# Introduction to Operation Management

## 040 Development

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# 2 Lean Operations

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# Leans Operations

The primary aim of lean operations is to ensure a seamless movement of materials, information, or customers, delivering precisely what customers value (flawless quality), in the exact amounts needed (avoiding excess or shortage), precisely when required (neither too soon nor too late), at the correct location, and at the lowest feasible cost. Initially developed for manufacturing processes, the concept of lean operations (along with its predecessors and variations like just-in-time and stockless production) was originally centered on planning and managing operations to provide products and/or services without generating 'waste'. Its goals were to offer value to the customer by supplying error-free products and services as quickly as possible and at minimal cost to the organization. Over time, the lean concept has been increasingly adopted by service organizations. Equally important, its focus has shifted towards a comprehensive view of lean as a strategy for operations and process enhancement. While its role in planning and control remains crucial for achieving a smooth, coordinated flow (without waste), it also emphasizes attaining perfect quality, in the right quantity, at the right place, and at the right time. Consequently, in practice, lean is largely regarded as a method for improvement.

## What is lean?

There are multiple ways to define ‘lean.’ The most common method, is to explain it by outlining its goals. Lean aims to provide exactly what customers value (perfect quality), in precise quantities (avoiding excess or shortage), exactly when needed (neither too early nor too late), at the right location, and at the lowest possible cost. However, be cautious with definitions of lean. They are numerous and varied, but few can fully or succinctly capture its essence. Some definitions are too narrow, focusing on the tools and techniques used in lean operations or the individual components that make up lean. Others are too broad or vague, lacking specific guidance on how to achieve the objectives outlined in our definition. An alternative approach is to identify the role lean plays within the broader scope of operations management activities.

Lean is a philosophy, a method for planning and control, and a collection of improvement concepts.

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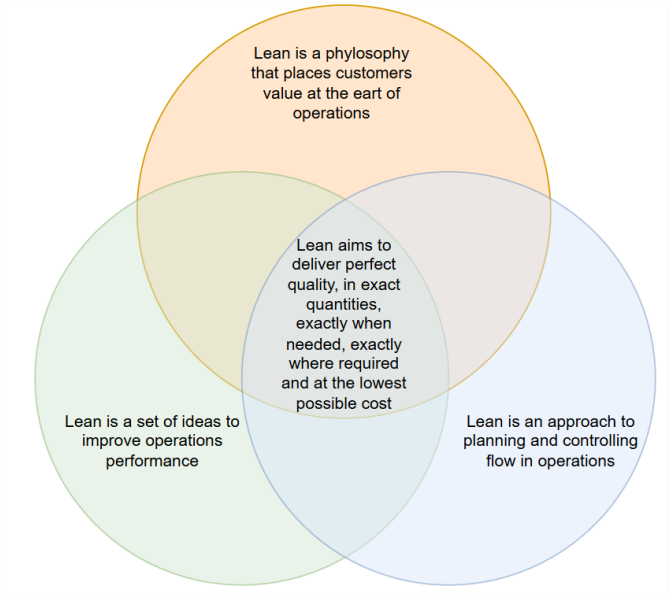


Figura 1. Lean can be viewed as having three overlapping roles – lean is a philosophy that places the customer at the heart of operations, lean is an approach to planning and controlling flow in operations, and lean is a set of ideas on how to improve operations performance

## Lean as a Philosophy

We will explore the numerous components that together make up lean. Each of these components is significant, but one in particular unifies them: lean is a philosophy that centers customer value in operations. By calling it a philosophy, we refer to a set of coherent ideas that provide a comprehensive rationale for managing operations. As we discuss the various elements of lean, observe how they complement each other. They are much more than a random collection of guidelines; they form a logical and consistent approach to managing operations overall. In fact, many of these elements are widely recognized as 'best practices' in operations management. The main goal of the lean philosophy is to align all activities towards adding value for the customer, which leads to the recurring theme of lean striving to eliminate all non-essential, non-value-adding activities.

## Lean as an Approach to Planning and Controlling Flow

Originating in manufacturing, lean was initially viewed as a method for managing the movement of resources within an operation to achieve efficient 'flow.' It was essentially an approach to synchronizing flow through the planning and control of activities within the operation. Often referred to as 'just-in-time,' its focus was on ensuring smooth flow and, as a result, reducing the inventories between processes. We will delve into this aspect later when we examine how lean addresses flow.

## Lean as a Set of Improvement Ideas

The core of a lean operation is a collection of improvement tools and techniques designed to identify and eliminate waste—any activity that does not add value from the customer's perspective. The increasing popularity of lean, with continuous improvement as one of its fundamental principles, has helped shift the focus of operations management towards viewing improvement as its primary purpose. Additionally, the


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emphasis lean places on the role of 'people'—the staff who perform value-adding activities—has reinforced the perception of lean as primarily an improvement mechanism. Lean depends on empowering people, skilled in improvement methods, to leverage their collective knowledge to enhance processes in ways that increase value from the customer's perspective.

This empowerment involves equipping employees with the skills and authority to identify inefficiencies and implement changes that enhance the overall value delivered to customers. By fostering a culture of continuous improvement, lean encourages staff to actively participate in refining processes, thereby driving innovation and efficiency across the organization. This approach not only improves operational performance but also boosts employee engagement and satisfaction, as team members feel valued and integral to the success of the organization. Ultimately, lean's focus on people and process improvement creates a dynamic environment where the pursuit of excellence is a shared responsibility, leading to sustained competitive advantage and customer satisfaction.

By integrating these principles, lean operations create a cohesive system where every aspect of the organization is aligned towards maximizing customer value. This alignment ensures that resources are utilized efficiently, waste is minimized, and processes are continuously refined to meet evolving customer needs. The collaborative nature of lean empowers employees at all levels to contribute ideas and solutions, fostering a culture of innovation and adaptability.

Moreover, lean's emphasis on eliminating non-value-adding activities helps organizations streamline their operations, reduce costs, and improve quality. This not only enhances the customer experience but also strengthens the organization's market position by delivering superior products and services at competitive prices.

In summary, lean is more than just a set of tools or techniques; it is a comprehensive approach that integrates philosophy, planning, and improvement strategies to create a responsive and efficient organization. By placing customer value at the core of its operations, lean enables organizations to thrive in a competitive landscape, ensuring long-term success and sustainability.


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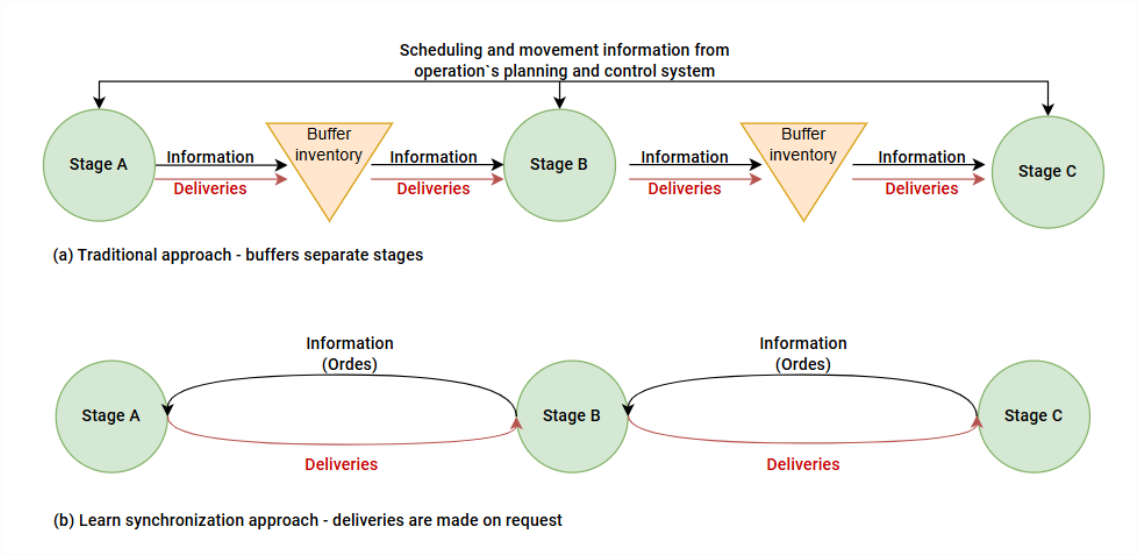


Figura 2. (a) Traditional flow versus (b) lean flow between stages

## How does lean view flow?

At the heart of lean philosophy is the focus on achieving seamless flow. In this context, “flow” refers to the smooth movement of resources through value-adding activities without generating waste. Lean operations manage this flow differently from traditional production methods.

### Enhancing flow through pull control

To grasp how pull control in lean differs from traditional flow management, consider two contrasting processes. Traditional methods assume that each stage in a process deposits its output into an inventory, which acts as a buffer between stages. The subsequent stage then draws from this inventory, processes the items, and passes them to the next buffer. This is known as a “push” production approach, where items are processed regardless of demand. These inventory buffers isolate each stage, allowing them to operate independently. For instance, if stage A halts, stage B can continue for a while. Larger buffers provide more insulation but come at the cost of increased inventory or queues, slowing down throughput as items wait between stages.

The main critique of this traditional method is its emphasis on insulating stages from each other. When a problem arises at one stage, it may not be immediately visible elsewhere, leaving the responsibility for resolution to those within the affected stage. In contrast, the lean approach, processes items and passes them directly to the next stage “just-in-time” for further processing. The goal is to perfectly align supply with demand, producing only what is needed. In this system, issues at any stage are quickly noticed throughout the process. If stage A stops, stage B and C will soon be aware, making the problem a shared responsibility that cannot be ignored. By preventing accumulation between stages, lean operations enhance the plant’s inherent efficiency. Traditional methods use inventory to shield each process part from disruptions, while lean exposes the system to problems, making them more visible and motivating the entire system to address them promptly.


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### Supporting pull control with kanbans

The setup shown exemplifies “pull control”. Unlike traditional mass production, where products are “pushed” into inventory to buffer demand fluctuations, pull control aligns supply with demand without relying on inventory. For example, some fast-food restaurants prepare food only when an item is sold, triggering production based on actual customer demand.

Kanbans are the most common tool for supporting pull control in lean operations. These simple signaling devices prevent the buildup of material, customer, and information inventories. The term “kanban” is Japanese for card or signal, often referred to as the “invisible conveyor” that manages the transfer of items between stages in an operation. In its simplest form, a kanban is a card used by a customer stage to request more items from its supplier stage. Some companies use physical kanbans, like solid plastic markers or colored ping-pong balls, while others employ electronic point-of-sale (EPOS) systems to generate digital kanbans for further production or stock delivery. Regardless of the form, the principle remains the same: receiving a kanban triggers the movement, production, or supply of one unit of product or a standard amount of service activity. If two kanbans are received, two units of work are produced, and so on. Some companies use “kanban squares”—designated spaces on the shop floor for workpieces or containers. Only an empty square prompts production at the supplying stage. Kanbans exist due to imperfect demand information, and ideally, their number should decrease over time as process improvements reduce waste and enhance flow.

### Improving flow by reducing inventory

Lean views inventory accumulation, whether finished products or work-in-progress, as a “blanket of obscurity” that conceals problems within the system. The obscuring effects of inventory, whether product, customer, or information inventories, are often illustrated with diagrams. The various operational issues are depicted as rocks in a riverbed, hidden by the water’s depth. The water symbolizes the inventory in the operation. Although the rocks are unseen, they impede the river’s flow and create turbulence. Gradually reducing the water level (inventory) reveals the most significant problems, which can then be addressed, allowing further reduction and exposure of additional issues. This concept also applies to the flow between entire processes or operations.

### Improving flow by decreasing capacity utilization

Returning to the process, when stoppages occur in traditional systems, buffers allow each stage to continue working, achieving high-capacity utilization. High-capacity utilization is central to mass-production approaches, where low unit costs are achieved through large-scale production, known as “economies of scale.” Often, extra production goes into buffer inventories or customer queues. In contrast, with minimal or no inventory to buffer against stoppages, a production problem becomes immediately apparent, affecting the entire process. This leads to lower capacity utilization, at least in the short term. For organizations that prioritize high capacity utilization, this can be challenging to accept. However, producing output merely to maintain high utilization is not only pointless but counterproductive, as excess inventory hinders improvements.

Lean emphasizes reducing all types of process variability through continuous improvement efforts. As these efforts yield results, the improvement path leads to

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shorter throughput times and higher capacity utilization. This is achieved by minimizing process variability, allowing the system to operate more efficiently and responsively to actual demand.

In summary, lean operations focus on creating a smooth flow of resources through value-adding activities by minimizing waste and aligning production closely with demand. This approach contrasts with traditional methods that rely on inventory buffers to insulate stages from disruptions. By exposing the system to problems and addressing them collectively, lean operations enhance overall efficiency and responsiveness. Kanbans and other tools support this pull-based system, ensuring that production is driven by real demand rather than arbitrary targets.

## How does lean address and minimize waste?

A key aspect of lean operations is its emphasis on eliminating all forms of waste. Waste is defined as any activity that does not add value from the customer's perspective, meaning it is not something the customer would pay for or benefit from. Therefore, what is considered waste depends on the customer's view of value. In many processes, only about 5% of the total throughput time is spent on activities that directly add value. This implies that for 95% of the time, operations are incurring costs without delivering direct value to the customer. Such insights can reveal significant hidden waste even in seemingly efficient operations. For example, simple tasks like applying for a driving license may take only minutes to process but can take days or weeks to complete.

### Causes of waste – muda, mura, muri

The Japanese terms muda, mura, and muri describe three causes of waste that should be reduced or eliminated.

#### Muda

Muda refers to activities in a process that are wasteful because they do not add value to the operation or the customer. The main causes of these non-value-adding activities include poorly communicated objectives (such as not understanding customer requirements), inefficient use of resources, and a lack of a systematic approach to continuously reducing waste. To be effective, activities must be clearly documented and communicated to those performing them. Tools like standard work and visual management help communicate objectives and ensure efficient resource use.

#### Mura

Mura means "lack of consistency" or unevenness, often caused by variations in customer demand or in how a process is executed. Mura can lead to overburdening some resources while others remain idle. Customer needs can vary in terms of what they want, how much they want, and when they want it. However, processes often change infrequently due to associated costs. For instance, hospitals schedule specialist clinics at specific times, and machines produce batches of similar products together. Responding to customer demands precisely and promptly requires high process flexibility. Standard work helps reduce variations in process execution, while set-up reduction and level scheduling can smooth production and align capacity with demand.

Symptoms of inadequate process flexibility include:

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- Large batches: Moving batches of materials, customers, or information through a process increases inventory as the batch progresses.
- Delays between activities: Longer changeover times make it harder to synchronize flow with customer demand.
- More variation in activity mix than in customer demand: If activity mix varies more than customer demand, some batching of activities is occurring

### Muri

Muri refers to the unreasonable or excessive demands placed on a process and its resources, leading to poor outcomes. Reducing muri involves smoothing demand (mura). Waste can result from failing to perform basic operations planning tasks, such as prioritizing activities (sequencing) and understanding the time (scheduling) and resources (loading) needed to perform activities. Avoiding muri requires understanding the nature of demand—whether it is stable or unpredictable—to calculate takt time. Takt time is the rate of production needed to meet customer demand. Knowing the takt time allows operations to align capacity with demand effectively.

These three causes of waste are interconnected. When a process is inconsistent (mura), it can lead to overburdening equipment and people (muri), which in turn results in various non-value-adding activities (muda). By addressing these issues, lean operations aim to create a more efficient and value-driven process that meets customer needs without unnecessary waste.

### Types of Waste

Muda, mura, and muri are interconnected causes of waste. Now, let's focus on the types of waste (specifically types of 'muda') that are central to lean philosophy and apply to all operations. Seven types of waste are identified:

1. **Overproduction** – This occurs when an operation produces more than what the customer requires. Producing too much, too soon, or "just in case" can lead to product obsolescence or excessive inventory, which can hide problems, as previously discussed. A pull system should align production with actual customer demand. (Toyota considers overproduction the most serious type of waste.)
2. **Waiting** – Any form of waiting hinders the flow of products or services to the end customer. People generally have better things to do than wait for a resource (like a machine or service professional) to become available. Whenever products, customers, or information are waiting in inventory or queues, no value is being added.
3. **Transport** – This involves moving products, customers, or information from one place to another without adding value to the customer. Moving items or customers around the operation, along with double or triple handling, does not add value. Changes in layout to bring processes closer together, along with improvements in transport methods and workplace organization, can reduce waste. Such changes can also significantly reduce the physical movement of staff, leaving them less fatigued at the end of the day.


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4. **Overprocessing** – This is when more work is done to a product or process than the customer requires. Overprocessing involves spending time and money on tasks that the customer does not value. A common example is when a customer must provide the same information for multiple similar but different documents.

5. **Inventory** – Represents capital expenditure that has not yet generated income; all types of inventory (product, customer, information) should be targeted for elimination. However, reducing inventory requires addressing its causes, such as irregular flow (mura). Inventories can mask production problems and hinder flow, as discussed earlier.

6. **Motion** – Refers to the movement of workers and equipment; excessive motion wastes time and can cause injury or damage. Excessive motion includes searching for materials, tools, or equipment due to poor organization.

7. **Defects/Rework** – When defects occur, they lead to additional costs and delays. Lean emphasizes precise quality levels. If quality levels vary, customers may not feel adequately served. Symptoms of poor variability and a high likelihood of defects include unreliable equipment or staff. Unreliable equipment or staff often indicate a lack of consistency in quality levels, leading to irregularities in supplying customers. This disrupts flow. Similarly, defective products or services (waste caused by poor quality) are significant in most operations. Errors in the service or product cause both customers and processes to waste time until they are corrected.

8. **An Eighth Waste?**

Many lean practitioners argue there is an eighth type of waste: the underutilization of people. Misaligning individual talents, skills, creativity, and knowledge relative to tasks results in a waste of available knowledge and skills. Examples include having skilled workers perform unskilled tasks or restricting decision-making authority to higher levels within a business. This misuse of human resources can prevent organizations from fully leveraging their employees' potential, leading to inefficiencies and missed opportunities for improvement.

By recognizing and addressing this eighth waste, organizations can better harness the capabilities of their workforce, fostering a more engaged and productive environment. Empowering employees to contribute their ideas and skills can lead to innovative solutions and improvements in processes, ultimately enhancing overall efficiency and effectiveness. Encouraging a culture of continuous improvement and valuing employee input are key strategies in minimizing this type of waste and maximizing the potential of the organization's human resources.

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## How Enhancing Layout Design Minimizes Waste

A key concept in lean operations is ensuring the smooth flow of materials, information, and people. Long process routes can lead to delays, inventory accumulation, and extended throughput times, none of which add value for the customer. Therefore, one of the first steps an operation can take to improve flow is to reevaluate its process layout. This often involves shifting the layout along the “natural diagonal” of process design, as discussed in Chapter 6. Generally, this means transitioning from functional layouts to cell-based layouts, or from cell-based layouts to line layouts. The goal is to create a layout that enhances systematization and control over the process flow.

On a more detailed level, effective layout strategies include positioning workstations close together to prevent the accumulation of inventory or customers, and arranging workstations so that everyone involved in a common task can see and assist each other. For instance, at the Virginia Mason Medical Center in Seattle, a leader in applying lean principles to healthcare, many waiting rooms have been significantly downsized or eliminated. This change emphasizes the importance of maintaining flow throughout the process, as patients have no place to be “stored.” In contrast, some hospitals have multiple waiting areas or “sub-waits,” where patients arrive in groups and move from one waiting room to another, which disrupts smooth flow.

By redesigning layouts to minimize waiting areas and encourage continuous movement, organizations can significantly reduce waste associated with delays and inefficiencies. This approach not only speeds up the process but also enhances the overall experience for customers or patients by reducing wait times and improving service delivery.

In manufacturing and other industries, similar principles apply. By organizing workstations and equipment in a way that supports a streamlined flow, companies can reduce unnecessary handling and transportation of materials, leading to faster production times and lower costs. This systematic approach to layout design helps in identifying and eliminating bottlenecks, ensuring that each step in the process adds value and contributes to a more efficient operation.

Ultimately, improving layout design is a fundamental aspect of lean thinking, as it directly impacts the ability to deliver products or services quickly and efficiently, meeting customer demands while minimizing waste.

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## How Enhancing Process Flexibility Minimizes Waste

To meet customer demands precisely and promptly, operational resources must be adaptable enough to change both their tasks and the volume of work without incurring high costs or long delays. Flexible processes can greatly improve the smoothness of workflow. For example, in aircraft maintenance, ensuring planes are regularly checked, repaired, and maintained is crucial to prevent accidents. While the primary goal of aircraft maintenance operations is to ensure high-quality maintenance, improving the turnaround time is also important. Faster maintenance can reduce the number of aircraft an airline needs, as planes spend less time out of service. Additionally, a more efficient maintenance process can increase profitability and allow major airlines with established maintenance operations to generate additional revenue by servicing other airlines' aircraft.

A lean analysis of the maintenance process, aimed to maintain or even enhance quality levels while reducing maintenance costs and increasing aircraft availability by shortening turnaround times. The analysis identified waste in the maintenance process, leading to two key findings. First, the sequence of activities on the airframe was dictated by tasks outlined in technical manuals from various suppliers, without considering an optimized sequence that could save time and effort for maintenance staff. By defining an overall sequence and allocating tasks with 'standard work' for preparing tools, materials, and equipment, efficiency improved.

Second, maintenance staff often waited for the airframe to become available, even though some preparatory tasks could be completed beforehand. By having staff perform these tasks during downtime, before the airframe was ready, the process became more efficient. These changes led to significant improvements in cost and aircraft availability. Additionally, work preparation became more standardized and rigorous, and maintenance staff were more motivated as many minor frustrations and obstacles to efficient work were eliminated.

This approach not only streamlined the maintenance process but also enhanced the overall work environment for the staff. By reducing unnecessary waiting times and optimizing task sequences, the maintenance team could focus more on their core responsibilities, leading to higher job satisfaction and productivity. The removal of inefficiencies and the introduction of standardized procedures helped in minimizing errors and improving the quality of work.

Furthermore, the increased flexibility in the maintenance process allowed the airline to better adapt to varying demands and schedules, ensuring that aircraft were serviced and returned to operation more quickly. This adaptability is crucial in maintaining a competitive edge, as it enables the airline to maximize the utilization of its fleet and reduce operational costs.

Overall, improving process flexibility is a vital component of lean operations, as it reduces waste, enhances efficiency, and supports a more responsive and agile organization. By continuously seeking ways to optimize processes and eliminate bottlenecks, companies can better meet customer needs and achieve sustainable growth.

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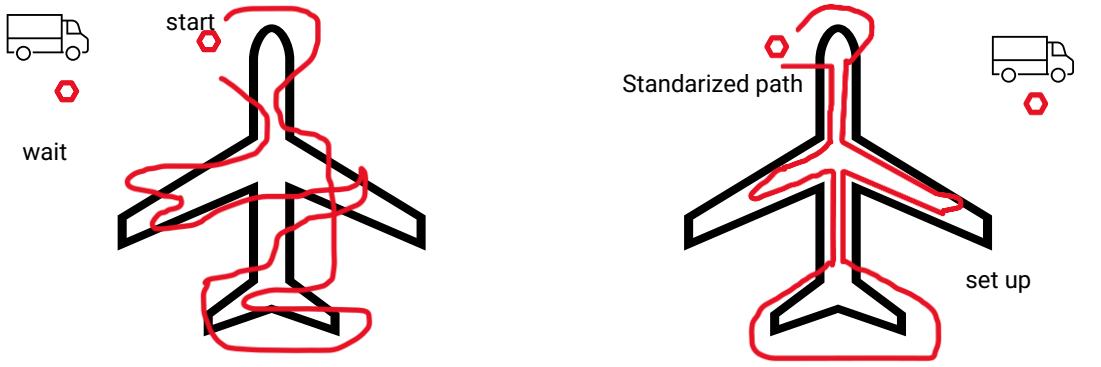


Before:
Maintenance staff follow the steps as detailed in the technical documentation.
The overall sequence of tasks is not optimized
Preparation of work a set-ups included as part of the task

After:
The overall sequence of tasks is defined and allocated to minimize non-value-added activity
Preparation work and set-ups may ve done ahead of time to minimize aircraft contact time
Increased productivity and reduced aircraft waiting time

Figura 3. Aircraft maintenance procedures subject to waste reduction analysis

### Adopting Small-Scale, Simple Process Technology

Lean principles often advocate for the use of smaller-scale process technology to minimize variations in flow volume. For instance, as shown in Figure 16.8, a single large machine might produce a batch of product A, then switch to a batch of product B, and finally a batch of product C. In contrast, using three smaller machines allows for the simultaneous production of A, B, and C. This setup is also more resilient; if the large machine fails, the entire operation halts. However, if one of the smaller machines fails, the system can still function at two-thirds capacity. Smaller machines are also easier to relocate, enhancing layout flexibility and reducing the risk of costly investment mistakes. Nonetheless, the total investment in capacity might increase because multiple parallel facilities are required, potentially leading to lower utilization rates (as previously discussed).

### Minimizing Changeover Times (Setup Reduction)

To meet demand precisely when needed, processes must be flexible enough to handle unexpected demand and switch quickly between tasks. Changeover times can often be drastically reduced—consider the difference between changing a car tire yourself and the under-three-second tire changes performed by a Formula 1 team. Setup reduction can be achieved through several strategies:

- **Measure and Analyze Changeover Activities**: Simply measuring current changeover times, documenting them, and analyzing the specific activities involved can lead to improvements in reducing these times.

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- **Differentiate Between External and Internal Activities**: “External” activities are those that can be performed while the process is ongoing, such as preparing for the next customer or task while waiting for it to arrive (as seen in the earlier example of aircraft maintenance). “Internal” activities, on the other hand, cannot be done while the process is active, like interviewing a customer while completing a service request for another. By identifying and separating these activities, the goal is to accomplish as much as possible while the process continues.
- **Convert Internal Activities to External Ones**: Another common method for reducing changeover time is to shift tasks that were previously done during the changeover to be completed outside of it. This can be achieved through:
    - Pre-preparing activities or equipment instead of doing so during changeover periods.
    - Accelerating necessary changes in equipment, information, or staff, possibly by using simple tools.
    - Practicing changeover routines, as regular practice and the resulting learning curve effect tend to decrease changeover times.

By implementing these strategies, organizations can significantly enhance their operational flexibility and efficiency. Reducing changeover times not only allows for quicker transitions between tasks but also minimizes downtime, leading to increased productivity and responsiveness to customer demands.

Moreover, the practice of regularly analyzing and refining changeover processes fosters a culture of continuous improvement. Teams become more adept at identifying inefficiencies and developing innovative solutions to streamline operations. This proactive approach not only reduces waste but also empowers employees to contribute to process enhancements, ultimately driving better performance and competitiveness in the market.

### Establishing Standardized Procedures

Standardized procedures involve documenting the most efficient method for carrying out a process, with explanations for why each step is performed in a particular manner. Rather than making a process inflexible, standardized procedures provide a foundation for ongoing improvement efforts. When process efficiency and quality are enhanced, these procedures are updated to reflect the best-known method for completing a task. Without standardized procedures, improvements in processes may not be maintained over time. They are crucial for setup reduction, ensuring that processes are executed consistently every time. Additionally, standardized procedures facilitate flexible working among staff, allowing them to quickly acquire the necessary knowledge to perform tasks in areas outside their usual responsibilities.

By implementing standardized procedures, organizations can ensure that all employees follow the most effective and efficient methods, leading to consistent quality and

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performance. This consistency is vital for maintaining high standards and minimizing errors, as everyone is aligned with the best practices.

Moreover, standardized procedures serve as a valuable training tool, enabling new or cross-functional team members to quickly learn and adapt to different roles within the organization. This flexibility not only enhances workforce versatility but also supports smoother transitions and coverage during absences or peak demand periods.

In essence, standardized procedures are a cornerstone of lean operations, providing a structured approach to process management that supports continuous improvement, operational consistency, and workforce adaptability. By regularly reviewing and updating these procedures, organizations can sustain improvements and remain competitive in a dynamic business environment.

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## Reducing Waste by Minimizing Variability

A major contributor to variability is inconsistency in the quality of products. Therefore, any discussion on lean practices should address how quality consistency is maintained within processes, often referred to as 'mura.' The principles of statistical process control (SPC) are particularly useful for understanding and managing quality variability.

### Levelling product or service schedules (Heijunka)

Balancing production schedules, known as heijunka, involves maintaining a consistent mix and volume of workflow between stages over time to minimize unevenness (mura) and overburden (muri). Traditionally, if a variety of products, such as different models of car components, were needed within a specific timeframe (often a month), a batch size would be calculated for each model, and the batches would be produced in sequence.

For example, consider an automotive plant producing three types of components over a 20-day period:

- Quantity of Component A required = 3000
- Quantity of Component B required = 1000
- Quantity of Component C required = 1000
- Batch size of Component A = 600
- Batch size of Component B = 200
- Batch size of Component C = 200

Starting on day 1, the plant begins producing Component A. By day 3, the batch of 600 A components is completed and moved to the next stage. Production of Component B starts and finishes on day 4, followed by Component C, with both batches dispatched by the end of that day. This cycle repeats, leading to large inventory build-ups and daily variations in production tasks.

Now, imagine the plant increases its flexibility (perhaps by using smaller, more adaptable machinery and reducing setup times) so that batch sizes are reduced to a quarter of their original size without losing capacity:

- Batch size of Component A = 150
- Batch size of Component B = 50
- Batch size of Component C = 50

With this setup, a batch of each component can be completed daily, and all three batches are dispatched at the end of each day. This results in smaller inventory movements between stages, reducing overall work-in-progress. More importantly, it establishes a consistent daily production rhythm. Each day of the month involves the same tasks, simplifying planning and control. For instance, if on the first day of the month, the daily batch of Component A is finished by 11:00 am and all batches are completed successfully, the plant knows that maintaining this pace means they are on schedule. In

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contrast, when each day differs, determining whether the schedule is being met requires more complex analysis.

*Batch size A = 600, B = 200, C = 200*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 250 A | 250 A | 100 A | | 250 A | 250 A | 100 A | |
| | | 150 B | 50 B | | | 150 B | 50 B |
| | | | 200 C | | | | 200 C |
| | | ↓ 600 A | ↓ 200 B 200 C | | | ↓ 600 A | ↓ 200 B 200 C |

(a) Scheduling in large batches

*Batch size A = 150, B = 50, C = 50*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 150 A | 150 A | 150 A | 150 A | 150 A | 150 A | 150 A | 150 A |
| 50 B | 50 B | 50 B | 50 B | 50 B | 50 B | 50 B | 50 B |
| 50 C | 50 C | 50 C | 50 C | 50 C | 50 C | 50 C | 50 C |
| ↓ 150 A 50 B 50 C | ↓ 150 A 50 B 50 C | ↓ 150 A 50 B 50 C | ↓ 150 A 50 B 50 C | ↓ 150 A 50 B 50 C | ↓ 150 A 50 B 50 C | ↓ 150 A 50 B 50 C | ↓ 150 A 50 B 50 C |

(b) Levelled scheduling

Figura 4. Levelled scheduling equalises the mix of products/service delivery each day

By adopting this balanced approach to production scheduling, European automotive manufacturers can achieve a more predictable and stable production environment. This consistency simplifies the management of operations, as it becomes easier to track progress and ensure that production targets are met daily. The regularity in production also facilitates better resource allocation, as the workforce and machinery can be optimally utilized without the disruptions caused by varying daily demands.

Moreover, this method reduces the amount of inventory and work-in-progress, leading to lower storage costs and less capital tied up in unfinished goods. The streamlined workflow enhances the plant's ability to respond quickly to changes in customer demand, improving overall agility and competitiveness in the market.

### Balancing Delivery Schedules

The concept of balanced scheduling can also be applied to transportation processes. For instance, consider a chain of convenience stores that needs to deliver various products weekly. Traditionally, the chain might send out a truck loaded with a single type of product to all its stores, ensuring each store receives enough to last a week. This approach is similar to handling large batches, as discussed earlier.

Alternatively, the chain could opt to send smaller quantities of all products in a single truck more frequently. This way, each store receives smaller, more frequent deliveries, which helps keep inventory levels lower. Additionally, the system becomes more

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adaptable to changes in demand trends, as more frequent deliveries provide more opportunities to adjust the quantities delivered to each store.


Figura 5. Delivering smaller quantities more often can reduce inventory levels

## How does lean consider improvement?

Lean philosophy views improvement as a continuous journey towards ideal operational goals, such as meeting demand instantly with perfect quality and zero waste. Although these ideals may seem unattainable, lean emphasizes the importance of gradually moving closer to them over time. This is where the concept of continuous improvement, or “kaizen” in Japanese, plays a crucial role. Kaizen is a fundamental aspect of lean, focusing on incremental and ongoing enhancements to processes.

One effective method for driving process-level improvements within lean is the Rapid Process Improvement Workshop (RPIW), also known as a kaizen event. These workshops typically last three to five days and involve a diverse team of employees who collectively examine a specific process to identify opportunities for improvement in line with lean principles. The team usually includes employees whose work is related to the process being analyzed, although they may not fully understand how their tasks fit into the overall process or affect other areas.

RPIWs are often facilitated by members of a centralized improvement team skilled in process improvement techniques. Before the workshop, this team may conduct a detailed analysis of performance data, which is then shared with participants to highlight areas of underperformance. This data-driven approach helps create a collective understanding of the need for change, a critical first step in any improvement initiative.

During the workshop, participants move from recognizing the problem to understanding it through techniques like “go-see,” process mapping, and value stream mapping. They then envision a future state where non-value-adding activities are eliminated to improve flow. Tools such as cause-and-effect diagrams are used to identify root causes and prioritize improvements. The team conducts rapid experiments using Plan-Do-Check-Act (PDCA) cycles to test process changes.

The composition of the RPIW team is vital for success. It should include individuals with the authority to lead change, those with social capital to support process changes, and people with the necessary technical expertise. A process owner should also be part of the team to ensure that actions from the workshop are implemented and progress is

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monitored. This collaborative and structured approach to improvement helps organizations move closer to their lean ideals.

The RPIW process is designed to foster a culture of collaboration and shared responsibility for improvement. By involving a cross-section of employees, the workshop not only generates diverse insights and ideas but also builds a sense of ownership and commitment to the changes being proposed. This inclusive approach helps break down silos within the organization, as participants gain a broader understanding of how their roles contribute to the overall process and impact other areas.

As the workshop progresses, team members engage in hands-on activities to test and refine their ideas. The use of PDCA cycles allows for iterative experimentation, enabling the team to quickly assess the effectiveness of proposed changes and make necessary adjustments. This rapid feedback loop is essential for identifying practical solutions that can be implemented immediately, leading to tangible improvements in process performance.

Once the RPIW concludes, the process owner plays a crucial role in ensuring that the momentum generated during the workshop is maintained. They are responsible for overseeing the implementation of agreed-upon actions, monitoring progress, and addressing any challenges that arise. This ongoing commitment to improvement helps sustain the gains achieved during the workshop and encourages a continuous cycle of learning and development.

### Encouraging Improvement by 'Stopping the Line'

The concept of the "Andon Cord," named after a Japanese lantern, is a powerful tool used in lean operations to halt activities when a defect is detected. Pulling the cord effectively "stops the line," providing a clear visual (and sometimes audible) signal that indicates the presence and location of a problem. In organizations that adopt this approach, employees are granted "line-stop authority," meaning they are empowered and obligated to alert others if an issue arises. By stopping the production line, immediate attention is directed towards resolving the problem. While this may seem to disrupt efficiency temporarily, the short-term loss is considered less significant than the cumulative losses that would result from allowing defects to persist in the process. Addressing issues immediately ensures they are corrected, preventing them from becoming ingrained in the system. For instance, online retailer Amazon has implemented a version of the Andon Cord to address customer complaints promptly.

### Gemba Walks – The Principle of Go-See

The practice of going to the "gemba" (or "genba") involves visiting the actual place where work is performed to gain a true understanding of the process. Organizations implementing lean use "gemba walks," where managers regularly visit the worksite to observe and understand the work from the perspective of those who perform it. This practice enhances the visibility of operations, fostering a deeper understanding of how work is done and strengthening the connection between management and the "shop floor." The guiding principle of the gemba walk is that "those who do the work know best how to improve the work." By engaging directly with the work environment, managers can identify opportunities for improvement and support employees in implementing effective changes.

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The Andon Cord and Gemba Walks are integral components of the lean philosophy, emphasizing the importance of immediate problem-solving and direct engagement with the work environment to drive continuous improvement.

**Andon Cord: Immediate Problem Resolution**

The Andon Cord system empowers employees to take immediate action when a defect or issue is identified. This proactive approach ensures that problems are addressed at their source, preventing them from escalating and affecting the entire production process. By stopping the line, organizations prioritize quality and problem resolution over short-term efficiency. This method not only prevents defects from propagating but also fosters a culture of accountability and continuous improvement, as employees are encouraged to take ownership of the quality of their work.

**Gemba Walks: Understanding and Improving Processes**

Gemba walks are a practice where managers and leaders visit the actual worksite to observe and understand the processes firsthand. This approach is based on the belief that true insights into process improvements can only be gained by seeing the work as it happens. During gemba walks, managers engage with employees, ask questions, and gather insights into the challenges and opportunities present in the work environment. This direct interaction helps bridge the gap between management and frontline workers, promoting a culture of collaboration and mutual respect.

By regularly conducting gemba walks, organizations can identify inefficiencies, uncover hidden issues, and gather valuable feedback from employees who are intimately familiar with the processes. This practice not only enhances the understanding of operations but also empowers employees to contribute their ideas for improvement, reinforcing the lean principle that those closest to the work are best positioned to suggest meaningful changes.

**Value Stream Mapping: Understanding Flow and Identifying Waste**

Value stream mapping is a powerful tool used to enhance the flow of materials, information, and people through a process. It provides a comprehensive view of both the direct activities involved in creating products and services and the indirect information systems that support these processes. The primary goal of value stream mapping is to distinguish between value-adding and non-value-adding activities, helping organizations identify and eliminate waste.

**Key Features of Value Stream Mapping:**

1. **Broader Information Scope:** Unlike traditional process maps, value stream mapping incorporates a wider range of information, including cycle times, waiting times, and process efficiency metrics.
2. **Higher-Level Perspective:** Value stream maps typically focus on a higher level of abstraction, encompassing 5–10 key activities rather than detailed steps.

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3. **Wider Scope:** These maps often adopt a supply network perspective, considering the entire set of activities that transform materials, information, and customers from start to finish.

**Steps in Value Stream Mapping:**

1. **Identify the Value Stream:** Select the process, operation, or supply chain to be mapped.
2. **Create the Current State Map:** Physically map the process and the information flow that enables it, capturing the current state of operations.
3. **Diagnose Problems and Suggest Changes:** Analyze the current state map to identify waste and propose improvements, creating a future state map that represents the optimized process.
4. **Implement Changes:** Execute the suggested improvements to streamline the process and reduce waste.

For example, a value stream map for an industrial air-conditioning installation service might reveal that only 8 out of 258 hours in the process are value-adding, highlighting significant opportunities for improvement.

**5S Technique: Simplifying and Organizing Work Areas**

The 5S technique, originating from Japan, is a straightforward methodology for organizing work areas to enhance efficiency and reduce waste. It focuses on visual order, organization, cleanliness, and standardization, helping to eliminate waste related to uncertainty, waiting, and searching for information.

**The 5S Components:**

1. **Sort (Seiri):** Eliminate unnecessary items and retain only what is needed.
2. **Straighten (Seiton):** Arrange items so they are easily accessible when needed.
3. **Shine (Seiso):** Maintain cleanliness and tidiness in the work area.
4. **Standardize (Seiketsu):** Ensure consistent cleanliness and order, maintaining perpetual neatness and organization across the workspace.
5. **Sustain (Shitsuke):** Develop a culture of commitment and pride in adhering to the established standards, ensuring that the improvements are maintained over time.
6. **Benefits of the 5S Technique:**
7. **Elimination of Waste:** By organizing the workspace and removing unnecessary items, the 5S technique helps eliminate waste related to searching for tools, materials, or information, thereby reducing delays and inefficiencies.
8. **Improved Efficiency:** With everything in its designated place and easily accessible, work processes become faster and more efficient, reducing the time spent on non-value-adding activities.


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9. **Enhanced Safety and Morale:** A clean and organized work environment reduces the risk of accidents and creates a more pleasant and motivating atmosphere for employees.
10. **Consistency and Predictability:** Standardizing processes and maintaining order ensures that operations are consistent and predictable, leading to higher quality outcomes and fewer errors.
11. **Cultural Change:** By fostering a sense of ownership and pride in maintaining standards, the 5S technique encourages a cultural shift towards continuous improvement and operational excellence.

**Adopting Visual Management**

Visual management is a lean technique designed to enhance transparency and communication within an operation or process. By making the current and planned states visible to everyone, visual management allows both those involved in the process and external observers to quickly understand what is happening. This is typically achieved through visual signals such as notice boards, computer screens, lights, or other indicators. Despite its simplicity, visual management offers several significant benefits:

- **Common Focus for Team Meetings:** Visual tools serve as a central point for discussions, helping teams align on goals and progress.
- **Safe and Effective Working Practices:** Visual cues can demonstrate proper methods and safety protocols, ensuring consistent adherence to best practices.
- **Performance Communication:** By clearly displaying performance metrics, visual management communicates how success is measured and what targets need to be met.
- **Status Assessment:** It allows for quick assessment of the current operational status, making it easier to identify issues or areas needing attention.
- **Task and Priority Understanding:** Visual management clarifies tasks and priorities, helping employees understand what needs to be done and when.
- **Performance Judgement:** It provides a basis for evaluating individual and team performance, fostering accountability.
- **Work Flow Identification:** Visual tools help track the flow of work, showing what has been completed and what is in progress.
- **Deviation Identification:** They highlight when processes deviate from the plan, enabling prompt corrective action.
- **Standard Display:** Visual management shows agreed-upon standards, ensuring everyone is aware of expectations.
- **Real-Time Feedback:** It offers immediate feedback on performance, allowing for quick adjustments and continuous improvement.

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- **Reduced Reliance on Formal Meetings:** By providing ongoing visibility, visual management reduces the need for frequent formal meetings, saving time and resources.

**Adopting Total Productive Maintenance (TPM)**

Total Productive Maintenance (TPM) is a lean strategy aimed at minimizing operational variability caused by equipment breakdowns. TPM involves all employees in maintenance activities, encouraging them to take ownership of their equipment and perform routine maintenance and simple repairs. This approach is applicable to both manufacturing and service operations.

For example, in a car wash, employees might regularly maintain power hoses to prevent downtime. Similarly, university staff may be encouraged to manage their digital environments by cleaning email inboxes, deleting old files, and updating software to maintain system speed and security. By involving all staff in maintenance tasks, TPM frees maintenance specialists to focus on developing advanced skills and improving maintenance systems.

is a comprehensive approach that integrates maintenance into the daily operations of an organization, aiming to achieve zero breakdowns and zero defects. It emphasizes proactive and preventive maintenance to improve equipment reliability and efficiency. Here are some key aspects of TPM:

- **Employee Involvement:** TPM encourages all employees, from operators to managers, to participate in maintenance activities. This involvement fosters a sense of ownership and responsibility for the equipment and processes they work with.
- **Autonomous Maintenance:** Operators are trained to perform basic maintenance tasks, such as cleaning, lubricating, and inspecting equipment. This helps in early detection of potential issues and reduces the likelihood of breakdowns.
- **Planned Maintenance:** TPM involves scheduling regular maintenance activities based on equipment usage and condition, rather than waiting for failures to occur. This proactive approach helps in extending the lifespan of equipment and reducing downtime.
- **Focused Improvement:** Teams work collaboratively to identify and eliminate the root causes of equipment-related problems. This continuous improvement process aims to enhance equipment performance and efficiency.
- **Training and Development:** TPM emphasizes the importance of training employees to develop their skills and knowledge in maintenance practices. This ensures that staff are equipped to handle maintenance tasks effectively and safely.
- **Safety and Environment:** TPM integrates safety and environmental considerations into maintenance activities, ensuring that equipment is operated and maintained in a manner that minimizes risks and environmental impact.

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- **Performance Measurement:** TPM uses key performance indicators (KPIs) to track the effectiveness of maintenance activities and identify areas for improvement. Common KPIs include overall equipment effectiveness (OEE), mean time between failures (MTBF), and mean time to repair (MTTR).

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