CHEAT-SHEET: LEAN MANUFACTURING

MOTIVATION & CHALLENGES

Lean Manufacturing or Just-in-Time (JIT) originating from Japan (Toyota) is the most established method for optimizing manufacturing operations. Many success stories confirm its underlying concepts' effectiveness, which can be applied in areas other than manufacturing (Lean Thinking, Lean Healthcare, Lean Administration, etc.). Over the last few decades, almost all major manufacturing companies have implemented at least some basic concepts of Lean to increase efficiency, reduce costs, and speed up product delivery.

However, many practical examples show that Lean is neither simple to implement nor inexpensive. Lean is not a well-defined management system with clearly defined implementation steps and rules. Some of its concepts are difficult or impossible to implement in more complex, non-repetitive manufacturing environments. Nevertheless, the essential Lean concepts should be considered in any case for the following reasons:

- Lean is about waste reduction, an issue that was never more important than these days ;
- Lean focuses on the improvement of the actual manufacturing and logistic processes, the only way to achieve substantial cost and lead time reductions ;
- Basic Lean principles can be implemented in any manufacturing environment and result in clean, safe, and ergonomic workplaces ;
- Some essential benefits can be obtained without major investments ;
- Lean helps to reduce operational complexity and thus minimizes the need for costly and complex planning solutions.

OVERALL PROCESS

Steps	Description	Essential questions
Step 1: Analysis	**Identification of waste:** Identifying non-value-added activities for the whole supply chain..	• Before implementing Lean, have you reached a scrap- and rework level constantly below 1%? • Do you measure the costs caused by overproduction and excess inventory? • Have you segmented the products based on the product life cycle and the volume and regularity of the demand?
Step 2: Choice of solutions	**Choice of Lean solutions:** Implementing the Lean solutions based on the maturity level of the Lean initiative.	• Do you understand the requirements for a successful implementation of continuous-flow manufacturing? • Have you identified non-value-added activities that can be removed without high costs? • Do you promote low-cost automation solutions? • Do you focus your efforts on process improvements impacting the overall performance?
Step 3: Implementation	**Continuous improvement:** Implementing Lean solutions in a continuous improvement process.	• Do you have overall planning for the Kaizen events (current-state and future-state value stream map)? • Do you have a multi-functional team that is 100% available for performing the Lean implementation (three to seven members)? • Do you have defined a model area for testing the Lean concepts?
Step 4: Verification	**Measuring manufacturing performance:** Verification of the impact of Lean solutions.	• Do you have reliable performance metrics for quality, inventory, customer service, and manufacturing costs? • Do you measure your main products' lead times (total time required to manufacture an item, including run time, queue time, inspection time, etc.)?
Step 5: Standardization	**Standardized work:** Consolidating implemented solutions and ensuring that the work is always executed in the same optimal way.	• Do you have product design rules in place to adapt products for efficient assembly and production? • Are all your processes responsible for guaranteeing the quality of their output (quality at the source)? • Are sales and purchasing promoting leveled customer and supplier deliveries?

GENERAL CONCEPTS

Non-value-added activities or waste

Everything in Lean is about eliminating waste, activities that consume resources but do not add value to the product or service. The genius behind this concept is that manufacturing performance is maximized by reducing waste instead of working harder or buying expensive equipment. The seven forms of waste are defined as follows:

Overproduction: To produce sooner and in greater quantities than customer demand and send parts to the next process step that are not immediately required.

Typical causes: Too high safety stock levels, over-optimistic sales forecasts, and poor product life cycle management (launch and end-of-life).

Inventory and WIP (Work-In-Progress): Obsolete and slow-rotating inventories and high WIP levels.

Typical causes: Large batch sizes, unbalanced capacities, poor flow between processes, and Overproduction.

Waiting: People or parts waiting for a process to be completed, for resources, or decisions.

Typical causes: Poor coordination of activities, too many priorities, and overloaded processes.

Transportation: Unnecessary transportation of people and parts between processes, plants, and suppliers.

Typical causes: Large distances between processes, multiple storage locations, and lengthy and complex material handling systems.

Over-processing: Processing beyond the standard required by the customer and unnecessary complex (over-engineered) processes.

Typical causes: Unclear customer specifications, lack of work standards, and complex material handling.

Motion: Unnecessary movements of people, parts, or machines. This waste is generally related to ergonomic problems.

Typical causes: Poor workstation layout and workplace organization, lack of space, and searching for tools and equipment.

Defects: Rework, nonconformities in processes and products, accidents, and breakages.

Typical causes: Unclear operation instructions, inadequate operator skills and training, and incapable processes and suppliers.

Critical success factors

Lean is difficult to implement because it is contrary to some traditional manufacturing practices and because the methodology does not explicitly address all elements required to implement Lean successfully.

Lean goals vs. Product costing: Some standard costing practices and performance metrics conflict with the goal of lead time reduction. Typical examples are choosing large lot sizes to minimize direct costs-per-item or to let run expensive resources even in periods without actual demand.

Quality at the source vs. Statistical process control: Continuous-flow manufacturing is only possible if each process sends only "good" parts to the following process. This concept differs from the classical approach of statistical process control (accepting a certain scrap- and rework-level) and quality inspection only at the end of the production process.

Improving manufacturing environment vs. Scientific management: Scientific management uses sophisticated (IT-)methods to improve performance. In contrast, Lean aims to reduce the complexity of the manufacturing environment to allow simple and inexpensive solutions.

Quality level: All fundamental quality issues must be solved before implementing Lean (scrap- or rework rates constantly below 1% to 2 %).

Product Design: Continuous-flow manufacturing is impossible if the products are impractical for manufacturing and assembly. Therefore, DFMA design guidelines (**D**esign **F**or **M**anufacturing and **A**ssembly = modular designs,use of standard parts, mistake-proofing techniques, and easy and efficient fasteners) should be used for all main product families.

Demand and supplier management – Leveling: Lean solutions are useless in an environment with constant demand surges and infrequent deliveries from suppliers. Long-term relationships with clients and suppliers are often required to level demand and supply.

PROCESS STEPS

The process of implementing the whole Lean concept or individual solutions follows the typical steps of any creative problem-solving approach: 1) Analysis, 2) Choice of solutions, 3) Implementation, 4) Verification, and 5) Standardization.

Step 1: Analysis

The following tools are essential, together with analyzing KPIs and process data, to identify the operations' current state and all non-value-added activities.

Genba walks: Genba walk means visiting the workplaces and aims to understand how work is done. The goal of this methodology is that the management understands the effectiveness of implemented solutions and what improvement activities must be planned.

Spaghetti diagrams: A spaghetti diagram visualizes the flow of workers and products in a process layout to identify potential areas of improvement (Transportation, Motion, Waiting, and Inventory).

Value-stream mapping (VSM): VSM is a pencil-and-paper method for visualizing the production flow by following a product's production path from beginning to end with the help of standardized symbols. This tool is perfect for identifying the ratio between value-added and non-value-added activities and wastes like Transportation, Waiting, Defects, Inventory, and Overproduction. VSM is also used frequently for planning all Lean activities (current-state value stream map representing all current problems, and future-state value stream map representing all planned improvements).

Step 2: Choice of solutions

A general approach for implementing Lean is first stabilizing the manufacturing environment before implementing in model areas continuous-flow manufacturing and the Kanban method (pull concept).

Stabilization and visual workplace:

The following three Lean tools help to reduce the fundamental inefficiencies (Waiting, Inventory, Defects, Motion, and Transportation).

5S: The 5S method helps to ensure clean, safe, and ordered workplaces and is the fundamental Lean solution. It consists of the following five activities:

1. **Sort**: Sorting and removing all unnecessary items ;
2. **Straighten**: Arranging items for easy and ergonomic access. All often-used items are placed closest to the workplace ;
3. **Shine**: Cleaning everything and solving all safety issues ;
4. **Standardize**: Creating visual guidelines for keeping the workplaces organized, safe, and clean ;
5. **Sustain**: Educating and communicating to ensure that everybody follows the standards.

SMED (Single Minute Exchange of Dies) or Quick Changeover: The SMED method helps to minimize lot sizes by reducing changeover times. Small lot sizes are an essential condition for continuous-flow manufacturing. It is implemented in the following three steps:

1. **Internal and external setup tasks**: Distinguish between internal setup tasks that can only be performed while the machine is shut down and external setup tasks that can be performed while the machine is running ;

2. Reducing internal setup tasks: Convert internal tasks to external setup tasks when possible ;

3. Streamlining setup activities: Streamline all setup activities by implementing parallel operations, eliminating adjustments, and improving storage and management of required parts and tools.

TPM (Total Productive Maintenance): The TPM method focuses on maintaining optimal conditions for the equipment to prevent breakdowns, speed losses, and quality defects. It consists of the following activities:

1. Inspecting and cleaning equipment: Clean and inspect equipment: Eliminate factors contributing to failure, eliminate sources of contamination, and lubricate ;

2. Work standards: Establish standards for maintenance, cleaning, and lubrication ;

3. Maintenance and inspection levels: Distribute the maintenance and inspection tasks to the three levels Expert, Supervisor, and Operator.

4. Operator training: Train operators in performing basic inspection and maintenance tasks (Operator level) ;

5. OEE (Overall Equipment Effectiveness): Establish the OEE measurement for all critical equipment (OEE = Availability of machine x Performance rate x Quality rate) ;

6. Standardization of inspection and maintenance: Introduce a scheduled inspection and maintenance program.

Visual management: Visual management helps to communicate the current state of the operations to everyone. These visuals cover generally performance and quality indicators (KPIs), safety rules, production scheduling, and priorities. Visual management is also essential for controlling and reducing inventory and WIP.

Continuous-flow manufacturing & Kanban method:

High production cost and lead time reductions can only be achieved by introducing continuous-flow manufacturing that differs significantly from the classical push and batch production. There exist two levels of continuous-flow manufacturing, leveled and smoothed production:

Push and batch production: Function-oriented organization, central inventory and waiting queues before every workstation (①), economic batch sizes, and centralized planning (**M**aterial **R**equirements **P**lanning MRP) based on customer orders and forecasts (②).

Leveled production: Product-oriented organization with dedicated resources or value-stream organization, FIFO (**F**irst-**I**n, **F**irst-**O**ut) lanes to minimize WIP (③), shared resources controlled by Kanban method (④), production scheduled by pacemaker process (⑤), and all products (within product family) produced in a time interval (EPEI = **E**very **P**art, **E**very **I**nterval, the shorter the interval, the better, ⑥). Essential requirements for leveled production are products with similar work content, low scrap- and rework rates (<1%), and reliable equipment (OEE > 70%).

Smoothed production: U-shaped production cells for minimizing waste (⑦), one-piece flow with operation times equal to TAKT (= available daily production time/average daily customer demand, ⑧), and all shared resources and suppliers controlled by the Kanban method (④). Smoothed production requires highly balanced work contents per operation.

Kanban (Pull): The Kanban method implements the pull concept, where material replenishment is only allowed after the material has been consumed. The client withdraws the needed items from the supermarket (⑨) and sends a replenishment signal (= Kanban, card in Japanese) back to the supplying process. The main advantage of the Kanban method is that it limits WIP, which is essential for controlling lead times. This method is only adapted for products with stable processes and demand.

Step 3: Implementation

All critical implementations of Lean solutions (modifications of the flow of material, reorganization of entire departments, etc.) should be done using the Kaizen approach. A typical Kaizen event (three – five days) is organized as follows:

Planning and preparation: Select the area and the team (four – six team members, including a Team leader and a Lean specialist). Collect, if necessary, additional process data for analysis (equipment efficiency, quality levels, lead times, etc.) ;

Day 1: The problem is analyzed, and possible solutions are developed and chosen based on a creative problem solving approach ;

Day 2: The ideal solution is tested (simulation), and the implementation is started ;

Day 3: Continuing implementation of the ideal solution ;

Day 4: Verification and presentation of the implemented solution. Establish work standards and an action plan for non-finished issues.

Step 4: Verification

The verification of Lean solutions is done with the help of KPIs:

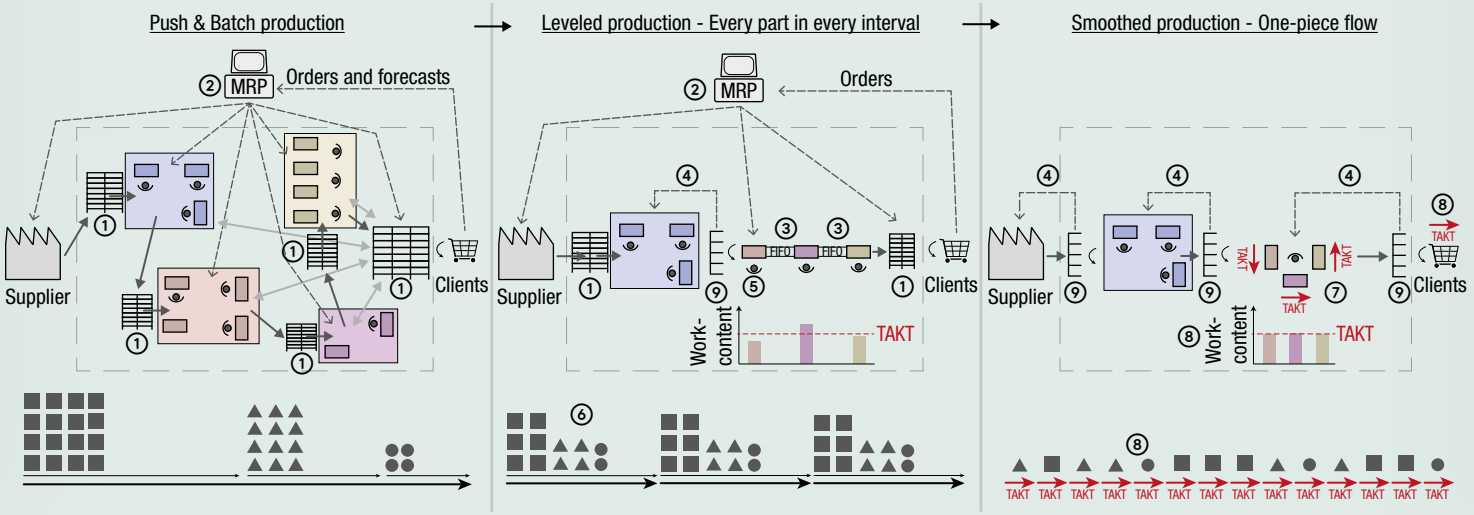
Plant-level: Customer service, DSI (**D**ays **S**ales of **I**nventory), Quality, Manufacturing costs, Delivery lead times, and Safety.

Department- or value-stream-level: First-time quality, Production lead times, Employee skills matrix, and Equipment efficiency (OEE).

Step 5: Standardization

Standardizing is essential for consolidating the implemented improvements and ensuring that the production process is always done in the same efficient manner.

Typical work standards: Inspection and maintenance plans (inspection frequency, parts to be replaced or inspected, lubrication instructions, etc.) and work and safety procedures (sequence of the work process, necessary tools, cycle times, and quality and safety requirements).



AUDIT

The following audit helps evaluate the maturity level of the Lean Manufacturing initiative

	People	Process	Tools
Level 4 Robust	The whole organization is actively involved in the Lean initiative. Most employee have participated at least once in a Kaizen event.	Smoothed production for main products: Cellular manufacturing with one-piece flow, speed of operations dictated by TAKT, and all shared resources and suppliers controlled by the Kanban method.	The visual management of the operations allows non-specialists to identify the current state of the operations. The Lean improvement process is guided by current-state and future-state value stream maps
Level 3 Essential	Sales and Purchasing are promoting smooth customer and supplier deliveries. The design department applies rules for products that are practical and simple to produce and assemble (DFMA). Training programs are available and promoted to train people in all aspects of the Lean concept.	Leveled production for main products: Product-oriented organization, all products within the product family produced in a time interval (EPEI), value stream scheduled by pacemaker process, and shared resources controlled by the Kanban method.	The KPIs in place identify the impact of Lean solutions and help to determine the potential causes of a problem.
Level 2 Minimal	Cross-training program for operators defined and applied. The top management has defined lean as a major initiative for improving manufacturing processes. A team is entirely available to implement Lean solutions.	Visual WIP and inventory control. Visual management in place of safety, quality, inspection, and maintenance rules. SMED and TPM are in place at all critical operations (bottlenecks). All workplaces are safe, clean, and ordered (5S).	A model area available for testing lean solutions. Visual management tools are available: Labels, markings, signs, whiteboards, and FIFO racks and lanes for inventory and WIP control. KPIs with cause indicators exist for quality, customer service, inventory, delivery lead times, and equipment efficiency (OEE).
Level 1 Insufficient	A limited number of people implement Lean solutions locally. No guidelines or standards exist for the implementation of Lean solutions.	Complex flow of material, and frequent rework and equipment stoppages. Production schedules are dictated by financial requirements, resulting in frequent month-end rushes.	No indicators are available for measuring delivery lead times and inventory levels.

TO GO FURTHER...

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Hopp W., and M. Spearman. **Factory Physics**, Waveland Press, Inc.: A classic book about manufacturing control, with some essential insights about Lean Manufacturing.

Lane G. **Made-to-Order Lean – Excelling in a high-mix, low-volume environment**, Productivity Press: How to implement Lean in a realistic manufacturing environment with thousands of different products.

Rother M., and J. Shook. **Learning to See – value-stream mapping to create value and eliminate muda**, Productivity Press: A classic book on value-stream mapping and the basic Lean concepts.

Shingo S., and A. Robinson. **Modern Approaches to Manufacturing Improvement – The Shingo System**, Productivity Press: A classic book from the co-creator of the Toyota Production System and the Just-in-Time.

Takeda H. **The Synchronized Production System – Going beyond Just-in-Time Through Kaizen**, Kogan Page Publishers: A detailed explanation of a step-by-step implementation of the different Lean Manufacturing tools and concepts.

Tapping D., T. Luyster, and T. Shuker. **Value Stream Management – Eight Steps to Planning, Mapping, and Sustaining Lean Improvements**, Productivity Press: A detailed description of implementing Lean using the value stream mapping tool.