Importance of Flow in Lean Thinking

Importance of Flow in Lean Thinking

An Interactive Learning Resource

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Contents

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Introduction

This learning resource was created to help instructors teach lean management concepts in undergraduate or graduate programs in business, engineering, or workforce development schools. It offers a theoretical background and animated simulations to explain the importance of one-piece flow in lean manufacturing environments, in contrast to batch production. Different from the more simplistic animations, where only the production of 10 parts is simulated, this resource is enriched with scenarios that benchmark one-piece flow and batch flow in a more realistic situation, displaying the continuous production of large quantities. It also explains the concept of excess inventory hiding problems, which lean practitioners commonly see as a barrier hindering the establishment of a continuous improvement culture.

About the Author

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PART I

IMPORTANCE OF FLOW IN LEAN THINKING

Learning Objectives

After studying this resource, students should be able to

- Distinguish the core features of batch production and one-piece production flow by relating them to the seven waste categories in lean manufacturing methodology.
- Estimate and benchmark the key performance indicators in batch production and one-piece production flow to determine the benefits of one-piece flow.
- Elaborate on why higher levels of inventory are not desired from a lean management perspective.

Introduction

Lean thinking ("lean" for short) can be described as a customer-centric management philosophy that focuses on eliminating waste from production processes. **Waste** is defined as any activity or design element that does not add value (as defined by the customers) to the products or services the organization offers. There are seven main waste categories[1] in lean, which were introduced by Taichi Ohno[2], and which are commonly referred to using the acronym **TIMWOOD**:

- **Transportation**
- **Inventory**
- **Motion**
- **Waiting**
- **Overproduction**
- **Overprocessing**
- **Defects**

In this resource, we will focus on *flow*, one of the main techniques in lean manufacturing that reduces waste in several of the TIMWOOD categories (some indirectly) when applied effectively. **Flow**, in simple terms, is the

1. Monden, Y. (1998). Toyota Production System: An integrated approach to just-in-time. Chapman & Hall.
2. Ohno Taiichi (1912-1990) was a Japanese industrial engineer and businessman. He is considered to be the father of the Toyota Production System, which inspired lean manufacturing. (See Toyota Production System on Wikipedia.)

opposite of batching between production processes, and the ideal situation is the **one-piece flow**, in which there is no work-in-process inventory between processes. As we learn more about why lean favours *flow* over *batching*, we will explore flow achieves reductions in most waste categories. Let's start with batching.

Continue to Part 1. Batching

1. Batching

Batching is the piling up of processed items before moving them to the next process. The goal is to minimize the setup/change over time between processing different items. Or, in the case of processing a single type of item, transporting items between production stages can be considered setup time. Production managers prefer to collect many processed items in a container before transferring them to the next stage rather than carry them one by one. Conveyor belts can overcome this hurdle when appropriate. Let's watch the following simulation to learn more about how batching works.

Simulation Part 1 – Batching: Small Orders

In this simulation, we illustrate a simplified production line for manufacturing badges. The production processes are cutting, pressing, and stamping. We assume the line is *balanced*, meaning each step or station has the same amount of cycle time. In this simulation, the **cycle time is 1.5 seconds**, and it takes **3 seconds to move a batch of ten pieces between stations**. We have received an order to produce **ten badges**. As you will see, each production stage **stacks ten processed items before moving them together** to the next stage.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://ecampusontario.pressbooks.pub/flowinlean/?p=5#oembed-1

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Key Performance Indicators – Small Order Batching

Let's compute our performance indicators for the small-order batching simulation.

Key performance indicators (KPIs)	KPIs for batching 10 badges
Total production time	Processing + moving + processing + moving + processing + moving 15 + 3 + 15 + 3 + 15 + 3 = **54 seconds**
Cycle time	54/10 = **5.4 seconds** per badge for a single batch of 10 badges
Production lead time	**54 seconds** (total duration a single item spends in the system – processing + waiting + moving).
Waiting time for the pressing station	15 + 3 = **18 seconds**
Waiting time for the stamping station	15 + 3 + 15 + 3 = **36 seconds**
Work-in-progress inventory	**10 items**

Continue to Part 2. One-Piece Flow

2. One-Piece Flow

In this scenario, as the name suggests, the parts flow through the production processes one by one. Each production stage sends the item as soon as it is processed to the next stage, which starts processing right away and transfers it to the next process in line once complete. Thus, a perfect flow of materials is achieved. Although this kind of perfect flow is almost impossible to implement for a whole production line, it is a theoretical ideal that lean practitioners strive to achieve.

Simulation Part 2 – One-Piece Flow: Small Orders

In this simulation, we illustrate a simplified production line for manufacturing badges. The production processes are cutting, pressing, and stamping. We assume the line is *balanced*, meaning each step or station has the same amount of cycle time. In this simulation, the **cycle time is 1.5 seconds**, and it takes **1 second to move a single piece between stations**. We have received an order to produce **ten badges**. As you will see, each production stage processes a **single item at a time** then moves it to the next stage.

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Key Performance Indicators – One-Piece Flow

Let's compute our performance indicators for the one-piece flow simulation.

Key performance indicators (KPIs)	KPIs for producing 10 badges with one-piece flow
Total production time	Processing (simultaneous) + "pressing" waiting for first piece + "stamping" waiting for first piece + moving items (simultaneous) 15 + 2.5 + 5 + 10 = **32.5 seconds**
Cycle time	32.5 / 10 = **3.25 seconds** per badge to produce 10 badges only
Production lead time	1.5 + 1 + 1.5 + 1 + 1.5 + 1 = **7.5 seconds** (total duration a single item spends in the system – processing + waiting + moving)
Waiting time for the pressing station	1.5 + 1 = **2.5 seconds**
Waiting time for the stamping station	1.5 + 1 + 1.5 + 1 = **5 seconds**
Work-in-progress inventory	**3 items**

Continue to Part 3. Continuous Production

3. Continuous Production

When running the production for ten badges only, the advantages of one-piece flow over batching are obvious. However, in the long run—assuming we have a continuously running production system—we should omit the waiting times of the workstations because each of them is fed constantly. Regardless of the feeding method (one-piece flow or batching), there will not be any waiting in a perfect system because the stations are provided with items constantly coming from preceding steps. Waiting time occurs only at the beginning of the production and will become ignorable in the long run (e.g., production of a million badges). Let's visualize the continuous production with batching to see how processes do not wait for parts.

Simulation Part 3 – Batching: Large Orders

In this simulation, we illustrate a simplified production line for manufacturing badges. We have received an order to produce **ten thousand badges**. As you will see, workstations keep **processing items in batches of ten without any waiting time**.

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Credit: Batching: Large Orders by Fatih Yegul and Conestoga College,

Key Performance Indicators – Large Order: Batching

Let's compute our performance indicators for the large-order batching simulation.

Key performance indicators (KPIs)	KPIs for batching (large order)
Total production time for each batch of ten badges	Processing + Moving + Moving + Moving 15 + 3 = **18 seconds**
Cycle time	18 / 10 = **1.8 seconds** per badge
Production lead time	**54 seconds** (total duration a single item spends in the system – processing + waiting + moving)
Waiting time for the pressing station	**0 seconds**
Waiting time for the stamping station	**0 seconds**
Work-in-progress inventory	**30 items**

Key Performance Indicators – Large Order: One-Piece Flow

Now, let's compute our performance indicators for the large order assuming a one-piece flow scenario. See the simulation for the small order one-piece flow for a visual representation of this scenario; the process is basically the same.

Key performance indicators (KPIs)	KPIs for one-piece flow (continuous)
Total production time for a single item	processing + moving 1.5 + 1 = **2.5 seconds**
Cycle time	**2.5 seconds** per badge.
Production lead time	1.5 + 1 + 1.5 + 1 + 1.5 + 1 = **7.5 seconds** (total duration an item spends in the system – processing + waiting + moving)
Waiting time for the pressing station	**0 seconds**
Waiting time for the stamping station	**0 seconds**
Work-in-progress inventory	**3 items**

It is interesting to note that batching has a better cycle time in the long run, thanks to the theoretical savings in moving time. However, production lead time and WIP inventory numbers are troubling in batch production.

So why does Lean favour one-piece flow over batching? Because batching creates huge amounts of WIP inventory (ten times more in our example) and dramatically higher lead times (7.2 times more in our example). Therefore, parts spend a lot more time in the system. Only a tiny fraction of this time is actual processing; the remaining is time waiting to be processed. From a customer's perspective, processing is the only value-added task; other steps, including waiting, are non-value-added tasks.

From a financial standpoint, the concept of inventory has mixed connotations. On the one hand, inventory is listed under assets on the balance sheet, in a way equivalent to cash. But inventory also has a holding/carrying cost, consisting of items such as material handling, space, insurance, and lost opportunity costs (i.e., the opportunity to earn income if the cash tied to inventory was invested in a financial instrument).

Lean's take on inventory is more operational than financial. In lean, inventory is a nuisance that hides operational problems and an obstacle preventing the organization from adopting a continuous improvement culture.

Continue to Part 4. How Inventory Hides Problems

4. How Inventory Hides Problems

The more WIP inventory a production system has, the more likely it is that the system will neglect the operational issues. Let's have another look at our batching simulation.

Simulation Part 4 – Batch Production Hides Problems

In this simulation, we have received an order to produce **one hundred badges**. As you will see, workstations keep **processing items in batches of ten without any waiting time**. At batch number 4, a worker notices that one item does not meet the design specifications, sets it aside, and completes the batch with nine items. Thus, our order is shipped with one missing badge, and the customer is invoiced for 99 badges instead of 100. The system moves on to the next order, which is possibly already late, leaving the defective part to be dealt with at some other time.

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Using the batching approach, it is possible that badges will continue to be shipped to customers with 1 unit less than the quantity ordered. It may take a long time for the engineers to find an opening in their schedule to analyze the cutting workstation and look for the root cause of the issue that creates the defects.

Now let's look at how the same problem would be handled in the one-piece flow scenario.

Simulation Part 5 – One-Piece Flow Reveals Problems

In this simulation, we have received an order to produce **one hundred badges**. As you will see, workstations keep processing items one at a time. Moving fast forward, a worker notices that one item does not meet the design specifications, which means it cannot be processed. The defective item is set aside, and the following station is supposed to wait for the arrival of the next good item to continue production. The situation will also force stamping to wait for one part. Because it is one-piece flow, the order can be shipped once one hundred badges are produced. In this case, the defective part that was set aside is not hidden beneath the WIP inventory and is easily noticeable.

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In a one-piece flow production system, it is not easy to look the other way when you have defective parts lying around: Each defect causes the line to pause and wait for the next good piece. Thus, the managers perceive each defect as a critical problem for the whole system that needs to be solved, leading them to look for root causes and solutions immediately. This approach plays a vital role in making the continuous improvement mentality part of the organizational culture.

Continue to Part 5. Conclusion

5. Conclusion

As we see in the simulation, designing production systems that are as close as possible to one-piece flow will considerably reduce the amount of WIP inventories. As a direct consequence, organizations can reduce WIP inventories and waiting times (lead time), two of Lean's seven main waste categories (remember TIMWOOD). Because less inventory will expose the process issues, companies will have stronger incentives to fix their root causes, which results in fewer defective parts. Manufacturing in smaller quantities rather than big batches also helps companies with overproduction waste by aiming for the ideal situation where it only produces as many as the customers need and only when they need them. Achieving one-piece flow may not have any noticeable impact on motion and overprocessing waste categories. However, unless countermeasures are taken (such as installing conveyor belts), one-piece flow might create extra transportation waste, as it requires more effort to move items one by one as opposed to moving them in batches.

How One-Piece Flow Impacts the Seven Waste Categories

Waste category	**One-piece flow production system**
Transportation	can create extra transportation waste unless measures taken
Inventory	reduces WIP inventory
Motion	may not have any noticeable impact on motion
Waiting	reduces wait time
Overprocessing	may not have any noticeable impact on overprocessing
Overproduction	produces smaller quantities, therefore avoiding overproduction
Defects	has less inventory, therefore increasing the incentive to fix problems and decreasing the potential for defects

Glossary

cycle time

the time required to process one item

defects waste

the parts or products that do not meet the design specifications and therefore must be scrapped or reworked

flow

the movement of raw materials and parts within a manufacturing facility as they are assembled to generate the final products

inventory waste

the holding of inventory causes waste by hiding problems and inhibiting continuous improvement efforts

lean thinking

a customer-centric management approach that eliminates waste from production processes

motion waste

the movement of people around a facility (i.e. walking) or at a workstation (i.e. reaching), which does not add value and can be minimized by facility layout and ergonomic workstation design

one-piece flow

a kind of production flow in which parts are processed and moved one by one from station to station with no work-in-process inventories between workstations

overprocessing waste

the addition of features not needed by customers to products, causing unnecessary processing

overproduction waste

producing more goods than current demand in anticipation of future demand to keep utilization levels high

TIMWOOD

transportation, inventory, motion, waiting, overproduction, overprocessing, defects

transportation waste

the use of resources to move raw materials from supplier to factory or parts from warehouse to workstations is unavoidable but does not add direct value to the product

waiting waste

the time spent waiting for parts or labour does not add value when organizations fail to generate smooth schedules

waste

any activity or element that does not add value to a product or service