

Lean Engineering - Best Practice in the Automotive Industry

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1. What is Lean Engineering?

The Toyota Production System (TPS) was developed in the automotive industry over several decades by Taiichi Ohno (Ohno 1988). Womack, Jones & Roos (1991) benchmarked Toyota against other automotive manufacturers and found that they were the industry leader in virtually measure. The successes of companies applying these lean techniques in a manufacturing environment have been well documented in *Becoming Lean* (Liker, 1997). Lead time, quality and productivity improvements on the order of 25-75% are common place when lean systems are aggressively implemented in traditional manufacturing environments. More recent studies on Toyota's Product Development System (Morgan 2001) demonstrate that one of the key enablers of a Lean Production System is a Lean Product & Process Development System.

Lean Product Development (or Lean Engineering) affects many organizations within an enterprise including Purchasing, Sales, Finance and Manufacturing. At the center of Product Development is clearly the Engineering organization. Morgan & Liker (2006) have shown that 3 elements must be integrated to create a high-performance Product & Process Development (PPD) System.

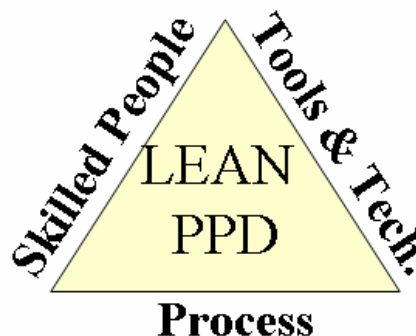


Fig. 1: Lean Engineering Principles (Lean product process development)

To create a Lean Product Development System, we must start by creating a Lean process. Once a Lean process is well defined, we can then implement the correct Lean Tools & Technology to support the process and develop the skilled people needed to work in the process. In their book, Morgan & Liker present in detail the techniques used by Toyota to form a Lean Product & Process System. This paper demonstrates the application of some of these Lean tools & processes and a methodology to implement a Lean PPD System.

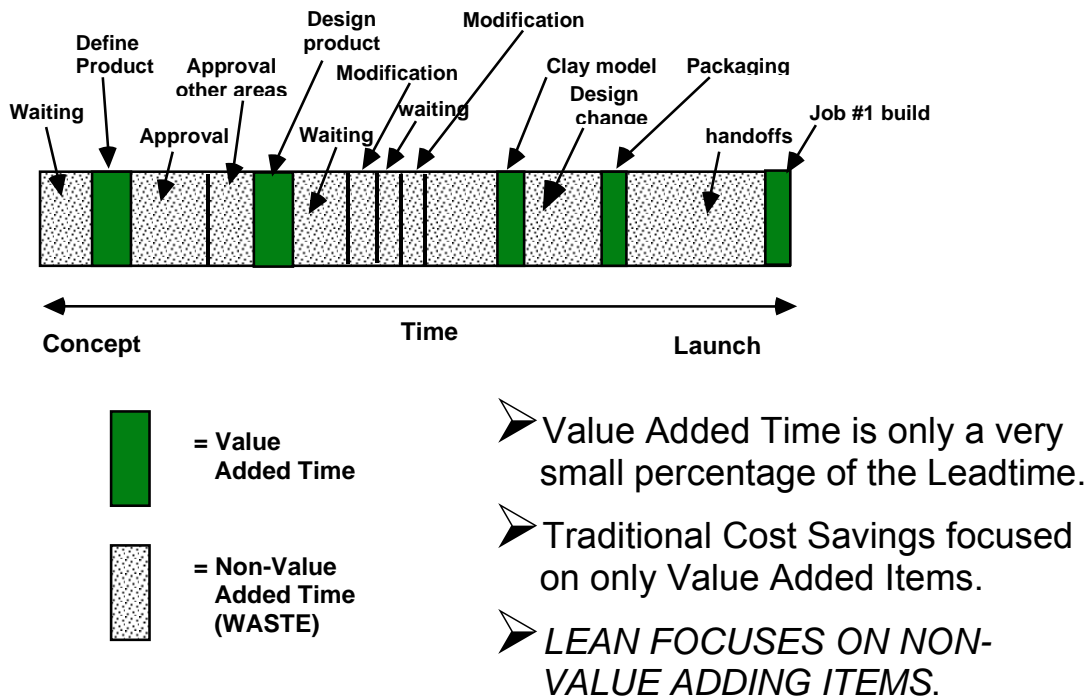


Fig. 2: Product Development Lead Time

When starting with a typical product development process, the added value part is only a small percentage of the whole process time, typically less than 10 %. This is due to some numerous steps which do not bring any value to the process. This “waste” is what slows down the development process and uses up key engineering resources. It has been shown that the lead time of a process is directly related to the part of waste. The longer the lead time is the more waste there is in the process.

Traditional improvement efforts to reduce the lead time have been to optimize the added value part by adding or refining some tools like

- high performance CAD systems
- Computation Aided Engineering, etc

Inversely the lean thinking consists of detecting and eliminating the waste. Typical wastes found in product development include: hand-offs, waiting, external quality enforcement, reinvention, non-value added transactions, lack of system discipline, arrival & process variation, system over-utilization, large batches, redundant tasks, stop & go tasks and unsynchronized concurrent engineering. Continuously attacking these wastes are at the heart of creating a Lean PPD System; the following sections provide examples of applying Lean tools & techniques to systematically eliminate waste.

2. Why Lean Engineering at Tenneco?

In 2004 Tenneco decided to expand the lean concept to the engineering world, especially in development and advanced engineering activities.

The objectives were multiple. Firstly, Tenneco as a major exhaust system supplier to automotive manufacturers, needed to face the ever growing demands from OEMs to take over broader tasks and responsibilities in the development, especially in the fields of

- CAD
- CAE
- Testing

Secondly, Tenneco decided to invest more in the area of research and advanced engineering in order to get more competitive and attract new customers. The emphasis was on the development of new products, new methodologies and tools, like CAD, CAE and testing. The main challenge was to meet these new requirements without getting any additional resources.

“Lean Engineering”, also called “Lean Product & Process Development” was introduced to solve these contradictory requirements. In a long-term strategy the introduction of Lean Engineering aims at changing the company culture and finding a new way to make business.

Lean Engineering shows us how to improve our processes in the engineering field with the aim to be more efficient by minimizing the existing waste in the current processes. Thanks to the obtained efficiency Tenneco is now in a position to gain manpower from the current process and finally to use it for high added value activities like research and advanced engineering.

3. What does Lean Engineering cover at Tenneco?

Lean Engineering covers 4 main domains:

- Processes: engineering processes including CAD, CAE and testing
- Tools: Standardization of product components and norms, knowledge books
- Skilled People: emphasis on training and mentoring.
- Visual management: “Obeya” room for projects and status boards for support functions

4. How is Lean Engineering practiced at Tenneco?

A specific and original methodology has been developed to introduce, run and sustain the lean activities. The goal is to transfer the lean thinking to the day-to-day work that is done in each area of the enterprise. This process consists of:

4.1 The identification of key issues to be addressed in the engineering world

A steering committee has the task and responsibility to define the critical areas to improve in the product development system. Members of this committee are senior managers, customer team directors and key technical experts. In addition to providing guidance, the committee reviews the progress on implementation on a monthly basis and if necessary triggers some corrective actions to accelerate implementation.

4.2 The definition of the selected projects

For each proposed project, a champion and team leader create a “scope sheet” that details the content, objectives, timing and resources required for the project. This sheet is submitted to the steering committee for discussion and approval.

<i>CONTINUOUS IMPROVEMENT EVENT SCOPE</i>	
<p>Event Description: 3. Technical Reports by the Acoustics Center</p>	<p>Event Dates: Workshop: Oct 11 – 14 , 2004. Week 42</p>
<p>Preliminary Objectives:</p> <ul style="list-style-type: none"> •High level of standardisation and automatisisation •Improved quality and overview •Link between customer and team requirements and report topics •Link between CAE and acoustics data •Report database 	<p>P. Garcia's office, R+D build., room 4.14</p>
<p>Customer Requirements (TAKT Time):</p> <ul style="list-style-type: none"> • to react quicker, more information on one page 	<p>Champion: Patrick Garcia Team Leader: D. W. Co-Leader: B. S.</p>
<p>Process Information:</p> <ul style="list-style-type: none"> •Esprit / ASLM Flow Chart •Basic reports •Requirement sheet for reports •Template overview. 	<p>Team Members Acoustics Technicians Acoustic Application Engineers System Integrators</p>
	<p>Facilitator: J Drogosz</p>
	<p>Consultant: U of M.</p>
	<p>Current Situation and Problems:</p> <ul style="list-style-type: none"> • Number of reports per year • High effort to create a report • Quality and information of reports criticized

Fig. 3: Scope Sheet

Most projects consist of a cross-functional team of typically 5 – 7 persons led by the project leader who reports to the champion.

4.3 Lean PPD-training program

An in-depth 5-day Lean PPD course was conducted by the University of Michigan for key personnel who were tasked to drive implementation of Lean Engineering. In addition, training and awareness was done at 2 additional levels:

- a 1-day-executive-program for managers
- a ½ -day-program for all employees

More than 300 persons were trained within 15 months



Fig 4: photo; Training class

4.4 Lean Implementation

Lean project implementation generally last between 6 months and not more than 9 months. They are divided into 3 main phases:

Phase 1: Lean Event

Phase 1 starts with a 4-day-on-site-workshop (Lean Event) during which the participants go to the place where the work is done, so called “Gemba “, to collect the required data on the current process and identify the wastes by creating a current state map. In a second step they define the future state map that incorporates lean tools and techniques to reduce the waste. In the third step, an action plan is created to close the gap between the current and the future state maps. The team then starts to work on implementation immediately during the workshop for 1 – 2 days. By the end of the workshop, the new process is documented and metrics are established that will be tracked in upcoming months as implementation is completed. Several workshops are typically run in parallel and supported by a Lean Sensei to help guide and challenge the groups through the process.

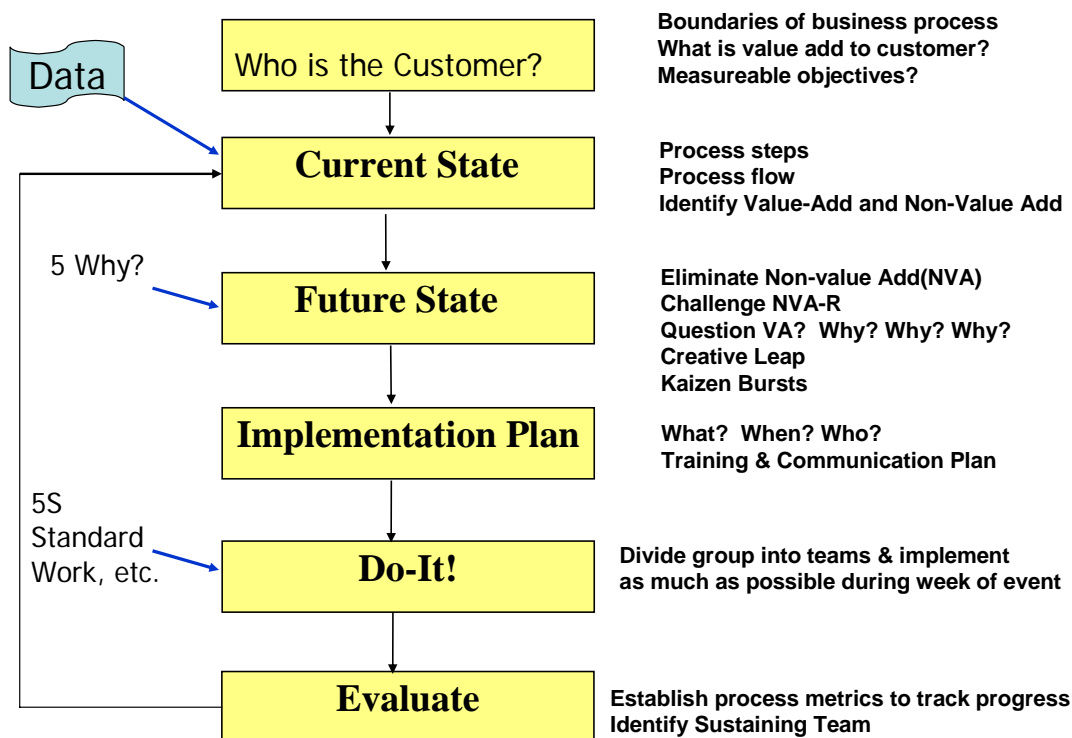


Fig 5: Flow of Lean Event

At the end of these 4 introductory days the results are presented to the Senior Management.



Fig 6: photo; Presentation to the Senior Management

Phase 2: Further implementation.

Weekly team meetings are held by the team leader to ensure that the implementation plan is properly running. Furthermore the progress and the results of each workshop are tracked monthly in form of a report out. Senior Management and Lean Sensei are actively participating in these monthly meetings, not only to get an update but also to support critical issues of the implementation plan if needed.

The current state of the in parallel running workshops is documented and distributed to all steering committee members. The implementation phase typically lasts between 3 and 6 months.

Lean Events Overview Wave2 Feb 05 - Sept 05

Status: 01.09.2005

Nr.	Title	Project leader / Champion	Objectives	Metrics	Project-status	% compl	Comments
1	FEA Automation Post processing	Hr.S. Hr.F.	<ul style="list-style-type: none"> • Optimisation of the computation phase = reduce lead time • Standardization postprocessing phase (report formats) • Automatization postprocessing phase (process) 	<ul style="list-style-type: none"> • Computation and post processing leadtime • Number of reports 		80	not communicated
2	Design Process. (Phase 2) EDE and Rybnik	Hr.K. Hr.H.	<ul style="list-style-type: none"> • Building of a supermarket. (Kanban) • BOS metrics monthly based on input data of task delegation form • Establish a blueprint of electronical workflow in SAP. Mapping of the Kanban System. 	<ul style="list-style-type: none"> • Value ratio • On-time delivery in % 		80	not communicated
3	Standardization of Products. Mufflers. Cross sections (Baffles/Endplate/ho using) (OE & AM)	Hr.B. Hr.W.	<ul style="list-style-type: none"> • To obtain an high degree of product standardization (OE/AM) • Clean up of the Cross sections catalog. • Documentation with plant nomination • Catalog transfer from Intranet to PDM ? • Current process to be described • AM involvement. Common catalog 	<ul style="list-style-type: none"> • no's of X-Section 		80	not communicated
4	Preparation of Quotation until CQA /Gate2	Hr.S. Hr.D.	<ul style="list-style-type: none"> • Alignment Engineering CC/CS • Team/Manufacturing • Standardization of the whole process • Improvement of data for management decision • Alignment of process to DIN/ISO 	<ul style="list-style-type: none"> • On Time Achievement of Tasks (OTAM) • Meeting Attendance during Quotation Phase 		80	not communicated
5	Optimization of Quality Matrix for Manifold Concept Development	Hr.G. Hr.S.	<ul style="list-style-type: none"> • To involve less People in Process • To avoid Meetings • To improve Data Exchange and Information Flow • To avoid useless Design Loops • To avoid non compliant Designs • Readiness of Input Data for KBE Methodology • To make sure that all Guide Lines are involved 	<ul style="list-style-type: none"> • Number of QM 		100	not communicated

Fig 7: Overview of the Lean Activities.
Monthly report to track the progress of each Lean Event

Phase 3: Sustain phase

This is probably the most critical phase. It must be ensured that the new process, the so-called future state map is actually being consistently used in the day-to-day work. The metrics must show at least 3 months of consistent results at the targeted levels after the implementation phase. Once this is achieved, the workshop is officially closed by the steering committee. It is then the responsibility of the team leader and champion to start the process all over again by creating a new scope sheet to propose to the steering committee another project to continuously improve their area of responsibility.

The figure below summarizes the Lean Engineering implementation methodology.

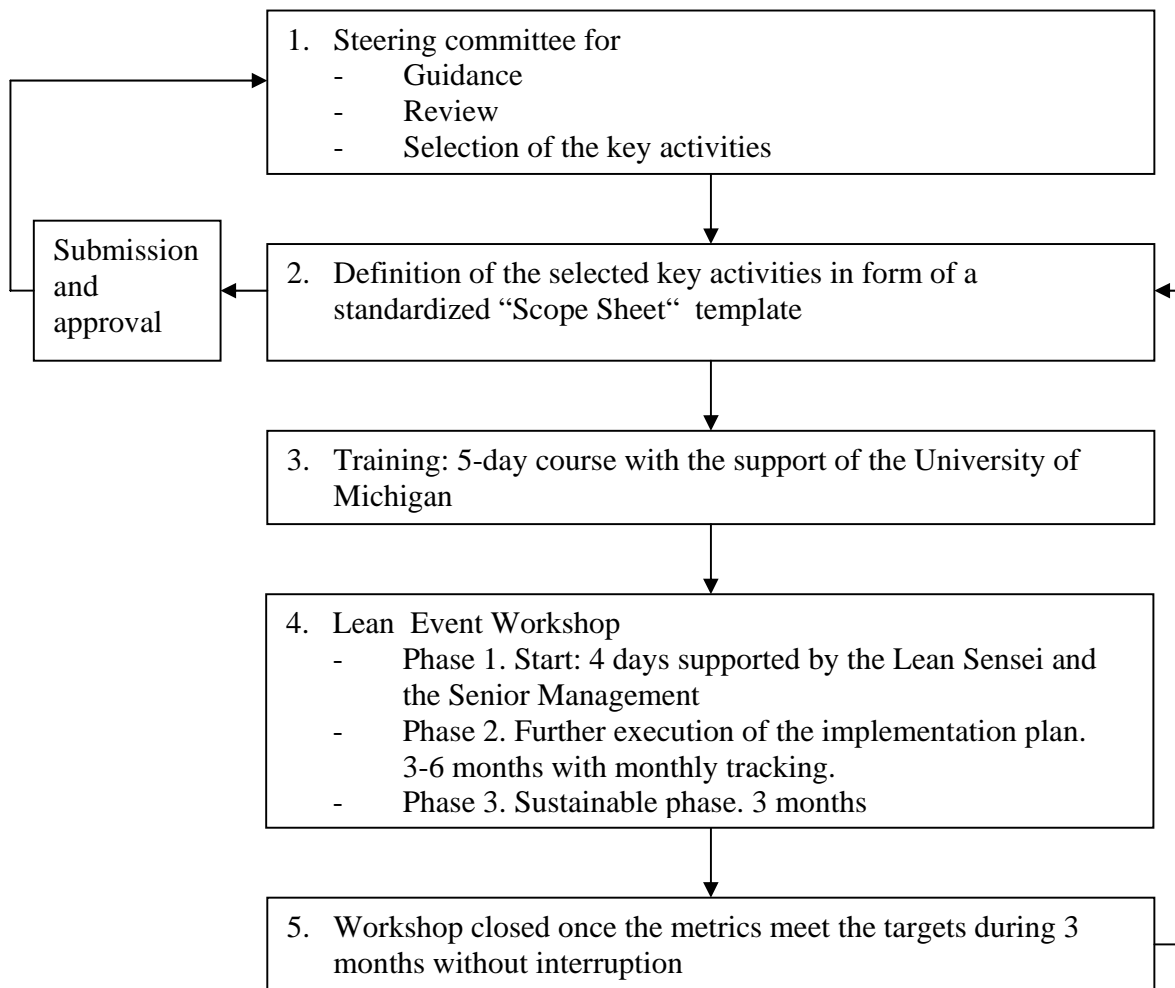


Fig 8: Process to identify, define, track and close the Lean Engineering activities

The following sections provide specific examples of the above process in action.

5. Case 1: Acoustics Test Report

During the development of an exhaust system the first prototypes need to be tested and the acoustic performance has to be documented in form of an acoustics report. Typically the tests are run on a chassis dyno using a vehicle or on an engine dyno and the engineers need the results as soon as possible so they may continue with their development efforts.

During the Lean Event, the team began with an analysis of the current process by interviewing more than 15 key people involved throughout the whole process. Based on this study it was discovered that:

- 2 reports were issued for the same test program. The acoustics engineers used their own format which was again rewritten by the systems integrator
- For each customer a different format was used!
- High amount of work due to unclear tasks and objectives
- 2 local data supermarkets with redundant information

The current state map below shows these wastes.

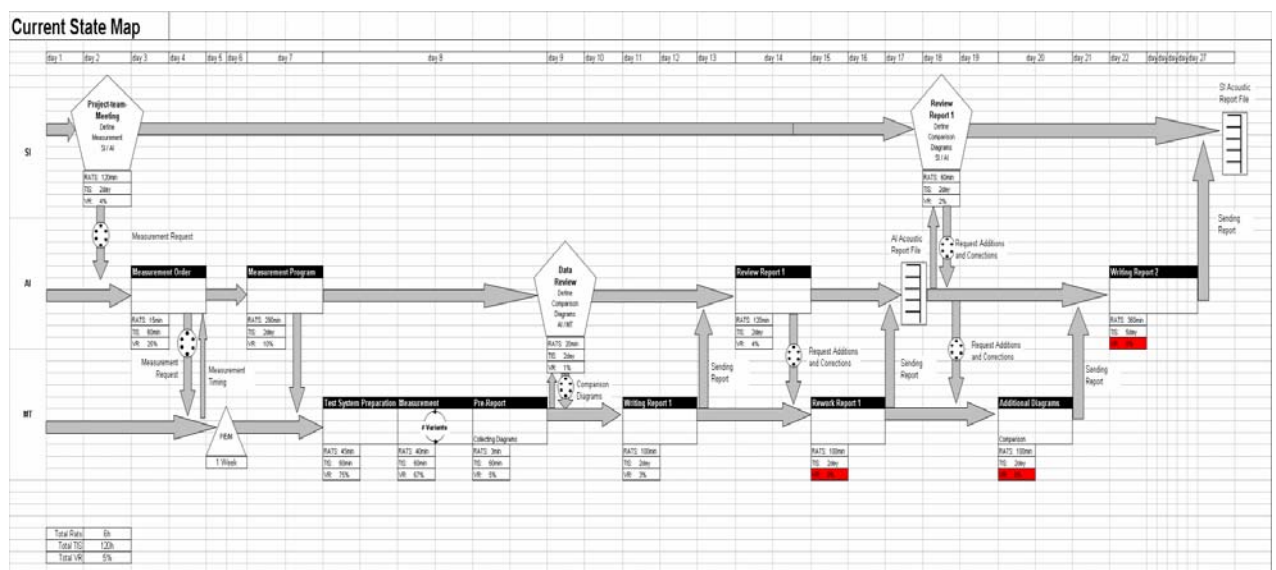


Fig 9: Current State Map

Applying some of the lean tools to eliminate the wastes, the team ended up with a future state map that included the following changes:

- One standardized report to cover the needs of acoustics engineers and the system integrator. This was done to avoid unnecessary changes due to personnel requirements.

- This format is to be applied to all the customers. Therefore the number of format decreased from 7 reports to 1.
- One meeting of all involved people directly after the measurement to clarify all future tasks. The acoustics engineer leading the meeting is guided by a check list and an order analysis form to ensure that only needed tasks are performed.
- Central measurement order and measurement report files are stored in a data supermarket to avoid local data stores
- Online data analysis.

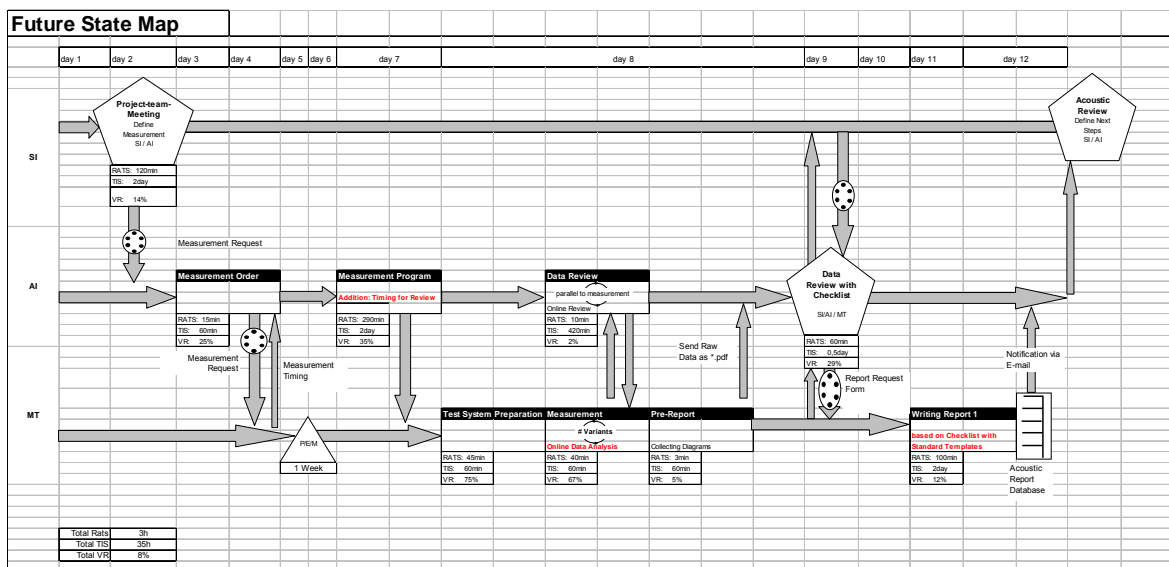


Fig 10: Future State Map

To come to this future state map an implementation was done

The key improvement highlights are

- Alignment of objectives and tasks between the active participants, acoustics engineers, system integrators and acoustics technicians
- Improved information flow by checklist and detailed measurement order
- Standardized report format
- Standardized test diagram format
- Central data base instead of multiple local databases
- Simultaneous data acquisition and pre-analysis

These improvements are tracked by 2 defined metrics (fig 11)

- the number of report templates from more than 7 to one standard template
- the speed of establishing a report from 19 days to 3 days

and are summarized in one sheet document (fig 12).

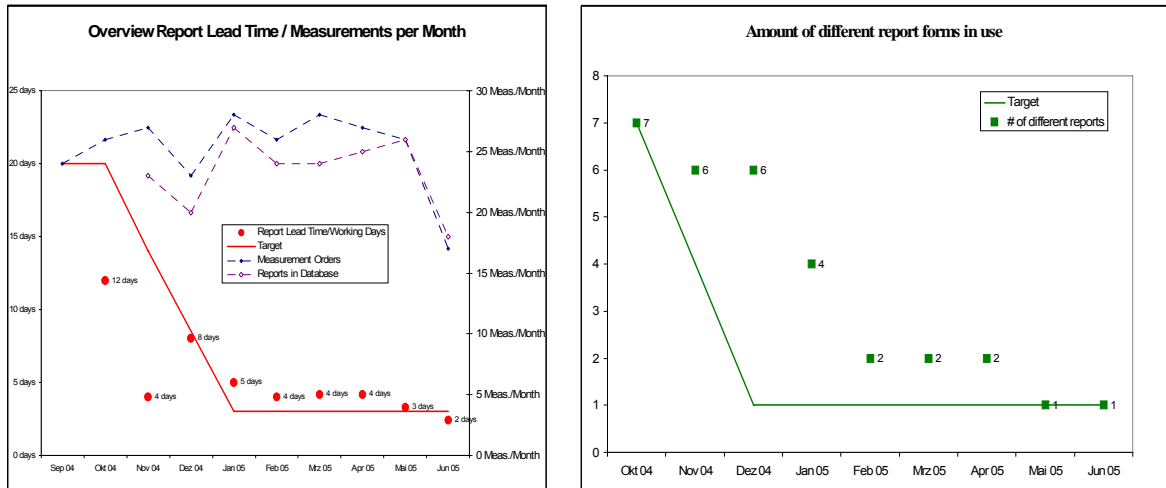


Fig 11: Metrics

CONTINUOUS IMPROVEMENT EVENT OBJECTIVES / RESULTS SUMMARY				
EVENT AREA: Technical Reports by the Acoustics Center		EVENT DATES: Oct 11-14, 2004		
DRIVER MEASURE	PRE-EVENT	OBJECTIVE	POST-EVENT	% IMPROVED
IMPACT ACTIVITIES (LEAN MFG COUNTERMEASURES)				
# report types	7	1	1	86%
# of preliminary report	3	0	0	100%
Data supermarket	7 local	1 central	1	86%
Productivity: Work time to create reports	15 h	3 h	4 h	80%
Productivity: Interpretation time of report	3.5 h	60 min	60 min	71%
Lead Time: Measurement done to internal report done	19 days	3 days	4 days	84,0%

Fig 12. Results Summary

6. Case 2: Standardization of Components

A typical component for exhaust systems is for the muffler cross section. There are several parameters for a given cross section, they include:

- type: oval round, triangular
- dimensions
- material
- wall thickness

The current state was a non-uniform list of cross sections for original equipment (OEM) applications and aftermarket (AM) applications.

During 3 workshops of nearly 6 months each we were very successful to

- create a new standard for cross sections for both, OEM and AM
- drastically limit the number of new cross sections by defining a check list and a process to be fulfilled if a new cross section has to be created.
- set up a cross section database

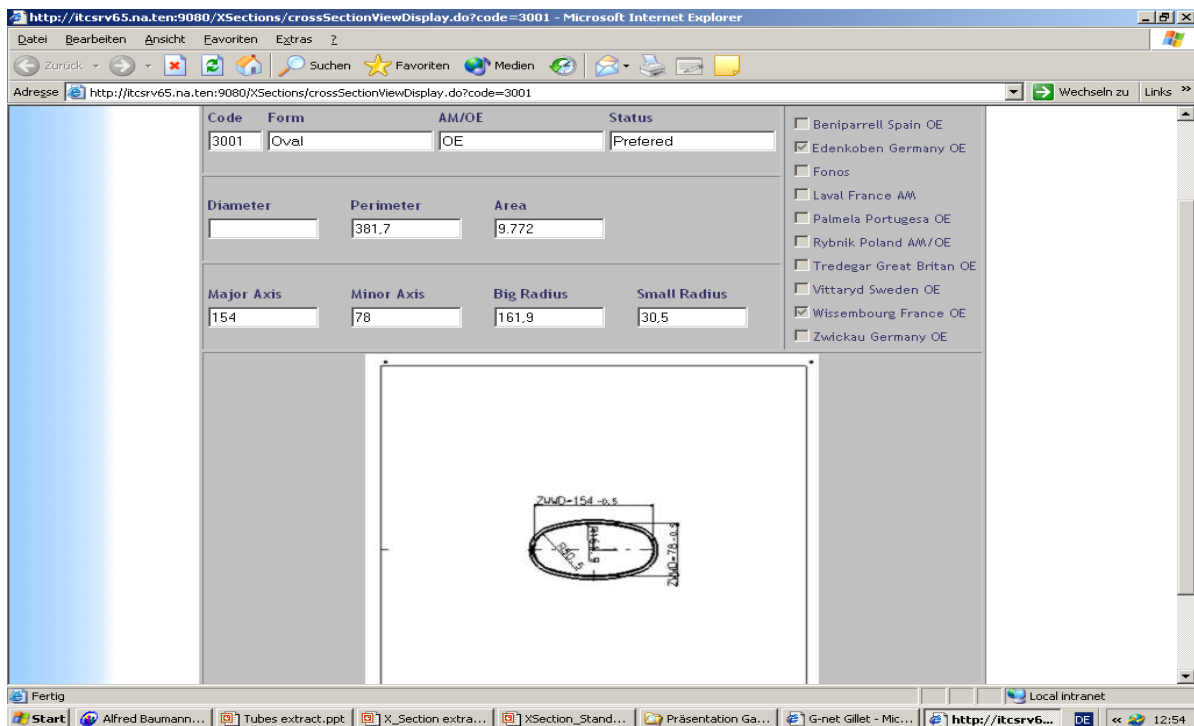


Fig 13: Screen Shot; Database

Through the lean workshops, the major improvement was the decrease of the number of cross sections by 50 % in 3 steps. Some issues related to

- different cross section numeration system for OE and AM
- manufacturing capacity
- quality and ownership of tooling

were also solved. Clearly, by reducing the number of cross-section, the manufacturing plants will be able to reduce the number of parts and quantities they need to hold in their supermarkets. In addition, there is less chance of parts being accidentally mixed up by line operators. Likewise, fewer parts will need to be tracked and warehoused for aftermarket sales.

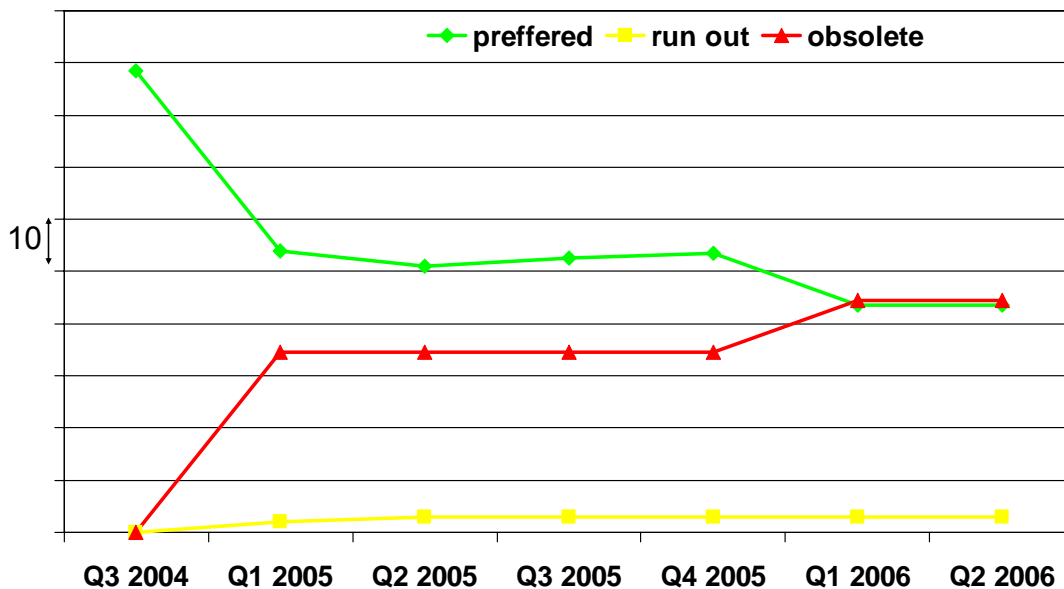


Fig 14: Spun Muffler Standardization; Reduction of Cross Sections

7. Conclusions

Lean Engineering has been introduced for nearly 2 years at Tenneco Europe Emission Control. In total more than 20 workshops of duration of 9 months in average have been conducted, 300 people educated and more than one third have already gained experience in implementation.

The collected experience shows that the success of such initiative is strongly dependant upon the following key factors:

- Train and communicate. It is essential to bring the message that lean is about eliminating the waste and not eliminating the number of heads. As expected the training gives the tools and techniques necessary to solve problems and implement countermeasures. All people within the organization need some level of training or at least awareness of lean principles in order to understand and accept the changes from a traditional to a Lean culture. Successes must also be communicated to the organization on a regular basis.
- Couple Lean training and workshop implementation. It ensures that what has been learnt will be applied right away and as a result learning will be retained!
- Track progress and report out on a monthly basis. The sustain phase is the most critical phase in the lean process. A robust review process with leadership helps to sustain the gains and continuously improve
- Get support by a professional with great experience (Sensei) They will provide the necessary guidance to senior management and provide a new perspective to your system.
- Active support of the Senior management. Senior Management must lead by example and be consistent in their expectations. People will take lean thinking seriously if their leadership are doing it themselves!
- Involve the people who do the work in the workshops and implementation. People are more prone to buy-in if they have been part of the process.

After these first 2 years Tenneco-Europe has already seen the following:

- The motivation and moral of our engineering community are higher. The involved engineers and technicians have the confirmation that they can act on their processes in a simple and effective manner.
- Beyond the formal lean methodology some key persons are already taking the initiative of changing the way of doing business and integrating stepwise this continuous improvement spirit into their departments.
- Some free-up resources are now being used to conduct some additional lean events and doing other value-added activities like product standardization, CAE and testing activities, and Knowledge Based Engineering.

A lot of work has been done to date but there is still more before arriving to a truly Lean Product and Process Development System. Continuing to use the methodology outlined in this paper, there is no doubt that it will be achieved in the years to come.

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