
Lean implementation within South African aircraft maintenance organisations

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Abstract: Globally, the implementation of Lean techniques has proven to be successful in improving quality while reducing turnaround times and costs within aircraft maintenance organisations (AMOs), including those organisations that are of a competitive threat to South African companies. Limited research has been conducted on Lean implementation in South African AMOs, leading to the motivation for this study: to determine the status of Lean implementation within South African AMOs. Quantitative and qualitative data were derived from interviews with senior management from a sample of Gauteng-based organisations. The results provided an indication of both their understanding and the status of Lean within their organisations.

Keywords: Lean; aircraft maintenance organisations; AMO; South Africa; maintenance; repair and overhaul organisations; MRO.

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1 Introduction

South Africa is increasingly becoming important as a regional hub for maintenance of aircraft operators flying in sub-Saharan Africa (ECORYS, 2009). Since 1993 the number of international airlines flying into South Africa has increased from 12 to more than 70 (Philbin, 2009). South Africa is home to more than 70% of aviation activities in the Southern African Development Community (SADC) region and its share of the region's aircraft has grown from 68% to 80%, in the period 1997 to 2007 (IATA, 2011).

South African aircraft maintenance organisations (AMOs), however, are faced with increasing competition from the Middle East, Far East and from within Africa. Examples

include Ethiopian Airlines which is currently in the process of expanding its hangar space which it intends to offer for third party work by 2014 (Bekele, 2009). HNA, the fourth largest Chinese airline group, bought a controlling stake in MyTechnic Turkey, an AMO developed from the ground-up as a Lean facility. According to Moody (2010), HNA together with MyTechnic “want to replicate the Lean, Greenfield model in other world regions, such as Russia, Southeast Asia or Africa”. In their opinion Africa has no major third-party AMO company and as such it ‘is a fantastic market’. South African AMOs face competition from African and global airline maintenance operators, not only from outside the continent but also, possibly in the future, from within the continent.

The current South African Industrial Policy Action Plan has identified the aerospace industry as a whole (of which AMOs are a part) as a sector with potential for the development of long-term advanced capabilities (DTI, 2010). In the face of increasing global competition, it is in the commercial interest of South African AMOs to build on their existing aircraft maintenance infrastructure to maintain and capture a larger share of the expanding African and global AMO market. In response to increased competition, AMOs in regions such as Europe, have identified the use of Lean principles from the management level to the shop floor in a concerted effort to remain competitive in a changing marketplace (Avitrader, 2010).

There appears to be limited publicly available current research regarding Lean understanding, implementation and experience, within the South African AMO industry. This work seeks to contribute to addressing this gap, through an investigation of the status of Lean implementation in South African AMOs.

2 Context

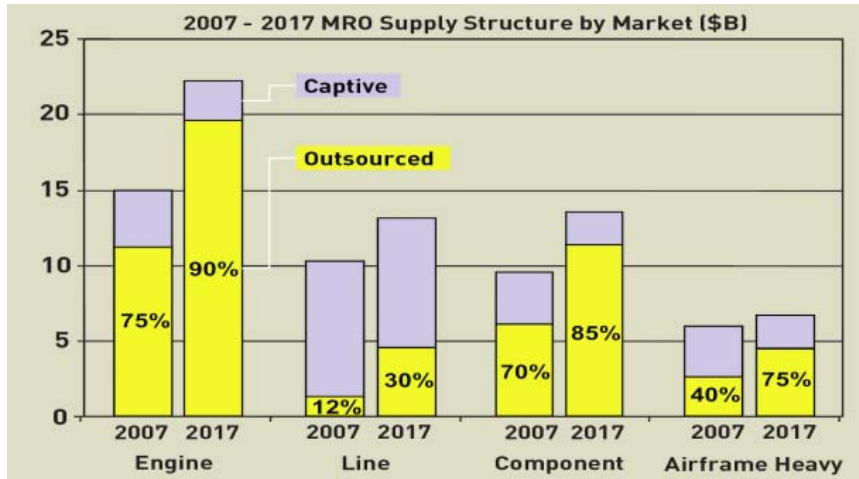
According to the International Civil Aviation Organization (ICAO) the airline industry has undergone major structural transformation within the last decade and continues to adjust to a dynamic market place. The full service network model of traditional state owned legacy airlines has come under increased competition due to the success of low-cost carriers. The adoption of liberalisation programmes, measures by countries to open up the air transport sector, and the ease of internet fare comparison, have transformed the operating environment for airlines and their service providers (ICAO, 2009).

Globally 26 airlines ceased operations in 2009 (Holland and Gubish, 2010). According to Doan (2010), the entire airline industry since 2001 has cumulated losses of \$56.8 billion, with only one year of profitability. Therefore, unrelenting focus of airlines on cost continues to drive change. ECORYS (2009) argues that “the growing competition in the air transport market will induce a reduction in margins and a structural change in years to come. Shrinking profitability from a level not satisfying to investors seeking a risk premium, in an environment of more risk adverse players in the financial markets can lead to a financial crunch (for operators)”.

Against this background, airline operators increasingly perceive aircraft maintenance as a non-core activity. Aircraft maintenance, once normally held in-house by legacy carriers, is now either seen as a potential profit centre or an activity to be outsourced to a third party supplier. It is estimated that 54% of global airframe heavy maintenance, 78% of engine maintenance and 16% of line maintenance is outsourced to approved maintenance organisations (AMOs) (Frost and Sullivan, 2010, cited in Smith, 2010). Additionally, ancillary services such as planning, record keeping and maintenance

accounts are also being outsourced to AMOs. The percentage of outsourced maintenance is predicted to further increase by 2017 (Figure 1).

Figure 1 Maintenance outsourcing 2007 to 2017 (see online version for colours)

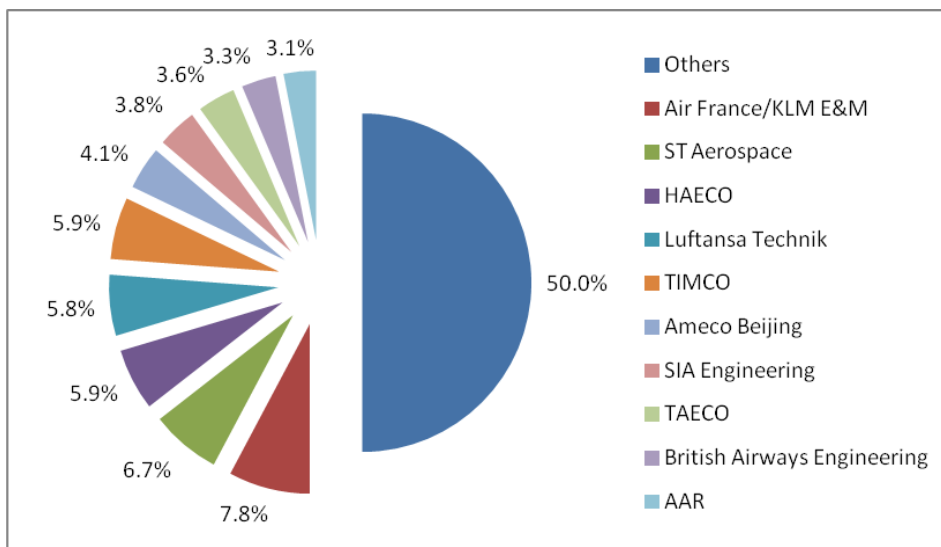


Note: Outsources includes separate MRO businesses that are owned or partially owned by airlines.

Source: Airline Fleet Management (2009)

AMOs are also referred to as maintenance, repair and overhaul organisations (MRO). This research report, however, will use the term AMO as it is the terminology most commonly used in South Africa.

Figure 2 AMO companies, global market share (see online version for colours)



Source: Smith (2009)

3 The global maintenance market

The total size of the global civil aviation maintenance market in 2010 is estimated to have been about USD\$45bn (Holland, 2011). While there are no accurate figures available for the number of AMOs in the world, no one company holds a major share of the global AMO market (Figure 2).

The AMO industry is calculated to have experienced virtually no growth over the period 2001–2010 due to the effects of global events such as 9/11, both Iraq wars, fluctuating oil prices and worldwide recessions (Holland, 2011). By 2018, however, the global AMO market is predicted to reach \$57 billion, with global compound annual growth rate (CAGR) of 2.3% from 2009–2014. The period of 2009–2011 being relatively flat with growth thereafter estimated at between 2.9% and 4.2% (Holland and Gubish, 2010; Holland, 2011).

4 African maintenance market

Currently, the African continent's AMO industry represents 4% of the total global AMO market (Bekele, 2009). An increase in African maintenance support requirements is predicated due to an increase in air travel and resultant demand for aircraft. ICAO reports that African passenger traffic has grown at 6% per year, for the past three years leading up to 2009 (Bekele, 2009) and is expected to grow at 7.7% until 2014, the second highest regional global growth rate after the Middle East's 9.4% (IATA, 2011). The future African demand of large aircraft is calculated by Boeing (2010) to rise to 1,130 by 2029 from a figure of 660 in 2009.

In addition to new aircraft entering Africa, there are requirements for maintaining the region's ageing fleet, of which 50% are over 18 years old, but will keep flying for the foreseeable future (Bekele, 2009). Increased maintenance oversight of this aging fleet is required to improve flight safety and decrease the current relatively high African accident rate. African carriers are 2% of global traffic but they represent 26% of global western-built jet hull losses. While safety in Africa had been improving, International Air Transport Association (IATA, 2010) figures show that Africa had an accident rate of 9.94 (measured in hull losses per million flights of Western-built jet aircraft) in 2009, significantly higher than the 2008 rate of 2.12.

In the short term, Africa is expected to be the world's second largest growing region for maintenance expenditure, at 4.2%, after the Middle East, at 6.6% (Bekele, 2009). Long term, the total AMO market for Africa is set to increase in monetary terms but its share of the global market is predicted to decline to 3%, in response to increased competition (Doan, 2010).

5 Maintenance and Lean

The most important factors in an airline's selection of an AMO are quality, turnaround time (TAT) and price, in that order (Canaday, 2010). To satisfy such requirements many AMOs globally have concentrated on process management to achieve improvements in terms of operational efficiency through the implementation of Lean. According to

Bozdogan (2010) Lean comes closest to providing a holistic view of company management systems by embodying a tightly knit set of mutually supportive precepts and practices driving its central value creating operations. By comparison Six Sigma, Theory of Constraints (TOC) and other approaches generally lack such a broad, internally consistent, holistic conceptual orientation. The trend at many AMOs and as institutionalised at many US Air Force (USAF) depots is to apply Lean first and then monitor with Six Sigma when flow is stabilised (Canaday, 2004). According to Arehart [cited by Holland, (2011), p.18] during 2009 and 2010 AMOs were forced to adopt survival strategies, due to the global recession. “The strong survivors in the industry made significant cost cutting investments during the downturn cycle. Process improvement programs like Lean and Six Sigma have helped many companies compensate for not being able to pass on cost increases to their customers” (Arehart cited by Holland, 2011).

Womack and Jones (2003) argue that “Lean provides a way to do more with less ... – less human effort, less equipment, less time and less space”, eliminating waste in the system and continuously moving towards meeting customer requirements. Waste reduction not only increases the profitability of an AMO but also supplies the customer with maintenance of high quality, on time. A study of the results of Lean implementation in the aerospace industry found rework and defect reduction of between 20% and 80%, productivity improvements of 27% to 100% and cost improvements of 11% to 50% (MIT, cited by Mathaisel, 2005). Lean is recognised by most AMOs globally as offering competitive advantage in competing for aircraft operator’s maintenance business.

6 Theoretical framework

The theoretical framework used in this study is based on the principles of Lean as described by Womack and Jones in their work *Lean Thinking* (2003). It was selected as a basis as it provides a concise overview of the tenets of Lean using five basic principles. Lean Flight Initiative (2011) states that *Lean Thinking* provides a “good overview of Lean from an enterprise point of view”, while The Lean Enterprise Academy UK (2011) advocates that the “book is the essential first step for all those embarking on the Lean path”. The five Lean principles, as set out by Womack and Jones (2003) and explained by Hines and Taylor (2000) are:

6.1 Principle 1 – value

Value is created by the producer (Womack and Jones, 2003) and needs to be defined in terms of the customer expectations of the product. These expectations can be broken down in different ways, but almost always include as a minimum: product quality, delivery schedule, performance and target costs (LEI, 2010). Specifying value accurately is the critical first step in Lean thinking (Womack and Jones, 2003) using the concepts of:

- *target cost* – based on the amount of resources and effort required to make a product of given specification and capabilities if all the visible waste is removed from the process

- *ultimate customer* – a Lean company knows what the ultimate customer requires, verifies that the customer receives what was requested and thereafter aligns the company performance targets against that which the customer perceives as value, not what the company perceives as value
- *Muda* – the Japanese word for waste and is central to understanding value. There are three different types of value activity within an organisation (Hines and Taylor, 2000) value adding, necessary non-value adding and non-value adding activity.

Lean is the removal of these non-value adding activities. Liker (2004) argues that exclusively focusing on Muda can be to the detriment of the productivity of people and the production system. When considering Muda, the concepts of Muri (overburdening people or equipment) and Mura (unevenness in production levels) need to be taken into account. Collectively Muda, Muri and Mura are referred to as the 3Ms.

6.2 *Principle 2 – value stream*

The value stream is the process involved in producing a product or service. It is the set of all the specific actions required to bring a specific product (whether a good, a service or increasingly, a combination of the two) through the three critical management tasks of any business. According to Womack and Jones (2003), these specific actions are problem solving, information management and physical transformation. Identifying the entire value stream exposes Muda. Processes in Lean are thought of as value streams (Kang, 2007). To make the value stream work, standard work is required, which is to say the best way to get the job done in the amount of time available and how to get the job done right, the first time, every time (Womack and Jones, 2003). Standardisation is the foundation on which future improvements can be based. It is impossible to improve any process until it is standardised and the process stabilised. Standardisation and the value stream form the basis of the third and fourth Lean principles; flow and pull.

6.3 *Principle 3 – flow*

Flow is the progressive achievement of tasks along the value stream so that a product proceeds from design to launch, order to delivery, and raw materials to delivery into the hands of the customer with no stoppages, scrap or backflows (Womack and Jones, 2003). The concepts of Takt Time (precisely synchronises the rate of production to the rate of demand by the customer, i.e., available production time divided by the rate of customer demand), standard work and visual control (are simple, clear and concise indicators that show at a glance the status of a machine, a work order, a tool, a bin, personnel resources or an entire plant in connection with a plan or defined objective) are necessary to give an immediate sense of how the work is flowing (Womack and Jones, 2003).

6.4 *Principle 4 – pull*

‘Pull’ in simplest terms means that no one stream should produce a good or service until the customer downstream asks for it (Womack and Jones, 2003). A pull system only releases raw materials or work in process (WIP) once the preceding process step completes the WIP it is currently working on. This method of WIP management is also called Kanban (Rouke, 2005). Kanban is a Japanese term meaning ‘card’ or a visible

signal. It is an inventory replenishment system associated with JIT, which was developed by Toyota (Crabill et al., 2000). The system triggers a visual demand signal to pull raw material or WIP inventory forward, into the next phase.

6.5 Principle 5 – perfection

Perfection is the complete elimination of Muda so that all activities along the value stream create value (Womack and Jones, 2003). Companies should compete against perfection, not just their current competitors, so they need to be able to gauge the gap from current reality to perfection (Womack and Jones, 2003). To achieve such perfection a company needs to set goals and communicate those goals throughout the company. Using Lean terminology the pursuit of perfection can be divided into two actions; Relentless Reflection (Hansei) and Continuous Improvement (Kaizen). One of the techniques of Hansei is the 5 Why's. Taiichi Ohno's practice of asking 'why' five times is a common technique whenever a problem is encountered, in order to identify the root cause of the problem so that effective countermeasures could be developed and implemented (Womack and Jones, 2003). The underlying assumption of Kaizen is that small improvements, continuously made to a process, will lead to significant positive change over time (Crabill et al., 2000). There are two levels of kaizen; system or flow kaizen focuses on the overall value stream, while, process kaizen focuses on individual processes.

Womack and Jones (2003) advise that Lean firms should only compete against perfection by identifying all activities that are Muda and eliminating them. They believe that benchmarking is thus a waste of time for managers that understand Lean thinking.

Table 1 Five principles of the Lean framework for the study questions

<i>Five Lean principles</i>	<i>Terminology within the principle that will be surveyed</i>	<i>Description</i>
Value	Target cost	Amount of resources and effort required to make a product if all waste removed from process
	Ultimate customer	The user of the product of which there might be several
	Muda	Japanese word for waste
Value stream	Value stream mapping	A visual representation of all the activities of a process
	Standardisation	Best way to get the work done in the time available correctly every time
Flow	Takt time	Production time divided by client demand
	Visual controls	Simple, clear, concise indicators or process status
	5S	Sort, straighten, scrub, systematise, standardise
Pull	Kanban	Inventory replenishment system to pull inventory/work in process
Perfection	Hansei	Individual responsibility
	Kaizen	Group continuous improvement process
	Benchmarking	Comparison with others

7 Research method

A qualitative approach in the form of semi-structured interviews was deemed appropriate as the nature of the work was exploratory; that is, asking ‘what’ and ‘how’ questions where the data obtained is in the form of words, using the interviewees’ interpretation, knowledge and observations (Yin, 2003). According to Remenyi and Money (2006) it is important to create a set of questions to support the actual evidence collection processes. The questions are set for the interviewer and not for the respondent and are in reality a reminder or prompts to the interviewer concerning the information which is to be collected. The questionnaire design was based on the five Lean principles (Womack and Jones, 2003) summarised in Table 1. These principles form the propositions, which besides reflecting important theoretical issues; also begin to tell where to look for the relevant evidence (Yin, 2003).

An extract from the questionnaire is provided in Figure 3. A further objective is to determine the understanding of the basic principles of Lean amongst management of South African AMOs.

Figure 3 Extract from the questionnaire: questions on value

Part 3: Value		
3. Value		
Value: -The critical starting point for Lean thinking is value. Value can only be defined by the ultimate customer. And it's only meaningful when expressed in terms of a specific product which meets the customer's needs at a specific price at a specific time (Womack and Jones, 2003, p.16)		
3.1 In one sentence who are your customers?	3.1a External Customer	
	3.1b Internal Customer	
3.2 In one sentence, what product/service is your business supplying the customer?	3.2a External Customer	
	3.2b Internal Customer	
3.3 Who/which department/person communicates with the customer regarding their needs?		
3.4 Does your company visit your customer or does the customer visit you? (Excluding when work is in progress for the customer).	3.4a Is it on a regular basis?	3.4b If yes, how often
3.5 Do you have a formal method for determining the customer's needs?	3.5a Who/which department/person determines what your customer wants?	
	3.5b What method is used?	3.5c To who are the results distributed?
3.6 Do you know your customer satisfaction following work completion against set service standards (KPIs) e.g. online delivery target, zero defects etc	3.6a If yes, to whom is this data communicated?	3.6c What is your On Time Delivery % success rate?
	3.6b Do you have KPIs standardized across the company?	3.7e If yes, what are your KPIs?
3.7 Do you determine if the customer is satisfied following delivery?	3.7a By what means?	3.7b How soon after delivery?
	3.7c Do you know your quality defect rate and in what form? E.g. %, cost	3.7d Do you distribute to staff the cost of the quality defect rate?
General cost questions. Target cost is based on the amount of resources and effort required to make a product of given specification and capabilities if all the current visible muda were removed from the process (Womack and Jones, 2003, p.35) Note: Will not deal with specific prices/costs in interview due commercial reasons.		
3.8 Do you know your cost of production?	3.9 How and who determines the price to charge the customer?	3.10 How often is the price reviewed?

This study focused on AMOs that maintain large fixed wing turbine powered aircraft engaged in commercial air transport operations based in Gauteng, South Africa. South African AMOs that maintain these aircraft were chosen to form the population, because;

- They hold the approval necessary to engage in the maintenance of aircraft of a size and range that can be flown internationally.
- Unlike engine or component AMOs, where cost is related to spare parts, more than two thirds of airframe maintenance is related to labour (Airline Fleet Management, 2009). Consequently airframe heavy maintenance is outsourced to regions with lower labour rates combined with the efficiencies that Lean can offer.
- Small aircraft, due to their limited flight range, are mainly serviced within their home country, thus international AMO competition for business is very limited.
- Maintenance of large piston aircraft, e.g., DC3/DC6 is a declining niche market due to the retirement of these aircraft, as a result of their age and high operational costs. These aircraft are now flown primarily as classic aircraft for their historic value by aviation enthusiasts.
- 80% of these AMOs are located within Gauteng province, providing convenient access for research purposes.

Analysis of the list of South African AMOs released by the SACAA revealed that 24 AMOs are applicable to this study. Those AMOs located in the Gauteng province (19) were approached, and nine were prepared to participate in the study. According to Eisenhardt (1989) between four and ten cases is usually adequate. Of the nine AMOs, eight hold SACAA approval for large aircraft. This sample size represents one third of the population of South African AMOs, that maintain large fixed wing jet powered aircraft, engaged in commercial air transport operations.

Face-to-face interviews were conducted with one (1) person per AMO. The interviewees occupied managerial positions, listed in Table 2 and were selected using non-probability purposive key informants sampling (Jankowicz, 1995). The Accountable Manager is a SACAA mandated position and refers to the person who is responsible to ensure that the AMO operates in accordance with SACAA legislation.

Table 2 Managerial positions of interviewees

<i>ID</i>	<i>Managerial position</i>
A	Executive Manager Engineering
B	Administration Manager Technical Department
C	Accountable Manager
D	Accountable Manager and General Manager
E	Quality Assurance Manager
F	Engineering Manager
G	Flight Line Manager
H	Accountable Manager
I	Executive Director Maintenance

According to Ahrens (2006) and Achanga (2006), if Lean implementation is not fully integrated in a company's management system, it is very often not successful. One of the critical factors for Lean implementation is top management commitment and support. Therefore, the respondents' knowledge of Lean would reflect its chances of successful implementation. Prior to the interview the interviewees were not informed that the

research was regarding Lean. Each respondent was contacted telephonically and asked to participate in research regarding AMO procedures. The interviews were approximately 70 minutes in duration. The interviewees were asked 44 primary questions and 92 applicable sub questions, based on responses to the primary questions.

Table 3 presents the AMOs' details. Where a company is both an AMO and an aircraft operator, the total staff includes technical staff and those involved in aircraft operations such as pilots, baggage handlers and check in staff. Technical staffs include those working in the AMO itself including AMO support staff. Staff numbers in facilities larger than 100 persons are rounded estimates by the respondent. Third party work percentage illustrates how much work is from external customers (100% = all work is from external customers. 0% = only company aircraft are maintained by the AMO).

The status of Lean implementation is dependent on the length of Lean deployment. Those companies implementing Lean for more than five years are more likely to have extended Lean to all levels, all facilities and multiple functional groups across the organisation (Littlefield, 2008). Therefore, the years the company has been in business and occupying its facility affects the success or otherwise of Lean. Over two thirds of the AMOs sampled had been in business in excess of 10 years, the remainder being 'start ups' within the last 2 years. Five of the AMOs had been in their current facility in excess of five years. According to Womack and Jones (2003) having processes in one physical location enables pull and flow, however, leasing of buildings restricts capability to physically alter the building to achieve efficiencies. The company's physical size, facility ownership and whether all AMO processes are in one building are shown in Table 3.

Table 3 Overview of the nine participating AMOs

<i>AMO ID</i>	<i>Years in business</i>	<i>Years in current facility</i>	<i>Size of facility</i>	<i>Activities</i>	<i>Company staff</i>	<i>AMO staff</i>	<i>% Third party work</i>
A	1	>10	4 acres	AMO	700	700	100
B	12	>10	4000m ²	AMO and operator	220	30	0
C	1.5	1.5	No accurate figure	AMO	37	37	100
D	12	>10	3,900m ²	AMO and operator	8	6	75
E	15	8	16,000m ²	AMO and operator	180	60	100
F	17	2	6,000m ²	AMO and operator	110	37	60
G	15	Currently moving	Currently moving	AMO and operator	800	150	0
H	1.5	1.5	2,100m ²	AMO	6	4	100
I	11	8	2,200m ²	AMO and operator	160	60	20

AMO facilities range in size from less than 2,100m² to about four acres with one third of the AMOs occupying their current facility in excess of ten years. All the AMOs, except one, occupies one site. Those AMOs which are part of an aircraft operator occupy more than one facility, with aircraft operations being a separate facility. AMO H has a large facility with a small staff complement because the facility also stores/parks large business

jets in the hangar, while not undergoing maintenance. Similarly, a large portion AMO D is not utilised, apart from storage of parts and unserviceable aircraft due for scrapping. This diversity may show a relationship with Lean implementation according to years in business, or facility build and occupation.

One (1) of the AMOs occupies purpose build ‘Greenfield’ facilities, which may influence the implementation of Lean push/pull/flow techniques. The green field facility serves high net worth individuals’ multi-million dollar business jets, local corporation aircraft and state aircraft. However, according to Wickens (1995), there are many examples where there is no requirement to have a Greenfield site to make major changes, arguing that “the key to success is not a Greenfield site but a Greenfield mind”. In a continuous flow layout the production steps are arranged in a sequence and this is easier to achieve if the facility is built as a Greenfield facility by the user or can be modified by the user if they own the physical facility. Greenfield is defined as a facility that the current AMO occupying it designed and built according to their specifications.

The AMOs sampled operate according to four AMO business models:

- 1 Three AMOs are solely AMO businesses and do not have aircraft operations. Two of these AMOs in the past were part of an aircraft operation but have now been set up as independent companies.
- 2 Two AMOs are part of an aircraft operation which is its sole customer.
- 3 Three AMOs are part of an aircraft operation but also provide AMO services to other customers.
- 4 One AMO is part of an aircraft operation that does not own the aircraft; instead it operates them for the owners. It supplies maintenance services to these aircraft and other customers.

The AMOs hold approval from the SACAA (Figure 4). Two of the AMOs holding EASA approval also hold FAA approval. One third of the facilities are, therefore, exposed and comply with best international CAA standards. One third of the AMOs comply with standards other than those required by CAAs.

Figure 4 CAA approvals and standards held (see online version for colours)

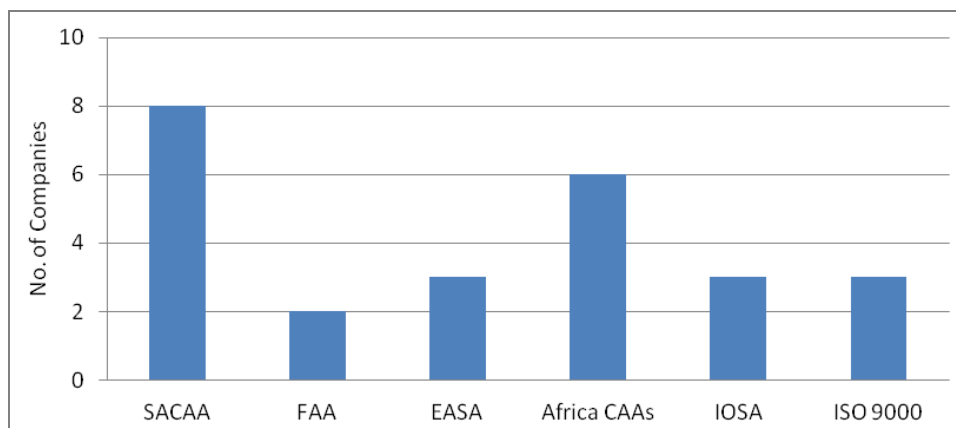
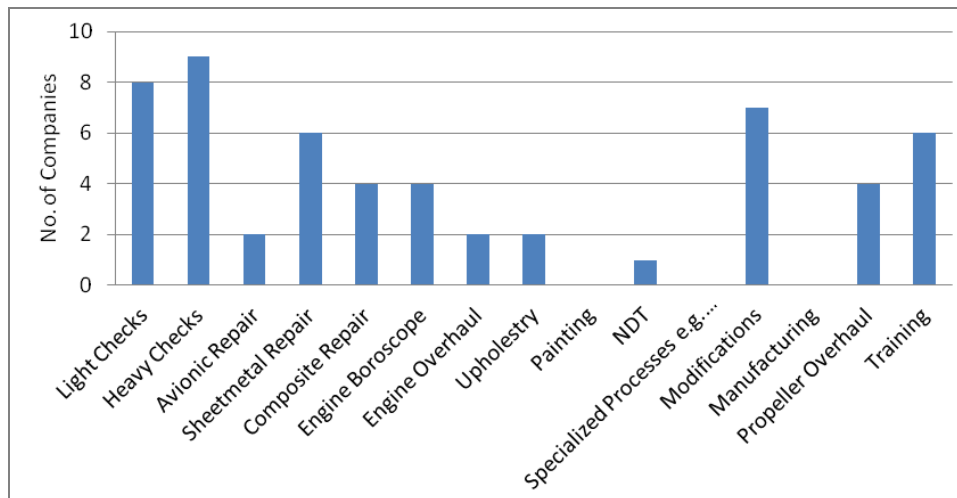


Figure 5 shows the capabilities of the AMOs. All the AMOs are involved in heavy aircraft maintenance checks, with the majority also engaged in light checks and the implementation of modifications, which are pre-approved by the OEM. The majority of AMOs questioned outsource their avionics/electrical work and engine overhauls. No AMO sampled performs manufacturing/design, painting (except for paint touch ups) or specialised processes, such as electroplating. Two thirds of the AMOs have a training function for in house staff, recognised by the CAA (for apprentices and cabin staff) and therefore possess formal methods of disseminating knowledge to their staff.

Figure 5 Maintenance specialities performed by the AMOs (see online version for colours)



8 Results and discussion

The implementation status of Lean in the AMOs was assessed based on the summarised responses of the interviewees to the questions developed according to each of the five Lean principles previously identified in Table 1.

8.1 *Lean Principle 1: value*

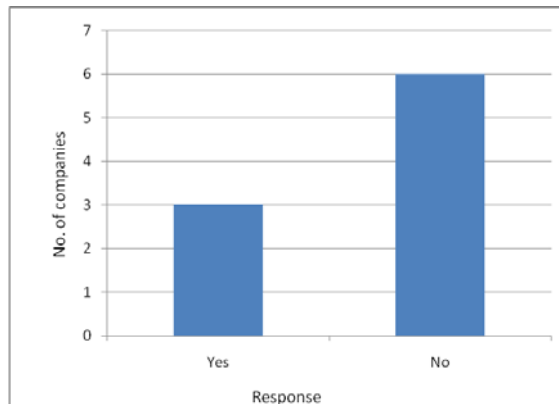
8.1.1 *Ultimate customer*

An understanding of and the treatment of the customer as ‘ultimate’ was not evident. All AMOs could identify their immediate external customer, either by specific operator type, e.g., business jet aircraft, a leasing company or an airline (two-thirds of respondents) or by a particular customer name. The respondents did not appear to understand the meaning of internal customer. Those AMOs that are part of an aircraft operating company mentioned the operations portion of the company as a customer but did not classify them as either an external or internal customer.

All respondents stated maintenance services as their product (five specifying services for a particular operator type, one for a particular aircraft type and two for a specific customer name, as 100% of their business is with that customer). Communication with

the customer was not consistent across the AMO's surveyed. Those who communicate with the customer regarding their needs varied from senior management to the marketing department. The regularity of the communication with the customer revealed that whilst specific communication intervals were given by certain AMOs, the impression received was that some intervals may be an aim that is not necessarily being achieved. Only three AMOs involved in line maintenance had contact more than once a month, often daily. This is due to the operational nature of line maintenance as all maintenance is perceived as urgent in order to keep aircraft serviceable. This communication would be of a technical nature related to a specific problem. Two AMOs had customer representatives on site full time. Knowing the frequency of visits, further questions were asked to determine how customer requirements were determined. Two AMOs had a formal method of determining customer needs, two AMOs had a process but it was difficult to determine if it was being followed, the remaining five AMOs had no formal method of determining customer needs. The AMOs operating a fleet of aircraft depended on their own in house planning department to supply details on their customer needs. The two KPIs mentioned by all respondents were aircraft serviceability and on time dispatch. No other KPIs were mentioned by any of the respondents. Five AMOs tracked customer satisfaction. Of the four AMOs that do not do so, two are in the process of implementing a customer satisfaction tracking system, but currently track on time deliveries only. One AMO mentioned that they are very transparent with the customer regarding all costing, man-hours and markups and this is how they gauge customer satisfaction. Of the AMOs that have a follow up process in place, it is mainly via verbal communication within two weeks of delivery. Of those AMOs that have no standard customer follow up process in place, one admitted they follow up intermittently, and have requested their quality department to perform follow up inspections on their fleet following delivery. Two of the largest AMO facilities had no formal follow up process regarding customer satisfaction. One small AMO facility mentioned that if the customer had a problem they would get a call of complaint very quickly. It should be noted that some of the AMOs with the highest on time delivery rates of the sample group, according to their own measurement systems, do not have a formal process to determine if the customer was satisfied following delivery. Further questioning regarding KPIs being set for each individual working within the AMO revealed that none of the AMOs sampled had such a process, however two AMOs are in the process of implementing KPIs against each job description

Figure 6 Knowledge of cost of production (see online version for colours)



8.1.2 Target cost

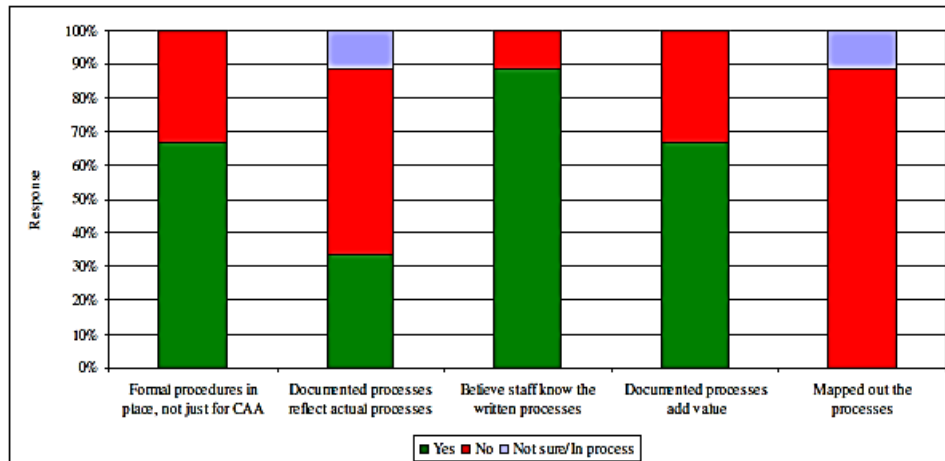
Figure 6 illustrates the outcome when interviewees were asked if they know their cost of production.

This lack of knowledge regarding target costs reflects the maintenance industry's lack of knowledge regarding the true cost of maintenance. Aircraft operators find it difficult to benchmark their cost of operation. Boeing has admitted that the actual cost of maintenance is little understood and is still in the process of being defined (Buyers, 2010). None of the respondents mentioned fixed price or power by the hour as a method used to charge their customers. According to Broadhurst (2010), however, internationally "maintainers used to charge by the hour for the necessary work to maintain aircraft, this developed into fixed pricing and then to concepts such as power-by-the-hour".

8.2 Lean Principle 2: value stream

Overall the findings of this study show that value stream mapping (VSM) does not occur. Figure 7 illustrates the outcome when interviewees were asked questions regarding whether they had procedures in place for all processes, not just those procedures that required recording to show compliance with aviation legislation in order to obtain approval to operate from a civil aviation authority. South African AMOs mainly record their processes in order to show compliance to an external auditor, such as the CAA or IATA, and not in an effort to increase productivity, improve quality and reduce waste. The majority of the AMOs admit that the recorded processes do not reflect reality. Process recording is perceived, by the majority of AMOs, as an additional CAA administrative burden, in order to maintain their approval to conduct business.

Figure 7 Process recording and mapping (see online version for colours)



8.3 Lean Principles 3 and 4: flow and pull

The questionnaire queried the interviewees on: work scheduling and computer software used, standardised work procedures, use of visual controls and inventory management.

The responses to the questions are influenced by the fact that none of the AMOs has accurately recorded their processes or performed VSM. The AMOs surveyed do not appear to operate according to push/pull principles.

Staff is arranged departmentally. The use of visual controls is limited. The majority of AMOs are dependent on the information recorded on their software systems. All the AMOs had specialised AMO software packages in place at their facilities that tracked inventory, scheduled WIP, Figure 8.

Figure 8 AMO computer software (see online version for colours)

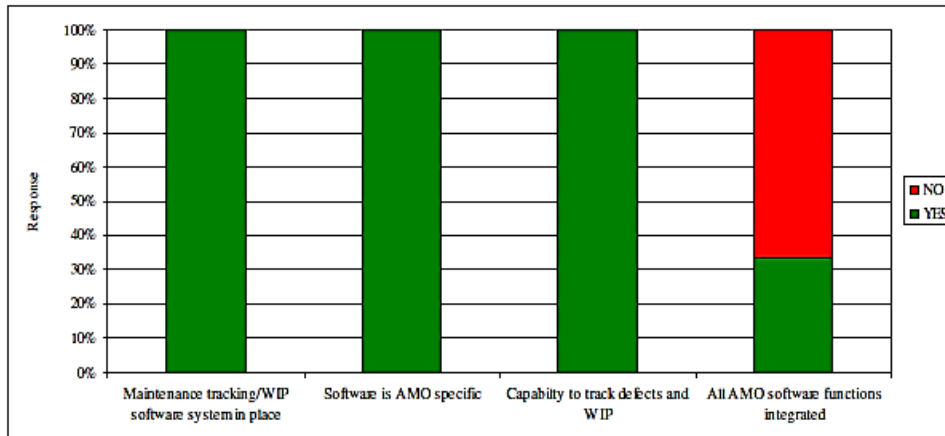
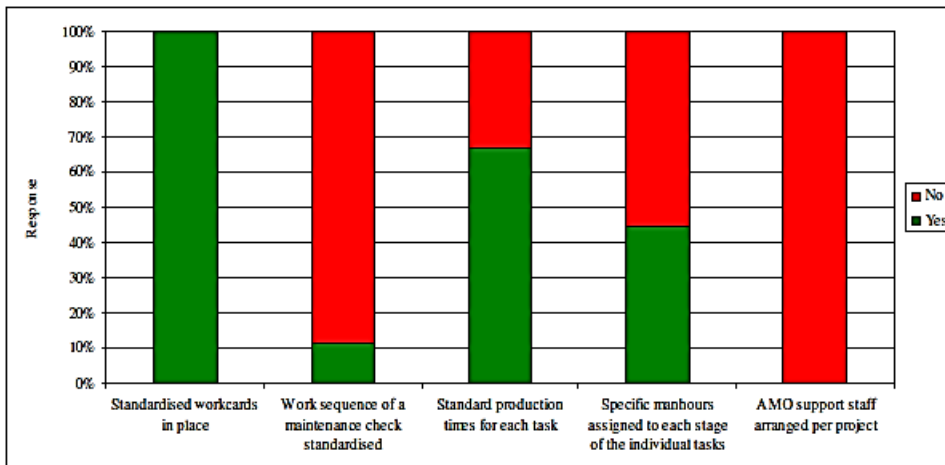


Figure 9 Process standardisation (see online version for colours)



The maintenance checks are not formally standardised (Figure 9) using experience from previous checks in order to improve the process. The maintenance check task implementation order is at the discretion of the aircraft crew chiefs. Most respondents are of the belief that you cannot standardise the maintenance check due to defects that will be discovered during performance of such maintenance. This concentration on the defects appears to have distracted the AMOs from concentrating on the scheduled work which

forms the majority of man-hours utilised to perform a routine maintenance check. There appears to be limited pre planning with regards to those defects that are most common, with most AMOs ordering spares as and when defects are discovered (Figure 10), believing this to be a JIT system. No evidence regarding the use of pulse maintenance, a form of maintenance task standardisation which is becoming more common within the global AMO industry, was apparent during interviews with the respondents.

Figure 10 Inventory control (see online version for colours)

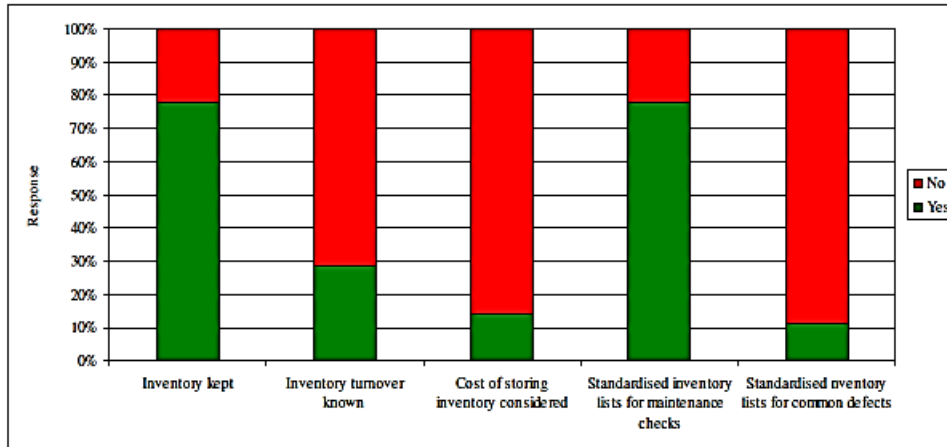
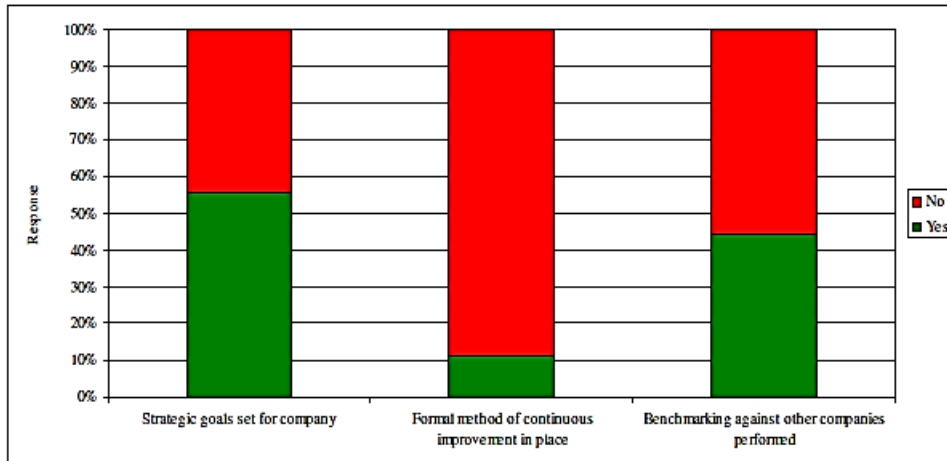


Figure 11 Continuous improvement and benchmarking (see online version for colours)



8.4 *Lean Principle 5: perfection*

As the concepts of value stream and its related techniques of flow and pull are not fully implemented in any of the AMOs surveyed, perfection of the entire process would not be possible as per the Womack and Jones (2003) requirements. This was proven to be the case for the AMOs surveyed. The nine AMOs appear to have no general strategic goals

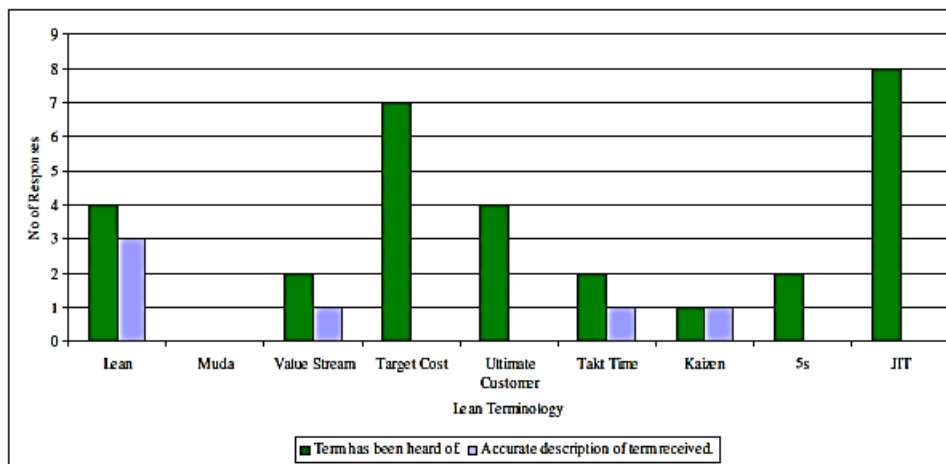
formally communicated to staff. Continuous improvement in the pursuit of perfection was not found to be evident at any of the AMOs surveyed (Figure 11). The respondents have a desire to measure their performance against other AMOs but do not know how to proceed in obtaining such data.

8.5 Knowledge of Lean

The third section of the questionnaire attempted to determine knowledge of Lean and its terminology amongst senior management of AMOs, whether obtained through implementation of Lean, formal Lean training or any other method such as reading trade publications or attending conferences. Prior to this section of the questionnaire the respondents were not exposed to any Lean terminology in the proceeding questions. Each of the respondents was asked if they heard of a specific Lean term. If they responded positively, they were further questioned on their knowledge of the term. A concise definition of the term was not sought but a general understanding of the term was recorded as a positive understanding.

This part of the study revealed that knowledge of Lean terminology is very limited amongst the management staff of the nine AMOs surveyed. Four respondents professed knowledge of the term Lean with one respondent admitting having heard of the term but did not know its meaning (Figure 12). On further questioning three respondents were accurate in their description of Lean and on further investigation it became evident that two of the respondents were exposed to Lean via a presentation that Embraer aircraft had given their AMOs. The other respondent had read about Lean in a magazine article.

Figure 12 Knowledge of Lean terminology (see online version for colours)



The term Muda was not known by any of the respondents, while two respondents replied that they had heard of the term value stream. On further questioning one respondent accurately described value stream. He was an attendee of the Embraer presentation. The term target costs, while receiving the second greatest number of positive responses with regard to identification of the term was however subject to mainly educated guesswork regarding its meaning. All responses were a variation of a theme on 'cost to aim for', but no respondent mentioned specifications or waste removal as being a part of target costs.

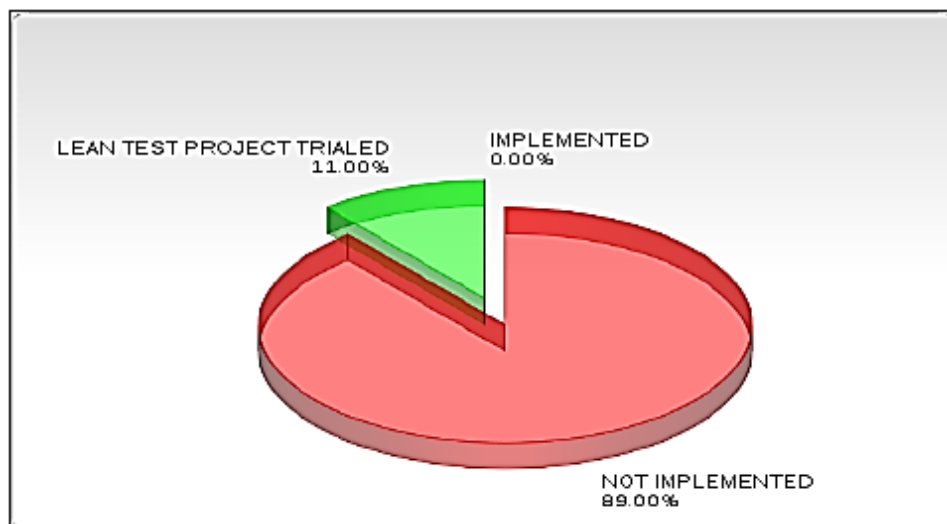
'Ultimate customer' was a term acknowledged by four respondents who all stated, in various forms, that in their opinion the ultimate customer was the entity that pays the invoice. No respondent mentioned the ultimate customer as being the final recipient of a product/service, as per Womack and Jones (2003). Two respondents heard of the term Takt Time. One respondent correctly described Takt Time, and on further questioning revealed that Takt Time formed part of his part time engineering studies. The other respondent had heard of the term at an Embraer course but admitted he could not remember its exact definition. One of the respondents who attended an Embraer course identified and correctly defined the term. Two respondents acknowledged knowledge of the term 5Ss. One respondent, who had attended the Embraer course, remembered one of the Ss, that of Shine. The other respondent could not remember any of the five Ss.

Eight respondents correctly stated that JIT is an abbreviation of Just in Time. Further questioning regarding the JIT philosophy varied widely. One respondent identified it as a Toyota methodology, while another recognised knowledge of the supply chain was critical for JIT to be implemented. JIT is understood by the respondents as having parts delivered to the AMO 'just in time' to meet an erratic schedule. JIT, however, is a technique for facilitating smooth flow where downstream production steps practice level scheduling to smooth out day to day order flow, unrelated to actual customer demand (Womack and Jones 2003). This further supports the findings on the limitations of the knowledge of Lean principles

8.6 *Lean implementation and experience*

The purpose of this section of the questionnaire was where Lean is found to have been implemented, to question the respondent if implementation had proven successful in increasing quality and productivity while reducing costs. This questioning was intended to have taken the form of open ended questions, but Lean was found not to have been implemented at any of the AMOs questioned (Figure 13).

Figure 13 Percentage of AMOs implementing Lean (see online version for colours)



One facility, however, after attending an Embraer course had recently implemented a small project on one aircraft required for maintenance check completion prior to the 2010 FIFA World Cup. They compared it to another aircraft of similar check size. The control maintenance check overran its end target date by two weeks, while the Lean maintenance check achieved output 5 days prior to its scheduled output date. As the questionnaire was conducted during the World Cup month of June 2010, the respondent could not comment on further Lean implementation intentions, as the maintenance check was still being reviewed.

9 Conclusions

Based on the sample used in this study, it seems that the status of Lean implementation in privately owned South African AMOs is relatively low. There is little evidence at present that Lean, in any form, is being embodied at any of the surveyed AMOs, apart from one limited test implementation. Knowledge of Lean and its terminology at the managerial level in the organisations is limited and there appears to be no recognisable production philosophy in place at any of the AMOs surveyed. The only principle that appears to be in existence is that of compliance with CAA regulations and on time aircraft departure.

South African AMOs are of the belief that aircraft maintenance, by its nature, is unpredictable due to the defects that may be found during the performance of a maintenance check. Efforts to control this unpredictability seem not to have been considered in depth. There will always be some level of task uncertainty within AMOs due to aircraft defects, but the use of Lean to reduce unscheduled maintenance events and the time it takes to respond to them can have a huge impact on an AMOs productivity and profit. This lack of any production philosophy be it Lean, or another, may be detrimental to the future competitiveness of the South African AMO industry. The South African AMO industry, the authors believe, is where the USA industry was in the 1990s. Taylor and Christensen (1998) describe this as a culture of “the self-sufficient, rugged individual” which has enjoyed success in the past. But it is a mindset that resists fundamental change; one that is cautious, conservative and slow to apply lessons learned in other industries, even in other airlines. It seems that maintenance in South African AMOs has not yet internalised the full meaning of a “wide angle systems view”.

An opportunity, thus, exists to expose and assist privately owned South African AMOs in understanding and implementing modern AMO management techniques, such as Lean, to ensure their future viability in the face of increasing global competition. At present South African government and support structures appeared to be primarily aimed towards OEMs, parastatals or derivatives of such parastatals. Organisations, such as the Aerospace Industry Support Initiative (AAD, 2010) make no specific mention of support to the South African AMO industry. While their emphasis to support aerospace R&D and OEM manufacturing in South Africa is acknowledged, other countries have identified the maintenance of such systems as an equally important sector, being an employment creator and a valuable contributor to the creation of a sustainable and competitive aerospace sector.

10 Recommendations

South Africa is faced with increased competition from Middle East, Far East and possibly Chinese AMOs based on the African continent. Considering this increasing global competition, the conclusion and limitations listed above, recommendations for future research are:

- To enlarge the survey population to incorporate all South Africa's large aircraft AMOs, including rotorcraft, interviewing persons at various positions within each AMO. The interviewees mentioned that they have never been interviewed before regarding their industry. They expressed a desire to obtain benchmarking data and further information on current trends within the South African AMO industry,
- To analyse the Lean implementation experiment conducted by one of the AMOs surveyed. This would be performed so as to determine how implementation was performed and any issues arising, which may be of interest to other AMOs seeking to implement Lean in South Africa,
- To determine how initiatives such as Aerospace Industry Support Initiative could assist privately owned South African AMOs to be globally competitive.

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