KEYWORDS Lean NPI Repair and Overhaul Aerospace

APPLICATION OF LEAN IN AEROSPACE

NEW PRODUCT INTRODUCTION PROJECT

A Case Study in Aftermarket Project from a Global Company

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ABSTRACT

Application of Lean in Aerospace Aftermarket New Product Introduction (NPI) project has been periodically discussed over the last ten years. An NPI project is selected from an APU and AMS components repair and overhaul service center to demonstrate the benefits of Lean application in a new capability project. The implementation of several Lean tools in the NPI project is analyzed and a conclusion is drawn based on two NPI project metrics and results.

INTRODUCTION

Lean philosophy and tools are widely used in aerospace manufacture industry. It regards the elimination of waste in machinery, materials, labor and methods of production and office procedures, identifying waste opportunities and reducing time to improve efficiency in manufacture. The New Products Introduction *(NPI)* process is different from the manufacture process. NPI is a set of activities beginning with perception and capture of market opportunities and ending with production and product delivery. The role of Lean in NPI is quite different from the traditional Lean philosophy and implementation. The function of Lean is to coordinate the existing initiatives and make them work more effectively and efficiently at a high level.

Customers always have greater demands on new innovative products, expecting to improve product quality within a shorter time frame and at lower costs. All these products have to go through an NPI process to reach their markets. The majority of company growth in market share or annual revenue is from NPI or innovation. In order for the products to reach the markets at the right time, at the right price and with the desired characteristics, a new and efficient NPI process is required. It was found that in electronics industry a late entrance to the market by six months can result in 33% reduction in profits over product lifecycle **[2]**. A Lean NPI process would capture customer requirements and thus identify value, create a concept that satisfies requirements and optimization of the value stream so that products will be delivered to the customer in a short turn-around-time with excellent quality. Therefore the application of Lean is necessary for NPI process.

Our facility is an aircraft Auxiliary Power Units *(APU)* and Air Management System *(AMS)* components repair and overhaul service center. On average, every year we perform three new capabilities projects per customers' request or marketing analysis to expand our business.

1. Lean in Aerospace NPI projects

Our facility started to apply Operation Lean System 15 years ago, particularly in OEM manufacture. It is mandatory to incorporate Lean into the New Products Introduction process at Lean Silver company for certification. We review our existing NPI process for our APU fuel control, enhancing it by using Velocity Project Development *(VPD)* Lean tools and then implementing the modified process in several new capability projects at APU and Air Management System Accessories repair and overhaul facilities. It is proved that project cycle time is shortened, production costs reduced and products quality improved after the new process is applied.

There is a standard phase-gate NPI project process with seven phases and six gates at corporate level. See **Figure 1** for standard phase-gate project process. Repair and Overhaul shops get involved in Phase 2, 3, 4 and 6. They play key role in Phase 6 delivery, support and improvement. Also, the Repair and Overhaul center needs to provide feedbacks through Kaizen to Products Action Committee *(PAC)* at concept definition, planning and specification and development phases. At the following sections analysis will be made on Repair and Overhaul *(R&O)* NPI project process to identify waste opportunities and create added value to NPI process at Phase 6.

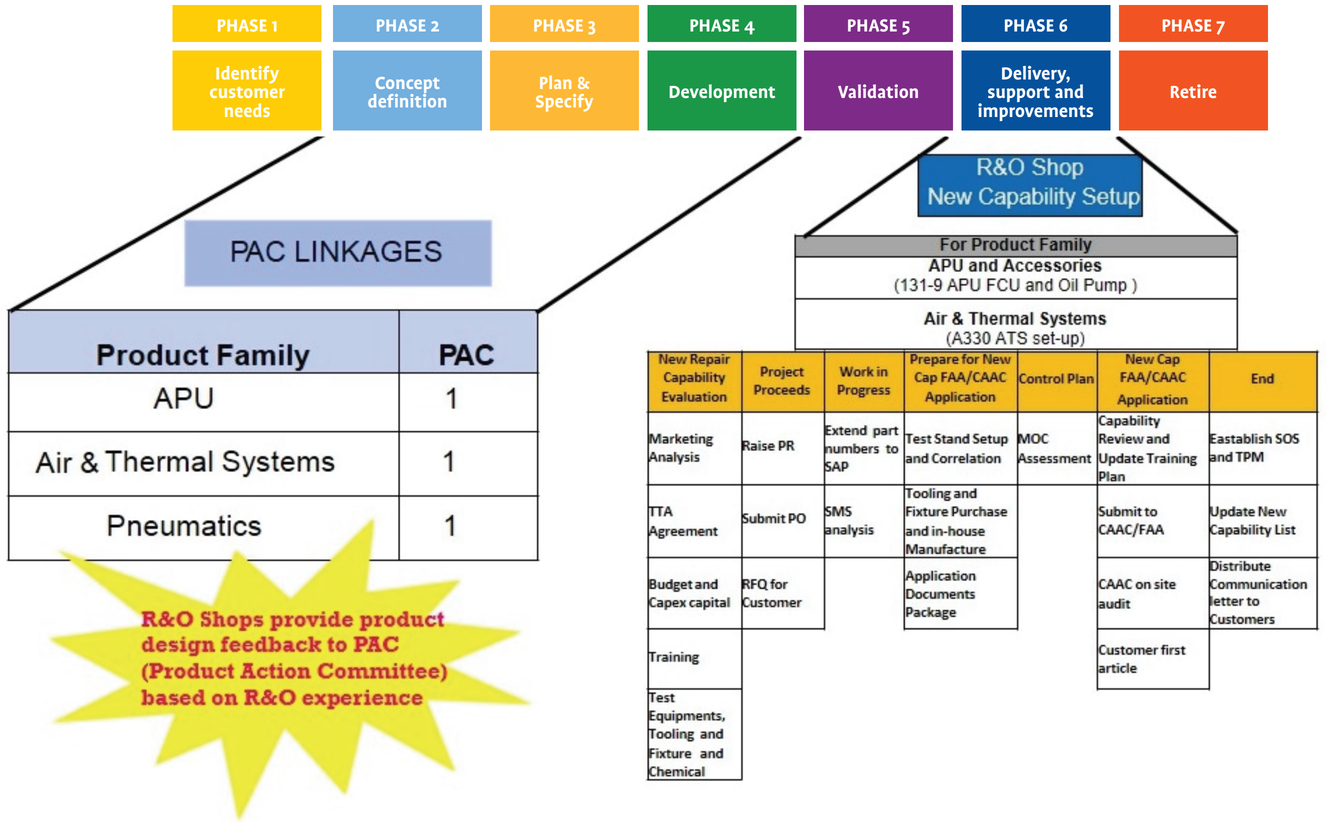

FIGURE 1. *Standard phase-gate NPI project process.*

2. Lean Application in Aftermarket New Capability Projects

The first consideration in the five lean principles is to specify what creates value from the customer's perspective. Drivers to Repair and Overhaul NPI projects are requests from airline customers or demands from market analysis. On time delivery of project to customer is top priority, which creates value from the customer's perspective.

The second step is to identify all steps across the whole value stream in NPI projects. A Lean NPI model has to be created before proceeding with value stream level analysis and investigation. Phase-Gate models are selected with four stages where NPI project activities take place. The four stages consist of the decision making stage, stage preparation, certification stage and delivery stage. The project manager determines a time frame with strict deadlines for each stage.

Time, quality and cost are the three outputs of aerospace aftermarket NPI project. It is believed that time is the most critical because the customer is sensitive to time-to-market delays. This is what is pulled by customer just-in-time and supposed to be our top priority in aerospace aftermarket NPI project. Lean tools are used to remove successive layers of time waste and thus create added value in NPI process to satisfy our customer.

Value Stream Map

Value Stream Map *(VSM)* is a visual tool used to see and understand the information flow and material through business. See **Figure 2** for NPI project value stream map.

Decision Making Stage

It usually takes a total of twenty days to get Capital Expenditure *(CAPEX)* budget approved in Capital Planning System *(CPS)* and Capital Routing System *(CRS)* systems. But the approval process is delayed due to time difference globally. Also, e-mail communication is not as effective and efficient as phone call conversation in global technical coordination. Those potential waste reduction opportunities were identified in the Capex approval process. Obtaining technical data from USA consumes up to two weeks. It takes a couple of weeks to check Technology Transfer Agreement *(TTA)* agreement to confirm that new capability part number is covered by the agreement. E-mail communication is time consuming in data requests. In Lean application immediate phone communication is carried out between US headquarter and the branch in addition to e-mail communication, which significantly reduces waiting time in the approval process. Consequently, CAPEX approval process is decreased to ten business days with data request cycle time reduced to three business days.

Preparing Stage

Test stand design and development is time consuming and expensive and is thus critical to the success of NPI project. In the APU fuel control NPI project seven months were spent to get the test stand completed by our US supplier, including test stand design, manufacture, assembling, testing at supplier site, transportation, custom clearance, on-site installation and testing, trouble shooting and correlation. Several waste opportunities are sought out during VSM analysis. Frequent technical communication occurs between USA test stand supplier and end user during the entire project cycle. Quick and effective communication with global supplier will definitely reduce waste time and expedite the project process. Additionally, customs clearance process needs to be standardized to reduce waste time. Early supplier involvements in the preparation of customs clearance documents are definitely helpful for time reduction.

In test stand development we use set based concurrent engineering. We shortlisted possible solutions and selected three final solutions, including 1) modification of current Hydro Mechanical Unit *(HMU)* test stand, 2) design and build up of a new 131-9 Fuel Control Unit *(FCU)* test stand, and 3) make a new test stand with combined capability to test 131-9 FCU, 331 FCU and 85 FCU. Finally we eliminate weaker solutions and gradually narrow the set of possibilities to converge on the first solution, modification of current HMU test stand. However, we are still interested in the other two solutions, obtaining all relevant specifications and documents. Currently the first solution can meet our requirements, without affecting our HMU testing capacity. Also, it is a cost effective solution for our site. If we receive more FCU from airlines customers in the future, the second or the third solution will be a good option. Information on the second and third solutions is considered as knowledge that is recorded and re-used, which is a 'value adding waste' which adds no direct value to the final solution, but the knowledge acquired will add value to future work. These types of waste can enhance value.

Make or Buy is considered in FCU tooling and fixtures preparation. Lead time of tooling and fixture purchase from Ground Support Equipment takes at least thirty-three weeks. Also costs are much higher. We decided to obtain OEM drawing and manufacture tooling and fixtures in our machine shop to reduce waste time. It just takes nine weeks to complete manufacture of twenty-six tooling and fixtures in our own machining shop, which significantly reduced the NPI project cycle time.

Certification Stage

Making an early appointment with Civil Aviation Administration of China *(CAAC)* is what needs to be done in the future, which would guarantee that CAAC audits our new capability on time and as a result reducing waiting time in the certification stage. Cross training engineers to do self-audit in new capability certification is a way to resolve short hand issues in the quality assurance team and subsequently reduce waiting time at self-audit.

Delivery Stage

First article repair is mandatory per CAAC requirements. We need a customer unit to do first article repair and testing in each NPI project. Communication with customer in advance would eliminate waiting time and improve efficiency and consequently decrease project cycle time.

Management of Information

In the lean manufacture level, warehouse inventory and WIP *(work-in-process)* are very important indicators. Level of DIP *(design in progress)* is a sign of the health for NPI process. Information flow and status are critical to NPI project and are important indicators for in progress design in NPI project. There are several ways to expedite the information process. We conduct a kick off meeting at the beginning of each NPI project and a closing meeting at the end of the project. A review meeting is held at the end of the decision making stage or preparing stage. All information from customer service, project manager, engineering, quality, operation, HSE and facilities and finance will be distributed and exchanged in the meetings, which expedites the information flow process, as a result reducing waste time and enhancing added value. Additionally we have an online library at the server's site

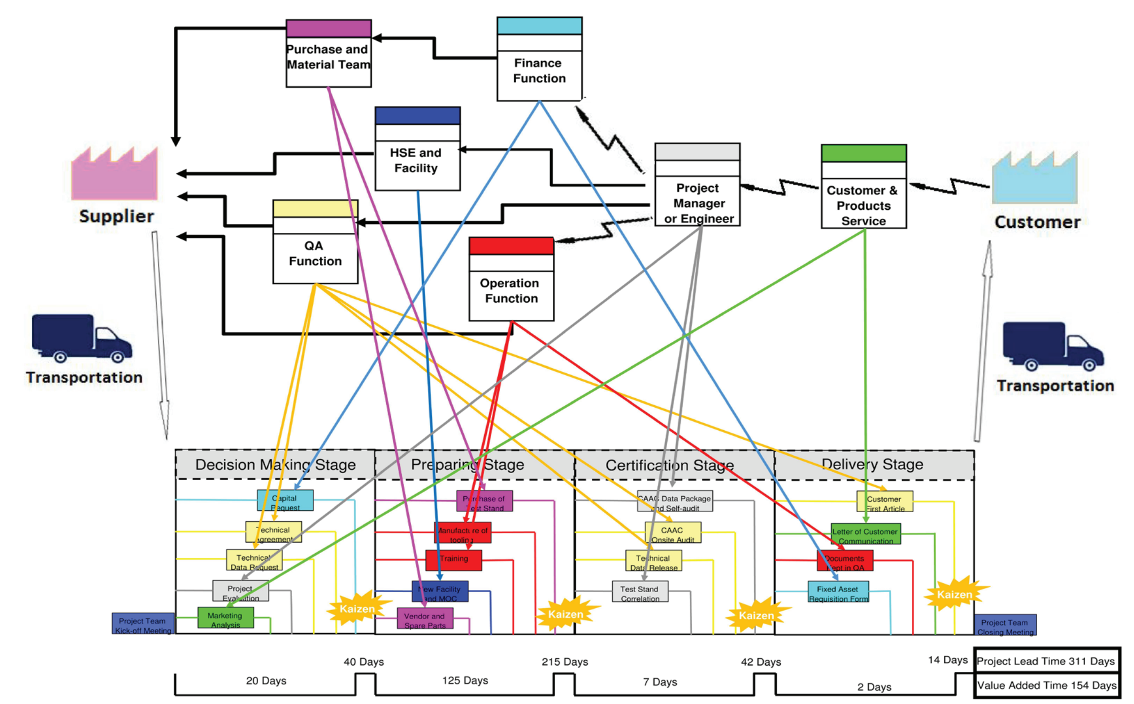

FIGURE 2. *Value Stream Map*

where an electronic copy of the updated manual, service bulletin, related engineering documents and quality documents are kept and maintained. Easy access to public technical information can reduce waste time in information search. Communication also has an impact on information flow and status. Follow-up e-mail exchanges are a quick and effective way to communicate with each function, particularly at the global level. Sending immediate feedback or receiving in time comments will reduce waste time and enhance added value to our customers.

Management of Workflow

A well-organized workflow is key to the success of aerospace repair and overhaul of NPI project. Prior applications of Lean NPI project work flow were not appropriately arranged. For example, training was not discussed at the decision making stage, particularly oversea training in Singapore or USA. Lead time and/or training costs could delay the implementation of a new capability project even with hardware testing in place and shop re-layout completed as schedule. Since the application of Lean in our new capability project, training lead time and training costs have been considered at project evaluation in the decision making stage, and consequently project cycle time has been significantly shortened. In addition, training quality has been improved by using engineering units at on-job-training at the preparation stage. Unserviceable units are requested as engineering units from Singapore or USA repair and the overhaul site. Technicians familiarize themselves with disassembly, assembly, cleaning, inspection, testing and repair processes using engineering units so that they complete the first article repair in less time and with better quality, thus reducing waste time and creating added customer value.

The work flow of project evaluation is enhanced in Lean application. In Lean application all related function teams are invited at the decision making stage to investigate, screen and identify potential waste reduction opportunities including operation, quality, finance, HSE and facility and Human Resources. We generated a NPI project evaluation form using Excel software, covering project plan, project benefits analysis, financial analysis, parts purchase or repair, development costs, tooling and fixture cost, testing equipment costs, training costs and facility renovation and layout change costs. The work flow change in our new capability project ensures that we consider all critical factors at the beginning, avoiding miscommunication between various functions at a later stage, hence reducing waste time and improving project cycle time.

Functional Engagement

Stage-Gate System is multi-functional, consisting of parallel activities carried out by employees from different functions. See **Figure 3** for engagement of functional teams. It is imperative for the sourcing team and operation team to be engaged at the beginning of the NPI project.

Aircraft parts have a long purchasing lead time, usually a couple of months at least. To buy a new part or repair existing parts is a trade-off issue that we need to consider at the beginning of the NPI project. Also, the cost of parts is important to the NPI project, which could cause low Return on Investment *(ORI)* and result in failure of the NPI project. In Lean application the sourcing team is involved in the NPI project at the decision making stage in order to ensure that qualified suppliers are selected based on overall preferred suppliers strategy. The purchase team will have a strategy for the development of preferred suppliers. Cost target is set for part purchase in the NPI project. The suppliers' manufacturing plan and logistics network are reviewed to ensure that they are aligned with our target. Dual sources or multiple sources are developed to ensure continuity of supply and cost management. Also, the sourcing team has a process and goals to support the NPI project to enhance speed, quality and drive down costs. These actions from the sourcing team benefit project cycle time, production costs and products quality.

It is mandatory to be engaged in the NPI project at beginning of the operation function because they are internal customers and end users of each NPI project. Cross functional participation at the decision making stage is to ensure production and process integration. Detailed operation capacity analysis is conducted for new capability project in cooperation with engineering, quality and production planning. If necessary, additional operation employees will be hired or employees will be transferred from other production teams to meet human resources requirements. Production process capability and control are established and used as baseline in new capability development. Target attainment of quality, Turn Around Time *(TAT)* and costs are reviewed in advance with operation function. Operation function performs a regular assessment for NPI project timing related to production schedule and production readiness. Regular and frequent reviews for production readiness are conducted by the operation team at the start of each NPI project. Engineering units are obtained for production team to perform disassembly, assembly and in-shop testing and thus validate products definition, optimize production plan and costs and simplify technicians' training. Operations need to be involved in packaging and logistics as well to ensure that optimized inbound and outbound packaging requirements are established consistent with logistic and trade compliance requirements.

Standardization

Lean tools including 5S are usually carried over into the NPI project, which provide the logical order for information in the NPI project, in order to rapidly gain an understanding of project status and standardization of processes for simplifying the working practices and reducing variability.

CAAC or Federal Aviation Administration *(FAA)* certification is vital to a new capability project. Standardization of certification process will be sure improving quality and save time in NPI project. Per our experiences obtained at previous new capability audit, we formalized the exiting CAAC new capability application data package, detailed description of substantiation and additional proof documents added to ensure that CAAC certification is accomplished on time and that the certificate is issued at the first time audit to avoid repetitive audits, thus reduce waste time.

Standardization of the customs clearance process will save project time as well. It usually takes three or four weeks to deal with clearance issues at China's customs before the lean application. A standard customs clearance process procedure is generated to standardize the process based on previous experiences. The most important is that we request our oversea suppliers to fill out China's customs documents at their facilities before the shipment of goods, which significantly simplifies the process and reduces hold time in customs. Hold time is three to four business days after Lean application in the customs clearance process.

TPM and Standardized Work

Total Productive Maintenance *(TPM)* and Standardized Work are also implemented in the NPI project to strive for perfection by continually removing successive layers of waste after delivery to production.

Function	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
	New Repair Capability Evaluation	**Project Proceeds**	**Work in Progress**	**Prepare for New Cap FAA/ CAAC Application**	**Control Plan**	**New Cap FAA/ CAAC Application**	**End**
HSE					MOC		
QA	TTA Agreement			Self-Adult		Customer first article evaluation	
OPS	Ops labor and capacity study	Raise PR	Manufacture of tooling & fixture	Test stand modify		CSSC on site audit	
MM		Releasing PO	Extend P/N to 5020 in SAP				
FIN							Fixed Asset Requisition Form
CPS	Project market feasibility study	R&O Pricing					To distribute communication letter to airlines customers

FIGURE 3. *Functional teams engagement*

3. Conclusion

NPI project cycle time is significantly reduced after Lean application. The New NPI project process has been implemented in two NPI projects, aircraft APU fuel control project and engine air turbine starter new capability project. It has been proved that APU fuel control project is completed within ten months and air turbine starter new capability project ends at the tenth month, there by project cycle time reduced by 25% on average. Our repair and overhaul service center is currently using the two new capabilities to provide repair and overhaul service to airline customers.

We have now set our goal of project cycle time to seven to nine months for our repair and overhaul NPI project. Before Lean application our cycle time target was twelve to eighteen months for a new capability project.

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ABBREVIATION

- APU - Auxiliary Power Units
- AMS - Air Management System
- CAAC - Civil Aviation Administration of China
- CAPEX - Capital Expenditure
- CPS - Capital Planning System
- CRS - Capital Routing System
- DIP - Design in Progress
- FAA - Federal Aviation Administration
- FCU - Fuel Control Unit
- HMU - Hydro Mechanical Unit
- HSE - Health Safety Environmental
- MOC - Management of Change
- NPI - New Product Introduction
- OEM - Original Equipment Manufacturer
- ORI - Return on Investment
- R&O - Repair and Overhaul
- TAT - Turn Around Time
- TTA - Technology Transfer Agreement
- VPD - Velocity Project Development
- VSM - Value Stream Map
- WIP - Work in Process

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