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Research Article

Lean management tools in aviation industry: New wine into old wineskins

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ABSTRACT

Airline companies carry millions of passengers worldwide every day, and the airline industry has experienced huge growth both domestically and internationally in recent years. However, many airliners suffer due to inefficient operations that cause many problems in their service quality and customer service level. Disorganized or mismanaged operations such as delayed or cancelled flights, lost luggage, or insufficient personnel lead to low operational efficiency and a huge negative impact on their profit. Besides, service problems and operational shortcomings in the aviation sector result in customer dissatisfaction and poor customer service levels. Lean management practices provide tailor-made solutions to address the problems experienced by airlines. These practices improve the efficiency of aviation operations while eliminating the hidden sources of the increased cost. Lean management tools and techniques such as Kaizen, TPM, Six Sigma, 5S, and JIT can help the aviation industry increase operational efficiency, reduce cost, and utilize employees' skills efficiently. In this paper, we investigate the application of lean techniques to operations in the aviation industry.

Keywords: Aviation industry; Aviation management, Aviation operations; Lean management

1. Introduction

Developed by Toyota Motor Company, lean management techniques optimize manufacturing and service processes by reducing time spent on non-value-added activities (e.g., waste) and improve quality and customer satisfaction. While lean management techniques can be applied to various businesses and manufacturing processes, they offer valuable improvements to the service industry. Aviation is one of the prominent sectors where lean management techniques can create substantial improvements.

Airport transportation constitutes a small portion of GDP; however, it is closely connected to the activities in other sectors such as airport operations and aircraft manufacturing. All of these activities are collectively named as "aviation industry." Many companies operating in the air transportation sector and the rest of the aviation industry have been dramatically affected by the sudden decrease in passenger demand due to the coronavirus pandemic [12]. COVID-19 pandemic was one of the biggest crises in aviation history. Despite its negative impact throughout 2020, the aviation industry continues to recover as the pandemic's effect gradually declines. The number of passengers dropped by 60 % to 1.8 billion, which caused $ 126 billion industry loss in 2020. It is expected that the airline industry will recover back to its 2019 levels of passenger traffic by the end of 2023, early 2024 [10].

Once the pandemic subsides, the dynamics of air transportation will not be the same as in the pre-pandemic period. Besides dealing with the increased passenger demand, operational costs, and safety issues, the aviation industry also needs to focus on health concerns. Hence, the airport operations must be organized meticulously to sustain operational efficiency. From check-ins to baggage claims, the airliners must improve the airport activities and sustain operational excellence to reach a desirable level of customer satisfaction. However, it is not easy since airport operations consist of successive and interconnected activities.

Lean management is the collection of systematic techniques that aim to optimize organizational resources by eliminating non-value-added tasks. Lean techniques support the concept of continuous improvement, which means never-ending

improvement of products or services by making little and consistent progress over time. Some of the lean management techniques included, but are not limited to, Kaizen, Poka-Yoke, 5S, Kanban, Just-in-time, Jidoka, Takt-time, and Heijunka.

Airlines must adopt a completely passenger-centric ecosystem and business approach as the aviation industry has been shaken by many global crises, such as the corona pandemic. Lean tools are tailor-made management techniques that enable airline companies to survive in such situations by creating resilient, agile, and flexible service systems. The potential improvements offered by the lean management techniques will create flawless and safe operations in aviation industry and reduce the operational cost.

Even though lean management techniques have a vast application in various industries, such as high-tech, automobile, construction, healthcare, and government, it has not found enough application in the aviation sector. Besides, the application of lean management in the aviation industry has not been adequately studied in the academy. This paper aims to fill this research gap by investigating the potential applications of lean management in the aviation industry. The authors introduce the core lean management methods and their promising implementation, and investigate the merits of lean management techniques and their applicability in the aviation sector.

This paper is organized as follows. Section 2 introduces the aviation industry. Lean management practices are discussed in Section 3. The application of lean tools on airline operations is given in Section 4. Finally, the conclusion and discussion are provided in section 5.

2. Aviation Industry

Aviation is activities surrounding mechanical flight and the aircraft industry [4]. Aircraft includes fixed-wing and rotary-wing types, morphable wings, wingless lifting bodies, as well as lighter-than-aircraft such as hot air balloons and airships." The aviation industry includes the design, manufacture, use, or operation of aircraft, while aircraft refers to any machines that can fly. These machines can be heavier or lighter than the air. Balloons and airships are lighter than air, for instance, while airplanes, autogiros, gliders, and helicopters are heavier than air [7].

We have witnessed important advancements in the aviation industry for the last two decades. The demand and supply pattern of the aviation industry has been extensively revised by the emergence of Liberalization, economic cycle trends, relevant aviation-external shocks, and Information and Communication Technology (ICT) [11].

2.1. Brief history of aviation

The development of flying, initiated with Leonardo da Vinci's work, spreads over four centuries. Count Zeppelin's airship (1900) and Wright brothers' airplane (1903) have led to a significant leap in the history of aviation [19]. Even though many think Wilbur and Orville Wright brothers were the first persons who performed the first man-powered flight, in reality, this attempt in 1903 was not the first in history. Humankind was able to fly using air balloons since 1783, and man-powered flights came forward since 1903. Eventually, manned space flight has been carried out using rockets since 1961 [16]. Jacques Charles and Nicolas-Louis Robert operated the first flight conducted through a hydrogen balloon on December 1, 1783. On September 19, 1784, the Robert brothers completed the first balloon flight of more than 100 km from Paris to Beuvry [13].

The aviation industry can be divided into six phases [13]:

1. **The epoch of the precursors:** This period witnessed the first gliding attempts.
2. **The pioneers of the heaviest air:** First flights of motor vehicles that could take off on their own were accomplished in this period.
3. **The First World War:** This period brought about the excessive production of warplanes.
4. **The end of the First World War:** The proliferation of commercial aircraft was witnessed after WW I.
5. **The Second World War:** Warplanes were one of the most used methods of attack in WW II. This period's plane had used a piston engine and a propeller. Jet engines and radars emerged at the end of WW II.
6. **The second half of the twentieth century:** Regular commercial air transport in all types of weather conditions has been initiated as a result of a surplus of aircraft and pilots after WW II. Jets and supersonic flights were born in this period. Four-jet airliners and airliners became popular and accessible in this era.

Figure 1 depicts a timeline of aviation after the 18th century. In figure 1, the milestones in the history of aviation are briefly described starting from George Cayley, who is considered as the first person to understand the underlying principles and forces of flight. The beginning of the 1900s witnessed a great leap in aviation, such as the man-powered flights conducted by the Wright Brothers. Today, solar-powered and electric-powered planes are rapidly growing, and it reshapes the future of aviation.

Aeronautics and air transportation possess three major advantages over other transportation modes. First of all, an aircraft can go from a given point to any other point on the Earth without any need to stop. The second advantage of air transportation over land or water is the ability to offer direct transportation between any points. The third advantage of air transportation is that the right of way is free. In other words, an aircraft can operate without any investment, such as the need for building highways like land transportation [19]

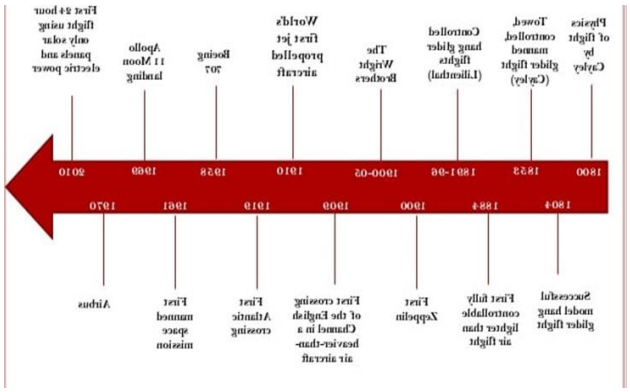

Fig. 1. Timeline of Aviation History after 18th Century [1]

3. Lean Management Practices

Lean Manufacturing is a comprehensive set of techniques that, when combined and matured, will allow you to reduce and then eliminate the seven wastes. This system not only makes your company leaner but subsequently more flexible and more responsive by reducing waste [21].

Lean Manufacturing has five primary elements: manufacturing flow, organization, process control, metrics, and logistics. These elements are the necessary features required to establish a robust lean manufacturing system [8]. The five primary elements in Lean Manufacturing are depicted in Table 1.

Table 1. Five primary elements in Lean Manufacturing [8]

Manufacturing Flow: Physical changes and design standards that are set up as part of a manufacturing cell.	1. Product/quantity assessment (product group) 2. Process mapping 3. Routing analysis (process, work, content, volume) 4. Takt calculations 5. Workload balancing 6. Kanban sizing 7. Cell layout 8. Standard work 9. One-piece flow
Organization: Carefully determining the roles and functions of employees, implementing improved ways of training and communication.	1. Product-focused, multi-disciplined team 2. Lean manager development 3. Touch labor cross-training skill matrix 4. Training (lean awareness, cell control, metrics, SPC, continuous improvement) 5. Communication plan 6. Roles and responsibility
Process Control: Endeavors for monitoring, controlling, stabilizing, and improving processes.	1. Total productive maintenance 2. Poka-yoke 3. SMED (Single-minute exchange of die) 4. Graphical work instructions 5. Visual control 6. Continuous improvement 7. Line stop 8. SPC (Statistical process control) 9. 5S housekeeping
Metrics: Creating visible, traceable, and result-based performance measures, improvement goals, and employee reward system/recognition.	1. On-time delivery 2. Process lead-time 3. Total cost 4. Quality yield 5. Inventory (turns) 6. Space utilization 7. Travel distance 8. Productivity
Logistics: All of the management efforts of processes for planning and controlling the material and information flow.	1. Forward plan 2. Mix-model manufacturing 3. Level loading 4. Workable work 5. Kanban pull signal 6. A, B, C parts handling 7. Service cell agreements 8. Customer/supplier alignment 9. Operational rules

Lean manufacturing became popular after the book "The Machine That Changed the World" authored by Womack, Jones, & Ross (1990) [22]. Lean manufacturing relies on producing higher quality products and services, reducing production costs, and waste elimination [14]. According to the United States Environmental Protection Agency [5], organizations implement lean to achieve the highest quality product or service at the lowest possible cost while obtaining

maximum customer responsiveness. There are three main goals for organizations to succeed lean implementation:

- Reduce the material quantity and production cost while producing a product or service
- Increase the production rate and become more flexible
- Improve the product quality.

Lean manufacturing builds its philosophy on continuous improvement that offers many benefits to enterprises, such as cost reduction, process improvement, and waste elimination. As a result, companies have a higher profit margin, increased customer service level and satisfaction, higher quality products, shorter lead times, and minimized manufacturing costs [9].

Enterprises use various methods and tools for lean manufacturing implementation. The eight-core lean methods are [5]:

1. Kaizen Rapid Improvement Process
2. 5S (It stands for five Japanese words: Sort (Seiri), Set in Order (Seiton), Shine (Seiso), Standardize (Seiketsu), and Sustain (Shitsuke))
3. Total Productive Maintenance (TPM)
4. Cellular Manufacturing / One-piece Flow Production Systems
5. Just-in-time Production / Kanban
6. Six Sigma
7. Pre-Production Planning (3P)
8. Lean Enterprise Supplier Networks

Companies receive several outcomes as a result of implementing these lean methods. Some of the most prominent outcomes are discussed in table 2.

Table 2. Outcomes of Lean Manufacturing implementation (adopted from [5])

Outcome	Explanation
Reduced inventory levels	Reducing the inventory level (raw material, work-in-progress, finished product) results in lower holding costs and other costs such as damage and spoilage.
Decreased material usage	Decreasing the need for inputs such as energy, water, metals, and chemicals results in diminished material waste during manufacturing.
Optimized equipment	Using less capital and resource-intensive machines lowers the costs.
Reduced need for factory facilities	The need for less physical infrastructure such as buildings, warehouses, and material demands by cutting down the need for space for production.
Increased production velocity	The time to produce a product from raw material to final delivery to the consumer can be significantly reduced by eliminating non-productive processing steps such as movement, waiting times, and downtime.
Enhanced production flexibility	Manufacturing systems' ability to reconfigure their production processes to adapt to fast-changing customer needs lowers inventory levels and minimizes overall cost.
Reduced complexity	Reducing the number of material types and quantity of parts and discarding non-productive process steps and equipment diminishes the variation and error in a manufacturing system by limiting complexity.

4. Lean Airline Operations

Lean operations have been attracting the attention of the airline industry in recent years. Since airline operations are process, labor, and capital intensive, a small change in operations that results in waste reduction produces a huge impact on customer service levels, employee productivity, and overall operations efficiency. Lean philosophy helps airliners eliminate waste sources, minimize variability, and remove inflexibility in operations. The implementation of lean techniques in airline operations leads to significant cost savings, improving employees' working conditions and customers' experiences, minimizing waiting times and delays, and increasing productivity in terms of labor hours. Furthermore, lean tools can be implemented to speed up aircraft taxi time and maintenance operations and train pilots [3].

The aviation industry is facing tremendous pressure and challenges due to the rapidly increasing competition, cost reduction concerns, and skill shortages, under the pressure of making the industry safer than ever as air traffic is rapidly growing. Moreover, increasing environmental concerns impose additional pressure on airlines to conduct

environmentally sustainable operations. Hence, airlines tend to focus on three main goals: improving productivity, enhancing safety, and assuring sustainability. This leads to the emergence of lean-safe-green practices in many branches of the aviation industry, such as aerospace manufacturing, air transport, and maintenance, repair and overhaul (MRO) [20].
Moving thousands of passengers from the airport entrance to boarding requires sequential activities such as check-in, luggage drop, security, lines at the gate, etc. A disruption in one of these activities results in delayed or missing flights or missing baggage. Hence, the operating efficiency in airports directly affects passengers and customer satisfaction [15].
The following statistics from the Federal Aviation Administration (FAA) indicate the air traffic and related data [6]:

- 16,405,000 flights handled by the FAA yearly
- 45,000 average daily flights handled by the FAA
- 10,000,000+ scheduled passenger flights yearly
- 5,400 aircraft in the sky at peak operational times
- 19,633 US airports (5,082 public airports and 14,551 private airports)
- 2,900,000 passengers fly every day in and out of the US airports
- 25,506,000 general aviation flight hours per year
- 44,500,000,000 pounds of freight per year
- 10,857,000 US jobs generated from aviation
- 5.2% aviation contributed to the US gross domestic product
- $488 Billion annual earnings from aviation

The numbers reported by the FAA demonstrate the size of the aviation industry. Many challenges exist in this huge system in which the operations consist of sequential processes. However, there is always room for improvement in the efficiency of the operations. The key challenges in airport operations are [15]:

- Delayed flights
- Missed connections
- Long layovers
- Lost luggage
- Cancelled flights
- Delays at the gates (after landing)
- Under-utilized aircrafts
- Idle staff and equipment

Airlines only make profits when an aircraft is flying; that is why airline companies are continuously striving to improve the aircraft turnaround times and on-time performance. Hence, unloading an airplane after its arrival and getting it ready for departure again and departure or arrival on schedule time are two main concerns and important factors for operational excellence of airliners. The lean and six sigma methodologies can be applied to the various processes in the aviation industry, such as ground operations, maintenance, flight operations [2].
A study carried out in 2016 [18] investigates the case of the practical implementation of Lean Six Sigma on Kenya Airways who wants to improve the on-time performance and reduce connecting baggage-related delays. The delayed flights result in higher ground handling operating costs, passenger compensation costs, and so-called "soft" costs or lost revenue opportunities due to brand damage. The five steps of the Six Sigma continuous improvement model, namely DMAIC (Define – Measure – Analyze – Improve and Control), reveal that connecting baggage handling is the main contributor to aircraft turnaround delays.

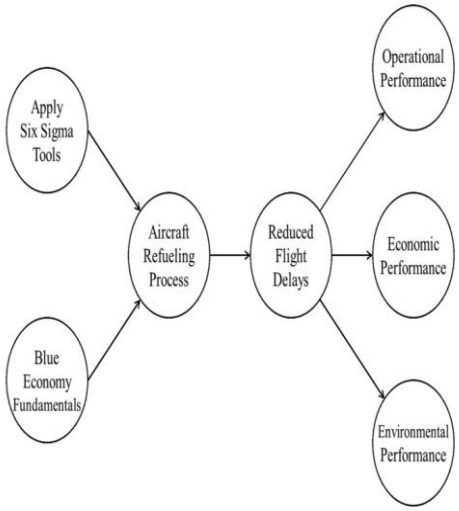

Fig. 2. Application of Six Sigma on Aircraft Refueling Process [17]

Another study [17] investigates how can the application of the six-sigma methodology improve operational, economic, and environmental performance in the aircraft refuelling process (see fig. 2). The authors conclude that the application of six-sigma tools in the aircraft refuelling process successfully reduces the amount of flight delays. Furthermore, the reduction in flight delays leads to lower environmental impacts on both water and air levels, such as reducing water use, energy consumption, and CO_2 emission during the aircraft refuelling operation.
Various issues in the aviation industry can be reduced or eliminated while improving operational performance by implementing Lean Six Sigma. Some of these issues and the benefits of lean implementation are discussed in table 3.

Table 3. Some benefits of lean implementation in airports [15]

Issue	Potential Benefit of Lean Implementation
Data collection	Gathering data is the first step to detect the areas and wasteful processes that need to be fixed. Some of the areas that need to be monitored include passenger traffic flow, number of delays, cancelled flights, and lost luggage. Feedback regarding the flaws in a process can be collected through surveys and focus group interviews.
Wasted Employee Time	Inaccuracy in determining the optimal staffing level leads to delays in check-ins, baggage carousels, and maintenance. Lean management tools help to optimize staffing levels and efficient use of employee time.
Departure Delays	Dealing with hundreds of passengers for each flight causes departure delays. Lean management tools eliminate delays and redundant actions by breaking the process into sub-processes and evaluating them individually.
Baggage Handling	Lean applications can detect the wasteful actions in transporting the luggage from the planes to carousels and set standards to improve the process that eliminate passenger waiting times on the carousels.
Customer Service	Processes variation happens when employees fail to follow a standard pattern; hence managing variations is an important quality improvement. Lean practices can eliminate the variations in standard processes such as check-ins at airports.

5. Conclusion and Discussion

The aviation industry faces many problems due to the increasing passenger demand, sustainability concerns, increasing operational costs, safety issues, and increasing pressure about environmental impact. Service problems and operational shortcomings in the aviation sector result in customer dissatisfaction and poor customer service levels. Automation and digitalization have been significantly integrated into airport operations to deal with these problems in the last decades.

Many processes in the aviation industry are sequential and meshed to each other. Delayed or cancelled flights, missed connection flights, lost luggage, long layovers cause customer dissatisfaction and negative impact on the company image. Airliners focus on improving customer satisfaction while ensuring safety by progressively improving their processes. These processes require meticulous planning and execution. Furthermore, as global competition and passenger expectations arise, airliners look for effective methods to better meet customer demands while lowering the operation cost. Lean management is a methodology that relies on eliminating waste, continuously improving the production process, and understanding and designing the processes based on the customers' perspective.

Lean tools and techniques such as Kaizen, TPM, Six Sigma, JIT, and bottleneck analysis can help the aviation industry reduce operation costs, utilize employees' skills efficiently, create a safer work environment, and coordinate the passenger flow at the airports. For instance, the DMAIC (Define, Measure, Analyze, Improve, Control) cycle of the Six Sigma method offers a great continuous improvement opportunity for the aviation industry. Airline companies are customer-centric service providers; hence they always focus on better understanding customer needs and expectations. Lean management, with its continuous improvement philosophy, provides a potential strength and competitive advantage to airline companies. In this sense, sustaining lean transformation will help airlines better adapt to fast-changing passenger demands. This paper can be further extended by investigating the applications of lean techniques in detail and improvements achieved in the aviation sector.

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