Lean methodologies implementation in a MRO (Maintenance, repair and overhaul)

Ana Isabel Lopes Leal Rodrigues da Costa Amaral de Fraga

Department of Engineering and Management, Instituto Superior Técnico

Abstract

This paper addresses the application of Lean methodologies to aircraft maintenance in TAP-ME (TAP Maintenance & Engineering).

As the aircraft on ground occurrence (AOG) is often caused by a lack of a wheel existence in the stock, it was decided to analyze with detail the maintenance process of this component. Several analyses were made using lean techniques as VSM (value stream mapping), VAT (value added time), spaghetti analyses among others. These lead to conclude that there was space to improve the TAT (turn around time) of the wheel maintenance, reduce intermediate stocks and improve productivity.

The solution to deal with such opportunities was defined and the results after 8 months of solution implementation were analyzed.

Key words: Lean, VSM, VAT, TAT

1. Introduction

The Lean methodology was created in the 50’s. It is a powerful tool, not only since it was one of the causes that transformed Toyota in one of the world’s best automotive fabric center but also as it has also transformed other industries such as banks, insurance or telecommunications. All have used Lean to reduce waste, variability, and improved flexibility creating a continuous improvement culture.

At its heart, Lean is simply a philosophy designed to help organizations, systematically it has been identified as an adequate methodology to eliminate waste and improve production activities (National Research Council Canada 2004). The five Lean principles are:

1. Value –specify what creates value and what doesn’t in the client’s perspective;
2. Value Stream –identify all the steps of the value stream that create inputs in outputs;
3. Flow – make the value flow by eliminating bottle-necks, bringing value adding steps closer together, eliminating ‘batching’ and queuing of activities and moving towards a process where value ‘flows’ continuously;

4. Pull – allow the client to pull the product or service which allows to eliminate stocks, complex inventory control systems and leftovers;

5. Perfection – strive perfection, removing several layers of waste as soon as they are detected; (Eaton 2009)

Within this methodology several tools are used, such as: VSM (value stream mapping), VAT (Value added time), Spaghetti analysis, visual management, among others.

Mapping the value stream is a process to identify and draw the flows of information, processes and materials throughout the value chain. This allows to work in a global perspective, and improve the whole picture and not only some parts (Rohter et al 1999).

Several books and articles were analyzed regarding Lean, a research for the implementation of Lean methodology in aeronautics was done and several articles about aeronautical fabrication were found, however nothing was found regarding the introduction of the philosophy in aircraft maintenance, with the exception of articles that appear in magazines.

It was felt at TAP-ME that the implementation of Lean would be the best tool to be used in the continuous improvement area. Even though Lean is thought for low variety and high volume industries, the contrary of what occurs in MRO environment.

The goal of this work is to study the implementation of a Lean Technique in the maintenance of an aircraft wheel, in order to improve TAT, reduce potential AOG occurrence due to lack of a wheel and reduce stocks.

2. Case study

This thesis is focused in the aircraft wheel maintenance performed at TAP ME. It has the goal to improve, through the use of lean techniques, the maintenance TAT (turn around time) of the aircraft’s wheel, reducing therefore the AOG (aircraft on ground) potential situations and facilitating the wheel circuit since it is removed from the aircraft until it is stored as serviceable in the stock.

TAP ME performs wheel maintenance to the TAP, SATA Internacional, French Air Force (FAF) and PGA fleet, and it also controls all their wheel stock with the exception of PGA.

The TAP fleet consists of:

<table>
<thead>
<tr>
<th>Aircraft Model</th>
<th>Nr. Aircraft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airbus A319</td>
<td>19</td>
</tr>
<tr>
<td>Airbus A320</td>
<td>17</td>
</tr>
<tr>
<td>Airbus A321</td>
<td>3</td>
</tr>
<tr>
<td>Airbus A330</td>
<td>12</td>
</tr>
<tr>
<td>Airbus A340</td>
<td>4</td>
</tr>
</tbody>
</table>

The Clients fleet is:

<table>
<thead>
<tr>
<th>Aircraft Model</th>
<th>Nr. Aircraft</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airbus A310</td>
<td>4</td>
<td>SATA</td>
</tr>
<tr>
<td>Airbus A320</td>
<td>4</td>
<td>SATA</td>
</tr>
<tr>
<td>Airbus A340</td>
<td>2</td>
<td>FAF</td>
</tr>
<tr>
<td>Embraer 145</td>
<td>8</td>
<td>PGA</td>
</tr>
<tr>
<td>Fokker F100</td>
<td>6</td>
<td>PGA</td>
</tr>
</tbody>
</table>

The part numbers (P/Ns) used at each aircraft are described in table 3:
Table 3 – wheel P/N and quantity by aircraft type

<table>
<thead>
<tr>
<th>A/C</th>
<th>P/N NLG</th>
<th>#</th>
<th>P/N MLG</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>A319</td>
<td>3-1531</td>
<td>2</td>
<td>C20195162/52</td>
<td>4</td>
</tr>
<tr>
<td>A320</td>
<td>3-1531</td>
<td>2</td>
<td>C205000000/100</td>
<td>4</td>
</tr>
<tr>
<td>A330</td>
<td>3-1547/96</td>
<td>2</td>
<td>3-1546</td>
<td>8</td>
</tr>
<tr>
<td>A340</td>
<td>3-1510</td>
<td>2</td>
<td>2612201</td>
<td>10</td>
</tr>
<tr>
<td>ER145</td>
<td>3-1551</td>
<td>2</td>
<td>3-1631</td>
<td>4</td>
</tr>
<tr>
<td>F100</td>
<td>1508133-1</td>
<td>2</td>
<td>1508131-5/5011166</td>
<td>4</td>
</tr>
<tr>
<td>A310</td>
<td>28635100 5</td>
<td>2</td>
<td>C20195000/150/160</td>
<td>8</td>
</tr>
<tr>
<td>A340 FAF</td>
<td>3-1547/96</td>
<td>2</td>
<td>3-1509</td>
<td>10</td>
</tr>
<tr>
<td>A310 TKN</td>
<td>28635100 5</td>
<td>2</td>
<td>C202111150/160/170</td>
<td>8</td>
</tr>
</tbody>
</table>

The wheel shop, that belongs to the component’s shop, works with 7 people and one team leader. This team works in two shifts during the week. The rest of the components’ shop works only in a single shift from 8h to 16h.

2.1 Analysis

2.1.1 Shop circuit
As the amount of hours flown by TAP fleet isn’t the same during all year, it flies more during summer, Christmas and Easter, more wheels are removed and installed during those periods (Figure 2).

A wheel that enters the shop may suffer 3 maintenance possibilities (figure 3): to be

overhauled (OVH), repaired (tire change) or checked (bench or visual – BCK-VI). After crossing information with several data bases it is verified that almost 80% of the wheels are repaired.

![Wheel work performed 2011](image)

Figure 3 – Quantity of wheels by work performed in 2011

As it can be seen in the following figure the TAT differs from the work performed in the wheel. The overhaul (ovh) takes more than 25 days and the tire change more than 13 days. Group 1 is considered visual or bench check.

![Average TAT by work performed](image)

Figure 4 – Average TAT by work performed

To understand this significant difference in the TAT for the two main activities (OVH and tire change) it was developed a VSM for each type of work (figures 5 and 6). Afterwards it was checked in the
shop the time spent and also the men needed for each action mentioned in the VSM.

The tire change consists of: the wheel enters the shop, it is disassembled, cleaned, than the screws are stripped with walnut, each half wheel performs eddy current, everything is inspected, assembled; the bearings are inspected, assembled with the rest. The tire is inflated and tested for 12 hours. At the end it is stored.

The main difference between a tire change and an overhaul is that each half wheel performs also walnut stripping, fluorescent or magnetic particles inspection and is painted.

It is important to highlight that the actions of cleaning, stripping and eddy current are performed by another area in the components’ shop that only works one shift.

After developing the VSM the VAT for each P/N was calculated and compared with the average TAT for 2011 for tire change and overhaul (table 4).

Figure 5 – VSM of a tire change

Figure 6 – VSM of an overhaul

As it can be seen in table 4, the average VAT for tire change is 2 days this was calculated by:
\[ \frac{\sum (\text{units by P/N maintained in 2011} \times \text{VAT for that P/N})}{\sum \text{units maintained in 2011}}. \]
The difference of the TAT between P/Ns is related to the existing stock and also priorities that are in the technicians' mind, independent of being real or not, this means that technicians bypass some P/Ns in relation to others.

The overhaul process differs from P/N to P/N due to wheels' manufacturer instructions. There are P/Ns that need to perform fluid penetranting inspection (FPI) or magnetic particles inspection (MPI), therefore it is needed to perform to each half wheel stripping and after FPI/MPI, painting. P/N 3-1509, 3-1546 and C20500000/100 due to their dimension to do not fit in the components’ tub thus it has to go to the TAP engine shop where there are larger facilities where FPI/MPI can be performed. Obviously this movement incurs in more time spent.

From table 5 it can be seen that the Average VAT for overhaul is 4 days which differs significantly from the 2011 average TAT. The principal reason for this is again the amount of stock that is in the shop.
As it can be seen from figure 7, more than 90% of the wheels that are in the shop are waiting to be maintained, they can be waiting for being assembled, painted, for eddy current, for FPI, for being transported, and so on. The majority of the wheels waiting were before the eddy current station and cleaning station. Therefore these two stations have been identified as the bottle-necks of all process. From this identification it was important to analyzed the waiting time of each wheel and also if this waiting time changed between repair and overhaul.

This analysis was done during January 2012, where every day it was verified the number of wheels before each station and checking a document paper called “ficha evolutiva” where it is registered each maintenance activity when it was performed and by whom. It was verified that the Tire change type of maintenance had priority over overhaul, as it can be seen by the reduced average waiting time the tire-change has in comparison with the overhaul.

The activities of the technicians were divided into (figure 9): VAT (working), Incidental (transporting material, reading the manual, signing documents, preparing equipment or talking with colleagues about work), Waste (absent, smoking, eating, waiting, talking).

As it can be seen above only 31% of the time was spent in activities that bring value added for the client; 27% of the time was in incidental activities. It must be highlighted that 16% are dedicated at transportation, which is explained by the fact that after being dissembled the wheels have to go to the eddy current station situated at the other end of the components’ shop.

2.1.3 Improvement opportunities
From the previous analysis the principal improvement opportunities detected are:

1. To improve TAT through: reducing waiting times, mainly in cleaning and eddy current, eliminating priorities by maintenance type or P/N, and improving communication between maintenance stations.
2. Level wheels existence by: reducing intermediate stocks and adapting stock to the real need of the fleet and segregating the surplus;
3. Improve productivity by using visual management tools, improving the process and
work methodology and bringing close together the equipment.

2 Solutions

3.1 Stock
Considering all the information retrieved in the diagnosis it is important to calculate the ideal stock. Currently the Logistics department calculates the stock considering the estimated demand: years’ removal * (P/N average TAT + TAT outside shop)/365 and afterwards uses the Poisson distribution to achieve protection levels. Additionally it was considered 2 days for the outside shop circuit. This formula used to calculate the P/N reserve is influenced by its shop TAT, however the shop gives normally priority to some P/Ns in detriment of others taken into consideration the existence of the wheels. This means that both systems influence each other.

Moreover, it was calculated the ideal stock for each P/N considering: [(2011 worst monthly wheel request *12)*(Ideal shop TAT + TAT circuit)/365] + 1 + station stock/flying kit. It was considered the stock stations’ equivalent to wheels already embodied in the aircraft, with the exception of Lisbon station, because this is no more than an advanced stock house. The reason for this decision is that is not possible in operational and financial terms to eliminate these stocks around the world. Imagine that a wheel was only sent to a station after being requested, in this case the following scenario was going to occur: an aircraft would land at Luanda, needing to change a wheel and the new one was only sent to from Lisbon in the following flight (that occurs the next day). The financial costs with passengers, hotel, image lost, etc. rapidly surpass the cost of a wheel. The same reasoning can be done with the flying kits.

In figure 10 the results are presented. In orange there is the stock of wheels considering the average 2011 TAT (15 days) and in green the stock with the ideal TAT (7 days). Except for the 3-1531 P/N, it is needed less 118 wheels, which represent $1.800.000. Therefore with a better and leveled TAT it is possible to reduce the actual stocks by selling the surplus wheels.

![Figure 10 – Stock comparison](image)

2.2 Pull system and FIFO
To achieve the ideal 7 days TAT, that is 5 working days, it is needed to give the same priority to all wheels. The solution is the installation of a FIFO (first in first out) and Pull system. Therefore the stock instead of being before each station it will be after.

To implement the Pull system, one person has to start at the end of the process. As the assembly station takes on average 92 minutes and it is possible to assembly 3 wheels simultaneously. It is needed 3 wheels after the inspection station. Before it was verified that 9 wheels were maintained daily (figure 11). The worst scenario is to assembly 9 wheels at the afternoon shift and the inspection takes only 5 minutes, so 6 wheels were
considered after NDT inspection, which together with the 3 at the inspection sums the 9 wheels.

![Disassembly, Cleaning, Eddy Current, Inspection, Assembly, PL/FPI, Painting diagram]

Figure 11 – Pull system implementation

Cleaning takes 58 minutes and it is possible to clean 3 wheels simultaneously. The cleaning time is the double of the eddy current, therefore it was needed 2 wheels after cleaning, however inside cleaning there is the walnut stripping station, where only one wheel can be each time. Thus it was decided to add another wheel after cleaning. The disassembly process takes 118 minutes, this TAT is the double of the cleaning and 3 wheels can be disassembled at the same time, so 6 wheels are put after disassembly station.

To eliminate the question related to priorities it is implemented the FIFO system together with Pull. The wheels at each station are above pallet, connected between them with a rolling system above. This means that the technician can only retrieve the wheel that is in front (which is the first that entered in that pallet).

3 Results

The implementation occurred between 18-Feb to 17-Oct 2013, during these 8 months it was analyzed the FIFO and Pull system.

![Average TAT (days) by maintenance type graph]

Figure 12 – Average TAT by maintenance type

The above graphic compares the same period (18-Feb to 17-Oct) of each year (2011, 2012 and 2013).

As shown in figure 12, the repair TAT was reduced from 16/13 days to 8 days, one more than the ideal calculated before. Regarding overall, the TAT was reduced from 2012 but was almost identical to the TAT of 2011, as the Pull and FIFO system were mainly implemented on the Tire change process.

The following figure shows the average TAT by P/N, for the repair maintenance. All 2013 P/Ns had an inferior TAT, in several cases substantially inferior as it is the case of P/N 286351005 or 3-1510. The most critical P/N 3-1531 maintained its TAT.
Related to the intermediate stocks those were inferior of the existing ones, as a result of the pallet system and visual identification of the maximum number of wheels at each position. However there was a change between wheels waiting inside the shop to wheels waiting outside the shop. The following figure shows the number of wheels at shop’s responsibility since 18-Feb-2011 until 17-Oct-2013.

From figure 14 it can be seen that there is a tendency to reduce the number of wheels at the shop, the maximum of 2013 didn’t achieve the maximum of 2011 and 2012. There is also a pick at the beginning of the implementation due to the fact that the intermediate stocks were mainly overhaul wheels. These have a longer maintenance, so the technicians had to maintain these first. After this “cleaning” the number of wheels started reducing, however during summer the number increased as a result of increase of TAP flights and technicians absence (parental licenses and work accidents). The wheels performing overhaul kept their number throughout the implementation of this project.

4 Conclusions and further researches

Having into consideration several literature related to the Lean methodology, it was found adequate to implement its’ tools in the wheel shop of TAP Maintenance & Engineering.

Firstly, a diagnosis was performed where a VSM, VAT, spaghetti analysis among other analyzes where performed. Several improvements opportunities were identified: reduce TAT, reduce intermediate stock, and improve productivity by using better visual management. It was then decided to tackle these opportunities with the implementation of a Pull and FIFO system, this occurred during 8 months in 2013.

By the end of the 8 months, a substantial reduction of the TAT of the wheels performing repair was observed. There was also a reduction in the amount of wheels at the Shop’s responsibility. After these conclusions it was decided to maintain the Pull and FIFO system in the wheel shop.

For future works it is suggested to analyze the TAP and SATA wheels stock, having into consideration the new TAT.
It could also be analyzed the changing from 2 to 1 shift. With only 1 shift all the components’ shop would work in the same timetable: NDT, cleaning, painting and wheel shop. With this change it is important to check again the amount of wheels after the NDT station, because this one was thought for 2 shifts.

Another possible future work is to improve the communication between the wheel shop and the Lisbon station, as it is where the majority of wheels are replaced. The ideal system would be as soon as a wheel was removed, the wheel shop should be informed and immediately a wheel was assembled and the Pull system started.

Moreover, the breaks maintenance system could be also analyzed using the same methodology.

Finally, it is suggested to acquire the trolleys with rollers and the rollers with lateral protection for the pallets to avoid the forgery of the FIFO system.

5 References

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