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***Research Article/Araştırma Makalesi***

# Lean Approach as a Process Innovation

Banu (SARIKAYA) ÖZKESER[1]

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**Abstract**
In 1990, Womack and Jones introduced the lean manufacturing plan in their book "The Machine That Changed The World". Three years later (and in the affect of this book round the world) Lean Aerospace Initiative (LAI) established with the aim of studying the implementation of lean manufacturing in the aviation field. Company A, a manufacturing company, has been implementing the lean approach concept since the year 2013 and in this study, gradually progressing through 7 stages. This article discusses the progress of lean implementation as a process innovation and the outcomes it has achieved in Company A. To gain a comprehensive understanding of the process, a comparison was made with existing literature on lean implementation in the HMLV (High-mix-low-volume) industry and specifically in the aerospace industry. Company A had to make modifications to certain lean tools before applying them, while also utilizing some tools directly. Overall, the application of lean manufacturing (in other words process innovation) in Company A has resulted in a 70% increase in production effectiveness, a 60% reduction in production lead time and defects, and a 60% decrease in inventory.

## 1. Introduction

Since its presenting by Womack in the year 1990, lean manufacturing has become a widely favored approach in the manufacturing industry for enhancing efficiency and effectiveness in the manufacturing process. It has been embraced not only by discrete industries like automotive or home appliances, as well as by service fields such as pharmaceutical, garment and consumer products. Furthermore, even the service industry has adopted lean manufacturing practices (Malik et al., 2024; Ferrazzi et al., 2024). The motivation behind implementing lean approach in the industry is diverse, driven in part by the constant need for competitive advantage in terms of cost reduction, improved quality, and shorter delivery times (Ferrazzi et al., 2024). In the aviation field, MIT launched the lean management approach in the year of 1993 through the Lean Aerospace Initiative (LAI), which was formed in collaboration with the U.S. Airforce. The aim was to address the challenge of rejecting state fundings for aerospace equipment purchasing (Murman et al., 2002). LAI brought together various stakeholders, including industries, government bodies, academics, and others, with the objective of exploring how lean principles could be applied to enhance efficiency and achieve more qualified outputs at lower prices (Murman et al., 2002). The outcomes of this initiative included specific stages of lean application at both the production and

[1] Corresponding Author. ORCID: 0000-0003-1335-2526. Ph.D., Koluman Automotive Industry Inc., Mersin/Türkiye

enterprise levels in the aerospace industry (Ferrazzi et al., 2024). For industry users, a major concern was whether the methodologies proposed were suitable for implementation in their respective companies, considering the differences in geography, demography and culture. They also sought guidance on the steps to follow in implementing lean practices and determining which lean tools would be most effective in achieving their desired objectives. Additionally, measuring the success of lean application (as a process innovation) and identifying key success factors and challenges posed further questions to be corresponded (Murman et al., 2002).

### 1.1. Objective

The aim of this study is to examine the lean phase implementation of a manufacturing company. The results will be analyzed in relation to existing literature to address the research questions and provide insight into the effective application of lean principles, which can be adapted to other industries.

## 2. Literature

### 2.1. HMLV and LMHV

Irani (2020) declared the aviation field that is categorized as a high-mix-low-volume (HMLV) industry. On the other hand, the field of automotive is classified as a low-mix-high-volume (LMHV) industry, taking into account its production capacity and the types of products it manufactures. In order to provide a clearer understanding of the distinctions between aircraft and automobile products. Table 1 illustrates the details in the study of Wildemann & Hojak (2016).

**Table 1.** Benchmarking table of aviation and automotive field (Wildeman & Hojak (2016))

| | | Aircraft (A320) | Automobile (Audi A3) |
|---|---|---|---|
| Product | Power (HP) | >66.000 | >100 |
| | Maximum speed in km/h | - 900 | - 200 |
| | Size in m (length * width * height) | - 40 * 34 *12 | 5 * 2 *1.5 |
| | Model portfolio (without derivative) | - 4 | - 12 |
| | Possible combinations for customer equipment levels | - $10^{34}$ | - $10^{35}$ |
| | Development time until SOP in years | - 7 | - 4.5 |
| | Customers worldwide | - 400 | - 100.000 |
| | Number of components (pieces) | - 3.000.000 | - 18.000 |
| | Selling price in EUR | - 9.000.000 | - 27.500 |
| | Operational life in years | - 40 | - 9 |
| | Fuel consumption per 100 km and person in liters | - 3 | - 5 |
| Production | Empty weight in tons | - 60 | - 1.6 |
| | Production capacity per year | - 260 (Hamburg) | - 130.000 (Ingolstadt) |
| | Shifts per day | 3 | 3 |
| | Assembly time in hrs. (only final assembly line without aircraft painting) | - 720 | - 21 |
| | Depth of added value (equity ratio) in % | - 30 | - 27 |
| | Number of workers per shift | - 500 | - 500 |
| | Production type | Mini-series production | Mass production |
| | Suppliers | - 2.000 | - 110 |
| | Logistical expenditure per production in percent of the selling price | - 5 | - 1.5 |
| | Staking points / weld points | - 1.000.000 | - 5.100 |

The differentiate between high-mix-low-volume (HMLV) and low-mix-high-volume (LMHV) can be observed in various aspects such as the range of outputs available in the marketplace, capacity of manufacturing,, the number of customers and the quantity of components used in the completed products. Aircraft manufacturing is strictly framed

on customer orders, known as "builds to order," with a significant portion of the total cost allocated to the design step (Badhotiya et al., 2024). In contrast, the LMHV industry follows an assembly process while HMLV can employ a manual cells' entegration, flexible production cells and job shop approaches (Irani, 2020). The overall environment of high-mix-low-volume (HMLV) differs from that of LMHV. Notably, HMLV distinguishes itself from LMHV in terms of facility layout and schedule of manufacturing with HMLV utilizing functional layouts and ERP systems (Ferrazzi et al., 2024).

### 2.2. Implementation of lean principles

Implementing lean manufacturing concepts as a process innovation involves establishing values, mapping value streams, creating production flows, utilizing pull systems, and striving for continuous improvement. The process of implementing lean manufacturing consists of three stages: developing lean skills, adopting a lean culture and focusing on ongoing improvement (Vargas et al., 2024).

Irani (2020) highlights the need to tailor the lean implementation proposed by Womack et al. (1990) to suit the specific characteristics of the HMLV industry. According to Irani (2020), the lean implementation process involves steps such as identifying the product family, conducting value stream mapping (VSM), recognizing waste types, eliminating bottlenecks, assessing performance, optimizing the value network mapping (VNM), and then repeating the process for other product families. Lane (2007) further emphasizes that in the HMLV sector, it is essential for companies to ensure high quality standards before implementing process innovation on the factory floor, extending them to office operations as well.

### 2.3. Lean tools used

Malik and friends (2024) highlighted the importance of tailoring the implementation of lean tools in the aviation industry to suit its unique characteristics. In their study, they identified seven specific lean tools that are well-suited for the aircraft industry.

- Visual Management
- One-piece flow
- U-cells
- Standard work instructions
- Poka-yoke
- Takt-time
- Multi-skills

The eight instruments possess the attributes of the aviation sector, exhibiting elevated requirements, diverse demands, intricate product composition, stringent safety and quality standards, and a convoluted supply network (Malik et al., 2024).

## 3. Methods

The study “Lean Approach As A Process Innovation” contents a case analysis approach to examine the implementation of lean practices as process innovation in a factory called Company A. The data for the case study were collected through examination of company documents, analysis of pictures, questionnaires. To ensure the validity of the data, they were cross-referenced with the company documents and other supporting data such as visual materials and questions&answers records. The final outcome of the data analysis was then compared with existing theories in the literature to derive a conclusion. The respondents of the questionnaries who are responsible for the implementation of lean practices in the factory, have been actively involved in the process since its inception and continue to serve as a change agent. It is important to note that unless explicitly stated, all the information presented in this study is derived from the documents.

## 4. Lean Implementation in Production Division at Company A

Company A, a southeast asian manufacturer, serves as an OEM (Original Equipment Manufacturer) and supplies parts to other OEMs as a tier-three supplier. It should be noted that tier-two suppliers play a crucial role in supplying components for assembly or equipment products, whereas tier-one suppliers are accountable for system integration. (Richter & Walther, 2017).

The production division at Company A plays a crucial role in the design and production of aircraft parts. This is because both the design and production processes are closely linked to ensure the airworthiness of the aircraft structure. In cases where certain processes cannot be carried out on the shop floor and require outsourcing, the decision must be approved by both the designer and the relevant authority. If the production of parts is to be subcontracted to another party, it is essential that the supplier's quality system aligns with the OEM's quality system. This ensures that the highest standards are maintained throughout the production process (DGCA, 2014, 2015).

Customer demand, fierce competition, and shifts in the environment are the driving forces behind Company A's commitment to continuous improvement. Besides serving as an OEM, Company A aims to elevate its status to tier 3 and 2 suppliers within the aviation field. In order to stay competitive, Company A must possess a distinct advantage. This is why Company A adopted lean principles. The initial move, Company A made to embrace lean practices was to engage a partner with expertise in lean methodologies. Subsequently, Company A assembled a dedicated team as the primary agents of change to delve into lean principles and their application at the partner's site, and initiated the lean implementation program on the production shop floor.

Company A opted for acquiring a partner who had already implemented lean practices. The chosen partner had a business portfolio similar to Company A in terms of product type, business size, machinery, and organizational structure, and had successfully implemented lean principles. To gain knowledge and expertise in lean manufacturing and applications, Company A sent a team of 15 individuals from 6 divisions in the Directorate of Production to the partner's facilities. These 15 individuals became the pioneers of lean transformation within Company A. Through their training, 15 people (in the team) successfully developed a comprehensive lean program, encompassing various tools, processes, and documents. To ensure the smooth execution of the lean implementation, Company A established four lean departments across different departments. Additionally, a steering committee was formed to oversee and regulate the implementation of the lean plan, guaranteeing its adherence to the predetermined objectives.

### 4.1. Lean internal training

Company A recognized that the success of lean would rely on the active involvement of all employees and management as a whole. To ensure the effective implementation of this lean program, Company A established a dedicated training center known as the "Lean Academy". The Lean Academy offered two main training programs: one of them is the initial training and the other one is the recurrency training. The Initial training provided an introduction to the theory and discussion surrounding lean, while also offering practical exposure to lean practices through the use of a model aircraft assembly process called the Lean Model Factory. Typically, the Initial lean training spanned a duration of two weeks and involved the participation of all 1800 employees and management officers in the Production Directorate. On the other hand, the Recurrency training was designed to update, enhance, and refresh the understanding and application of lean theory and practices. The course content and syllabus for the Recurrency training were tailored to the maturity level of lean application on the production floor.

### 4.2. Lean manufacturing implementation

Company A has devised a Lean Maturity Model to guide the implementation of process innovation steps on the production floor. The progression through the stages is based on phases, with each side potentially having varying durations for each phase. The introduction of lean tools is only done after the team is fully trained and proficient in using the tools effectively.

After the training was completed, the initial step taken by each department was to establish a Multi-Function Team (MFT) with the primary objective of creating a Value Stream Mapping (VSM) in order to pinpoint inefficiencies and strategize for the future. The future state outlined in the VSM is then segmented in various Target Improvement Plans (TIP) which will serve as Key Performance Indicators (KPIs) for each department. VSM and TIP serve as the foundational elements for the subsequent stages, which involve selecting the appropriate tools and assembling a team. TIP includes determinations regarding which lean tools should be utilized to enhance performance, setting timelines for tool implementation, and ensuring the availability of necessary supporting tools. These supporting tools are

utilized to gauge the extent of deviation from performance targets and to rectify any irregularities that may arise.

To effectively implement lean tools, Company A has established a daily routine of 15-minute meetings at all levels. These meetings serve as a means to monitor operations, identify deviations, and find solutions to problems. The first level meeting is conducted among machine operators and led by the lead team. Team leads then hold level 2 meetings under the supervision of supervisors. Supervisors, in turn, participate in level 3 meetings led by managers. Lastly, managers gather for level 4 meetings, which are overseen by the head of the division. Additionally, division heads and directors hold level 5 meetings once a week. It is worth noting that meetings from the first level to the fourth one take place on the production floor, allowing management to directly observe and address any issues. These meetings, known as QCD-SP meetings, focus on matters related to product quality, cost, delivery time, safety, and personnel. The discussions are facilitated by the QCD-SP panel. These meetings play a crucial role in staying informed about product status and fostering a lean culture among all involved. Any problems that cannot be resolved in the QCD-SP meetings are handled by the MFT team.

Multifunction team is a team that has the primary responsibility of resolving issues that arise in the field and cannot be resolved during QCD-SP meetings. MFT is comprised of individuals from various functions within the production floor. The inclusion of personnel from various functions aims to foster effective communication and eliminate any existing silos. If a problem cannot be immediately resolved, MFT will escalate it to a larger forum known as the Practical Problem-Solving Meeting ( in shortly called as PPSM). The PPSM includes not only MFT members but also representatives from other departments within Company A who can contribute to finding a solution. All decisions and the problem-solving process are meticulously documented and managed in accordance with the required procedures. These records are essential for ensuring the quality and certification processes of the product. The "5W" method is one of the standard procedures employed in problem-solving. The daily QCD-SP meetings also serve to enhance the capabilities and responsiveness of both MFT and PPSM teams in addressing production floor issues. The ultimate objective of implementing lean principles in terms of human resources is to cultivate a well-trained, responsive, and lean-minded MFT and PPSM, collectively known as the Quick Response Team (QRT).

### 4.3. Lean tools used by Company A

Company A describes lean manufacturing as a production system that aims to meet customer demand while maintaining agreed-upon standards of quality, cost, and delivery time. The main objective is to eliminate non-value-added activities. The application of lean tools is customized to the proficiency of the team involved, following predetermined stages in the maturity model. Prior to their implementation, certain lean tools underwent modifications to ensure sustained performance, measure achievements, and identify the underlying causes of issues. Table 2 shows the updated lean tools utilized by Company A.

**Table 2.** Classifying of lean tools at Company A

| Lean Grouping | Lean Tools | Modified Lean Tools |
|---|---|---|
| Improvement strategy | • 5S<br>• Kaizen<br>• Line balancing<br>• OEE<br>• Pull system<br>• Standarization<br>• Takt time<br>• TPM<br>• VSM | • E-Kanban<br>• Multi Function Team<br>• Quality Management Board<br>• Quick Response Team<br>• Target Improvement Plan<br>• Vendor's supply: Tooling, Part supply,Aux Material, Sealant, Fastener |
| Maintain the improvement | | • Process Confirmation<br>• Improvement Tracking System |
| Measure the deviation | | • KPI<br>• QCD - SP Meetings<br>• QCD – SP Panels<br>• Tracking OEE<br>• Performance Tracker |
| Root cause of deviation | • Andon | • Practical problem solving |

A concise explanation of some of the lean tools utilized are:

- Following the completion of training, the 5S activity is conducted by adhering to the operational instructions provided by the lean department. Additionally, the implementation of OEE is also carried out.
- Line balancing and takt time are established during the creation of VSM. These are arranged in various configurations to accommodate the product variations that have been previously made. The objective is to promptly respond to any changes in customer demand.
- Standardization is an integral part of the aircraft manufacturing industry, where each part must adhere to specific working processes as regulated. Therefore, standardization is an inseparable aspect of the overall process.
- TPM is a tool utilized to enhance OEE. While OEE can be implemented at the initial phase, TPM can only be introduced once the team has acquired proficiency in detecting, measuring, and rectifying deviations. Additionally, a comprehensive understanding of TPM and equipment maintenance is essential
- The pull system is applied by Company A to fulfill the requirements for consumable materials such as cutting tools, sealant, fasteners, and other standard parts.
- Company A strives to achieve kaizen as its primary objective. To instill kaizen, continuous efforts are made through regular meetings and by change agents or team management during every opportunity.

Brief overview of various lean tools:

- The performance tracker serves as a visual management tool for monitoring production status, strategically placed on the production floor for easy visibility by all stakeholders. Regular updates are made during shift changes, following the successful integration of QCD-SP meetings by the employees.

- QCD-SP meetings are conducted daily on the production floor, involving the manager and division head. This practice aligns with the principles of gemba genchi genbutsu in TPS.
- The reduction of inventory in consumable materials is achieved through the vendor's supply method employed by Company A. A designated area on the production floor is allocated for vendors to place their products, which are equipped with an e-Kanban system for inventory management.
- Target improvement plans and Key Performance Indicators (KPIs) serve as valuable tools, similar to a future state of value stream mapping, in order to drive progress and achieve desired outcomes.
- In-station quality controls and the identification of root causes through the 5Why's technique are facilitated by the utilization of multi-function teams, quick response teams, and practical problem-solving methods. These tools effectively address and resolve issues in a timely manner.

### 4.4. Outcomes

Company A is currently in the completing process of the seven phases, determined before. As of now, the implementation of lean production approach in Company A has resulted in a significant increase in production effectiveness by 70%, along with a reduction in manufacturing lead time and defects by 60% and 40%. Furthermore, inventory has been reduced by up to 60%. These improvements have not only enhanced performance but also garnered trust from the global aviation industry, leading to orders from one of the world's largest Original Equipment Manufacturers (OEMs). Although Company A currently operates as a tier 3 supplier, it is anticipated to ascend to a tier 2 supplier in the future. Upon reflecting on the experience of implementing lean, it becomes evident that uplifting human resources and maintaining consistency in implementing lean culture require special attention from all parties involved. Therefore, it is crucial for top management to remain committed to these aspects.

## 5. Results and Discussion

Company A implemented lean for two main purposes. Firstly, they aimed to establish a lean operation process within the industry. This was achieved by applying various lean tools to streamline operations and improve efficiency. Secondly, Company A wanted to develop a QRT (Quick Response Team) that embodies a lean culture and attitude. To accomplish this, they formed a well-trained MFT (Multifunction team).

Moreover, Company A's decision to adopt lean practices aligned with the findings of the research conducted by Malik and friends (2024). Their primary goal was to enhance their competitive edge to secure contracts from major OEMs. Additionally, they aimed to leverage lean production methods to improve the quality, reduce costs, and shorten delivery times for their domestic OEM components.

By the way, Company A's decision to partner with a lean organization has proven to be highly beneficial in terms of time and effort saved in determining the appropriate platform and tools to use. Additionally, this partnership has allowed Company A to gain valuable knowledge on how to effectively implement lean practices throughout the various stages of their operations. It is important to note that implementing lean is not a simple task, as research has shown that a significant number of companies (90%) have struggled to apply lean in a proper manner, resulting in subpar results. Only a small percentage (approximately 2%) have achieved the desired outcomes (Malik et al., 2024). Therefore, it is crucial to have a thorough understanding of lean principles and the overall functioning of the company before embarking on a lean implementation journey (Malik et al., 2024). In this context, the availability of a lean implemantation provided by LAI specifically tailored for the aviation field proves to be immensely helpful, serving as a comprehensive guide for the necessary steps and tools to be employed.

Furthermore, The establishment of Company A's Lean Academy demonstrates Company A's strong commitment to preparing its workforce, not only by enhancing their understanding of lean principles, but also by equipping them with the necessary skills. Company A also highlights the importance of tailoring the implementation of lean tools to the level of expertise of its employees. This aligns with existing literature, which emphasizes the significance of having a solid grasp of lean culture, skills, and applications for all stakeholders involved (Malik et al., 2024; Crabill et al., 2000; Vargas et al., 2024). It is noted that one of the main hurdles in implementing lean practices at Company A is effectively managing its human resources, echoing the sentiments expressed by Hallam & Keating (2014).

In addition to the previous results, mentioned in the study of Bozdogan et al. (2000), the concept of lean revolves around the principles and actions of everyone participating in the procedure. Company A utilizes lean practices to achieve what they deemed crucial in order to succeed in the competitive world, as a response to the customer's demand for a refined QRT. However, the literature reviewed did not mention the objective of implementing lean as obtaining a team that can promptly respond.

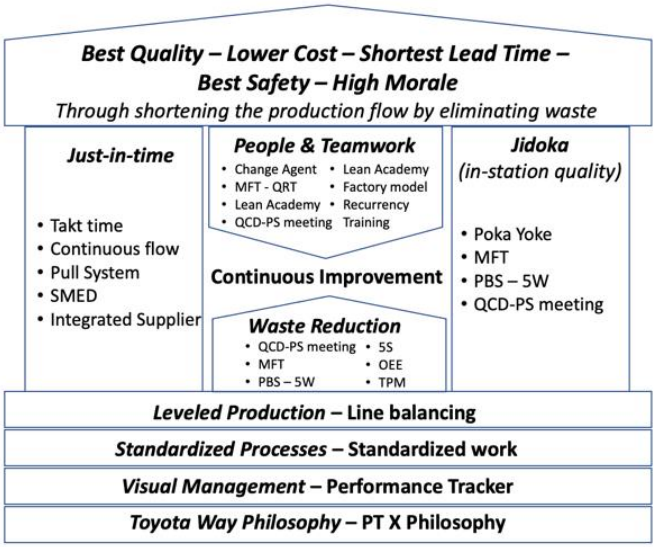
Upon reviewing Company A's actions, it can be deduced that the strategies implemented align with the recommendations found in the literature (Crabill et al., 2000; Irani, 2020; Vargas et al., 2024; Womack et al., 1990). Instead of introducing the complete pull system in phase 6, Company A aimed to achieve a QRT and incorporate suppliers of consumables into their operational framework. While utilizing LAI, adjustments were made in phase 6 to meet the company's specific objectives. Company A established a dedicated lean department to develop and oversee operational protocols and oversee the implementation of lean practices.

Company A employs lean instruments and updated lean arguments that are similar to those used in the Toyota Manufacturing Style. These tools are utilized across all job shop operations. In terms of the Value Stream Mapping (VSM) technique, Company A applies it to product families that share similarities in process or technology groups, rather than limiting it to a specific product type. This approach aligns with the findings of Irani (2020). Regarding the pull system, Company A utilizes it not as an integral part of the manufacturing step, but rather as a means

to streamline the process of placing order for materials that can be used up and reduce waste. Consequently, this paper completes that the lean tools in the literature study proposed by Irani (2020), including the modified VSM, can be effectively implemented.

Figure 1 shows lean tools used by Company A in TPS House.

**Figure 1.** Lean tools use by Company A at TPS House (TPS is adopted from Liker, 2004)




## 6. Conclusion and Recommendations

Company A has achieved success in process innovation by implementing lean principles, primarily due to its ability to find the right lean partner and prioritize the readiness of its workforce. One aspect that has not been extensively discussed in the literature is the goal of establishing a QRT (quick response team) alongside achieving a lean production process. Company A has followed the recommended stages of implementation suggested by LAI, making necessary modifications based on their specific needs and ensuring the competence of their employees before introducing lean tools. Company A has utilized all available lean tools in the HMLV industry, including those that required modifications, such as VSM (value stream mapping). To assess their lean maturity, Company A has adopted a quality checklist form, too. Consequently, Company A's implementation of lean aligns with the principles outlined in the literature. To gain a more comprehensive understanding and be aware of process innovation's effects, further researches on lean application in other industries are recommended.

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