Lean Strategies for Future Body Shop Development and Operation in the Automotive Industry

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Submitted to the MIT Sloan School of Management and the Engineering Systems Division in Partial Fulfillment of the Requirements for the Degrees of

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Abstract

There are several body shops which are similar by size of workforce, level of utilization and product complexity but which differ considerably by investment required, shop size, uptime, inventory levels and quality accomplished. The purpose of this thesis is to explain why those differences exist. The methods used to understand differences were direct observation, first hand working experience on the line and participation in workshops, analysis of internal and external bibliography, and interviews to line workers, supervisors and managers within different functions. Differences are observed and described in the design and operation of the shops. A "Lean" body shop, named in such a way given their reduced use of resources to accomplish better results, follow an integrated design process where product and process are tightly integrated, maintain similar product architectures across generations enhancing standardization and modularity, similar shop architectures across plants, close relationships with suppliers, elimination of complexity in manufacturing processes, flexible conveyance processes and the use of proven technologies. In addition, a lean body shop's operation works as a coherent and integrated set of practices under three systems: *The Social System*: Engagement and development of workforce that acts as enabler; *The Technical System*: Tools to reduce waste and increase quality; *The Problem Solving & Continues Improvement System*: An ever learning and improving organization where problems are visualized, solved and countermeasures implemented and shared. Finally, this thesis provides insights into the change management processes associated with the transformation into lean body shops, from establishing a sense of urgency and guiding coalition to empowering broad based action employee action and anchoring new approaches in the culture, and performs a case analysis on a successful lean transformation: NUMMI.

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Chapter 1 - Background

This thesis is meant to explain why some body shops outperform others, what management can do to increase performance of the laggard sites, and how what is learned from comparing across body shops can help improve other areas within our outside the automotive industry. **Chapter 1** will explain why body shop performance—and sources for differences in performance—are a topic of strong interest. In short, body shops can have a large impact of cost - due to their capital intensiveness –, quality – due to their influence in dimensional accuracy-, and flexibility - based on the number of models they can support -. This will lead to the problem statement to try to understand the differences in performance and then generate a hypothesis around how body shops are designed and operated. **Chapter 2** will explain the research methods used to understand and document the differences. **Chapter 3** shares the observations, discusses and explains why these two different body shops have different performance as well as how a transformation to a lean shop can be accomplished. Finally, **Chapter 5** provides recommendations to General Motors, other industries or firms, highlights limitations on the research, conclusions and application, and offers opportunities for further research in the area.

1.1 Introduction

The auto industry is in the middle of a transformation. The recent economic downturn has highlighted the true inefficiencies within the industry and proven that there is still room for improvement.

Specifically, General Motors has taken huge leaps in their improvement journey since the 80s. Quality has skyrocketed as can be seen by JD Power awards to a long list of its vehicles. But on its relentless pursuit for improvement there are still numerous opportunities one of which will be explored in this thesis.

In the industry, one of the areas where less attention has been given is the design and operation of the body shop, as show by the focus of existing productivity benchmarks such as the The Harbour Report (Harbour, 2008). One of the reasons of this lower historic interest is the reduced number of workers involved, compared for instance to assembly. Nevertheless, a body shop can have a large impact on a) cost, given their capital intensiveness and space requirements b) quality, since it is the first place where the car is shaped as such hence greatly impacting dimensional accuracy c) flexibility, since it constrains the number of vehicles that can be produced in a factory. This thesis will try to shed some light in this space.

1.2 Problem Statement

There are significant differences in performance across body shops in terms of investment, size and quality as shown in table 1 where a comparison between two plans. One will be coined as "Lean Body Shop" given the reduced use of resources (investment, size, inventory) while accomplishing higher quality. The other will be named "Traditional" in contrast.

Note that in order to keep confidentiality of the real information, for each metric the traditional body shop number sets the baseline (100%) and then a value is determined for the lean body shop on a percentage basis. For instance, if in a traditional shop the cost of a shop were to be $100 million, a 27% value for the lean body shop would mean that the new shop would cost $27 million.

Table 1: Performance comparison between traditional and lean body shop

Metric	Traditional Body Shop	Lean Body Shop
Investment ($)	100%	27%
Shop size *(sq ft)*	100%	55%
Uptime *(% of time system available)*	100%	125%
Work in process *(inventory in the system)*	100%	17%
Scrap rate *(% material wasted)*	100%	42%

The data displayed represents two different unionized body shops within the same company, in the same country, with similar levels of utilization, product complexity, outsourcing degree and automation level (number of operators). The numbers were directly obtained from an internal benchmarking database updated regularly and with consistent metrics across body shops.

This document tries to further understand some of the reasons and explanations behind this visible contrast. Hence, this project will help provide a better understanding of the philosophies and details GM and other companies in their lean journey might benefit from and that will enable them to move more quickly in making improvements. It will also introduce ideas on how to successfully implement such changes.

1.3 Hypothesis

This project intends to inductively answer the research question of why body shops, such as the two detailed in the problem statement, have different performance. The hypothesis is that there are certain characteristics in their design and operations that explain the better performance.

Firstly, there are key differences on how the body shops are designed: the process for designing them, the approach towards product architecture and body shop architecture, the relationship with suppliers, the manufacturing processes selected and associated technologies, the conveyance processes selected, and how tooling is approached.

Secondly, there are key characteristics in how these body shops are operated. These characteristics are: : 1) a social system that engages workers, 2) a continuous improvement system that enables workers to follow a structured process in problem solving and 3) a technical system that implements tools to reduce waste and improve quality.

1.5 Introduction to General Motors

General Motors Company, one of the world's largest automakers, traces its roots back to 1908. With its global headquarters in Detroit, GM employs 235,000 people in every major region of the world and does business in some 140 countries. GM and its strategic partners produce cars and trucks in 34 countries, and sell and service these vehicles through the following brands: Buick, Cadillac, Chevrolet, GMC, GM Daewoo, Holden, Opel, Vauxhall and Wuling. GM's largest national market is the United States, followed by China, Brazil, the United Kingdom, Canada, Russia and Germany. In addition, GM's OnStar subsidiary is the industry leader in vehicle safety, security and information services.

1.6 Introduction to Lean Literature

In order to review existing literature, we first look into the origins of "Lean". The term "Lean" was coined in a 1988 article in the Sloan Management Review (Krafcik, 1988). Its roots came from the efforts of Japanese firms to rebuild and attain competitiveness after World War II in an environment of low demand volumes and low capital available, as very well explained by Womack (Womack, 1990). By the 1980's, an awareness of this competitive advantage was beginning to be recognized. In "The Machine That Changed the World" by James Womack, Daniel Jones, and Daniel Roos (Womack, 1990) and as part of the MIT International Motor Vehicle Program they discuss the results of a 5-year study of Toyota and other auto manufacturers to discover the differences between Toyota's production strategy and traditional mass production . The ideas of lean manufacturing were further explored in

case study form in the author's subsequent book, "Lean thinking" (Womack, 1996). Here they provided a definition to Lean: *Lean thinking provides a way to specify value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively. In short, lean thinking is lean because it provides a way to do more with less—less human effort, less equipment, less time, and less space—while coming closer to providing customers with exactly what they want.* In addition, Taiichi Ohno much earlier provided the following goal for the Toyota Production System: "*To reduce costs and maximize profits through total elimination of waste*".

In addition to James Womack and Taiichi Ohno and his collaborators, there have been many other renowned authors that have contributed to the body of knowledge of Lean, such as Jeffry Liker, Steven Spear, Yasuhiro Monden, John Shook, Takahiro Fujimoto, or to some specifics building blocks within lean such as Shigeo Shingo, Imai Masaaki, Nakajima, Edward Deming, Genichi Taguchi all of which will be cited as appropriate throughout this document.

Specifically on the lean design of systems, Morgan and Liker (2006) in their book "The Toyota Product Development System", Allen Ward (Ward, 2007) in his book "Lean Product and Process Development" and Womack et al (1990) in "The Machine that Changed the World" provide a good explanation on the lean philosophies applied to product design.

Chapter 2 – Methodology

The purpose of this chapter is to explain what was measured and how it was measured, in order to collect data and enable its discussion In order to understand differences in the design and operation (technical, social, and continuous improvement systems), the following methods were used:

2.1 Methods for determining differences in body shop design

The methodology for determining differences in product design was first to identify categories (e.g. design process, product architecture…) and then proceed with interviews to body shop development teams exposed to different body shops, plus analysis of current literature on lean product development to gather qualitative insights into each category.

2.2 Methods for determining differences in social systems

The methods used for determining differences in social systems were first interviews to line workers, direct observation between the relationships of workers and management and analysis of existing literature in employee empowerment, distributed leadership and social systems.

2.3 Methods for determining differences in technical systems

The main method for determining differences was the analysis of external literature on the different elements (e.g. SMED, TPM, Kanban, Continuous Flow, Standardized Work…), direct observation on the floor of the latter, trainings on the different elements and firsthand experience on the line.

2.4 Methods for determining differences in continuous improvement systems

In the continuous improvement system we focused on the process that different body shops follow from the problem detection, through the problem solution and to the sharing of that knowledge. As methods, we employed direct observation of the shop floor, interviews at different levels of the organization (line workers, supervisors, managers and executives). This was reinforced by trainings, workshops, first line working experience as well as analysis if internal and external literature. Finally, and outside auto manufacturer's facilities, interviews have been conducted with subject experts in areas such as lean thinking, leadership or lean transformations within the Massachusetts Institute of Technology and the Lean Enterprise Institute.

Chapter 3 - Analysis and Discussion

Following the methodology described in Chapter 2 we collected some observations which will be described and discussed throughout this chapter. We will split the discussion into the design phase and the operation phase. A summary is provided in table 2 and 3, respectively.

Table 2. Differences between lean and traditional body shops during the design phase

	Traditional	Lean
Design Process	Fully centralized design, with siloed functional areas	Involvement of final plant in design and seamless integration of product and process design
Product Architecture	Sharing of parts across model and generation is limited	High degree of product commonality across new models and generations
Shop Architecture	Each plant is different	Different plants share similar layouts; Reduced shop size
Suppliers	Reduced development of suppliers; Selection mainly based on cost	Joint improvement efforts, sharing of benefits
Manufacturing processes	Complex processes	Reduced complexity and automation used mainly to support worker
Conveyance processes	Fixed monuments used for conveyance	Flexible conveyance processes
Technologies and equipment	Use of unproven technologies	Technologies thoroughly trialed and tested; flexible equipment
Tooling	Tooling fully done centrally	Engagement of final user in tooling design

Table 3: Differences between lean and traditional body shops during operation

	Traditional	Lean
Social System	Frequent blaming, lack of communication, alignment and greater purpose, workers are just told what to do, narrow job descriptions, lack of training and development	Engagement of workforce through respect, teamwork, communication, trust; Empowerment and accountability of those at the lowest level of the organization; Culture that supports learning
Technical System	Limited standardized work in place or followed, errors frequent and carried over through several process steps, large buffers	Tools implemented and in use focused on performance of individual steps (e.g. error proof systems, standard work, TPM), organization of steps to produce final output (e.g. continuous flow, small lot) and hand offs or coordination of processes steps (e.g. Kanban)
Continuous Improvement System	Problems are not surfaced nor root caused but only solved, hence repetitively coming up.	Organization creates opportunities to visualize problems, follows structured process to problem solve them, experiments & performs trials, and standardizes and shares countermeasures

3.1 Body Shop Design: Differences between traditional and lean shops.

This section tries to provide a comparison and some insights into the Body Shop Design and what are the key characteristics that create the opportunity for a much leaner operation downstream. The main observations derived from the analysis of the design of lean body shops and traditional body shops will be grouped in 8 key dimensions:

3.1.1 Body Shop Design Process

The main differences identified through the methods previously described between the design processes of a traditional body shop and a lean body shop include the **level of integration between the workflow** and the **level of centralization.**

Regarding the first one, we have observed that a traditional body shop have a lack of integration of product design (the body) and manufacturing process design (the body shop), pushing work "over the fence" to each other. On the other hand, a lean body shop design has a seamless integration of product design and body shop manufacturing process design, working together and simultaneously, thus creating a high level of manufacturability and performance in the final designs. To support this discussion, James Morgan (Morgan, 2002) highlights the creation of highly synchronized cross-functional tasks as a key enabler of creating flow in the design process. In order to achieve such synchronization, some factors such a strong and formal project leader (also addressed by Womack, 1990), module development teams that work collaboratively, simultaneously and under common goals for an early integration when decisions have most impact in the success for the program, reflection to improve coordination or availability and sharing of common information are important.

Regarding the second point, the level of centralization, the traditional body shop appears to have designs finished 100% centrally and then executed on site by a central team that leaves the site when the project is completed. Hence, systems are overdesigned to avoid assistance of the central team over time and therefore increasing costs. For instance, excesive buffers or redundant machines are example of over designs of the body shop. The lean body shop, on the other hand, involves final users upfront giving a sense of ownership to the local site. In addition, local organizations are self-reliant, increasing uptime due to knowledge of their system, but at the same time share learnings at a global level.

3.1.2 Product Architecture

From the body architecture perspective, the main differences observed between a traditional body shop and a lean body shop include the **body architectural changes across new models, body architectural changes over model generations and the platform expertise.**

First, traditional body shops have models with different architectures, and the level of commonality between new models (among new product introductions) is very limited. On the other hand, the lean body shop has products with high degree of commonalities across models, which makes plants more flexible to switch from one model to another, reuses the equipment between the models as well as builds on common learnings for the new models.

Second, traditional body shops have each model generation (former and new product introduction) with new architectures, with the level of carry over very limited. There are also structural changes done to non customer visible parts. On the other hand, lean body shops have different generations of the same model with only changes in the visible parts, changes that are focused on the aesthetics. This enables the number of changes (e.g. new machinery, new tooling, new designs, new suppliers) to be reduced, maximizing the number of carry over parts between generations.

Architectural commonality is closely linked to standardization. It implies the use of the same equipment across multiple models and variants, and product lifecycles, either because the product elements are the same, the manufacturing elements are the same or because they embed flexibility (e.g. the same framing station able to work for different bodies). Manufacturing standardization can be at three levels: manufacturing processes (assembly sequence, clamping points, number of spots, joining technologies), configurations and setup of cells and systems (cell make up, jig configuration, transport mechanisms), and equipment components (robots, controls, welding guns). According to McKinsey (2006) examples of the first level (Manufacturing processes) are Toyota's new Global Body Line that standardizes the framing process across several car models, VW or Ford's main dimensions and joints that are standardized within platforms and Open's side panel cells designs. Secondly, BMW has standardized robot cell set-ups and logistics equipment which enables them to flexibly reuse existing equipment. Finally, DaimlerChrysler has standardized welding guns in its body shops from over 400 previously to fewer than 20 today.

The potential impact of standardization according to McKinsey (2006) is a 20% reduction in engineering costs due to standard design elements, 25% reduction in equipment costs due to improved sourcing opportunities, and +15% impact in equipment efficiency due to higher equipment and process reliability. Certainly, there will be an initial investment in the form of a significant initial effort

to establish standards and then an ongoing administration and updates. This means that the more number of models and variants the standards encompass, the quicker and higher the pay offs of the initiative. In addition, standardization becomes essential for enabling a short time to market.

The levers to implement such standardization can be (McKinsey, 2006): systematic implementation of simultaneous engineering processes, target-oriented definition of product design requirements by the production division – not only for visible cost drivers, but also for complexity drivers and close feedback loops between product development, equipment suppliers and production.

Thirdly, in traditional body shops most of the employees that design new generations of bodies are recent joins in the team. On the other hand, in lean body shop the expertise is kept between generations through some stability in the people involved so that carry over parts are maximized. This is accomplished with internal practices such as maintenance of platform experts within the teams, with promotions not necessarily meaning the experts will leave the group.

3.1.3 Body Shop Architecture / Layout

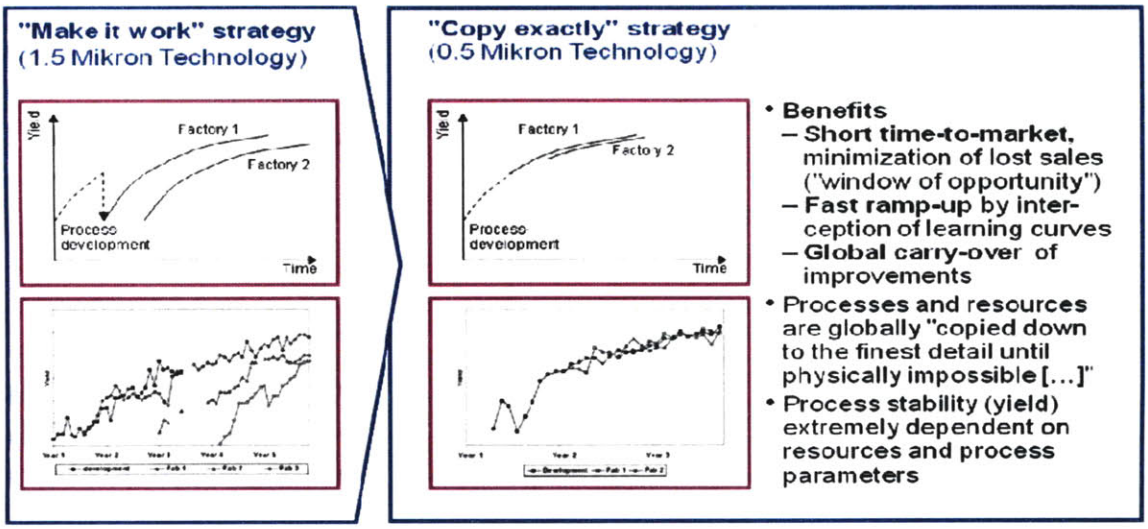
The main differences identified between a traditional body shop and a lean body shop include the **zoning strategy**, the **architecture across plants** and the **size**.

In a traditional body shop, for each car generation equipment is acquired and positioned as needed. There might be some grouping by state of value adding (e.g. parts / subassemblies / assembly lines) and there is typically no clear upfront decision on the lifetime of equipment in the different zones. On the other hand, a zoning strategy in a lean body shop defines the expected life of each equipment and re-use opportunities across models, and positions them in a way in which value added.

In addition, in a traditional body shop each plant is laid out differently which limits which models can be manufactured in which plants. Contrary to a traditional one, a lean body shop has very similar layouts across plants, with similar zones and equipment arrangements, making it easy to move products, people and knowledge across sites. Equipment's locations is fairly pre-determined and standardized, simplifying car model changes.

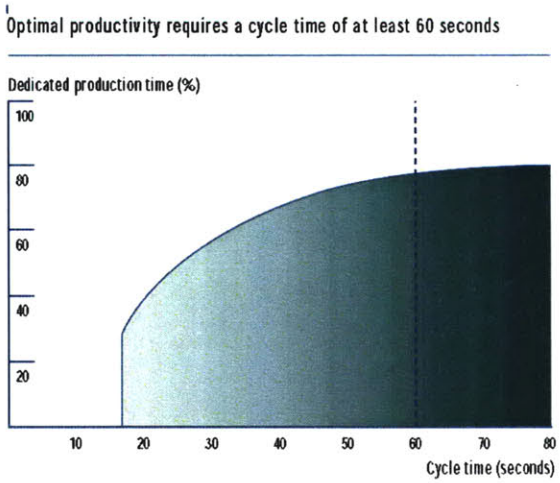
Having the same architecture across plants helps to drive higher economies of learning that can be obtained by transfer of experience across several production plants and lines and also helps with higher economies of scale which can obtained by the reuse of design and installation of applications for multiple plants. To support this argument and as a case analysis, in figure 1, we can see the impact of Intel's Copy Exactly practices.

Figure 1. Case analysis of Intel copy exactly. Source: McKinsey (2006)



Finally, a shocking difference between traditional and lean body shops is the size of the shop. On traditional shops, large buffers are required to avoid downtime which consequently increases the size of the overall body shop, and hence requiring longer conveyors, more walking and transportation. In addition, defects are slower to be discovered since they are buried in the work in process inventory, and processes are less synchronized. A lean shop is a small shop, with small buffers. Although the size is partly a consequence of the processes and equipment used, it is also a lever by itself than can be used to minimize travel of workers, and transportation of parts and total lead times. Maurer (2001) performed an analysis of the ideal range of cycle times (time a body is within a station). Given that the time bodies spend between stations is relatively constant (around 12 seconds) having less individuals stations means that the overall time cars spend in the shop is smaller, spending more time dedicated to production (less travel waste time, and hence proportionally smaller body shop) (figure 2)

Figure 2. Cycle time influence over production time. Source: Maurer (2001)



3.1.4 Relationship with suppliers

There are two main aspects on the relationships with suppliers (body shop equipment): what the **role of supplier/customer** is and **how to develop suppliers.**

On the traditional body shop, the selection of suppliers is based mainly on cost, which means there is a high turnover of suppliers across models and projects based on a high competition level. Given such a turnover, there are no projects to develop suppliers or joint improvement exercises and suppliers guard jealously information about their operations (Womack, 1999) believing that they will keep the ability to hide profits from the customer.

On the other hand, in a lean body shop there is a long term relationship with suppliers, developing functional expertise in them and involving them upfront in the design process. There is an effort in developing lean capabilities on the extended supply chain, coaching them as well as working together in improvement projects. For example, there are resident engineers (Morgan, 2002) from suppliers assigned to the organization, to integrate the various organizations and spread standardized operation procedures and technical knowledge. Objective prices are set and then through value engineering and value analysis the costs are reduced by join efforts by the supplier and the customer in order to provide a profit for the supplier (Womack, 1999).

As a side note and to understand the process of knowledge diffusion, S. Helper and J.P MacDuffie (Susan, 1997) studied the degree of self sufficiency within lean production as a function of the degree of identification and dependency on the customer (the teacher). If these are too high the supplier will be tempted to continue to rely on the customer for assistance; if they are too low, the learning relationship may break down.

3.1.5 Manufacturing processes

This dimension tries to explore the main differences in approaches regarding manufacturing processes between a lean and a traditional body shop.

The first is the **level of automation** (content of work performed by machines versus workers). In a traditional shop automation is always considered a plus and the more the better. On the other hand, in a lean shop automation is used intelligently and as a help to the worker, not necessary as a substitution. The "human touch" in the operations is considered essential to allocate quality and productivity responsibilities to the line worker. For example, when a part is uploaded into an automatic guided vehicle it is the worker that gives the "OK" by pressing a button, at which point the automatic vehicle

begins to transport the parts. The worker owns the process of uploading and transportation, while the machine facilitates and eases the process.

The second aspect is the **complexity of operations**. In a traditional shop, there is a focus on adding as many elements and complexity to the manufacturing process as required to manufacture the planned product. On the other hand, in a lean shop there is a focus on elimination of processes that do not add value to the end customer, through value engineering. For instance, by eliminating touch points (number of times the product is manipulated throughout the manufacturing process).

Finally, manufacturing processes are designed taking into account defects, breakdowns as a standard, thus creating measures to address the symptoms such as buffers, bypasses or line overspeed. On a lean shop there is a continuous challenge on the assumptions when designing the shop (e.g. does welding need to produce sparks?).

3.1.6 Conveyance processes

This dimension discusses different approaches towards conveyance, the way parts are carried from one process step to the next. There are two aspects worth discussing: **flexibility** and **handling processes**. Firstly, in traditional shops conveyance fixed systems are designed upfront and stay unaltered for the life of the equipment (e.g. conveyors). Lean shops instead tend to use flexible systems (e.g. Automatic Guided Vehicles), easier to change, redesign, improve, thus giving flexibility to the system.

Secondly, in a traditional body shop parts are placed and stored in containers, moved across the factory and later unpackaged to be used. On a lean shop there is a focus on elimination of movements, touching points and containers or racks. For example, conveyors feeding directly the line with no-container solutions (also known as minomi) are popular uses.

3.1.7 Technologies and equipment

The traditional body shop typically uses any type of technology that will increase quality and lower cost, without taking into accounts predictability, reliability and learning curves. Lean shops try to trial, test and experiment with innovations offline and only use proven and reliable technologies on the line (Womack, 1990). Equipment is typically small and very flexible, which also enables a high density of equipment (e.g. robots) and hence eliminates the need for conveyance supporting processes. In addition and as stated in existing literature, big machines block the view of the factory (Whitney, 1998).

3.1.8 Tooling

Tooling is understood as the physical element that is customized to the part being manufactured and is used to help the equipment and/or the worker to create a finished or semi finished product in that production step. The process for tooling design and manufacture is very different between shops. Typically a traditional shop will have the tooling designed and manufactured centrally (not in the plant) and then hand it to them (the plant) with no input from the latter. On the other hand, to achieve lean shops it is required that the central organization engages with the final user (the body shop) to design the appropriate tooling, leaving the latter some flexibility to finally adapt it locally.

3.2. The Body Shop Operation: Differences between lean and traditional shops

For a same type of work, there is a great disparity in the performance that different organizations achieve. Part of these disparities are based on how complex systems of work are managed and this section aims to provide an explanation of the principles, practices and tools to explain such differences in the Body Shop. The discussion will focus around three systems: the enablers (social system), the specific waste reduction and quality improvement tools (technical system) and the competitive advantage of creating an ever learning improving organization (problem solving/continuous improvement system).

We will explore the key items in each system but it is worth highlighting that, in our opinion, in a lean body all three systems need to act together and each of them supports the other. It is worth spending some time understanding the underlying principles of why we believe the three elements act as a system: First, we consider there is a reinforcing loop between taking care of the workforce and their commitment with the company. Taking care of the workforce begins by understanding that they can be active contributors and need to be informed, taught, trusted and respected. When in addition empowered and provided with a support structure, their level of commitment increases, which makes it easier for them to improve the system. By following a problem solving and continuous improvement process, results will be achieved and will be shared with those that made them possible, creating hence a reinforcing loop. To implement changes or countermeasures to problems, there will need to be technical tools in order to affect the bottom-line. In fact, most tools without trust and empowerment to the workers will not be half as effective. For instance, error proof systems that are not maintained, standard work that is not followed, areas with their own agendas and searching their local optimums and for instance accumulating buffers, production and maintenance teams that do use analytical tools together to reduce set up times, or different process steps working at different speeds, producing what

they want and when they want it are just misuses of technical tools that take place when these are available but the right social system is lacking.

In addition, without a social system (defined in this thesis as the engagement and empowerment of the workforce) that encourages trust and accepts failures, improvements will never take place. Similarly, improvements that are not translated into waste reduction and quality improvements through a technical system do not improve the company's bottom-line and performance. In addition, tools and processes in a factory without people using and improving them fall as useless artifacts.

3.2.1 The Social System

The Social System could be understood as the engagement and development of the workforce. It is the substrate or enablers that make the other two systems grow and flourish. It is the culture, way of doing things and the leadership that drives the workforce to reduce waste, build in quality and improve continuously through solving problems.

We will first list the observations on a lean body shop within some predetermined dimensions and then discuss those different dimensions.

3.2.1.1. Observations on lean body shops

Greater purpose and social connectivity

- Visible values and mission statement in each department and at every entry point into the factory. These highlight the role of quality, the role of the worker in contributing to the mission and the role of the customer.
- Sense of sharing common goals. For example, some shops finish meetings with a shared cheer.
- Company is property of everybody, not management. Same dress codes, absence of management cafeterias or reserved parking spaces.
- Social events. From managers serving food to workers, to activities outside work, including participation in non profit activities.

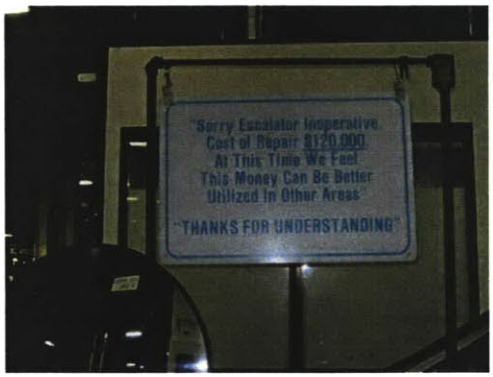
Respect and Teamwork

Communication

- Regular company-wide business updates, with Key Parameter Indicators (KPIs), customer quality audits results, job attendance, suggestion rates and status of employee suggestions, status of improvement efforts and open questions.
- Periodic newsletters about improvements, updates, status of company etc

- Workers have access to inventory real time systems, to be better informed of the state of their area.
- Sincere communication, as exemplified in figure 3 where it states "*Sorry Escalator Inoperative. Cost of repair $120,000. At this time we feel this money can be better utilized in other areas. Thanks for your understanding*"

Figure 3. Example of sincere communication



Mutual responsibility

- Commitment to workforce, with very careful and minimal use of layoffs.
- Workers rotate between process steps and functions, hence sometimes are customers or suppliers to a specific process, which managers assure it increases their interest in a defect free outcome for every step.

Teamwork

- Group and team leaders support the team, even working through breaks to catch up lost production due to breakdowns, testing or trials.
- Team leaders act as redundant capacity within the group to enable bathroom breaks, trainings, improvement efforts etc.
- Maintenance people do not just sit in some corner waiting for operators to call them when a problem occurs but they stand and move around the working area to be closer to the workers and support in case of need.
- Roles and tasks for every worker are clear, so that communication between workers is value added (not just to solve misunderstandings).

Trust

- Workers are the ones holding the stop watch and doing time and motion studies
- Every week, groups of managers perform safety walks (audits to examine safety issues in an area) and share results with the workers in the area.

Empowerment and accountability of those that perform the job

Organizational structure

- Hourly workforce organized into teams of five to seven members lead by a team leader. Team leader is responsible for tasks often performed traditionally by industrial engineers, quality control staff and other specialists. This includes training, quality control audits, work standardization, preventative maintenance and administrative paperwork. If a team member is absent, the team leader fills their place on the line. This creates peer pressure against absenteeism.
- Kaizen shop (composed of line worker) supports creating utensils to run trials or create structures to implement solutions.

Training & development

- Training is given to all workers at all levels. Internal promotion is encouraged and additional training is given to interested aspirants.
- All managers and staff have to spend time working on the line periodically

Job descriptions

- Workers update boards and use visual information on how the system is running / what issues there have been.
- Repairs are done by any worker, especially those in the line, instead of a specific repair group to foster feedback into the origin of the problems.
- Basic maintenance, such as tip changes, is done by line workers.
- Workers are cross trained for different processes. This polyvalence is tracked with charts that show who is able to do what or able to teach certain tasks. This also gives a visual clue that helps manage situations when there are problems – who will replace who? These rotations provide flexibility to the system, improve ergonomics, provide higher work satisfaction and more opportunities for improvement (workers have broader scope of experiences).
- Workers have important roles in defining processes: first as part of pilot teams (working with engineers to define the first version of a process) and also in the day improvements and changes owning the solutions and implementing them.
- Change is managed at the floor level with team member involvement. For instance, during a roll out of a new process, a Primary Process Owner (line worker) is identified and will be the expert of the process during the launch, which keeps standards in place and in use in the shop floor.

- For instance, the place and fit door job are done by same worker. Hence, more importance is given to placing parts correctly than to fitting them later and there is a clear link between both jobs.

The Learning Organization

- The most active line workers (the ones with most improvement activity) are rewarded and promoted to work in the kaizen shops. Kaizen shop helps team members to build their little inventions. A view of a typical kaizen shop can be seen in figure 4, with all the tubes, tables and utensils ready to create simple solutions.

Figure 4. Image of kaizen shop

- Public recognition with boards, public postings and awards given out to given to individuals that have contributed to improvement efforts
- In suggestion program there is a focus on quantity of suggestions instead of only those with big payoffs. Even for the suggestions that are rejected, the manager goes back to worker to discuss and find better alternatives for achieving the same objective.

3.2.1.2. Discussion

Based on the above observations, we will discuss what makes a lean body shop different from a traditional body shop grouped under some dimensions:

Greater purpose and social connectivity

Sense of belonging to a group with common goals and aligned towards a greater purpose. There is long term thinking and workers feel a sense of responsibility over the outcome of their job to achieve such vision. This helps to encourage the feeling of belonging to the same group and hence social connectivity.

Respect and Teamwork

In order to enable a high performance system, the social system needs to embed an organization that fosters communication, mutual responsibilities between members, fairness and trust. Additionally, in order to achieve global optimum and alignment, all shareholders and perspectives must be included in

the decision and consensus built. In addition, a lean system has no room for slack or waiting times which creates a demanding pace. Given operations and people are interdependent, the worker placed upon an amount of stress that needs to be compensated with behaviors that support each other and act as a team.

These are some key dimensions of respect and teamwork:

- Communication and honesty. Communication of the good and bad news, informing the workforce. Readily available information about the state of the system is available to anyone (e.g. boards…). Communication is between everyone in the company, not just management to workers, and includes the facts and information relevant to decisions that need to be taken.

- Mutual responsibility. The workforce is not considered a mere resource than can be disposed of when unnecessary. For example, to engage workforce and encourage improvement efforts there is a guarantee of redeployment if current job role stops to exist due to improvements.
  On the other hand, workers feel a responsibility to perform. There must be reciprocity between management and workforce and a long term relationship between both constituents. Having management take short term actions to maximize profits in exchange of worker's interest will be a double edged sword. An example is the use of metrics that do not just track performance but also worker satisfaction or the use of safety audits that show management truly cares. Another example might be management not laying off workers even if they had economic reasons to do so such as lower production volumes. Furthermore, workers have a sense of responsibility over other workers. Instead of layoffs, they might agree to reduce working hours of each worker. This, of course, creates a debt and sense of belonging in those workers not left behind. In addition, the care that is taken for the worker motivates and engages them to perform improvements, which consequently increases profitability and enables investing in relationships, trust and care to the worker. This is in fact a very powerful reinforcing loop.

- Fairness. Fairness in the wider meaning of the word: fair promotions, awards, treating people with fairness… There are common rules to compare behaviors against, and the enforcement is normally done at lower group levels, not by the manager that usually will not be present. Hence, these groups are able to manage and organize themselves, creating greater cohesion and flexibility. In addition, fairness also means giving credit to those that make accomplishments possible and avoiding favoritisms.

- Trust. Trust is a key element of the social system that enables a lean body shop. Trust has several elements: trust on the worker in order to increase responsibilities, trust on the manager because he or she will do what is needed.

  The line worker has the ability to stop the line if there is a problem such a equipment malfunction or quality issue. The so called *Jidoka* helps prevent passing of defects, helps identify and correct problem areas using localization and isolation and makes it possible to build quality at the production process. Having such power on the worker's hand means management has to trust on the worker's criteria and encourage the worker to raise issues

  On the other hand, the worker must be comfortable to share all the details knowing that they will not be used against him or her and thus enjoy a safe environment where mistakes will not hinder improvement efforts, mistakes can be shared, and there is no fear for having ideas rejected.

Empowerment and accountability of those that perform the job

In literature commonly known as distributed leadership, people directly doing the job are given the power to take the initiative, lead efforts, organize and change their jobs, but also have ownership and accountability over the performance (quality, productivity…) of their area. This means identifying opportunities (in fact, most improvement ideas should come up from the person closest to the work), organizing and leading improvement groups, changing standard procedures, doing basic repairs, maintenance, administrative tasks, housekeeping and quality control, and their own rework in order to see the defects generated. In effect, the lean system transfers the maximum number of tasks and responsibilities to those workers actually adding value to the car on the line (Womack, 1990).

In order to place such high demand on a regular worker, the system has to provide in exchange:

- Organizational structure that supports those performing the job. This includes a team structure where there is a team leader, also very capable on the line, which is a redundant resource that can step in to replace a worker in case of sickness, training, improvement efforts or issues. In addition, group leaders and managers do not mandate on how the job has to be performed (this is to be done by the worker) but to coach and support in problem solving, aligning resources and solving trade-offs. Typically, the standard procedures would be owned by the Group Leader which enables cross sharing between shifts. In addition, there might a group that supports continuous improvement efforts.

- Training, development and mentoring. The worker needs to be trained and coached in order to be capable of performing such varied tasks. This means a strong training effort by the organization but recognizes the self-worth of each individual. It also accepts that the best ideas

do not have to come from the most senior person, but maybe someone else closer to the facts, who is trained and can generate new points of view.

- Wide job descriptions. Workers must be capable of working in different roles to step in to replace other colleagues. This creates polyvalence and hence adds flexibility to the system.

The learning organization

Creating a learning organization is also very related to the improvement cycle of discovering, understanding, experimenting, trying and implementing that will be detailed in the problem solving system. According to John Kotter (Kotter, 2004) there are five key characteristics exhibited by life-long learners: the propensity to take risk, humble self-reflection, aggressive solicitation of opinions from others, careful listening and openness to new ideas. In order to enable a learning organization, the following behaviors will be important:

- Fostering curiosity. Become a learning organization means inspiring people and then fostering then to understand and try new things. Peter Senge in his book The Fifth Discipline defined a learning organization as a place (Senge, 1990) *"where people continually expand their capacity to create the results they truly design, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together"*.

- Tolerating mistakes and avoiding blaming. Mistakes means there has been something tried, and it will be important to appreciate when they are surfaced.. It is important to identify problems and act consequently, but not to punish those that make mistakes. There should be no finger pointing, but rather people owning the problems.

- Rewarding those who prevent problems, not those who solve them. Firefighters are much more visible but it is really that person that prevents the fire from occurring by root causing the problem and preventing it in origin that should be rewarded. The process of root causing is what really makes a company move forward increasing its capabilities.

3.2.2. The Technical System

We will first list the observations on a lean body shop and then proceed with an analysis and discussion.

3.2.2.1 Observations

Practices focused on individual elements

Practices focused on having best performing individual elements can be small and simple changes, fast to try and implement. Many of them are actually designed by the worker.

- Simple hoist to grab side doors, such as the one shown in figure 5. Instead of a complex structure this one just hangs from a bar and attaches to the door.
- Worker pulls parts directly from Automatic Guided Conveyor (AGC) into the car, avoiding traditional double handling from conveyor to rack to car (figure 6).

Figure 5. Simple side door hoist

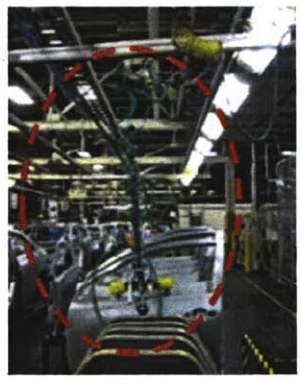


Figure 6. AGC direct to line delivery

- Racks that carry parts can be on top of a turning table, so that when parts are used on one side, it can be turned and worker accesses to the unused parts from the other side. At the same time, conveyance can replenish the back empty side without disturbing the worker.
- Reuse a welding robot as a material handler, acting as two effect robot (welding + handling, as a function of the side of the robot extremity).
- Plastic protections for the AGC racks that avoid the part hitting the rack when pulled out
- Part ejector in equipment and a parts holder. When the machine is finished with the work in process part, it ejects it automatically into the parts holder. Then the worker comes with a new unprocessed part, places it into the tooling and picks ups the processed part. With this system, the worker arrives to the machine loaded a part, avoiding the wasted movements of first picking up the processed part from the tooling, storing it somewhere and then bringing the

new part (figure 7, the parts holder in yellow and the robot on the top part, with the panel foaling into the part ejector after processing).

- Simple changes to reduce reach, for instance modifying racks by placing one of the boxes perpendicular to the rack in a holder to make it easier for worker to reach (figure 8, with the gray box sitting on the rack extension).

Figure 7. Parts holder

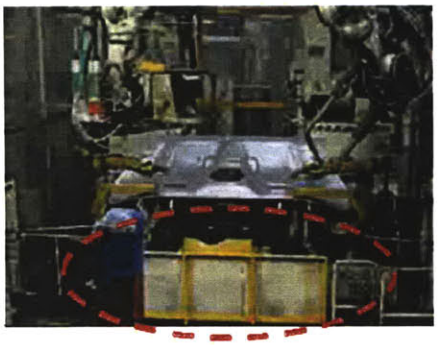


Figure 8. Small rack modifications

- Hoists return automatically to stand-by position, defined by the team members as the place where movements and reach is minimized.
- Containers with wheels to make it easier to move things if needed.
- Tilted dollies to reduce reach by worker (figure 9, with the gray tilted dollie holding parts).

Figure 9. Tilted dolly

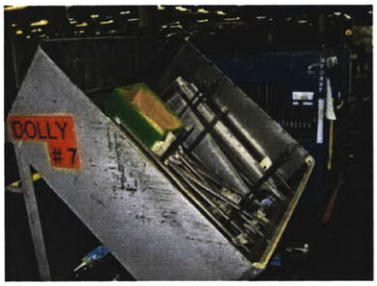


Figure 10. Inspection at source

<u>Error proof systems</u>

- The worker performs the incoming inspection of panels by using a foot pedal that activates a light (figure 11, the worker is examining the panel)
- A light flashes when a specific process is missed for a specific part model.
- Automatic change of die with new part to avoid using the wrong die with the wrong part.
- The line automatically stops if a certain part has not been installed or for instance the torque of the bolt installation does not reach a certain threshold.

Standard work and workplace

- Standard work defines the least wasteful process. For instance, instead of having a worker start a machine by pressing a button, the trigger for the start itself is a lever located in the natural path of the worker while moving between two machines, so that by hitting it while moving the worker activates the machine.
- Standard work audits, performed periodically by middle management. Auditing how the worker is performing the standard work shifts the focus from "blaming the worker" to "blaming the standard work", creating opportunities for improvement.
- Established work standards even in bypasses (temporary changes in product flow due for example to machine failures) to avoid chaos when breakdowns occur.
- Standard location for items, with clear visuals to avoid placing wrong parts, wrong quantities or in the wrong place (figure 11, standard sheet displaying what is held at that location, quantity, where it is supplied…).
- Marks on floor to indicate where trucks should stop (figure 12, line delimiting where the conveyance truck should stop).

Figure 11. Identifications of standard location

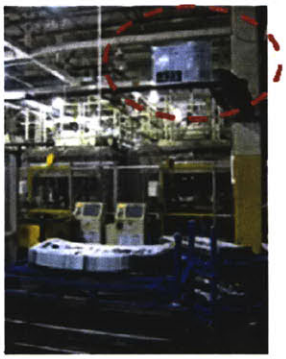


Figure 12. Standard marks on floor

Increasing uptime

- Flexibility of workforce: teams redistribute themselves across stations as a function of the workload.
- Service parts manufacturing during downtime of other processes.
- Use aluminum foil to cover tooling to simplify tooling cleaning and maintenance. This way, to clean the tool when it is dirty the foil is discarded and a new one is placed.
- Maintenance activities, including TPM (e.g. checking spark distance to prevent equipment wear and tear).

Practices focused on the organization of elements

- Use different aisles for replenishment of material and for pick up of finished product. This eases flow of materials across the body shop.
- Share of jigs between models. The only aspect that changes between models is the external clamp, which changes automatically as a function of the next part, thus reducing set up times.
- Automatic Guide Conveyors transport parts between areas, give predictability to service times, increase protection of parts during transportation, but the worker is still on control of the process by placing the parts in the feeders and hitting the OK button. This eliminates the need for complex structures/conveyors and gives flexibility to the system for larger parts.
- Preventative actions to improve performance as a system such as clean car to eliminate particles that will reduce problems later in paint.
- Multipurpose equipment increase flexibility and reduces space and investment. For example, the use of robots that have on one side welding capabilities and on the other material handling capabilities. This translates in addition investments into the specific robot but overall lower investments and space needed.

Practices focused on hand offs / coordination

Some examples of implementations:

- Worker pulls supplies from warehouse by pressing a call button. Then bulk material is replenished by conveyance.
- For low moving parts, when a downstream process needs parts, the worker presses a call button and the upstream (supplying) process begins production.
- To indicate that buffer levels are low in the customer process, a light starts flashing on in the supplying process (figure 13, the light shown on the top part flashes when the buffer is low).
- Parts needed from warehouse can be indicated visually (figures 14, showing which parts the customer process needs and which ones it does not need).

Figure 13. Low buffer flashing light

Figure 14. Visual indicator for part supply

- Hand off tables between processes positioned to minimize worker's movements.

- Simplified ways of moving parts that reduce worker's movements, for example with the use of ramps where parts hang and slide, which also keeps the order sequence of the parts

3.2.2.2 Discussion

The Technical System, the one most documented in lean literature given it is the most visible in any organization, includes all the practices and processes to eliminate waste and build in quality. Lean literature (Liker, 2003) discusses three types of wastes: Overburdening (pushing workers or machines beyond comfortable limits), Unevenness (fluctuations in the flow of material, people and information) and activities that consume resources but do not create value (correction, conveyance, overproduction, motion, waiting, inventory and processing).

All elements act hand in hand and simultaneously. Applying some practices while leaving others behind creates a dysfunctional system and attention must be given to all the different practices. Here we will provide a summary of the main tools available and how they fit together, without going into depth for each of them. Much has been written in the literature on the specific tools and this chapter does not intend to provide a thorough examination of each but instead give a holistic picture on how they are related, complement each other and provide an introduction and references to additional bibliography for each one.

For instance, a team might first use a Value Stream Mapping (VSM, described briefly in the continuous improvement section) to identify opportunities, then prioritize and take action. Then, the team might decide to create standardize work and implement 5S to increase consistency and stability in the system. In addition the VSM might show opportunities in reducing waiting and transportation times and the work is redistributed and balanced across work steps, thus improving the flow and lowering lead times. It is important to highlight that value is specified in the eyes of the customer and everything that does not add value to the customer is waste.

We will describe in the next paragraphs practices within three main categories: practices focused on improving the performance of each isolated element and its output, those trying to improve how these elements are organized to produce the final product and those focused on improving the handoffs or coordination of work between the elements. There is also a clear linkage between the performance of these three groups: for instance, if an element is creating a high number of defects, then there will be typically high inventories on the floor which deteriorate how the product flows through the different steps (e.g. increasing total lead time) and making it harder to quickly detect quality issues. By implementing error proof systems in origin, which is an element-focused action, flow is also improved and there are fewer chances of mistakes in the communication between elements.

1. **Practices focused on the individual steps**

- Creating error proof systems (*Poka Yoke*). Poka Yoke is the concept of a low cost highly reliable device that will stop processes in order to prevent the production of defective parts. The idea is to avoid producing bad parts (thus, creating waste) as soon as a problem is detected. It is very linked to source inspection: detecting issues in the place of origin.

- Establishing a standard work (SW) and workplace (*5S*). A standard is how a job is organized including the human motion, the production sequence and the timing (how often a part must be produced as output of a certain process). Standard processes should define what the best way as for today for doing a certain thing is. It helps to set the baseline for improvements, detect deviations and sustain them afterwards. In fact, increasing formalization of procedures and structures tends to reduce role conflict and ambiguity, thereby increasing work satisfaction and reducing alienation and stress (Rizzo et al, 1970). It is also a common knowledge for people to understand, train, perform and improve tasks. Typically audits would take place to highlight deviations.

  According to Adler (1993), formal work standards developed by industrial engineers and imposed on workers are alienating. But procedures that are designed by the workers themselves in a continuous, successful effort to improve productivity and quality can be much more powerful, creating the learning bureaucracy as he calls it. This achieves 3 things: 1) serves management by improving quality and productivity 2) involves workers in the design and control of their own work, increasing their motivation and job satisfaction, altering the balance between labor and management and 3) services the entire of the entire organization by creating a formal system to encourage learning, capture and communicate innovations.

  5S focuses on standardizing not the tasks but the work place. The idea is to provide a specific location for everything using visual controls. This creates a safe, clean and efficient workplace, status-at-a-glance, identifies abnormalities or out-of-standard conditions. The 5S are: Sort: Remove all unnecessary items; Set: Make all necessary items easily accessible; Shine: Clean and inspect area; Standardize: Establish standards and maintain performance, Sustain: Continually improve.

- Increasing Uptime: TPM is the productive maintenance implemented by all employees, not just the maintenance teams. It includes the equipment improvement, autonomous maintenance, skills training for operators and maintenance personal, improved maintenance management and maintenance prevention activities (Nakajima, 1989).

2. Practices focused organization of steps to produce the final output

A value stream is a sequence of processes or activities to include all of the actions (both value added and non-value added) required to bring a product or service from concept all the way to the customer. The goal is to align the different elements in the most effective way in order to produce the highest quality output at the lowest cost, by creating flow. The question is what steps and in what order must be performed to deliver value to the customer (Spear, 1999).

Enablers:

- Production leveling (*heijunka*). Heijunka is the overall leveling in the production schedule of the volume and variety of items produced in given time periods and is a pre-requisite for Just-In-Tim delivery.

- SMED (Single Minute Exchange of Die) is a process developed by Shigeo Shingo (Shingo, 1985) to reduce change over times. This will drive down lot sizes and hence, improve flow. The idea is to observe how changeovers are done currently, separate what is internal (machine needs to be stopped to perform the task) and external tasks (machine doesn't need to be idle). Then, the goal is to convert as many internal activities to external ones.

- Production cells, are group of machines that drive process from beginning to end with fully dedicated assets.

- Takt time. To establish flow, there needs to be a stable rate at which parts come out of the system. This is defined as the takt time, and is derived by customer requirements.

Elements:

- Creating small lot or one piece flow production. This means producing all product varieties when needed in small increments, ideally one at a time, versus a batch system.

- Establishing continuous flow, with an arrangement of people, machines, material and methods in sequential order to allow a smooth uninterrupted flow. This translates into no waiting or queuing time between the different steps.

3. Practices focused on handoffs or coordination of process steps

Hand-offs between process steps must include the exchange of information, services and material and answer the question of how (timing, content) someone learns what they are supposed to start and what they need in response to that signal. These hand-offs enable the connection of different process steps

seamlessly. They must be standardized, direct and unambiguous (Spear, 1999), otherwise there will be rework, wasteful interaction and noise in the system.

One way to define what is needed and by when within push systems (e.g. scheduling of production and then manufacturing according to plan) is using MRP (Material Requirement Planning) software, where scheduling is performed in order to meet some due dates or requirements. Pull systems, on the other hand, only produce when required, what is required in the amount required. These systems have been associated with *Kanban,* the cards generally implemented to establish such systems. A *Kanban* is the small sign that serves as instruction for production and conveyance, as well a visual control tool to check for over production and to perform improvements. *Kanbans* are the basis for supermarkets, the location of inventory between process steps.

To implement pull systems, the system must be fairly stable because otherwise it will be hard to determine how much to stock of a certain part in a supermarket. That is why elements discussed before such as leveled production are important enablers. In addition, it may seem unnatural to stop producing and have idle machines if there is no order to that effect and there must be a shift in mentality from maximizing utilization to producing what is needed when it is needed. This way, inventories will be kept at a minimum, defects will be surfaced much quicker (they will not be hidden in piles of stock) and lead times will be reduced. It is worth highlighting that when there are products in excess, it is hard to find what one needs. Similarly, it is very easy to hide problems in mountains of inventory before they are detected, and very hard to trace them back to the point of origin.

In reality, systems are a mix of push and pull depending on the timeframe considered. For example, one must plan what will the number of employees needed for the long term (push system). And evidently, a component cannot be pulled backwards until the mines, but rather there will be some inventories throughout the value chain. Hence, there will be push/pull frontiers. In any case, the goals is to pull as much as possible to make hand-offs much more precise in timing, quantity and location.

It is also worth noting the concept of Just-in-Tim which is widely covered in literature. Just in Time refers to the manufacturing and conveyance of only "what is needed, when it is needed and in the amount needed". It is build upon three principles: The Pull System, Continuous Flow and Takt Time, elements already described above.

3.2.3. Problem Solving and Continuous Improvement System

We will firstly share observations and then proceed with a discussion.

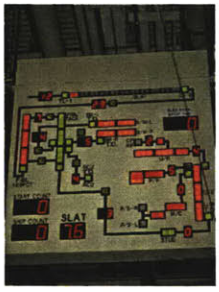
3.2.3.1. Observations

Creating opportunities to visualize problems

Detect deviations

- To detect deviations, there are charts and photos highlighting how the non defective output should look, and what potential defects look like to make it easy for everyone to visually recognize them. In addition, there might be a real example part within the station so that the worker can compare it with the one in production.
- To detect out of order sequence, when every part is inserted into the flow the part number is written (e.g. 75, in pen, on one side of the part) and hence in every step a defect of out of sequence part is very easy to detect just by comparing the part that is physically in the machine and the one that should be there (through production planning visuals, for instance)
- Inspection software is used throughout the process, not only at the end.
- There are boards and displays that show the layout of all stations, events and countermeasures, production numbers, team composition and who is capable of doing what, performance of each member on quality, quality defects tracking, yearly KPIs, tracking of business plan objectives, safety tracking, and standardized work sheets among others. Team leaders and team members track and update daily performance, and it is also used by managers.
- There are other panels that highlight issues, where they are happening, and real time production numbers. Three different versions are represented in figure 15. All these help set a common language and facilitate information sharing, and raise awareness of issues brought up by team members to group leaders or maintenance. In fact, there might be different sounds as a function of the intended audience.

Figure 15. Andon displays



- Robots have transparent cover instead of colored ones so that any worker can observe what is happening inside a robot from outside without needing to enter the space, which facilitates problem solving
- Sharing with suppliers information of issues or defects that have arisen, within hours of detecting problems on the line, to aid the flow of communications.
- All stations in final line move at same time, making the bottleneck clearly visible.

Structured process to problem solve

Most of the solutions detailed throughout this section have been actually identified and implemented by workers. An example we will shortly describe is the automatic elevation of containers via an X shaped elevator (sample shown in figure 16) when the container sitting on top is being emptied to address injuries to the worker. The workings are simple: if the box weights less (it is emptier), the machine elevates the box in order to keep it always at constant height for the worker.

First, the problem is detected (e.g. injury), then the problem is broken down (injury is the upper part of the back and normally happens to workers that have spent a substantial part of their day in station Y), then root causing (e.g. ergonomically bad position), and placing countermeasures (e.g. elevating containers automatically to avoid the worker leaning down below comfortable position).

Figure 16. Sample of automatic elevation mechanism

In addition, problems might appear in the car (defects). In this case, the defect is identified by a certain worker downstream and logged into an inspection system. As a function of how repetitive that defect is in the following vehicles or the level of importance (prioritization), an alert is automatically sent to the area in charge of that part. Then, the group leader or team leader walks backward the line to detect where the defect starts showing up. At that location, the point of occurrence has been identified. Then, a team focuses on observing and root causing the issue. Some countermeasures are identified, tested and finally implemented. To do so, the workers of the relevant areas are involved and the support groups help creating solutions for trials. In addition, the defect would be shared in the daily meetings as well as the progress of the temporary and permanent countermeasures to address it.

Experimentation, trial and implementation

- Workers use a support group to manufacture and assemble simple elements (e.g. racks) to test countermeasures.
- Old replaced equipment is not thrown away, but kept for kaizen activities and by-passes.
- Manual stations embedded in line design, available for trials.
- There is time between shifts to experiment; workers receive support from kaizen group and maintenance to perform changes.

Standardize, sustain and share

- Meetings everyday where managers from one area explain key improvements done, the progress followed, while other managers listen and look for applications of process or results within their areas.
- There is a communication on actions taken on the initiatives (e.g. to reduce sparks), with the status, progress, benefits etc as shown in figure 17.

Figure 17. Sample report out

4.2.3.2 Discussion

Complex systems can be initially best designed but will need self correction, improvement and innovations over time. To meet this goal, a problem solving and continuous improvement system is needed. This system is actually the hardest to establish and replicate and system creates an internally generated competitive advantage. That is one of the main reasons why Toyota is considered to still have a competitive advantage (Fujimoto, 1999).

This system is rich and complete and not to be confused with kaizen events, which is one of the most used practices to display continuous improvement efforts nowadays. Improvements and opportunities must be embedded in every job and role in the company, everyday, not something to be checked off in periodic improvement events. Each employee of a lean body shop is looking continuously for opportunities for improvement, following an established process for studying them, testing solutions and implementing countermeasures, as explained in the following steps. We will describe this system through 5 key elements: creating opportunities to visualize problems, following a structured process

when those opportunities occur, then experimenting, doing trials and implementing changes, sharing those learning globally and finally having leadership support the above process.

1. Creating opportunities to visualize problems

Problems should be considered the raw material for improvements. Problems mean opportunities if correctly identified, analyzed and countermeasures. This section discusses the first step of identifying them.

- Challenging the current state. All employees should have curiosity and challenge the assumptions of the status quo. It is responsibility of all to identify problems (e.g. next station identifying quality issue of the previous station). There is a mindset of looking for problems and sometimes also using analytical tools to highlight opportunities such Value Stream Mapping (VSM). It helps identifying what is really value added activities and non value added activities through a mapping of all the physical and informational flows, buffers and times, for instance. This process helps to reveal sources of waste such as overproduction ahead of demand, unnecessary processing steps, waiting for the next processing step, unnecessary transport of materials, excess inventories, movement of workers, production of defective, parts or services or production of goods and services that do not meet customer needs.

  Eliminating indulgence will help surface problems. Indulgence can be for example in the form of high inventories or bypasses when the system fails, that deviate the attention by eliminating the tension. Literature often describes this situation as the iceberg that is hidden below the waterline and only when the level of water decreases the true problems arise. In addition, there must be a support network to train to challenge (developing the workforce within the social system) as well as a support structure to deal with opportunities as will be described later on.

- Setting standards and built in tests to detect deviations. Tests should be based on what the customer of the process in question expects and what output does the system have to achieve in order to be a success. Work should be highly specified. Only when you know what to expect you can realize that there is a problem (Spear, 1999).
  Predefined standardized work (SW) is a useful way to detect deviations. Deviations can be quickly detected when comparing what the worker is doing versus what the standard process prescribes. Workers involved in the work must be participants in the standardized work creation and modification in order to achieve ownership; otherwise it will generate bureaucracy without reaping the benefits. By having workers adapt the SW to best practices, improvements are sustained. In addition, using SW as a communication tool eliminates interactions and everyone is on the same page.

- Surfacing problems where and when they happen. Visual management also helps to detect problems. Any system that provides real time feedback on how the system is behaving also helps in supporting a data driven approach for decision making. Representative tools include *Andon* (real time displays or calls for attention), Statistic Process Control, or public boards. The key for any visual system is to be used by everyone in order to reveal problems, communicate, generate interest and maintain focus and ask for help or draw attention. The social system already described the trust needed to make this type of tools work. If an operator doesn't have the trust to raise problems or feels defensive when other people come to help, it will never succeed.

2. A structured process to problem solve

A structured approach towards problem solving is required. Sometimes the popular A3 tool is used as a framework: an A3 format paper that includes the problem solving steps (more information can be found in Shook, 2009). The process is followed working as a team and with a systemic approach, involving areas affected during each phase. These types of involvements are known in literature as *Kaizen events, Jishuken, Quality Circles* etc. Essentially we can find the following steps:

1) Identifying the gap. Comparing the current state with the ideal state, identifying the gap.

2) Breaking down and understanding the problem. Clarifying the point of occurrence based on facts (where the problem occurred) gathering qualitative and quantitative facts. This translates into finding where the problem starts by walking backwards from where it is detected. Breaking down the large and vague problem into smaller prioritized problems might also help. For instance, there might be an issue on a car's door. Breaking down and prioritizing the problem might mean finding out that it typically happens on the model A, during the second shift on cars of blue color. It means understanding the what, where, when and who and then seeing where it is most important and where it occurs the most (by size, urgency, potential to expand…).

To understand the problem, there is no substitute for direct observation (Spear, 2004), also known as *Genchi Genbutsu* (Go and See). In order to grasp the current state of the system or better understand what is happening, one must look at the scene in first person, ideally while the problem still is hot. This requires trust between the workers and the rest of the organization, understanding that things will not be changed unless the worker performing the job is consulted and involved.
Other tools that might be useful to better understand the problem are histograms, scatter plots, Pareto charts, control charts or cause and effect diagrams.

3) Setting a target. This helps to set expectations. It should be a challenging, concrete and measurable one, indicating how much and by when things will improve. It should be at the prioritized problem at the point of occurrence level.

4) Focusing on the root cause, not the symptoms. It is important to draw the cause and result relationships and find the root cause at the point of occurrence. Literature mentions the *5 why* process as useful (keeping asking why until the root cause is found. At the point where the answers are not related to the problem, too many whys have been asked). The goal is to reach sufficient depth to draw the true root causes, and it might sometimes include exploring a branch with various root causes that will be explored further. It is important to find the root cause based on facts to back it up. Possible dimensions for the root case might be the man (is the worker doing the process correctly?), the machine (is it worn out?), the material (is the part in time?) or method (is the standard process right?). If the root cause has been found, then when countermeasures are implemented, the prioritized problem at point of occurrence will be prevented.

5) Developing countermeasures. Developing the highest impact countermeasures that prevent the root causes from occurring, taking into account the effort, costs, resources or risks of the alternatives. First a tree structure might help to organize ideas. Each one might include the action, by who, when, how. Then to select the most important ones, we might assess each one against the effectiveness, cost and resources needed or risks (e.g. safety, customer's inconvenience) associated.

It is worth highlighting that in addition to the countermeasures that directly attack root causes there will be other "temporary" countermeasures taken to solve an existing undesirable situation or to bring the original condition, within and scenario of importance of speed in recovery. Since it takes time to plan and implement the real countermeasures, these temporary actions are sometimes needed but must be as such only temporary and will not prevent the problem from occurring.

Though literature clearly emphasizes to stop the line always when a problem arises (Liker, 2004), reality shows that there is a judgment based on how critical and how repetitive the problem is which derives into stopping or not the line. Due to this fact, going to the point of origin and point of occurrence is key to determine the severity of the problem and determine the decision.

There are other methodologies widely covered in literature, such as Six Sigma (originated in Motorola) with its commonly used DMAIC steps, FMEA, process capability (Cp and Cpk) or TQM that will not be described here but can be useful to create stability and predictability in a lean system. Demming also popularized the PDCA cycle: Planning actions, Doing them, Checking and monitoring results and

reflecting (acting) on learnings (Demming, 1986). PDCA's cycle can be map to this section: Plan (identify problems, set targets, root case, develop countermeasures), Do (experiment, implement countermeasures), Check (monitor), Act (standardize, spread improvements and reflect).

3. Experimentation, trial and implementation

After detecting a problem and following with discipline a problem solving process, it is time to test countermeasures. These are some important principles in such affair:

- Frequent, simple, low risk experimentation. Small, simple, and frequent experiments to solve problems and achieve ever-improving productivity (Spear, 1999). This means a series of high speed, low cost, fast feedback experiments. In this sense, the use of pilot tests is useful where small teams or small tests can be run so that the discovery process is not disruptive to the organization as a whole. For example, the use of boards with magnets and colors to test a countermeasure might be very low and flexible but effective way.

- Proposed changes should be structured as experiments. This means setting expectations and testing results. For complex experiments, DOE (Design of Experiments) and statistical tests (such as t-test) might be useful.

- Team effort. The team involved in identification of problems and problems solving should be part of experimentation, trial and implementation. It should involve those doing directly the work since they are part of the solution and best able to test countermeasures. This also helps to build alignment and ownership. A strong communication is also needed as part of this and progress and results must be shared with the members involved.

- Action plans. For implementation, there needs to be an action plan for each initiative, indicating clearly the who, what, when, where, why and how.

4. Standardize, Sustain and Share improvements

A big part of corporate learning is the sharing of local learnings for global benefit, and then sustaining those improvements. These are elements to enable such sharing:

- Standardization to consolidate best practices. After an improvement effort, there has to be a standardization effort to set the new baseline and to be able to communicate and share the new way of doing things with the rest of the organization. This will help anyone, anytime

replicate it and produce the same results. It might include manuals, forms, checklists or flow charts, for instance.

- Sustain by monitoring. In order to sustain, Key Parameter Indicator and visual management against targets set can be used.

- Improvements developed with other groups (sometimes called *Jishuken*). These are management triggered improvement activity, where different sites might be working together to resolve an issue.

- Global sharing. Spread improvements across shifts, areas and sites (sometimes called *Yokoten*). How knowledge generated from solving one problem is disseminated to become common knowledge, and sharing not only the methods and procedures but also the reasons why that route was taken, and mistakes made during implementation. A useful method to achieve such sharings are reports outs or open presentations. These public events also as a way to energize (Liker, 2004).

5. Role of leadership supporting the above process

- Broad based innovation. Innovation does not come just from the top, but from everyone around the organization. It is a workplace of scientists, each employing the scientific method to evaluate processes and create plans for improvement. (Spear, 1999). When there is an over-reliance on a few top leaders to drive innovation, eventually systems fails. The key is to ensure that leaders can develop innovative capacity in their subordinates. Hence, the role of management is to be a support system rather than an authority system.

- Managers should coach, not fix. Managers act as coaches, enablers and teachers. The reason is that lower-level workers are better able to observe and experiment since they deal with actual production. This approach is in direct contrast with most other companies where only managers (and not workers) solve problems. Coaching is for example done through education and using common a language. A common language might be for example using "A3", widely documented by literature for instance by John Shook (Shook, 2009).

3.4. Change management perspective on lean transformations

In the previous sections we first introduced how a lean body shop is designed and operated. In the current section, we discuss the change management dimension to the implementation/transformation of a existing traditional body shop into a lean body shop.

3.4.1 General principles for effective change management

Change management is a subject widely studied. In our discussion hereafter we will focus on the work by Janice Klein (Klein, 2004), John Kotter (Kotter, 1996) for the general principles for change management and also James Womack (Womack, 2003) who in his book Lean Thinking devotes a section on how to effect lean transformation. It is also worth highlighting that change management has been studied from three perspectives: top-down (represented by John Kotter, for instance), leading from the middle (as detailed by Janice Klein) and bottom-up (where workers drive the process for change that gets disseminated into the rest of the organization, also studied by Janice Klein). It is true that a successful change process will most likely include elements of these three approaches, but we will focus mainly on the first one to explain lean transformation which has high impact and is typically initiated by senior management.

John Kotter highlights an eight-stage process of creating major change, with potentially some stages taking place simultaneously, which will be described hereafter. He affirms that future organizations must possess first a distinct organization-wide sense of urgency. That includes the necessity to eliminate complacency. Organizations will be forced to make changes often, and a sense of urgency is the best tool to counter this complacency, as it often allows employees to better cope with frequent change. Another essential attribute is higher level cooperation together with a guiding coalition. When members of an organization work together, it is easier to get that organization moving in the right direction and, therefore, successfully implement change. These individuals must also be able to effectively build and communicate vision. When members of an organization are consistently working as a team as well as acting upon a well-developed and well-communicated vision, it is much more likely that those beneath them will follow their example. This leads into engagement of the workforce or "broad based empowerment". A broad leadership base coupled with effective delegation will make communication and decision-making much faster and more efficient processes.

Stage 1. Establishing a sense of urgency

For change to happen there needs to be a sense of urgency that helps paint the right picture to the whole organization in order to spark the initial drive. This includes an honest and convincing dialogue about what is happening in the marketplace and with the competition, potential threats and scenarios for the future, including also for example discussions with customers or industry people.

A high level of complacency and a low sense of urgency, Kotter asserts, constitute the two most significant impediments to change. In his book he also highlights the main reasons for complacency and ways to address them: A leader must make a crisis visible to cause employees to see internal problems, he must eliminate false signs of security, set standards of achievement high enough that business as usual will not be enough, broaden functional goals and their measurement to encompass company goals, explain the reality of performance through the use candor and external feedback, increase employee interaction with the customer, facilitate and encourage honest discussions and eliminate "happy talk" and emphasize future opportunities and the possibility of success in leveraging those opportunities.

Stage 2. Creating the guiding coalition

After the initial spark, key support is needed to move the change forward. This means involvement and visible backup by leaders within the organization, and management buy in. Leaders can be part of management or outside the formal hierarchy. To move change forward there has to be a team of influential people that build urgency and momentum around the need for change.

For such a team to be successful in leading change, it is crucial that its members share a sense of problems, opportunities, and commitment to change. The most typical goal used to bind a team together is a commitment to excellence, and a strong, genuine desire to maximize the performance of the organization. Furthermore, these teams must possess significant credibility within the company in order to be effective. In summary, Kotter states that to build a guiding coalition one would need to find the right people, create trust, and develop a common goal. This stage is aligned with James Womack's (Womack, 2003) recommendation to find a change agent early in the process.

In her book, Janice Klein (Klein, 2004) maintains that true change comes from within an organization, from those who are knowledgeable about the challenges and opportunities within the firm's culture and daily operations. Insiders may be comfortable, and insensitive to possible performance gaps, and outsiders, such as consultants, have trouble achieving followership. Certain people, "outsiders on the inside" are key to driving innovation, adaptation, and real change, because they have outsider points of

view while being able to leverage insider relationships to cause others to question the status quo. In other words, these are the people who will facilitate change.

Stage 3. Developing a vision and strategy

Kotter claims that vision is a central component to all great leadership and that it is essential in breaking through the forces that support the status quo. After the initial spark and momentum, there has to be a strategy on moving forward linked to a shared vision. Taking the ideas and solutions that have been generated throughout the initial two stages, a clear vision must be articulated as well as a strategy to execute that vision. Leadership defines what the future should look like, aligns people with that vision, and inspires them to make it happen despite the obstacles.

Janice Klein states in addition that lasting change cannot be pushed on others but rather pulled into the organization when end users recognize there is a gap between current status what is needed to achieve strategic objectives (Klein, 2004).

Womack (Womack, 2003) highlights that in lean transformations maybe it is required to acquire the knowledge and also recommends the step of mapping the value stream as a way to understand the current state and then maybe exploring options like reorganizing the firm by value stream or product family as a new strategy.

Stage 4. Communicating the change vision

It will be important to communicate frequently, and for example embed it in regular meetings and everyday events. Communicating and leading by example is important to demonstrate the kind of behavior that is expected from others. Kotter observes that in order for change to take place there needs to be a shared sense of a desirable future, which will certainly not be created by communication alone but it will enhance the adoption process. Two of the pitfalls he describes are under communication of the vision and inconsistent messages.

Stage 5. Empowering broad-based employee action and removing obstacles

It will be important to take action to remove obstacles quickly. This will be facilitated by having leaders whose main roles are to create the structures, visions and support in order for the whole organization to deliver the change. Leaders also identify people who are resisting the change and understand them see what is needed. Kotter suggests that the guiding principle of any successful change effort is the

involvement and empowerment of employees in the facilitation and leadership of change in the middle of the organization. Change cannot be pushed, but the need to change has to be recognized and wanted by those who will be most affected by it. Instead of command and control, a model of influence will be much more powerful. Finally, it will be important to recognize and reward people for making change happen.

Stage 6. Generating short-term wins

Since nothing motivates more than success, having early taste of victory will be very powerful. Within a short term, it will be important to have results that the organization can see. In addition, low hanging fruit with low risk of failure and little need of support from critics of the change can be initially used. However, these short-term wins are only effective if they are visible to many, the terms are unambiguous, and the victory is closely related to the change effort. A victory generated to meet these requirements creates excitement, certainty, momentum, and serves also to quiet critics.

Stage 7. Building on the change

Kotter argues that many change projects fail because victory is declared too early. Real change runs deep and quick wins are only the beginning of what needs to be done to achieve long-term change. While celebrating small victories is important in any change operation, too much emphasis on them will produce a false sense of security. Also, each success provides an opportunity to build on what went right and identify what can be improved.

On the other hand, Womack recommends creating a lean promotion function within the companies as a way to build on changes, as well as continuously launch improvements and convincing suppliers and customers to take the next steps.

Stage 8. Anchoring new approaches in the culture.

To make changes sustained in the organization, they should become part of the culture. This means changing the way ways of doing, the norms and behaviors in order to embrace and sustain the changes implemented. This way, even if the driving force of the change leaves, the changes will persist.

Edgar Schein (Schein, 1992) states that *the culture of a group can now be defined as a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and therefore, to be taught to new members as the correct way to perceive, think,*

and feel in relation to those problems. Hence, as the group solves new problems to adapt to the new environment through the change and it considers it valid, culture will change.

3.4.2 Case study on successful implementation

There have been several successful examples of lean implementations across industries, geographies and functional areas. For the purpose of this thesis, based on the level of existing documentation, the proximity on the industry and the historic relevance of being one of the first successful cases on American soil we will study the case of New United Motor Manufacturing (NUMMI), the joint venture between GM and Toyota. We will map the analysis to the 8 stages described in the previous section.

Much has been written about NUMMI, mainly by Paul Adler, John Krafcik, Eric Jacobson, Wellford Wilms, Michel Reich and David Levine. We will focus mainly on the work of the first three.

Introduction

Krafcik (1986) provides some good initial context: Toyota and General Motors announced their planned joint venture on February 17, 1983. GM was to supply the facility, an assembly plant in Fremont, California idle since March 1982 and market the new car, while Toyota was to provide vehicle design and plant management techniques. The plant philosophy was to be a very close copy of Toyota's Takaoka plant in Japan. The partners were to split the $400 million capital investment necessary for start up. After an anti-trust investigation the US Federal Trade Commission granted formal government approval for the venture on April 11, 1984. With 800 of a planned 2,500 member workforce on hand, the first Chevrolet Nova rolled off the assembly line in December 1984.

In addition Adler (1993) emphasizes the improvement leap: The GM Fremont plant had an abysmal record of productivity, quality and labor strife. When it closed in 1982, there were over 2,000 outstanding grievances, and absenteeism was running at 25%. Within two years of start-up, the new plant had become the most productive auto assembly plant in the US and the quality of the plant's principal product, the Nova, was ranked by consumers and internal GM audits in the highest category among domestic and foreign cards. Moreover, worker moral seemed high: in the first four years of operation, only some 30 grievances had been filed, absenteeism averaged 2.5%, turnover ran between 6 to 8% and over 50% of the workers annually participated in the suggestion program.

It is worth highlighting that the NUMMI turnover has some differences versus a pure brownfield (existing operation). First, it was a new start for a shutdown operation. Second, the management team was completely new and hence leaders did not have to change the mindset of the management team.

Third, NUMMI rehired workers (from the former workforce) who were predisposed to the lean systems

Stage 1. Establishing a sense of urgency

One of NUMMI's success arguments is the fact that the workers were cowed by their experience of unemployment and their continuing fear of renewed unemployment. Brown and Reich (1989) cite that 40% of the displaced GM-Fremont workers were still unemployed at the end of 1983, and that displaced workers who did find jobs in other industries experienced pay cuts averaging 40%.

In addition, the US automobile industry, once the leader in the world, was at that time in a crisis. Tough import competition, and a dramatic shift in consumer preferences, made the 1980 and 1981 the two of the worst years in the industry's history. The US automakers had just experienced losses of over 7 billion in total and hundreds of thousands of UAW workers were on layoff. In fact, four out of five auto assembly plants in California had been permanently lost.

Stage 2. Creating the guiding coalition

Management leadership. Eric Jacobson (1986) documents that the first key hire was the Director of Human Resources. The goal was to bring someone that had no previous experience in the automotive industry but had great knowledge on how to work with union leadership, in addition to being very honest. Bill Childs was hired and then he was involved in fulfilling the Director of Labor Relations and Plant Manager positions with people that demonstrated that they would turn responsibilities over to the workers. Jim Cain and Gary Convis respectively fulfilled those positions.

Union leadership. Paul Adler (1993) explains that shortly after the initial agreement of the joint venture was reached, the new venture began discussions with the unions (UAW). A letter of intent signed September 21, 1983 insured that the United Auto Workers would be recognized as the bargaining agent for the venture's employees, that the company would pay prevailing US auto industry wages and benefits, and that a majority of the workforce would be hired from among the workers laid off from GM Fremont (but seniority would not be a factor). In return, the UAW agreed to support the implementation of a new production system and to negotiate a new contract. A new collective bargaining agreement was signed in June 1985. Union officials were very involved in the recruitment of workers and managers, and had a key role in supporting and implementing the new production system.

Toyota staff. Toyota sent a core staff of between 30 to 35 managers and production coordinators to staff the venture. They stayed on for three to five years. They were supported by a group of 30 to 60 lower- level Toyota manages and engineers who served as trainers. The latter rotated out after three months.

GM staff. General Motors was limited by the Federal Trade Commission on the number of personnel on its payroll allowed to work at NUMMI, loaned only a small group of managers who rotated back into GM after three years. In order to augment GM's learning, GM also set up a liaison office which arranged short tours for visiting GM staff and made available to the GM system a range of materials on NUMMI methods.

Stage 3. Developing a vision and strategy

Wilms (1993) states that most evidence suggests that if GM had set out alone to recreate this plant from its old workforce, it would have failed because old beliefs were too deeply etched into the managers and workers to accommodate the radical change that was necessary. The company's success stemmed from the creation of a new "third" culture, one that was not either completely American or Japanese. This hybrid enabled the new company to break away from the old conflict-ridden culture and start anew.

First, the new managers were hired through the criteria of honesty, humility, groupism, sensitivity, listening and communication ability, reinforcing the vision for the type of plant NUMMI would be.
Initial managers played a very influential role in establishing a mutual vision between management and labor force where their futures were intertwined.

Second, team leaders hired were congratulated by managers and union officials as having been selected to a special work force that was going to produce the highest quality vehicle in the U.S. In fact, the vision was to turn around the place.

Thirdly, team members were brought on board as to building a car they would be proud of and they would be building it in a way they could be proud of. Eric Jacobson (1986) cites a worker talking about the assessment process "*First of all, that assessment was real challenge. But the greatest part was the feeling of accomplishment that came afterwards when were were told that we'd not only done well on the written test, but that we had shown on the second and third that we were creative individuals who could achieve great things. And they acted like they meant it – which blew our minds! The went on to hint about the responsibilities that we'd be given and the roles we'd play in turning the reputation of this place around*" "*Do you know what it's like to play a major role in building the highest quality vehicle in America?*" asked one team member. "*The same pride they instilled in us back then has stuck with*

us. I own two Novas. In fact, everyone on my team owns a Nova. The reason for this is that we feel we were responsible for that thing, and we want to show it off".

Stage 4. Communicating the change vision

This was not a minor change process affecting part of an organization, but instead a major change turning around a whole production facility. Management and unions were constantly communicating the vision of building the highest quality car in the US while walking the talk with actions that enforced trust.

Stage 5. Empowering broad-based employee action and removing obstacles

Eric Jacobson (1986) thoroughly relates the process of making everyone participant in this change process. Of the initial group of over 700 hourly workers selected, nearly 200 were given the option to become team leaders. These individuals were told that the selection committee had chosen them for a leadership role not only because of what they had demonstrated during the assessment test, but because of their past records. Many of these had been exhibiting leadership skills outside of work for years that had gone unnoticed on the job site. These individuals were now being told by management that their skills had been recognized and it was the desire of NUMMI to unitize them to the fullest.

Should they accept the opportunity to become a team leader, they would have to agree to play many roles. They would first go to Japan to be educated and shown how the production system worked. They would work on line in the Toyota Takaoka Plant where they would learn the operations that they would be required to come back and teach. They would be trained to be proficient at every operations performed within their team. Upon their return, they would be able to select their own team members from the pool that has resulted from the assessment. They would then function as a trainer and instruct team members in the operations of the team. They would further be required to go through several hours of training to learn how to resolve problems, enforce quality, keep charts on team members, make work standards, serve as social director etc. They would also have to communicate and motivate the team members.

As reactions to this offer, a team leader stated "*I walked out of that building with my head held high! After seven years of doing the exact same job, I was now being offered the opportunity to manage an area of the plant. I knew I could handle it, and man, was I excited!*" As additional proof to this team leaders statement lies in the fact that since the plant opened, hundreds of workers had gone through team leader training on their own time on weekday evenings. Many of them claim they were taking the classes simply to be more effective team members.

There were also clear socialization processes: spending so much time with simulations, role player, team members selected by their team leaders and hence enjoying some sense of importance, and even group and team leaders travelling together to Japan.

In addition and targeted at the broader team member population, before starting their new jobs all new hires participated in a four day orientation program that explained the team concept, production system, quality principles etc. To achieve a full engagement of the workforce and a commitment between management and workers NUMMI developed a no layoff policy *"The company agrees that it will not lay off employees unless compelled to do so by severe economic conditions that threaten the long term viability of the Company. The company will take affirmative measurers before of any employees, including such measures as the reduction of salaries of its officers and management, assigning previously subcontracted work to bargaining unit employees, seeking voluntary layoffs and other cost saving measures"* This would effectively let team members know that when they contribute ideas for more effective operations they are not jeopardizing anyone's job.

Stage 6. Generating short-term wins

Quick wins were necessary for workers in order to increase commitment. An example, there was a worker that approached management prepared to fight for some extra floor mats for members of his team. The manager responded that in fact he could pick out not one but five or so different types, then display and offer them to the whole assembly line. He wanted just a dozen of mats for the team and he ended up with the whole assembly line having them, in fact the ones that they could all choose from.

Regarding the product, the first car had to be of a high quality in order to support the vision. It took 250 employees and two and a half weeks to build the first card. Each time the line was stopped, people would gather to problem solve. With such a low moving line, the final product had no defects and reinforced the vision of the company.

Stage 7. Building on the change

The initial momentum was spread into the more tan 300 production teams that in a decentralized way worked on continuous improvement projects in their areas. They were trained, empowered but more importantly motivated and committed to change and its success.

At points where the spirit was lower management worked on renewing it. For instance, Osama Kimura, one of NUMMI's presidents launched an initiative in the early 90s to renew NUMMI's spirit by finding

problem areas and visibly accelerating energy for improvements, showing the commitment to the campaign with buttons and banners.

According to Adler (1993), wider change at NUMMI was built upon three sources of motivation 1) the desire of excellence, with trainings increasing the real and perceived capabilities, 2) A mature sense of realism. Given the competitive nature of the industry, unless they improved competitors would take their market and their jobs 3) the positive response to respect and trust, which made them believe they share common goals with management.

Stage 8. Anchoring new approaches in the culture.

As was mentioned above, a new culture was needed and created at NUMMI. According to Wilms (1993) NUMMI integrated two different cultures around some fundamental concepts like employment security, mutual respect and trust. In nature, Japanese communitarian believes frequently conflicted with American individualism but a fair balance was achieved. Eric Jacobson (1986) affirms that six values were established in the new culture: equality, teams that work, right to fail, recognition, worker responsibility and supplier relations.

Chapter 5 - Conclusions

This thesis has provided insights into better ways of designing and operating a body shop. Firstly, it identified the performance gaps between two different body shops and then discussed the source of differentiation during the design phase as well as the operation phase. In the body shop design step, we examined 8 main dimensions: the body shop design process, product architecture, body shop architecture, relationship with suppliers, manufacturing processes, conveyance processes, technologies and equipment and tooling. Then, in the body shop operation we considered three subsystems: the Social System, the Technical System and the Problem Solving / Continuous Improvement system. Finally, we also provided guidance on the change management process to drive a lean transformation, with a list of general principles to reach a successful outcome, and a case study of historic value on an implementation.

5.1. Specific recommendations

Achieving the full potential of a system is the result of an integrated approach with a high number of moving pieces working in rhythm. Lean Strategies in Body Shops must be explored not only from how the shops are run (the Operation) but also from the origin of the shop (the Design).

On one hand and with regards to the body shop design, the lean body shop follows an integrated design process where product and process are tightly integrated, maintain similar product architectures across generations enhancing standardization and modularity, similar shop architectures across plants, close relationships with suppliers, elimination of complexity in manufacturing processes, flexible conveyance processes and use of proven technologies.

On the other hand, the lean body shops is operated in a way that employees are engaged, tools are in place and in use in order to achieve waste reduction, and improvements are continuously performed. To achieve high levels of global performance over time, there needs to be a holistic approach and coherent set of practices under three systems: *The Social System*: Engagement and development of workforce that acts as enabler; *The Technical System*: Tools to reduce waste and increase quality; *The Problem Solving & Continues Improvement System*: An ever learning and improving organization where problems are visualized, problem solved and countermeasures implemented and shared. It is worth highlighting that without a social system that encourages trust and accepts failures, improvements will never take place. Similarly improvements that are not translated into waste reduction and quality improvements through a technical system do not improve the company's bottom-line and

performance. In addition, tools and processes in a factory without people using and improving them fall as useless artifacts.

Finally, a discussion about change management processes associated with a lean transformation provided some insights into the process to follow for changes to successfully happen: from establishing as sense of urgency and guiding coalition to empowering broad based action employee action and anchoring new approaches in the culture. In fact, a case analysis on a successful transformation (NUMMI) revealed that these required key dimensions were satisfied during the transformation.

5.2. General implications for other industries or firms

Design concepts like cross functional integration, standardization, and flexibility are important to most industries, even outside the automotive and hence this thesis provides some useful discussion on those lines of thought.

In addition, the three systems introduced as part of the body shop operation chapter are applicable to a wide range of industries. Every company will have to work on enablers to engage the workforce to make it deliver improvements. With the help of technical tools those improvements will cause financial impact. This thesis provides a broad list of elements within the social, technical and problem solving systems that can help any company in their journey. Specifically, the very detailed examples of implementation can serve as source of inspiration for new solutions.

Finally, the change management discussion in this project is highly relevant, not only to lean transformations, but to any other change management process. There needs to be a sense of urgency for the change to be wanted, a team that drives the change and engages the whole organization, short term wins and sustained changes in the culture. The case analysis of NUMMI contributed with some lessons that are applicable to a traditional plant trying to introduce lean:

- First, there has to be a problem or undesired situation that acts as coordinating device for the whole workforce and helps define the new vision. In the case of NUMMI it was the shutdown of the factory, the levels of unemployment, the low quality of the products, and the reduced alternatives to survive.
- Second, first steps are very key (who starts the process, who is added to the team, what are the first behaviors that lead by example). At NUMMI, unions were involved upfront, new management was recruited and was key in creating an initial atmosphere of trust..
- Third, only by spreading the change and involving the rest of the organization will the process be sustained. At NUMMI, the goal was to have people feel special: special of being selected

from a long list of candidates, of being trained, taken care and given the tools and room of action to support the change process and anchor the new culture within the organization

5.3 Limitations and remaining questions for further research

First, the performance comparison that gave shape to the problem statement only compared two body shops. That by itself is a limitation and it might be worth expanding the sample to increase the reliability of the conclusions.

In addition, certain elements have been excluded from the current project, such as the role of execution of a design into a real body shop or the role and importance of feedback loops between the design and operation of body shops. We focused on the individual elements of design and operation, and a broader analysis might be insightful.

Finally, only a static picture of a lean transformation has been provided without analyzing the dynamic perspective on such implementation. That is, what is the right order in the steps to follow or how events or milestones benefit or hinder future progress on the transformation.

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