

# **Factors Influencing Effectiveness of Lean Maintenance Repair and Overhaul in Aviation**

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## **Abstract**

In order to improve efficiencies and minimise costs, maintenance, repair and overhaul (MRO) services in the aviation sector are increasingly embracing lean philosophy and advances in technology. The central tenet of lean philosophy is to eliminate non-value adding activities from value streams. While the take-up of lean philosophy is increasing, there are indications that aviation MRO services are facing challenges in implementing lean and this inevitably impacts on the effectiveness of such continuous improvement programmes. This paper presents findings from a study on aspects of lean philosophy in aviation MRO organisations. The focus of the study is on critical success factors that can impact the effectiveness of continuous improvement and lean waste reduction programmes in aviation MRO organisations. Findings from the study showed that emphasis needs to be placed on technical, non-technical and managerial considerations when implementing lean in aviation MRO organisations. In addition, also observed is a shift of emphasis in critical success factors when operating cloud-based aviation MRO systems in comparison to traditional aviation MRO systems.

## **Keywords**

Maintenance, Repair and Overhaul; Aviation; Lean; Critical Success Factors

## **1. Introduction**

There continues to be a growing interest for lean philosophy in Maintenance, Repair, and Overhaul (MRO) services including in the aviation industry (Mathaisel, 2005; Al-kaabi et. al, 2007; Ayeni et. al. 2011; Ayeni et. al. 2015). Lean philosophy, whose roots are in manufacturing, has been extended to service industry and found success, for example, in aviation services, healthcare, IT operations, and retail management. The central tenet of the lean philosophy is to eliminate waste from value streams. Lean waste, conceptualized as anything that does not add value to a process, can manifest in a variety of ways, as overstocked and underused inventory, and misallocated labour, time, transportation and logistics. From a customer's perspective, value-added activities are necessary and customers are willing to pay for the activities (Bamber, 2000; Glass, 2016).

Aviation MROs can realize significant performance improvements by implementing lean practices across their operations and processes (Bartholomew, 2009; MIT, 2005). MRO could be defined as 'all actions that have the objective of retaining or restoring an item in or to a state in which it can perform its required function' (Vieira & Loures, 2016). Included in the action set are combinations of technical, corresponding non-technical and managerial activities. In aviation, the main objective of MRO organisations is to retain or restore aircraft to a state in which they can safely perform its required design functions (Al-kaabi et al., 2007).

Aviation MRO are known to commit high economic costs including significant work and training hours for service personnel in order to keep appropriately maintained aircraft fleets and deliver the safety, comfort, and quality services offered by airlines. According the International Air Transport Association (IATA, 2015) the maintenance cost for an airline is 17% of the operational cost. During 2014, the global market of MRO's costs were \$62.1 billion,

excluding overheads, with a 3.8% increase per annum; the market size is estimated to reach \$90 billion in 2024 (IATA 2015).

The processes involved in aviation MRO is inherently complex for several reasons including a premise that aviation MRO activities cannot be precisely defined solely within manufacturing or service term alone as they are a product of both (Al-kaabi et al., 2007; Ayeni, et al. 2016). Added to the complexity is the fact that each component needs to be certified by competent airworthiness institution and this does demand a high level of requirements to guarantee safety operations (Vieira & Loures, 2016). Moreover, due to the high-quality requirements, the constrained pool of authorized companies available to serve parts and services in the sector can limit the options available to MRO organisations in selecting and managing the associated supply chain network. Overall, if not appropriately managed, the complexities associated with MRO organisations can bring about lean wastes in the MRO operations. Traditionally, MRO operations are plagued with long maintenance cycle times and as a result incurs margin-eroding inefficiencies and costs. Wastages arising from technological, non-technical, and managerial reasons are at the root of the inefficiencies. With MRO organisations increasingly embracing a continuous improvement mind-set, the benefits and challenges of lean philosophy in aviation MRO settings are beginning to be better understood (Bartholomew, 2009; Thomas et al., 2008; Luchtvaartfeiten.nl, 2015).

Whilst it has been generally accepted that the lean enterprise model is a proven method for eliminating waste from the value stream and for creating flow, there are significant issues regarding transitioning to lean systems for MRO organisations. It has been observed, for example, that aviation MRO services can experience significant delays in terms of implementation of modern procedures such as lean production; and this is true across the aerospace industry (Sacristán-Díaz et al., 2012). The field of aviation maintenance is advancing; the current aeronautical maintenance landscape is much more competitive than 20 years ago and requires organizations to constantly improve to continue in the market. MRO organisations are continuously working to sustain their competitive edge and preserve their future, adapting to the demands of the sector, with opportunities to embrace new technologies such as cloud-based systems (Antonucci, 2011; Uhlmann, 2014; Zhang et. al., 2015).

This paper presents findings from a focus group study on aspects of lean philosophy in aviation MRO organisations. In particular, the focus of the study is on critical success factors that can impact on the effectiveness of continuous improvement and lean waste reduction programmes in aviation MRO organisations. A contribution of this paper is in recognising possible shift of emphasis in the critical success factors when operating cloud-based aviation MRO systems in comparison to traditional aviation MRO systems.

The remainder of the paper is structured into four sections. Section 2 provides an overview of lean MRO services in the aviation industry. This is followed in Section 3 by a description of the research methodology adopted in this study, which principally is based on focus group. Section 4 contains analysis and discussion of the results obtained. Section 5 concludes the paper and offers suggestions for areas of future work.

## **2. Lean MRO Services in Aviation**

Central to the lean philosophy is a drive towards eliminating non-value adding activities and efficient use of resources (Carrasqueira & Machado, 2008). Non-value adding activities are wastes, i.e. any activity that increases cost of products and/or service without adding value from a customer's perspective. Traditionally, focus has been on the classical seven wastes typically found in operations namely defects, overproduction, waiting, transport, inventory, motion, and excessive processing. In recent times, more waste types such as energy waste has been discovered and included in drives for leanness. In typical manufacturing environments, 5% of the total activities are reported to be value-adding activities, 60% non-value-adding activities, and 35 % are necessary but nonvalue adding activities (Hines & Taylor, 2000). Successful implementation of lean philosophy can lead to significant reduction in the time from customer order to delivery, helps in the reduction of cycle times, increase productivity, and improve overall service quality (Mathaisel 2005). The philosophy is not restricted to manufacturing and its application in aviation MRO services has been demonstrated. However, there are recognizable differences between approaches to lean in manufacturing and those in MRO services (Bamber & Dale, 2000). The business dynamics of asset maintenance and those of production are fundamentally different (Brown, Collins, & McCombs, 2006; Clarke, Mulryan, & Liggan, 2010) and there also some differences in lean waste types e.g. over maintenance, scrap, unneeded spare parts,

misallocated labour time, old broken tools, and obsolete jigs and fixtures. Notwithstanding, transition to a lean MRO service could be for many companies the solution to market continuity and maintaining a global competitive status. Some improvements have been demonstrated. For example, improvements caused by lean introduction in MRO serviced have been reported by the MIT Lean Aerospace Initiative (2005) to result in:

- Set up time: 17-85 percent improvement.
- Lead time: 16-50 percent improvement.
- Labour hours: 10-71 percent improvement.
- Costs: 11-50 percent improvement.
- Productivity: 27-100 percent improvement.
- Cycle time: 20-97 percent improvement.
- Factory floor space: 25-81 percent improvement.
- Travel distances (people or product): 42-95 percent improvement.
- Inventory or work in progress: 31-98 percent improvement.
- Scrap, rework, defects or inspection: 20-80 percent improvement.

The benefits of lean MRO cuts across technical, non-technical and managerial considerations, with value measured in terms of the cost reductions and performance improvements particularly when service providers and operators are able to reduce the number of unscheduled maintenance events with employees fully engaged in the procedure of recognizing and minimising wastes. Large MRO companies with great capacity of resources and personnel are more willing to adopt the lean philosophy, evidenced by top five MROs reported to use lean as a process improvement methodology (Thomas et al., 2008). The savings and benefits that FedEx obtained by adopting lean philosophy is highlighted in Bartholomew (2009) and another example is provided in Luchtvaartfeiten.nl (2015) for Lufthansa.

There are some difficulties in implementing lean MRO especially for MRO SMEs such as repair shops. A lack of culture and knowledge about continuous process improvement in the SME MRO sector seems to be one of the reasons for the difficulties. For example, process optimisation knowledge has been found to be sometimes insufficient in the MRO SME framework (Bandurski et al., 2013) so also is the difficulty often presented by imprecise forecasting for the purpose of inventory management. A supposition that aviation MRO sector pressures are consistent with what lean principles can achieve is perhaps one of the main motivations for adopting lean in the sector. However, whilst there is reported increase in the number of lean adoption, most companies are in general not very successful in implementing their lean programs (Schonberger 2008) hence a need to fully understand the critical factors that influence success of lean in organisations. According to Boynton & Zmud (1984), critical success factors (CSFs) are ‘those few things that must go well to ensure success for a manager or an organisation and, therefore, they represent those managerial or enterprise areas that must be given special and continual attention to bring about high performance’.

Several CSFs for applying lean have been described in the literature. For instance, Dora et. al (2013) found skill of workforce, in-house expertise, and organizational culture as the most important factors for successful implementation of lean manufacturing practices in the European food processing sector. For lean MRO services, CSFs consisting of project management, organizational infrastructure, education and training, monitoring and evaluation of performance, technological competence, supplier management, users’ appreciation and consultant participation are commonly reported for Lean MRO services (Luchtvaartfeiten.nl, 2015). It has been noted in the lean manufacturing literature that CSF for implementing lean should be contingent on the characteristics of a particular context, which makes every situation different from another.

Technology, particularly the emerging industry 4.0 paradigm, has featured in the literature as an important dimension to achieving effective lean MRO services. Uhlmann (2014) suggests that the use of cloud based MRO can reduce lead time of spare parts and tools in the supply chain, with reduced maintenance cost and streamlining shared information traffic. Emerging cloud-based framework for aviation MRO services such as those of Zhang, Zhao et al. (2011), Antonucci (2011), and Zhang et al. (2015) have demonstrated capacity for improvements in lean MRO services through technology.

### **3. Research Methodology**

A focus group format is adopted in this research to elicit a range of views from participant regarding aspects of Lean MRO services in aviation sector. Focus group is recognized as a research technique that involves bringing a small

number of people, typically between 8 and 10, together with a moderator to discuss a specific topic. It is an alternative to individual answers to formal question. The approach used in this study is a synchronous online focus group (Krueger & Casey, 2002). The participants are aerospace engineers who work professionally within the aviation MRO services in Spain. Inclusion criterion regarding participants for the study were based on considerations for professionals with aerospace engineering background who are involved in the aviation MRO services sector in Spain and who may be affected by the adoption of lean philosophy in their organizations. The focus group participants were recruited through invitation letters sent via electronic mails with consent and instruction forms attached. Consent form was obtained from the participants before the start of the focus group session. Furthermore, participants were informed about their right to withdraw at any point.

The focus group session was conducted in March 2017 using Adobe Connect as the online platform. The moderator was located in England whilst the participants were based in their respective offices in Spain. The session was conducted in Spanish language and the duration was approximately 1 hour. The session was recorded and later transcribed to English language for analysis. The study was conducted in accordance with the University of Hertfordshire ethics policy and was approved by the university's science and technology ethics committee with delegated authority (ECDA) under protocol number ENT/UG/UH/02094.

The focus in this paper is on the lean aviation MRO aspects of the focus group discussion. This involved three main phases regarding participants input to the discussion. In the first stage, participants were presented with two pre-designed information flow maps for aviation MRO services. The two maps were adapted from:

- Sahay (2012), showing through a functional diagram, the flow of information in an internal distribution of an MRO company with all the integrated services (line, base, engineering, components etc...); the map is referred to in this paper as the traditional approach, and
- Zhang et al. (2015) for a lean MRO cloud-based ecosystem operating in a multi cloud setting with a recognition of the different main aviation stakeholders, drawing upon the stakeholder allocation presented (Antonucci, 2011).

In the second phase, the participants were asked to individually rank for each setting i.e. the traditional and the cloud-based MRO organisations, the significance of a set of CSFs that can impact on the effectiveness of lean in those settings. The critical success factors are: project management, organizational infrastructure, education and training, monitoring and evaluation of performance, technological competence, supplier management, users' appreciation and consultant participation. In the form, a scale 1 to 5 with its corresponding legend is presented. In the third step, the individual ratings were feedback to the participants and a discussion of the results took place.

## 4. Results and Discussion

Eight MRO professionals participated in the focus group deliberations. All were over 18 years old and have at least three years of aviation MRO experience in Spain. Table 1 shows the profile of the focus group participants.

<b>Gender (N=8)</b>			<b>Primary Job Responsibilities (N=19)</b>		
Male	n	(%)	Maintenance planning	3	(15.79)
Female	6	(75)	Policy development	2	(10.53)
<b>Stakeholder affiliation (N=8)</b>	2	(25)	Consulting	1	(05.26)
Aviation OEM	1	(12.5)	System Engineering	1	(05.26)
Aviation Operator	4	(50)	Data analysis	5	(26.31)
Aviation MRO organization	1	(12.5)	Management	3	(15.79)
Aviation component supplier	3	(37.5)	Formation	2	(10.53)
<b>Years of experience (N=8)</b>	2	(25)	Production	2	(10.53)
10+ years	3	(37.5)			
5-10 years	2	(25)			
5 years or less	3	(37.5)			

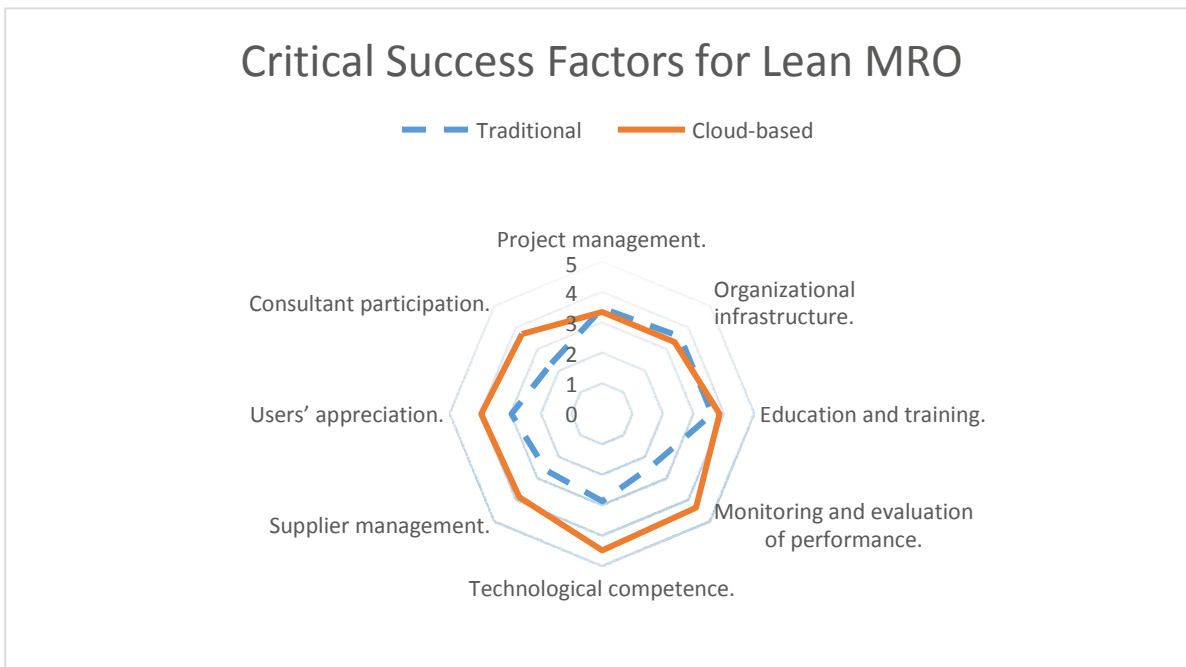
**Table 1: Socio-demographic profile of focus group participants.**

The participants recognised both the traditional and cloud-based information flow maps presented to them and were comfortable with their representations for aviation MRO services. Majority of the participants expressed a general

understanding of the intended purpose of Lean MRO philosophy, which they described generally as offering increased competitiveness and reducing non-value wastes, so as to increase customer appreciation of service and product in the aviation sector. According to the participants, two CSFs are joint first in the context of the traditional MRO systems. The top factors are: a) organisational infrastructure and b) education and training. Organisational infrastructure is taken to mean a set of company's procedures and policies based on defined roles, responsibilities and duties of its employees. In contrast to the traditional MRO services, the focus group participants suggest that technological competence is the top CSF in the context of the cloud based aviation MRO ecosystem. The results are shown in Table 2 and illustrated by a radar chart in Figure 1.

Critical success factor	Approaches		Difference Points [%]
	Traditional MRO Information system [Impact %]	Cloud-based Aviation MRO Ecosystem [Impact %]	
<i>Project management.</i>	70	67.5	2.5
<i>Organizational infrastructure.</i>	72.5	67.5	5
<i>Education and training.</i>	72.5	77.5	-5
<i>Monitoring and evaluation of performance.</i>	47.5	87.5	-40
<i>Technological competence.</i>	57.5	90	-32.5
<i>Supplier management.</i>	52.5	77.5	-25
<i>Users' appreciation.</i>	60	80	-20
<i>Consultant participation.</i>	47.5	75	-27.5

**Table 2: Critical success factor for lean MRO in traditional MRO services and cloud-based aviation MRO ecosystem**



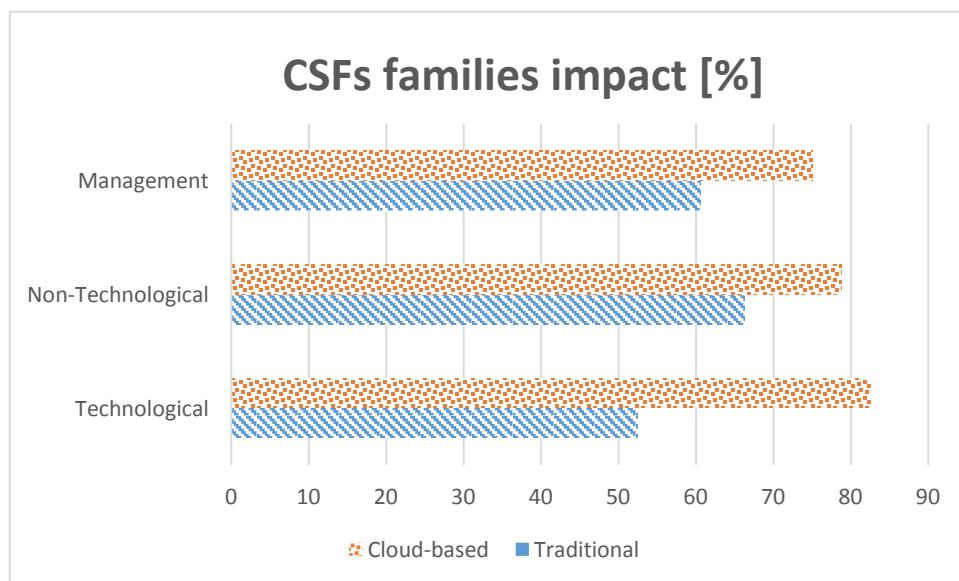
**Figure 1: An assessment of critical success factors for lean MRO**

All the eight critical success factors presented to the focus group participants are found to be significant in the context of lean MRO implementation effectiveness with about 40% ratings for each factor. Regardless of the information flows, i.e. either the traditional or the cloud based in lean MRO services, project management, organisational infrastructure, and education and training are important critical success factors with no significant differences in how they are perceived across the two systems.

Differences in the perception of the CSFs are observed in monitoring and evaluation of performance, technological competence, supplier management, users' appreciation, and consultant participation. The largest differences are recorded for monitoring and evaluation of performance with 40 percentage point difference, technological competence with 32.5 percentage point difference, and consultant participation with 27.5 percentage difference skewed towards the cloud-based lean MRO services. This result suggests that the characteristics of the cloud-based technology do play a key role in the effective implementation of lean MRO service. The observed differences between traditional and cloud-based MRO services regarding user appreciation and supplier management factors reflects two of the important characteristic attributes of cloud-based systems, where the concept of real-time and shared information is centred on improving the relationship with service users as well as the improvement of the supply chain.

The need for consultants, amplified in lean cloud-based MRO services is an indication, as suggested by the focus group participants, that most stakeholders in the aviation MRO sector are just starting to understand industry 4.0 technologies and they do not have the expertise required for cloud-based systems. The participants observed that as a result there is a clear upward trend from part of operators, manufacturers, and aviation MRO organizations to hire IT experts and analysts

The results presented in Table 2 and Figure 1 above are analysed from the perspective of technological, non-technological, and managerial factor groupings. In the analysis, technological grouping comprises of technological competence, and consultant participation; non-technological grouping comprises of education and training and user's appreciation; management grouping comprises of organizational infrastructure, project management, supplier management and monitoring and evaluation of performance. The results of the groupings are shown in Figure 2.



**Figure 2: Critical success factors for the effectiveness of lean implementation in MRO services from technical, non-technical and managerial perspectives.**

Figure 2 presents some interesting results. All three groupings, i.e. management, non-technological, and technical, are significant when considering the implementation effectiveness of lean in MRO services. For the traditional MRO services the priority order appears to be non-technological, managerial and technological. While for cloud-based

MRO services, the priority order is technological, non-technological, and managerial. This shows a significant contrast in lean implementation in traditional and cloud-based MRO settings; one which stakeholder should be aware of and learn to exploit. Arguably, MRO organisations that adopt cloud-based approach should have a well-defined and appropriate organizational infrastructure, with a clear visibility of the company business in their physical and information flows. The MRO organisations which use the traditional approach must compensate for these shortcomings by paying special attention to the factors of the management grouping. More emphasis will have to be placed on technical issues for cloud-based MRO services, including those associated with security.

It is important to highlight the considerable delay in the implementation of continuous improvement techniques such as lean in the aviation sector compared to other industrial sectors such as automotive. During the focus group deliberations, it became clear that some participants whose experience are from small MRO organisations have less experience of lean MRO compared with those who acquired their experience in large MRO organisations. The variability between the activities developed by MRO organizations, as well as their capacity and size, appear to be critical points, in order to determine the adoption of cloud-based approaches as well as process improvement procedures. The focus group accepted that small firms have the advantage to be more flexible than large companies and this filters through in the implementation of lean in MRO organisations. This agrees with related studies that small business managers do often bring change more quickly in small firms than is generally possible in larger firms principally due to the reduced level of bureaucracy, shorter communication lines, and less constrained by tradition (Abdollahzadegan et al., 2013). In essence, the informal nature of smaller businesses and leadership of owner/managers can make implementation of lean easier in small firms than in large (Haksever, 1996).

As shown in Tables 2 and Figure 1, the need for consultants including a specialist or an industrial engineer can be critical particularly for cloud-based lean MRO services. Due to the limited budget and the only moderate attractiveness for highly experienced engineers, the participants noted that smaller firms are inclined to hire young industrial engineers and recent graduate, or share perceived implementation risks with external consultants. This is broadly in agreement with the findings in the literature (e.g. Matt, 2013)

The following extracts from the transcripts of the focus group deliberations reinforces the above discussion. A participant, with OEM experience, remarked:

*'From my experience, the implementation of lean methodology in conjunction with other techniques as six sigma is much more beneficial than the lean implementation alone; it is possible to obtain benefits and results from both methods, taking advantage of the compatibility of the two approaches.'*

One participant with experience in both OEM and aviation component supplier organisations stated:

*'The continuous process improvement methodologies will be a necessity for all aviation MRO organizations in order to survive in the current competitive sector. In my organizations, we use agile techniques for the improvement of process, with the intention to maintain our competitiveness in the sector.'*

One participant who works for a MRO organization said:

*'The supply chain is the base in which all maintenance activities are supported, be able to have the right material in the right place at the right time, makes the difference with the competitors. In order to achieve this objective a lean MRO could use the cloud-based aviation ecosystem to improve the relation with the suppliers, reducing delivery times and sharing with them demand information in real time, based on the data extracted from the cloud ecosystem.'*

Regarding user appreciation in lean MROs in the context of cloud-based systems, an OEM participant said:

*'One of the greatest inefficiencies found in the communication with our users is the constant repetition of the same technical queries by different operators. If we were able to share the information generated by previous queries through a platform, it would save a lot of time and we could avoid the constant repetition of processes.'*

The following is a typical comment:

*'The airlines and the MRO organisations are not experts in the IT field or maybe are not enough sufficiently familiar with the lean philosophy. In any case, the participation of consultants mainly during the induction phase, supposes an aid of great value for management and training.'*

Finally, the focus group reinforced believe that lean is a viable philosophy for aviation MRO organizations but not sufficient by itself to achieve all the strategic goals of an aviation organisation. A point noted by other researchers (Ayeni et al., 2011). To achieve the desired leverage, the focus group went further by emphasising the need for stakeholders to understand the clear shift of emphasis in the critical success factors when implementing lean in a cloud-based MRO setting. These findings may be contingent on the characteristics of each aviation company and without accounting for the identified factor especially on a case-by-case basis, implementation may face difficulties, stressful, and fraught with significant uncertainty making key stakeholders such as suppliers, customers, or investors experience negative outcomes.

## **5. Conclusions and Future Work**

Effective lean waste reduction with the benefits of increased resource utilisation and productivity is achievable in aviation MRO services. Technological advances such as cloud-based systems should in principle help leverage the gains of lean in MRO services. There is however important critical success factors to be aware of when implementing lean in MRO organisations. This paper presented an analysis of the critical factors using results obtained from a focus group. Based on the analysis and discussion of the results it is concluded that there are differences in the significance of some of the critical success factors for effectiveness of lean implementations in traditional aviation MRO organisations compared to a cloud-based aviation MRO organisations. Monitoring and evaluation of performance, technical competence, consultant participation, user appreciation, and supplier management are emphasised more for lean implementation effectiveness in cloud-based MRO organisations. Project management, organisational infrastructure, and education and training are also important critical success factors for lean implementation in both traditional and cloud-based aviation MRO organisations. Management, non-technological, and technical groups considerations are found to be significant when considering the implementation effectiveness of lean in MRO services. The emphasis placed on how these groupings will affect the effectiveness of lean implementation differs in traditional and cloud-based MRO settings. More emphasis is on the technological factor grouping for lean implementation in the cloud-based MRO services. Future work could focus on how these results can be embedded in the processes for lean implementation processes for MRO services in the aviation sector.

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