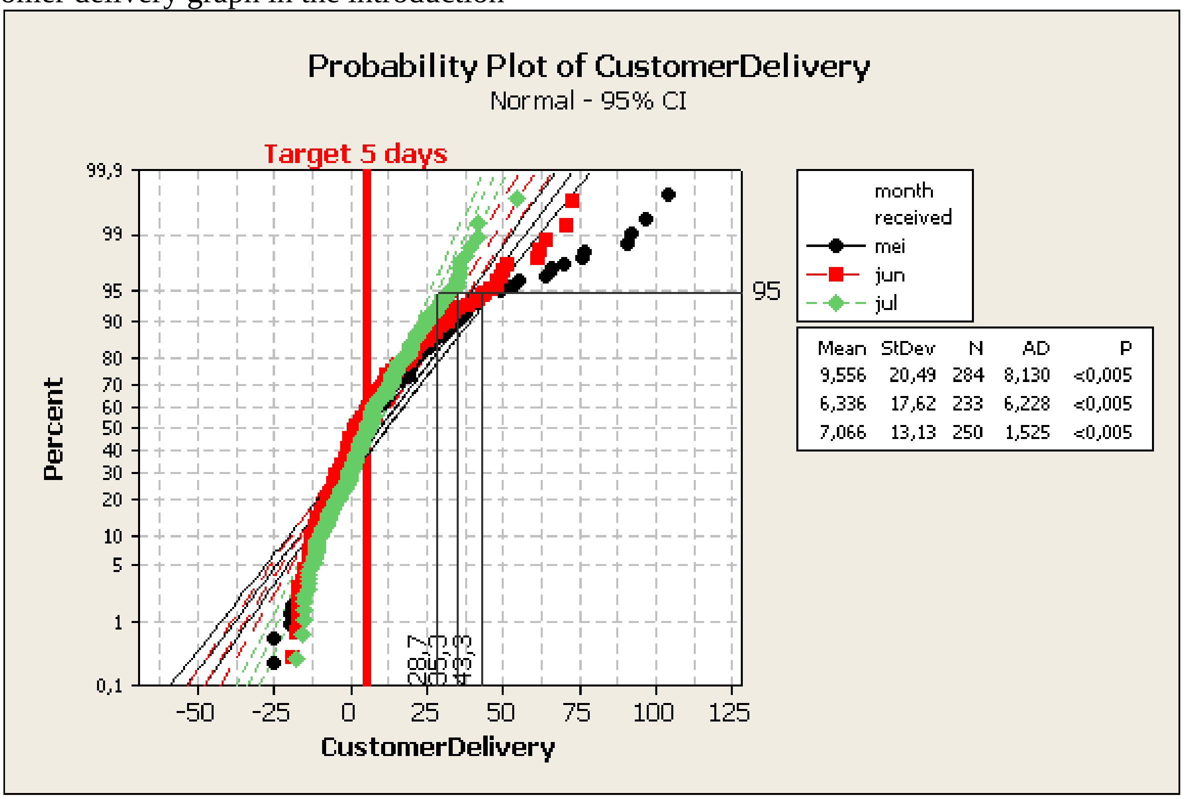


Figure 3: Probability Plot of Customer Delivery

(Figure 1). The graph veered off severely towards the end indicating a lean problem. Subsequently steps were taken to remove waste and make the process lean. The customer delivery graphs for the months June and July are shown in Figure 3.

Firstly by looking at it, it is quite obvious that the June (red) line has straightened as compared to May (black) and that the July (green) line is even straighter than the June line. This means that the standard deviation has gone down, more specifically: the standard deviation has gone from 20.49 days in May to 17.62 days in June and further decreased to 13.13 days in July. This is a remarkable and positive outcome, however, the data are not normally distributed yet. There are several reasons why this is the case. Firstly, inherent with any implementation there is some waste. It takes a couple months before everything is flowing smoothly. Secondly the implementation started during the vacation period. This meant that there were instances when the shop was at half the usual capacity. Taking this into account it is remarkable that the results are so positive. Finally, no strict input rules were in place at the time. This meant that sometimes a valve was given preference over others and this distorted the customer delivery data, as the valve that went before its turn was done relatively early while the valve that was supposed to enter the shop got done even later. Lastly, as mentioned before once the TAT has a normal distribution, six sigma tools can be used to reduce the TAT.

## Conclusions

The new business process is designed and implemented based upon Lean Six Sigma analysis. The TAT line has been straightened considerably but it is not a normal distribution yet. The standard deviation has gone down considerably which means the process has become more predictable. Applying lean manufacturing theory to this MRO process has been shown positive results already within a short period of time. By following the research method DMAIC the performance of the processes could be identified and defined to form a solid basis to redesign the business processes. The research method has given the managers, supervisors, planners more insight into the status of the shop. It also means that bottlenecks or problems are localized more quickly. The theory on lean and Six Sigma has added value improving the performance of the repair processes and the joy of working within the workforce.

Further research is necessary to monitor the progress made and to continuous improve the processes.

## Literature


Brue, G. "*Six Sigma for Managers*", McGraw Hill Professional, United States of America, 2002

Commandeur, H.R., "*Industriele Economie en Bedrijfshuishoudkunde*", Erasmus University Rotterdam, Faculty of Economic Sciences, 2005.

EPCOR B.V. "*European Pneumatic Component Overhaul & Repair BV*", http://www.epcor.nl, site updated: 14th April 2007, site accessed: 3rd September 2007.

George, M.L., "Lean Six Sigma: *Combining Six Sigma Quality with Lean Speed*", McGraw Hill Professional, United States of America, 2002.

George, M.L., *"Lean Six Sigma for Service",* McGraw Hill Professional, United States of America, 2003.

George, M.L., Rowlands, D., Kastle, B., "*What is lean Six Sigma?*", McGraw Hill Professional, United States of America, 2004.

George, M.L., Rowlands, D., Price, M., Maxey, J., Jaminet, P., Watson-Hemphill, K., Cox, C., *"The Lean Six Sigman Pocket Tool Book"*, The McGraw Hill Companies, United States of America, 2005.

*"Lean Manufacturing and the Environment"*, United States Environmental Protection Agency, October 2003 (www.epa.gov/innovation/lean.htm)

Muller, W.H., *Green Belt Course*, EPCOR B.V., Amsterdam, 2007.

Nichols, M.D., Hayler, R., *"What is Six Sigma Process Management?"*, McGraw Hill Professional, United States of America, 2005.

Ohno, T., *"Toyota Production System: Beyond Large Scale Production"*, Diamond Inc, Tokyo, Japan, 1978

Rother, M., Shook, J., *"Learning to See"*, The Lean Enterprise Institute, Massachusetts, United State of America, 2003.

Pyzdek, T., *"The Six Sigma Handbook"*, McGraw Hill Professional, United States of America, 2003.

Womack, J.P., Jones, D.T., *"Lean Thinking"*, Free Press, 1998.

Womack, J.P., Jones, D.T., Roos, D., *"The Machine That Changed The World*: *The Story of Lean Production"*, Harper Perennial, 1991.