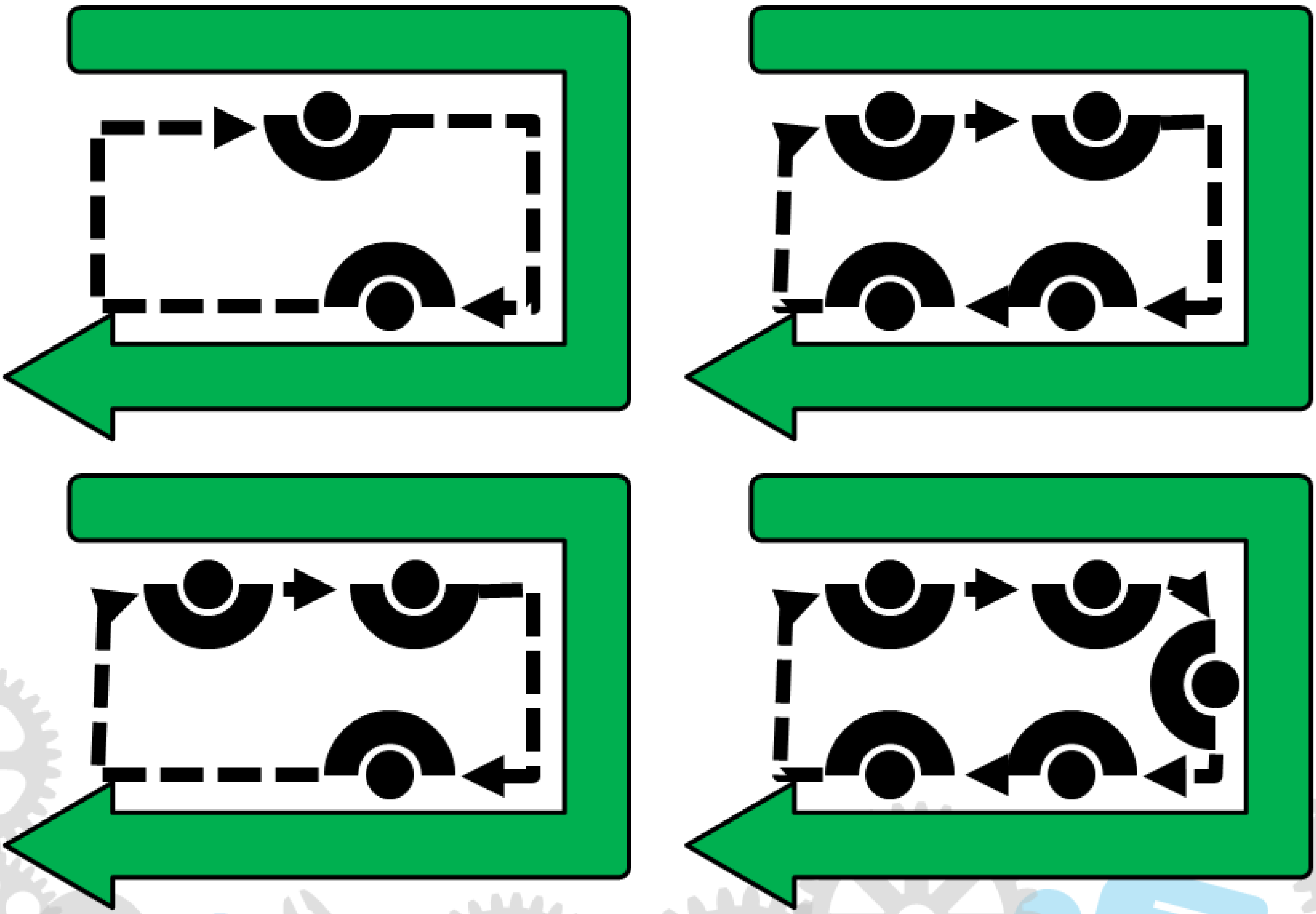
Collected Blog Posts of AllAboutLean.com

2017

Christoph Roser



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AllAboutLean.com Publishing
Offenbach, Deutschland
2020

AllAboutLean.com Publishing, Christoph Roser, Hafeninsel 14, 63067 Offenbach, Deutschland, printed by Amazon Media EU S.à r.l., 5 Rue Plaetis, L-2338, Luxembourg

ISBN of the different versions

- 978-3-96382-019-9 Paperback in color
- 978-3-96382-020-5 Kindle eBook
- 978-3-96382-021-2 Free PDF for download at AllAboutLean.com

Bibliographic information published by the Deutsche Nationalbibliothek: The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available on the Internet at http://dnb.dnb.de.

Other Books by Christoph Roser

“Faster, Better, Cheaper” in the History of Manufacturing: From the Stone Age to Lean Manufacturing and Beyond, 439 pages, Productivity Press, 2016. ISBN 978-1-49875-630-3

Fertigungstechnik für Führungskräfte. 2. überarbeitete und erweiterte Auflage, 293 pages, AllAboutLean Publishing, 2019. ISBN 978-3-96382-004-5 (Manufacturing fundamentals textbook for my lectures, in German)

Collected Blog Posts of AllAboutLean.com 2013, AllAboutLean Publishing, 2020. ISBN 978-3-96382-007-6

Collected Blog Posts of AllAboutLean.com 2014, AllAboutLean Publishing, 2020. ISBN 978-3-96382-010-6

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Collected Blog Posts of AllAboutLean.com 2017, AllAboutLean Publishing, 2020. ISBN 978-3-96382-019-9

Collected Blog Posts of AllAboutLean.com 2018, AllAboutLean Publishing, 2020. ISBN 978-3-96382-022-9

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Preface to the 2013–2019 Collection of Blog Posts

Having successfully written my award-winning blog, AllAboutLean.com, for over six years now, I decided to make my blog posts available as collections. There will be one book of collected blog posts per year, from 2013 to 2019. This way you can store these blog posts conveniently on your computer should my website ever go offline. This also allows you a more professional citation to an article in a book, rather than *just a blog*, if you wish to use my works for academic publications.

This work is merely a collection of blog posts in chronological sequence, and hence does not make a consistent storyline but rather fragmented reading. I am also working on books that teach lean manufacturing. These will also be based on my blog, but they will be heavily edited and reworked to make a consistent storyline. The one I am currently writing focuses on pull production, and hopefully it will be available soon.

The blog posts in this collection are converted into a book as closely as I can manage. However, there are a few changes. For one, on my blog, image credits are available by clicking on the images. This does not work in printed form, hence all images in this collection have a caption and a proper credit at the end of this book. Besides my own images, there are many images by others, often available under a free license. I would like to thank these image authors for their generosity of making these images available without cost. Detailed credits for these other authors are also at the end of this book.

Additionally, a few images had to be removed due to copyright reasons. These are, for example, images from Amazon.com. My blog also includes videos and animations. However, the print medium is generally not well suited to videos and animations, and I do not even have the rights to all videos. Hence, I replaced these videos with a link to the video, and edited the animated images. On digital versions of this book (Kindle eBook, pdf, etc.), these links also should be clickable. No such luck with the print version, unfortunately.

Since my goal is to spread the idea of lean rather than getting rich, I make my blog available for free online. Subsequently, I also make this book available as a free PDF download on my website. However, if you buy it on Amazon, they do charge for their eBooks. If you want a paper version … well … printing and shipping does cost money, so that won't be free either.

I would like to thank everybody who has supported me with my blog, including Christy for proofreading my texts (not an easy task with my messy grammar!), Madhuri for helping me with converting my blog posts to Word documents, and of course all my readers who commented and gave me feedback. Keep on reading!

As an academic, I am measured (somewhat) on the quantity of my publications (not the quality, mind you!), and my Karlsruhe University of Applied Science tracks the publications of its professors. In other words, one of my key performance indicators (KPI) is the number of publications I author. Hence, I will submit these collected blog posts as publications. On top of that, I will submit every blog post in this book as a book section too. Hence, I will have over three hundred publications including seven books, with me as an author, in one year! It will be interesting to see the reaction of the publication KPI system on this onslaught 🙂. I just want to find out what happens if I submit over three hundred publications in one year 🙂. I don't know if I will get an award, or if I will get yelled at, but it surely will be fun. I will keep you posted.

Table of Content

1 The Lean Bucket Brigade – Part 1: Overview

Christoph Roser, January 04, 2017, Original at https://www.allaboutlean.com/bucket-brigade-1/

Figure 1: Bucket Brigade (Image Roser)

Many topics in lean address how to deal with uncertainty and fluctuations (or *mura* for unevenness). There is a particularly neat trick for manual lines that self-organizes fluctuations in the workload: **the Bucket Brigade** (also known as *bump-back* or *bouncing line*)! It does have some advantages, but it also has quite a few limitations and prerequisites for it to work. Most importantly it works best only for very short cycle times as for example picking materials. Unfortunately, these requirements are rarely mentioned in literature. Let me show you the basics work in this post before I go into some of the trickier details in the next post.

1.1 Examples for Transport

The term *bucket brigade* originally comes from firefighting, and is in general used for transportation using a human chain. People create a human chain by standing approximately 1 meter apart. Goods are transported by handing them from person to person. This could be, for example, buckets of water (in case of a fire), empty buckets (also in case of a fire, to refill the buckets), boxes for loading and unloading, or any other type of goods. The image below shows a bucket brigade handling cleaned bricks for reuse in Germany shortly after World War II.

Figure 2: Recycling bricks in Germany after World War II (Image Deutsche Fotothek under the CC-BY-SA 3.0 Germany license)

The advantage of the bucket brigade is that there is little walking involved. Rather than walking back and forth with an bucket, a person stays on the spot and merely hands the items to the next person. An additional benefit is that there is a fast cycle of holding a load and not holding a load, which is less strenuous than holding a load for a long time followed by a long break.

1.2 Bucket Brigade in Lean Manufacturing

The term *bucket brigade* made it into lean manufacturing, although the name does not exactly fit well in my opinion. A bucket brigade in lean manufacturing **DOES** indeed involve walking. The advantage of a bucket brigade is to avoid waiting times for operators in the case of uneven workload.

1.3 Prerequisites

Figure 3: Checklist (Image ClkerFreeVectorImages in public domain)

For a bucket brigade to work, you have a few prerequisites. Strictly speaking, they are not all necessary, but it makes things much easier.

- **Short cycle times**: Short cycle times reduce waiting times during the hand-over of the part and avoid trickier in-process hand-overs. This is actually a requirement that makes the use of this bucket brigade difficult for many flow lines (more on this in my next post). In fact, most practical examples are in pick-and-place or commissioning of materials due to the short process times.
- **Manual flow line**: A bucket brigade works only for a flow line, not for a job shop. There must be a clear and identical sequence of steps for all parts passing through the system. It also helps if the processes are manual processes, where the operator does not have to wait for a machine.
- **More processes than workers**: A bucket brigade requires more process steps than workers. The workers are shifting between different processes to balance the uneven workload.
- **All workers trained in all processes**: Since the workers move between different stations, they should all be trained in how to operate every process. Okay, to be precise, only the first worker would need to know the first process and the last worker the last process, but all workers would need to know all processes in between the first and the last process.
- **Processes nearby**: The farther away the processes are, the more difficult it will be to operate the bucket brigade.
- **Uneven workload**: The bucket brigade is well suited to balance out uneven workload. If the workload is even, you don't need a bucket brigade (although it would still be possible). Relevant here is *not the average workload, but the short term workload*. In other words, if randomly one part may be faster or slower than the average, you have an uneven workload. Most processes I have seen do have somewhat random uneven workloads.
- **Bottleneck at the beginning**: For the bucket brigade to work properly, the first processes should be the slowest. You need to have an increasing speed along the line. The first processes should be slower, and the last processes faster. Alternatively, you can put the slow worker at the beginning and the fast worker at the end of the line – although this selection can give you labor problems by calling a worker "*slow*" (more on this in my next post).
- **No buffer inventories**: Buffer inventories combined with bucket brigades can lead to quite inefficient waiting times (more on this in my next post).

1.4 How It Works: The Common Way

For a "normal" bucket brigade, there are three rules for an individual worker. The worker gets the part from the preceding worker and then moves with the part along the line until he can give the part to the next worker.

1.4.1 1: Receive part from preceding worker

Any worker on the line can get a new part, either from the preceding worker or from the inventory at the start of the line. Hence, an idle worker walks back along the line until he meets the preceding worker (or the start of the line). The worker then takes over the part from the preceding worker.

In the image below, the blue worker walked back along the line until he met the worker at station 1. The blue worker takes over the part from the preceding worker. Here we have two possibilities. Either the preceding worker just finished his part at station 1 and can give it to us right away, or the preceding worker is still working on the part at station 1. In the latter case, we could either wait for worker 1 to finish or take over while the part is still in process 1.

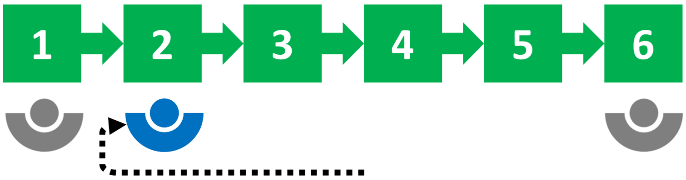


Figure 4: Bucket Brigade Step 1 (Image Roser)

As you can imagine, taking over the part halfway throughout the process is risky, as it requires good communication to know exactly what is already done and what still has to be done. I will talk about these problems a bit more in the next post.

1.4.2 2: Move along the line with a part

After the worker receives a part, he walks along the stations as he processes the parts in the sequence of the stations. In other words, when the part is completed at this station, the worker moves the part to the next station and processes the same part in the next station. For example, in the image below you see a blue worker at station 3. After the worker completed processing of the part at station 3, he moves with the part to station 4 and processes the same part at station 4.

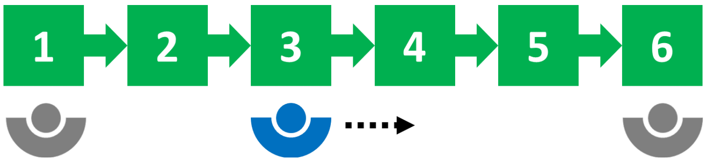


Figure 5: Bucket Brigade Step 2 (Image Roser)

1.4.3 3: When you meet your next colleague

Sooner or later the blue worker will meet the subsequent worker (or the end of the line). If it is the end of the line, the worker will store the part (e.g., in a box) and walk back along the line.

If it is the next worker, the worker will give the part to the next worker and walk back along the line. For example, the blue worker below at station 5 meets the next worker at station 6. He then hands over the part to the next worker and walks back along the line.

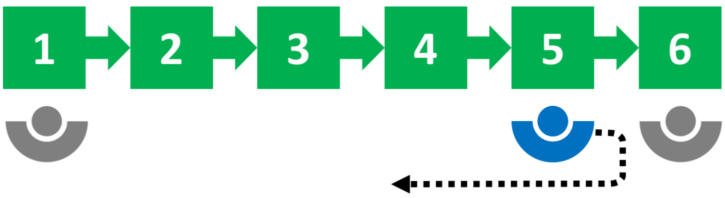


Figure 6: Bucket Brigade Step 3 (Image Roser)

There is a slight complication here. It depends on whether the next worker is walking back without a part (good) or if the next worker is still busy with a part (not so good). Ideally, the next worker is currently working back along the line and can take the part right away.

It is a bit more tricky if the next worker is still busy. In this case, the blue worker should wait or (if he can) help the next worker. Only when the next worker has given his own part to the subsequent worker or to the end of the line can the subsequent worker take over the part from the preceding worker. I will talk about this situation a bit more in my next post.

1.5 Summary

Overall, each worker will work in loops. The size of the loop is not fixed. If a worker has stations with a busy workload or encounters a problem, his loop will automatically become smaller and the loops of the other workers bigger. For example, in the images below, if process 3 temporarily becomes slower, the other two workers will have bigger loops, hence the worker in the middle can take more time to work on process 3.

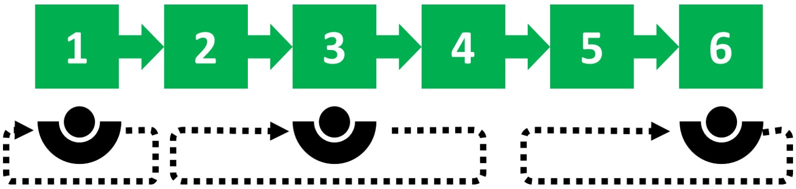


Figure 7: Bucket Brigade Loops (Image Roser)

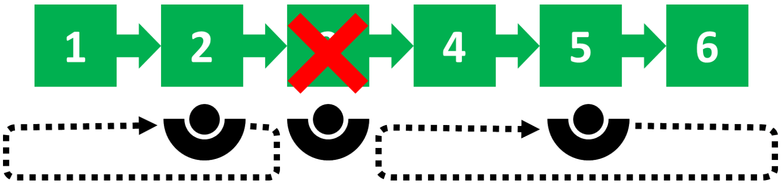


Figure 8: Bucket Brigade Loops Problem (Image Roser)

Overall, the workers always move back and forth between the preceding worker (or the start of the line) and the succeeding worker (or the end of the line). Note that the fastest worker is at the end, and the slowest at the beginning. Also note that the workload of the first two workers changes over time.

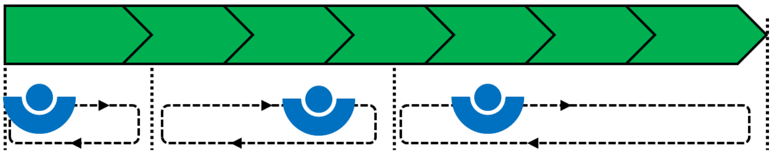


Figure 9: Animated Bucket Brigade Loops. The original image can be found at https://www.allaboutlean.com/bucket-brigade-1/ (Image Roser)

Of course, there are still lots of details that need to be taken care of. I will talk more about this in the next post. In the meantime, **go out and organize your industry!**

2 The Lean Bucket Brigade – Part 2: Details and Caveats

Christoph Roser, January 10, 2017, Original at https://www.allaboutlean.com/bucket-brigade-2/

Figure 10: US Marines Bucket Brigade (Image Christopher M. Carroll in public domain)

In my last post I explained the basics of the bucket brigade as a self-organizing manufacturing line. The key to making this system work is the process for handing over the part to the next worker. An unsuitable hand-over could mean lots of waiting time for the workers. Hence, I would like to go into more detail on how to do the hand-over of the part.

The hand-over process can happen when the subsequent worker walks back along the line or when the preceding worker moving forward catches up with the subsequent worker. Let's look first at the easier case of walking back.

2.1 Walking Back

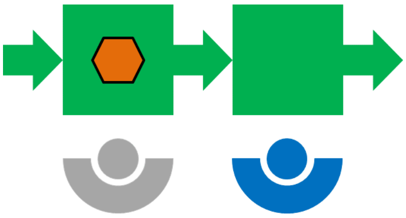


Figure 11: Animated Bucket Brigade Hand Over – no Waiting. Animated image can be found at https://www.allaboutlean.com/bucket-brigade-2/ (Image Roser)

As part of the rules of a bucket brigade, a worker without a part has to walk backward until he meets the preceding worker. In the example picture, the blue worker walks backward until he meets the gray worker at process 3. The blue worker then takes over the part from the preceding gray worker.

Ideally, the preceding gray worker just completed a part at process 3 that can be handed over. The succeeding blue worker would then process this part at station 4. This would be the perfect situation.

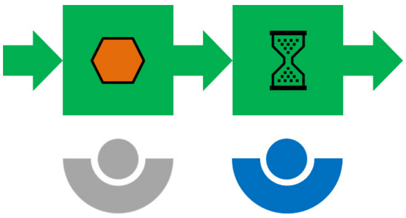


Figure 12: Animated Bucket Brigade Delayed Hand Over. Animated image can be found at https://www.allaboutlean.com/bucket-brigade-2/ (Image Roser)

In reality, however, the gray worker may not yet have completed the part at his station. Now you have two options. First, the blue worker could simply wait until the gray worker completes the part, and then take over the part. This would obviously include waiting time. Hence, a **short**

cycle time would keep this waiting time short, whereas a longer cycle time would create quite a bit of waste by waiting.

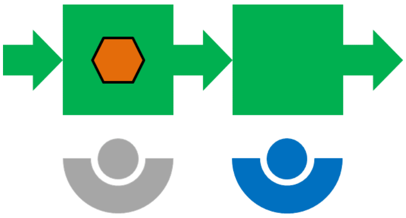


Figure 13: Animated Bucket Brigade in-process Hand Over. Animated image can be found at https://www.allaboutlean.com/bucket-brigade-2/ (Image Roser)

Alternatively, especially for longer cycle times, it is also possible for the blue worker to take over the part from the gray worker while the part is still in the same process. However, this is risky. The hand-over process now also requires additional information. What work in the current process is already completed, and what still has to be done? There is a higher risk of the blue worker overlooking a step in the process, believing that the gray worker has already done that.

2.2 Moving Forward

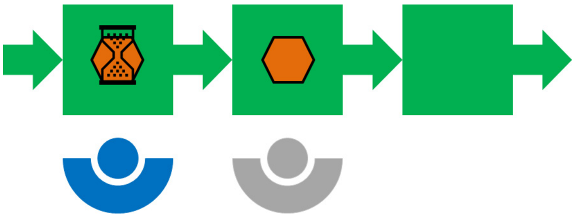


Figure 14: Animated Bucket Brigade Walk Along Forward. Animated image can be found at https://www.allaboutlean.com/bucket-brigade-2/ (Image Roser)

Moving forward along the line should always be with a part. The blue worker in the image moves from station to station together with a part. It is possible that at one point the blue worker will catch up with a subsequent worker (gray in the image). In this case the blue worker has to wait until the gray worker completes his process and moves forward.

Again, we have waiting times. The blue worker cannot hand over the part to the gray worker until the gray worker himself gets rid of his part (by giving it to the next subsequent worker or at the end of the line). I repeat, **the part can only be handed over if the subsequent worker gets rid of his part and is ready to walk backward**.

This problem of waiting for the next worker depends heavily on the work speed. Where is your bottleneck? If your bottleneck is at the end of the line, all workers have to wait for the subsequent worker, and you will have lots of waiting times. The image below shows a possible worst case. All other workers have to wait for the last worker to finish his process, before the workers can move forward.

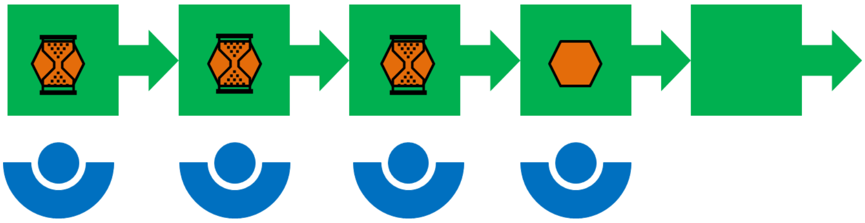


Figure 15: Animated Bucket Brigade Delay Forward. Animated image can be found at https://www.allaboutlean.com/bucket-brigade-2/ (Image Roser)

2.3 Why Not Just Use Buffer Inventory?

All the above examples have no buffer inventory between the processes. This is intentional. It may be tempting to use a similar system with buffers in between, but … don't. The animation below is an extreme case, where the last worker has a problem. The first worker slowly builds up a lot of inventory in the line.

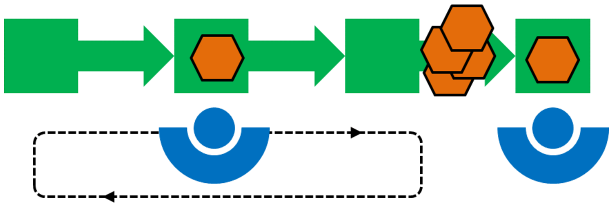


Figure 16: Animated Bucket Brigade filling Inventory. Animated image can be found at https://www.allaboutlean.com/bucket-brigade-2/ (Image Roser)

After the last worker has solved his problem, the first worker would have to wait for the entire time until the last worker has completed all material. Overall, a very inefficient system if you add inventory.

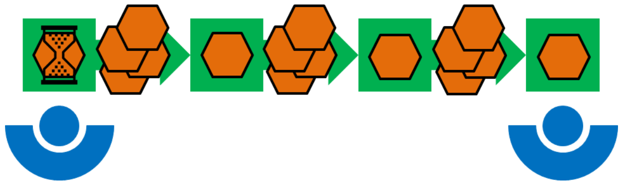


Figure 17: Animated Bucket Brigade emptying Inventory. Animated image can be found at https://www.allaboutlean.com/bucket-brigade-2/ (Image Roser)

Naturally, in the above case the first worker would not wait forever, but would maybe make himself more useful. But this would be either a more complex standard (not good) or a non-standardized and hence chaotic and random action (also not good).

It may be possible to have a working bucket brigade using buffer inventories, but I believe it will be difficult. There are lots of things to take care of to make this work, and there is a risk of the result being worse than a normal balanced flow line.

2.4 Some Examples

Here are some examples of bucket brigades. The first one is a training example from the Universidad Tecnológica de Pereira, where they assemble Lego pieces.

The Video by fiiutp is available on YouTube as "BRBCK.wmv" at https://youtu.be/WK1TaTXhQJ0

The second example is from the food industry, where food is prepared in front of the customer at Chipotle and Subway.

The Video by jgccolombia is available on YouTube as "Chipotle Bucket Brigade and Subway Assembly Line" at https://youtu.be/LBXb9TnMDOw

John Bartholdi at http://www.bucketbrigades.com/ also has a lot of links with examples from industry.

2.5 Summary

A bucket brigade works best for **short cycle times**; otherwise you will have either lots of waiting times or potentially tricky in-process hand-overs. The two example videos above both have rather short cycle times in the range of one to five seconds. In fact, many bucket brigade examples are manual pick-and-place or commissioning tasks, where each *process* is merely a quick handling of a part. However, there are also some examples of more complex bucket brigades (e.g., a wire harness with a cycle time of around one to two minutes).

A bucket brigade should have an **increasing process speed** (or worker speed) along the line to avoid workers getting stuck behind a slow process (or worker). Hence, the bottleneck should be at the beginning of the line.

And, unless you really know what you are doing, **avoid using buffer inventories**. They can create situations with extremely long waiting times.

Overall, the bucket brigade is a possibility for handling variable workloads in some situations. If a bucket brigade does not work for your case, you may simply do a proper line balancing, or think about a *pearl chain* (where you sequence products with different workloads to have an overall balanced workload).

I hope you enjoyed the post (especially the animations – they are quite a bit of work to do!). **Now go out, carry the bucket forward, and organize your industry!**

3 How to Determine Your Lot Size – Part 1

Christoph Roser, January 17, 2017, Original at *https://www.allaboutlean.com/lot-size-part-1/*

Figure 18: Nursing Puppies (Image otsphoto with permission)

There are a few factors that can influence lot size: machine batch size, changeover time, size of the container, shipment sizes, and the size of your customers' orders, which then are combined in the set up of the information flow. All of these factors can be influenced to move toward the true north of lot size one! Also, do not confuse the lot size with the number of parts per kanban. They are related but can be different. In this series of three posts, let me explain in more detail how the factors come together for you to determine the lot size of your processes.

3.1 True North: Lot Size One

Figure 19: The perfect lot size … (Image otsphoto with permission)

The perfect lot size is one. You should always strive to move your production to smaller lot sizes to improve lead time, reduce inventory, and overall become more lean.

But, please, please, don't just set all lot sizes to zero. That will probably create havoc in your production and may result in a gigantic waste of money. Instead, lot size reduction is a gradual process. You improve your system to allow smaller lot sizes, and then you reduce the lot size, before improving the system even further and allowing even smaller lot sizes.

In fact, some production systems may never achieve lot size one. If you produce standard screws, having a lot size one is highly unlikely. Even a lot size of one package may be difficult. Yet, overall, reducing lot sizes is a move in the right direction. See, for example, my post on Toyota's and Denso's Relentless Quest for Lot Size One for some outstanding examples of these efforts. But now let's look at what can influence your lot size. Important: You do not need a hard number in the first go. Instead, do a lot of back and forth between the different steps to achieve an overall good number.

3.2 Changeover Time

Figure 20: Formula 1 quick changeover of tires (Image Francesco Crippa under the CC-BY-SA 2.0 license)

Switching from one product type to the next may take time. Ideally, this changeover time is zero, but in many cases it is not. If it is zero, then you can have a lot size of one for this process. If not, you may need to use a larger lot size.

The relation between changeover time and lot size is unfortunately not simple. Accountants and their lean-incompatible accounting prefer to maximize the lot size. The bigger the lot size, the fewer changeovers you need, and the more time you can use productively. Unfortunately, there's no way to measure the benefit of flexibility, and hence people usually assume this benefit to be nonexistent.

There are mathematical approaches to determine the ideal lot size based on your changeover time, but none that I really trust. The math may ignore factors, make (often hidden) assumptions, and overall may not be worth the effort.

A much better approach is to take the available working time, subtract the time needed to produce the parts (including breakdowns, etc.), and then use the remaining time to do as many changeovers as possible to minimize the lot size. (Remember the true north from above: lot size one is the goal.) This is much better than the accountant's approach, but it also suffers from the flaw that your working time is not a hard number, and neither is your customer demand. However, this is a good starting point.

You can also involve the experts for the processes, such as the foremen and supervisors on the shop floor. They usually know the capabilities of the processes very well. But keep in mind that they often prefer larger lot sizes for similar reasons as the accountants: less unpopular changeover, more production.

Overall, I recommend making a best guess based on all the available inputs, and then going a little bit lower (i.e., round down, or reduce by 10%–30%, etc.). Even for experts it is easy to underestimate the benefits of smaller lot sizes.

And again, **your changeover time can be influenced!** See my series of posts on SMED for the systematic process of reducing changeover times.

3.3 Container Size

Another factor influencing the lot size is the container size. Usually you need to transport your parts, often in a certain box/pallet/container size. How many parts can you fit in your container?

Figure 21: Cage Pallet Box (Image Elmar Zenner under the CC-BY-SA 4.0 license)

Often, this may be a dedicated packaging size (i.e., a blister or foam packaging, a bottle crate, or a egg carton). In this case it may be odd to use a different quantity than indicated by the container size.

In other cases this may be more flexible (i.e., a standard industry box, pallet, or pallet cages). In this case you may also choose not to fill it to max capacity.

Again, **the size of your packaging can be influenced.** If it is a simple box, then you can use smaller boxes. If it is a dedicated size, then you may over time buy smaller sizes.

3.4 Shipment Sizes

Figure 22: Probably NOT your logistic fleet (Image Uwe Aranas under the CC-BY-SA 4.0 license)

In a related situation, if you are receiving deliveries from your suppliers, then it may not make sense to send a truck out every time you need a screw. Overall, you can't get a good trade-off between the shipping cost and the cost (or benefit) of your inventory.

There is a whole field of research concerning economic order quantity (EOQ) – although there are many assumptions that are not really realistic for daily use. The biggest problem is that they can not determine the value of flexibility obtained from small lot sizes.

3.5 Customer Order Size

Figure 23: That's my order size! (Image desertsolitaire with permission)

Yet another factor that can influence the lot size is the order size of the customer. But again, this is also fuzzy, and also **much less significant than it sounds**. Importantly, the "customer" can be both an external customer or an internal customer (i.e., the next production line within your company or plant that takes over your products). But first the theory:

If your customer always orders a certain number of parts, then (theoretically) your lot size does not need to be smaller than this minimum customer order.

Unfortunately, I have a problem with this logic. First of all, I envy anybody who has a customer that always orders the same size. In my experience, this rarely happens. If it happens at all, then it's probably with a lot size of one, which does not help you much here either.

Secondly, the benefit of smaller lot sizes is not only to serve your customer better, but to also be a better customer to your suppliers. Furthermore, having smaller lot sizes is also beneficial for your suppliers (both external suppliers and internal production lines delivering parts to your processes).

Overall, you should not completely ignore customer order size, but it is probably more of a soft factor that may not have much influence. Also, depending on your relation with your customer, **you may also have the possibility of influencing the size of the customer orders.** There are many anecdotes of companies that successfully managed to switch their customers from a monthly order to a weekly order (or less) with benefits for both sides.

In my next post I will talk more about the influence of machine batch size, and also some special considerations for the processing industry and administrative processes. So, until then, **go out and see if you can reduce your lot sizes!**

P.S.: This series of posts is based on a question from Curtis Rosché.

4 How to Determine Your Lot Size – Part 2

Christoph Roser, January 24, 2017, Original at https://www.allaboutlean.com/lot-size-part-2/

Figure 24: Duck & Ducklings (Image Radoslaw Ziomber under the CC-BY-SA 3.0 license)

A good lot size has a significant impact on the performance of the system. In this second post, I look at the influence of the machine batch size on the lot size. I also briefly go into the lot sizes for the processing industry, and also administrative processes. In my next and last post I will look at how to manage different lot sizes in different parts of the value stream.

4.1 Machine Batch Size

Figure 25: Batch size one part – milling (Image Kitt Amaritnant in public domain)

Another influence of your lot size is the capacity of a machine, or the machine batch size. In many cases this is simple. Often, a machine can process exactly one part at a time, as for example the milling machine shown here. Hence, the machine itself can already do a lot size one.

However, there are other processes where the lot size may be larger than one. This may be, for example, an industrial oven for heat treatment that can fit multiple parts, or an injection molding machine that always makes multiple parts in the same shot, or any other kind of machine that makes multiple parts at the same time. Food processing often has one tank full of "food" for processing that is then filled into smaller packages. This tank is then your machine batch size.

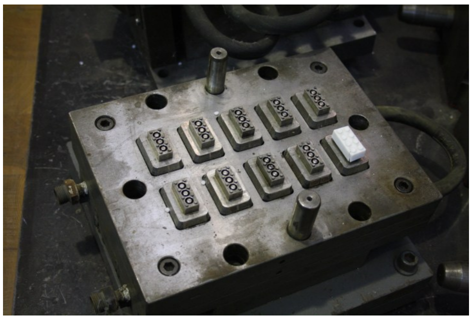


Figure 26: Batch size 10 Legos – injection molding (Image Arne Hückelheim under the CC-BY-SA 3.0 license)

However, the machine batch size does not automatically influence the lot size. It depends if the batch must be the same part. Imagine an industrial oven for heat treatment. You can fit a certain quantity in the oven, but the parts do not necessarily have to be of the same type. Unfortunately, they often do have to be the same type for process quality reasons. For example, you may fit a tray of muffins in the same oven where you are baking a turkey, but it won't be good for either the turkey or the muffins ☹.

Figure 27: Batch size 12 muffins – baking (Image Imogenco in public domain)

Even if the parts have to be of the same type, do you need to use the full capacity of the process? If an injection mold has 10 cavities for parts, it will be difficult to make only seven. However, an industrial oven may work with less-than-full capacity. Check with your process experts if this is possible or if this would require adjustments to the process to ensure consistent quality.

And, always remember, **this machine batch size is a number you can influence when ordering new tools or machines**. Often, two smaller ovens have a higher flexibility than one large oven.

4.2 About the Processing Industry

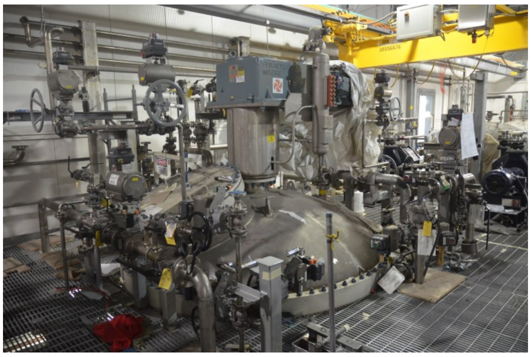


Figure 28: Chemical Process (Image PEO, Assembled Chemical Weapons Alternatives under the CC-BY-SA 2.0 license)

Chemical processes are a bit trickier. First of all, what is a lot size of one in the processing industry? Is it one molecule? Certainly not! While you can measure your output in liters or kilos, you cannot "*count*" it. "*How many water would you like to have?*" … doesn't work that way.

If you fill it into containers for the end customer (e.g., jars of tomato sauce or buckets of paint), then you have your lot size again. "*How many **bottles of** water would you like to have?*" is now a valid question. If your process chain finishes with such an end-customer container, then you know again what a lot size of one is – although for economic reasons you may still produce in larger lot sizes than one.

Figure 29: Tank Truck (Image Cjp24 under the CC-BY-SA 4.0 license)

However, most chemical industry is for other industry, and the size of the delivery is much more flexible. In my experience the batch size in processing industry is determined by the size of the processing vessel. If your chemical reactor (or similar) can fit 500 liters, then that is what you will use as a lot size in most cases.

You may choose to reduce the lot size by filling the container to less-than-full capacity, but this usually is only sensible for exotic products or small orders. (E.g., if the customer orders only 50 liters per year in total, you will not make a 500 liter batch. However, I would recommend using a smaller vessel for this case.)

Overall, you can always use smaller processing vessels to increase flexibility and lead time. But, like with discrete products, there is no single right answer.

Also (and I will talk about this more in my next post), you do not have to use the same lot size throughout the entire process. You can decouple the process by having a larger storage tank/pile/container between processes, where you can change the lot size. Yet, this may not always be a good idea, since a) most chemical processes have much less steps than mechanical manufacturing, and b) **many chemical products are subject to aging or may require traceability of the batch, which is incompatible with mixing old and new in a tank**.

Overall, in most processing industries, the lot size is the size of the processing vessel. If multiple vessels are used in sequence, then the largest vessel usually determines the lot size.

Figure 30: Windmill (Image DonGatley under the CC-BY-SA 3.0 license)

There is also processing industry that does not work in batches, but uses a continuous process. This could be, for example, a grain milling process or a rock crusher to produce gravel. In this case the changeover (both time and wasted product from cleaning) usually defines the lot size.

The approach is then similar to other manufactured products: involve your experts and nudge them to a lower lot size.

As with all other considerations so far, **your lot size can be influenced here too!** For batch processing you could organize a smaller batch. For continuous processing you could do a changeover workshop (a.k.a. SMED).

4.3 About Administrative Processes

Figure 31: Office Environment (Image Phil Whitehouse under the CC-BY-SA 2.0 license)

Administrative processes are also common in industry (and elsewhere). However, in my experience, the question of a good lot size rarely pops up. Most administrative processes have a lot size of one anyway, simply because every task is usually slightly different. If every task is slightly different, then it is not even possible to have a lot size larger than one.

In fact, I had difficulties coming up with an example of larger lot sizes in administrative processes. But here's one: When I grade the exams of my students, I do them in larger lot sizes. Actually, I grade all answers to question 1, then all answers to question 2, and so on. This way I reduce a "*mental changeover*" from question 1 to question 2 after every exam, and also achieve greater consistency (i.e., quality) in my grading.

Overall, administrative processes often have a lot size one anyway, simply because there are often no two tasks the same. If there are almost identical tasks, then the (mental or other) changeover time is the primary factor determining a larger lot size. The "size of the customer order" may also be of influence. But usually the administrative "lot size" is of much less importance than a manufacturing lot size.

I hope you enjoyed this second post of my series of three on lot sizes. My third and final post on lot sizes will look at the information flow and how to manage different lot sizes in different parts of the value stream. So stay posted. In the meantime, **go out and organize your industry!**

P.S.: This series of posts is based on a question from Curtis Rosché and Shaw Ma (for processing industry).

5 How to Determine Your Lot Size – Part 3

Christoph Roser, January 31, 2017, Original at https://www.allaboutlean.com/lot-size-part-3/

Figure 32: Cat with Kittens (Image sheilaf2002 with permission)

This is the third and final post on lot sizes (Part 1 and Part 2). After considering all the factors of the processes and inventories (changeover time, batch size, customer order size, and container and shipment size), we now look at how to set up the information flow. This is especially important if we want to have different lot sizes in different sections of our value stream.

5.1 Information Flow Set-Up

All the previous data points can be taken in any sequence for any process along the value stream. You just need to get an overview where you have what kind of requirements. And again, these data points do not have to be the final values or set in stone; they just have to help you determine where you may have to focus.

In this step, you will merge the different requirements together while creating the information flow of the system. (If you cannot change the information flow, then you are locked in with the lot size you have.) There are two main questions: Where do you decouple the material and information flow, and what lot size do you need for which part of the information flow? This involves quite a bit of going back and forth between these two steps, and occasionally going back to get better data from individual processes or material flows.

5.1.1 Where to Decouple the Material and Information Flow

Ideally, you make a quick sketch of the value stream. The main question here is where to decouple the material and information flow. If you have a pull system (e.g., a kanban system), the decoupling would be at a supermarket. Take, for example, the three-process system below. Between each process you could either add a supermarket or a FIFO lane.

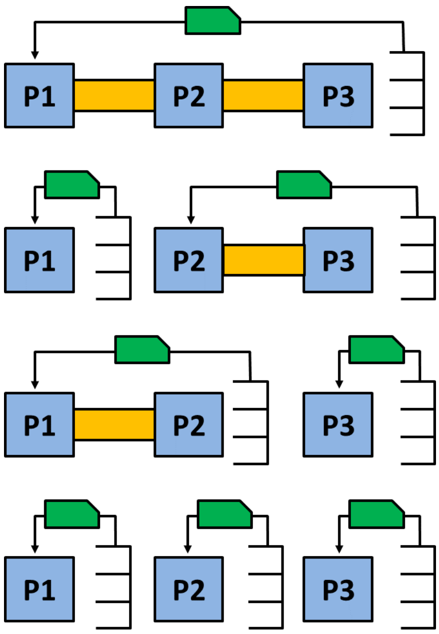
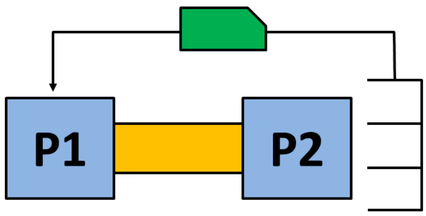


Figure 33: Kanban loop options for three processes (Image Roser)

For more on this, see my post series [Ten Rules When to Use a FIFO, When a Supermarket.]() The first rule of these ten rules concerns the lot size. It is generally recommended to add a supermarket if you want to change the lot size. The lot size within one kanban loop should stay the same, although there are exceptions possible.



Example	Lot Size P1	Lot Size P2
1	100	100
2	100	50
3	100	30
4	100	200

Figure 34: Examples of different lot sizes for kanban loops (Image Roser)

If the lot sizes are equal, as in example 1 above, then there is no problem whatsoever. If the next process has a lot size that is an even fraction of the previous process (example 2), then there is also no problem. In effect, the second process is forced to have the same lot size as the first process.

Lot size differences, however, are a problem if the second process doesn't have an even fraction lot size, as in example 3. If you need to use exactly this lot size of 30 every time (e.g., a batch process that fits exactly 30 parts), then there will be either ten parts left uncompleted of the lot size of process 1, or the lot size of process 2 will be short by twenty parts. If the lot size of 30 is only a minimum requirement, it will be less of a problem since you can always increase it to the required number of parts.

Finally, if the second process has a larger lot size than the first process, as in example 4, then there is a risk of not completing a full lot with the second process.

Overall, again, try to use the same lot size across the loop unless there is a good reason not to. If you want to change the lot size, it may be good to add a supermarket.

Even if your system is a push-type system (no kanban or CONWIP), this also works. In this case the question is if you want to have a FIFO lane between processes or a non-FIFO buffer stock.

5.1.2 What Lot Size for Which Part of the Information Flow

The lot size within a loop should ideally be constant. The lot size within a loop depends on the processes and inventories in the loop, for which we collected the data above. Here we have to distinguish different situations:

- **Exact Size**: All other values need to be multiples thereof. This is, for example, an injection molding machine. If your mold makes 10 parts every time, then your lot size has to be a multiple of 10 (i.e., lot size of 10, 20, 100, 500, etc., but NOT a lot size of 7, 15, or 25).
- **Upper Limit**: The number cannot be higher, but can be less. The lot size must be a multiple of that number or a smaller number. This is, for example, a pallet cage. Imagine a cage cannot hold more than 115 parts, but it can hold less. You could put only 100 parts in the pallet cage. If you have a pull production, ideally one kanban represents one container/box/pallet. The lot size can then be multiple kanban. Again, the lot size has to be an exact multiple of the number of parts per kanban. This gives you more flexibility in finding a good lot size. If you go too far away from the number, however, you may consider another container (i.e., if you want to put only 15 pieces in a pallet cage that holds 115, then you are wasting a lot of space).
- **Approximate Values**: The number is based on an estimate or rough value. Hence, it can be adjusted both upward and downward. This can be, for example, the number determined from your changeover processes. As this is an imprecise value anyway, you can easily adjust it a little bit up or down to suit your needs.
- **Lower Limit**: The number has to be at least that value, and can also be more. This is usually not common, but can happen if your boss listens too much to the accountant and then simply gives you a minimum lot size number.

From these numbers you have to determine the lot size for the particular loop.Also, please be aware that the lot size may also differ for different products. A high runner product may have a much larger lot size than an exotic product on the same loop. Let's make an example shown below.

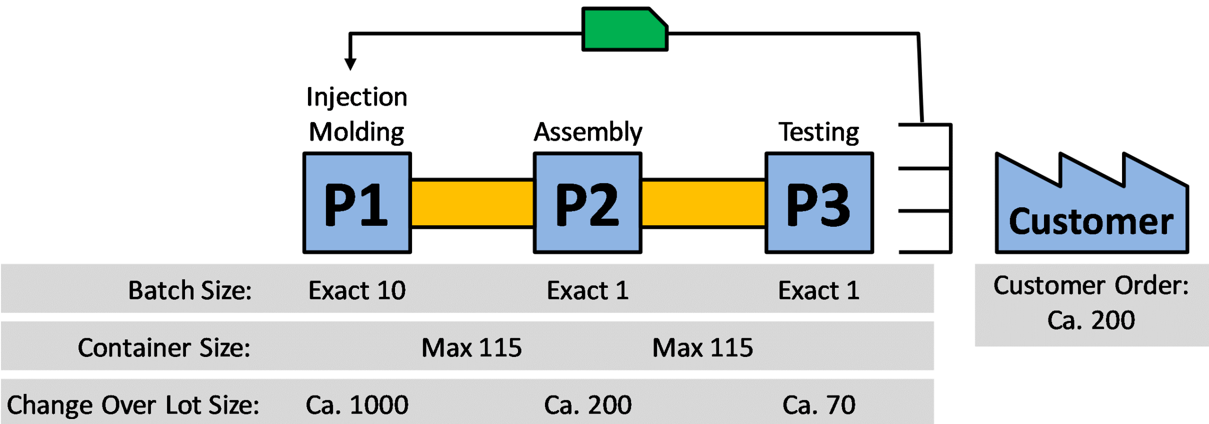


Figure 35: Examples of different lot sizes in a loop (Image Roser)

You have three processes in a kanban loop. The first one is an injection-molding process with exactly 10 parts for a mold. Hence, it would be good if the lot size is an exact multiple of 10. The other two processes of assembly and testing have a lot size of 1, which we can ignore since we already have a multiple of 10.

The containers between the processes fit 115 parts. Since this is not a multiple of 10, we have to use less (e.g., 110, 100, or 90 parts).

A suitable lot size for the changeover is mostly influenced by the injection-molding process, which suggests around 1000 pieces before changing over. Assembly and testing are more flexible, so they don't matter much anymore.

Hence, overall, you could go for a lot size of 1000, with 10 kanbans (containers) of 100 each, or equally valid but more space efficient with **a lot size of 990 and only nine kanban (containers) of 110 pieces each**. I probably would prefer the lot size of 990 (9 boxes of 110 each) since I need one box less and hence space for one box less, but this is up to you.

More interestingly, could I add a supermarket between process P1 and P2? Process P1 would have a lot size of 990 pieces. Process P2 and P3 may then have a smaller lot size of only 200 pieces (or maybe 220 for two boxes of 110 each). With a bit of SMED on process P2, you may even get the lot size down to one box of 110 pieces.

As you can see, this process involves quite a bit of going back and forth between the decoupling of the material and information flow, the lot sizes, and the raw data obtained from the processes and inventories.

Finally, a minor point is even numbers. Humans somehow prefer to work with round numbers. Hence, they probably like a lot size of 300 more than a lot size of 298. But again, this is a minor point. If your analysis determines 298 to be better than anything else, by all means, use 298.

That is it. Now you know what influences your lot size. Unfortunately, it is not a simple answer. There are lots of assumptions and uncertainties going into the determination of the lot size. Hence, there is no single "*right*" answer. Instead, there is usually a range of good lot sizes. So, don't fret it if you should use 10% more or less for a lot size. In case of doubt, go a bit lower, but otherwise take your best guess based on the information and considerations described in this series of three posts. **Now go out, see if you can reduce the lot size, and organize your industry!**

P.S.: This series of posts is based on a question from Curtis Rosché.

6 The Chaku Chaku Line

Christoph Roser, February 7, 2017, Original at https://www.allaboutlean.com/chaku-chaku-line/

Figure 36: Water Stairs (Image Britt Reints from Pittsburgh, PA under the CC-BY-SA 2.0 license)

Chaku Chaku is a way to operate a semi-automated manufacturing line. One (or more) workers walk around the line, add parts to the processes, and then start the process. While the process works on the part automatically, the worker adds the next part to the next process, and so on.

6.1 Introduction

The word "Chaku Chaku" comes from Japanese. It can mean either "*Load, Load*" (着々), or it can simply be the sound the machine makes while unloading (ちゃくちゃく), similar to "*Clack-Clack.*"

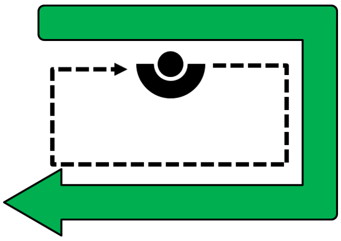


Figure 37: One Person in U Loop (Image Roser)

The basic principle of the Chaku Chaku line is very simple. The worker moves around the line from process to process and only loads the parts into the machine. After loading the part, the worker starts the machine and moves to the next process. At the end of the line, the worker starts again from the beginning.

Yet, as always, there is a bit more detail.

6.2 The Processes

The system has to be a flow line. Chaku Chaku does not really work with a job shop. The processes themselves are semi-automated, and the machines can operate on their own once a part is inserted.

6.2.1 Automatic Unloading

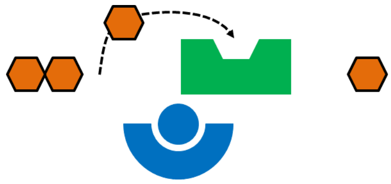


Figure 38: Animated Chaku Chaku Automatic Unload. Animated image can be found at https://www.allaboutlean.com/chaku-chaku-line/ (Image Roser)

Usually, the loading of the machine at the beginning is manual. The ejection of the part after the process is completed is automatic.

This is due to the cost of automation. It is usually a bit complicated to bring a part from the buffer into a well-defined position in the machine. On the other hand, it is much easier to simply eject the part from the machine into a much less well-defined position in the next buffer. Hence, the Chaku Chaku line has much less complexity than a fully automatic line that includes automatic transport of the material.

This automatic ejection is actually so common that a Japanese term made it into the lean vocabulary: Hanedashi (はね出し, to jump; to leap; to spring up) means automatic unloading of machines.

Automatic ejection has another advantage. If the worker carries the part to the next station, he can put it in the (empty) station right away. If he has to unload the part first, then it is either a two hand operation or he has to put the first part down. In any case it is more cumbersome.

6.2.2 Manual Unloading

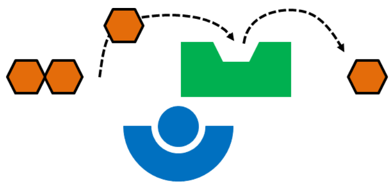


Figure 39: Animated Chaku Chaku Manual Unload. Animated image can be found at https://www.allaboutlean.com/chaku-chaku-line/ (Image Roser)

Nevertheless, it is also possible to have a manual unloading of the part, although technically it is then no longer a Chaku Chaku line. Yet the Chaku Chaku line may include some manual unloading processes too. Overall, the automatic unloading is often cheaper than the time the worker needs for manual unloading. On the downside, however, the worker may have to unload while holding the next part in the other hand, which can make a cumbersome operation.

Similarly, there may be even processes that are completely manual, where loading, processing, and unloading is done by hand. Again, strictly speaking, this would no longer be Chaku Chaku, but if a few processes of the line are manual it would not be too much of a problem either.

6.3 Starting the Processes

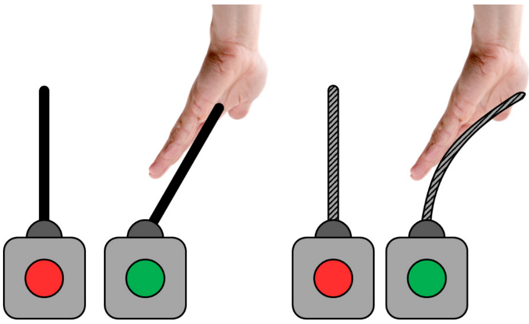


Figure 40: Animated image of a Nagara switch. Animated image can be found at https://www.allaboutlean.com/chaku-chaku-line/ (Image Roser)

The processes may start automatically when closing an safety cage or when a light curtain no longer detects a hand in the machine. In these cases the machine has to be robust enough that starting with a missing or not yet completely placed part does not harm the worker, the product, or the machine. More commonly, the worker may start the process manually. Especially with manual starting of the processes I have sometimes seen the use of a switch designed for swiping rather than pressing to allow faster actuation.

This also has its own Japanese word, Nagara switch (ながらスイッチ, flexible rod switch), although I am a fan of using plain English rather than fancy words in a foreign language. I have seen both stiff and flexible switches. This may shave a few more seconds off the workload and increase efficiency, requiring only a little investment.

6.4 Organization of Multiple Workers

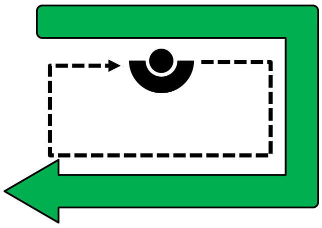


Figure 41: One Person in U Loop (Image Roser)

The number of workers in a Chaku Chaku line can be flexible. Naturally it has to be at least one, and fewer than the number of processes.

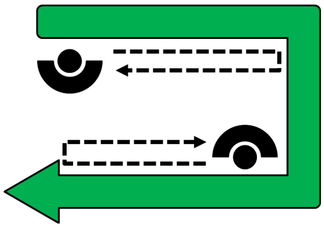


Figure 42: Bucket brigade (Image Roser)

You can have more than one worker, in which case you have multiple options for how to manage the workers. You could do a bucket brigade, where the workers move forward until they meet the next worker and then return backward until they meet the preceding worker (check my recent post on [The Lean Bucket Brigade](#) for details).

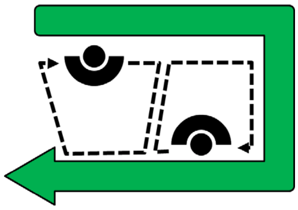


Figure 43: Baton touch (Image Roser)

Another possibility is the baton-touch approach, where each worker is responsible for a section of the line, and hands over the work to the next worker. This is probably the most common way to manage the work distribution.

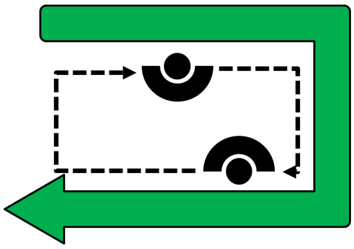


Figure 44: Rabbit chase (Image Roser)

Finally, there is the option of a rabbit chase, where all workers do the same loop behind each other.

A fully staffed line where every process would have its own worker is no longer a Chaku Chaku line, and a large part of the benefit of automatic processing is lost.

6.5 Line Balancing

Figure 45: Line Balancing (Image eelnosiva with permission)

As for the number of people, this depends on the workload. In fact, the line balancing is a bit trickier. The total workload for humans is the combination of all loading machines and starting the machines, plus walking time (plus unloading and manual operations if present). The automatic processing does not count.

The work content for one person is then roughly the total work divided by the number of people (although not exactly, because the workload may not be evenly divisible). However, the work content of one human cannot be faster than the slowest process. If the human work is faster than the slowest process, then the human would have to wait for the process to complete. Hence, we cannot put too many workers in the system.

I have seen Chaku Chaku systems with one, two, and three workers. I can imagine systems with more, especially if the line is longer. But avoid over-stuffing the number of workers in a Chaku Chaku line, or the efficiency will decrease.

6.6 Process Sequence

The worker could work with the material flow or against the material flow. Here it is my strong advice to have the worker work with the material flow. This is much more intuitive.

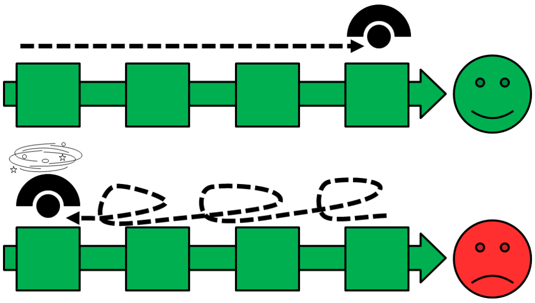


Figure 46: Direction of Chaku Chaku (Image Roser)

If the worker works with the material flow, he has to reach only short distances. He can pick up the part from the inventory when he walks past it, and then put it in the machine right away. If he walks in the other direction, he would have to reach over the machine to get the part from the buffer (or walk back from the buffer to the machine) before inserting the part.

It gets even worse if the line involves manual unloading, as the worker would constantly have to walk back and forth between processes. Overall: **Have the worker work in the direction of the material flow!**

6.7 Buffer Inventories

A Chaku Chaku line usually does not need buffer inventories, except between the different workers in the case of a baton-touch system above. Especially for manual unloading, a buffer is actually detrimental. If you unload the part, it would be easiest to load it right away in the next machine, rather than placing it in an inventory and picking up another part from the same inventory.

6.8 Benefits and Disadvantages

The advantage of the Chaku Chaku line is that it is often a good compromise between automation (processing and ejection) and manual work (loading and starting process). This may increase the overall productivity, although it does involve quite a bit of walking, which by itself is a waste again. An U-shaped line or cell is preferred, or any type of line where the end is close to the beginning.

On the other hand, the worker needs to know all steps of the process for working in the Chaku Chaku line (unless you use the baton-touch approach). This may make training a bit more difficult, although the work is usually not very challenging. (In Germany, unions often don't like Chaku Chaku due to the use of unskilled labor).

Sometimes there is also a second complaint: that the work is monotonous and boring. Make sure the workers in the Chaku Chaku line get some job rotation and can work on something different for a change.

On the positive side again, Chaku Chaku lines often need little or no inventory between the processes, and are a version of one-piece flow. Besides reducing inventory, this also improves the lead time.

6.9 Examples of Chaku Chaku Lines

A Chaku Chaku line with one worker:

The Video by Arturo Archundia is available on YouTube as "LEAN SIX SIGMA" at https://youtu.be/5iNXiOCY2HY

Chaku Chaku line with multiple people (shown until about 0:33, afterward other processes and material transport).

The Video by Jose Donizetti Moraes is available on YouTube as "Chaku Chaku e Misuzumashi" at https://youtu.be/Bh2MO14oi94

Yet another Chaku Chaku line, this time Bosch in Japan. The Chaku Chaku line starts at 3:13. There are also sometimes multiple people in the line.

The Video by H. Ümit Kilic is available on YouTube as "Chaku Chaku Video" at https://youtu.be/vRdTguRYnSI

Overall, I hope this information was helpful for you, as this is a popular topic in lean manufacturing (although in my view it feels like there is still more writing about than implementation of Chaku Chaku). In any case, **go out and organize your industry!**

7 150th Anniversary of the Birth of Sakichi Toyoda

Christoph Roser, February 14, 2017, Original at https://www.allaboutlean.com/150th-anniversary-sakichi-toyoda/

Figure 47: Sakichi Toyoda (Image unknown author in public domain)

Exactly 150 years ago, on February 14, 1867, Sakichi Toyoda (豊田 佐吉 Toyoda Sakichi) was born. He is known in Japan as the King of Inventors (which is probably a bit of an exaggeration), father of the Japanese Industrial Revolution, and also the founder of the Toyota industrial empire. Time to take a look back in history on his life.

7.1 Youth

Figure 48: Born here February 14, 1867 (Image Yanajin33 under the CC-BY-SA 3.0 license)

Sakichi Toyoda was born February 14, 1867, in Yamaguchi (now Kosai, Shizuoka), to Ikichi and Yui Toyoda (豊田伊吉; 豊田ゑい). His father was a carpenter and part-time farmer, and he had two younger brothers and one sister.

While the family was not rich, they were not poor either, and could afford to send young Sakichi to elementary school, which he graduated from after four years. Afterward, he started training as an carpenter.


Figure 49: Emperor Meiji – The new broom sweeps clean! (Image Uchida Kuichi in public domain)

Another significant event happened eleven days before his birth, on February 3, 1867: Emperor Meiji (明治天皇 Meiji-tennō) ascended the throne at age 14, following the surprising death of his father (poisoning is suspected). Later in the same year, the last shogun of Japan, Yoshinobu Tokugawa (徳川 慶喜), resigned.

The new emperor was now no longer a puppet of the shogun, but truly in charge. This started the Meiji restoration, which **radically transformed Japan from a Middle-Aged feudal society to a modern industrial state within only a few decades**. Without this, Sakichi may have spent his life as a carpenter, and Toyota may not have happened at all.

7.2 Getting Into Looms


Figure 50: A young Sakichi Toyoda (Image unknown author in public domain)

Sakichi was inspired by a book, *Saigoku risshi hen* (西國立志編), the Japanese translation of *Self-Help* by Samuel Smiles. Smiles wrote, among other things, about inventions, including the Jacquard loom, getting young Sakichi interested into looms and significantly influencing his future career.

Hence in 1885, at age eighteen, young Sakichi changed careers. Instead of carpentry, he wanted to work with looms. He applied for a position at a weaving company, and traveled all over central Japan to learn more about looms – much to the concern of his parents. Please note that Sakichi was not the only young bright mind looking into looms. There were many others, as it was almost a boom to develop new looms. However, Sakichi turned out to be the most successful.

7.3 Patents and Companies …

Figure 51: 1890 loom by Sakichi Toyoda (Image Yanajin33 under the CC-BY-SA 3.0 license)

Finally, in 1890, he patented his first loom (only five years after Japan established a patent law). He produced only four to five looms in his newly established factory, Toyoda Shoten. Unfortunately, while the loom had a much better productivity, it was not a commercial success, as a French patent with a different solution had the same benefit at much less cost. Additionally, his invention coincided with a recession in the weaving industry.

Hence he moved back to his hometown, where in 1893 he married his first wife, Tami (豊田たみ), from another carpentry family. In 1894, his first son Kiichiro Toyoda (豊田 喜一郎) was born. However, this marriage did not last long, and he married his second wife, Asako (豊田浅子), in 1897. This marriage resulted in a daughter, Aiko (豊田愛子), in 1899.

Over the next decades, Sakichi founded at least eight companies or factories in Japan and China, not to mention multiple partnerships. It is really hard to keep track of them all. For a good source, see Mass & Robertson below.

Figure 52: Sakichi Toyoda in middle age (Image unknown author in public domain)

One company he established was the **Toyoda Loom Works** (in 1906 or 1907). Until then all looms were custom made and parts were not interchangeable. While in search of a solution, he met the American Charles A. Francis, who was teaching mechanical engineering in Tokyo. Francis introduced Sakichi to the American System of Manufacturing and helped him to introduce interchangeable parts. Together with numerous inventions from Sakichi, the Toyoda Loom Works soon became the largest loom producer in Japan.

In 1910, Sakichi visited Europe and the USA. Touring many weaving factories, he found the looms to be quite inferior to his own products, both in quality and in productivity. He secured his inventions through US patents.

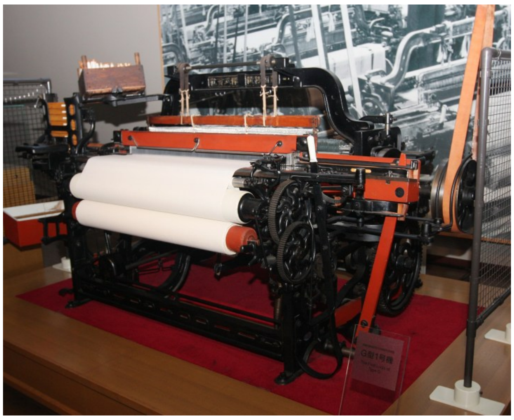


Figure 53: Toyota Model G (Image Morio under the CC-BY-SA 3.0 license)

In 1924, Sakichi – or more likely his son Kiichiro – invented the most famous product: the Model G loom. This loom was not only fully automatic, including automatic shuttle change, but stopped whenever a problem happened. For the production of this new loom, Sakichi established the **Toyoda Automatic Loom Works** in 1926, a direct competitor to his other company, **Toyoda Loom Works**. The first thousand or so looms were for testing and Toyoda's own factories, before sales began in 1927. Even though this loom was three times more expensive, it increased productivity by a factor of ten. The product was a stellar success.

7.4 The Platt Brothers

Figure 54: Former headquarters of the Platt brothers (Image Alexander P Kapp under the CC-BY-SA 2.0 license)

The UK loom company Platt Brothers became interested in the patents of the Model G. In 1929 they and Toyoda agreed to a sales price of GBP 100,000 for rights to worldwide sales of the "*miracle loom,*" excluding Japan, China, and the USA.

Toyoda sent blueprints, looms, and an engineer to the UK to help the Platt brothers in establishing their production. Soon after the engineer returned, the Platt brothers contacted Toyoda, complained about insufficient data, and demanded a reduction in payment. Toyoda in turn pointed out low-quality manufacturing as the primary cause. After some back and forth, they agreed to a price reduction.

7.5 Succession

Figure 55: His son Kiichiro Toyoda (Image unknown author in public domain)

Toyota lore has it that Sakichi Toyoda, while on his deathbed, begged his son Kiichiro to start a new automotive company, and gave him the money from the Platt brothers.

Unfortunately, not much of this is true. The money from the Platts was spent on bonuses for the employees, and the new company was financed through traditional means. Additionally, his son Kiichiro could not take over his father's companies due to a legal quirk: Sakichi's daughter married Risaburo Kodama, whose relatives gave Sakichi quite a bit of money. Hence, due to social obligation, Sakichi adopted Risaburo as his own son. Adopting your adult son-in-law may sound weird to you, but in Japan such adult adoptions are still common. Hence Kiichiro was now, legally speaking, no longer the eldest son. Therefore, the Toyoda loom business went to the now-eldest son, Risaburo.

Sakichi wanted Kiichiro to establish a company too. Kiichiro was significantly influenced by Henry Ford and the American automotive boom of the 1920s, and wanted to create a car company in Japan. Hence, they established an experimental car research division at Toyoda Automatic Loom, producing cars from 1933 onward. In 1937, this company was established as an independent company, the now famous Toyoda Motor (later renamed to Toyota Motor).

However, Sakichi had little influence in that, as he died in his home on October 30, 1930, aged sixty-three, from cerebral hemorrhage and pneumonia.

7.6 Legacy

Figure 56: Sakichi Toyoda, 1867–1930 (Image unknown author in public domain)

Sakichi Toyoda is known in Japan as the King of Inventors, and credited with eighty-five patents. However, most of the patents, especially the ones after 1921, were by his son Kiichiro or another group of researchers. He is credited with the famous lean method of 5 Why's – where you repeat asking "Why?" five times to determine the root cause of the problem.

There are many inventors. There are many entrepreneurs. However, few inventors manage to bring their invention to a commercial success without third-party help. Sakichi Toyoda is such an exception, combining lifelong tinkering with looms with a strong entrepreneurial spirit.

Overall, I hope this brief history is inspiring to you. Now **go out and organize your industry!**

P.S.: If you would like to read more about the history of manufacturing, then check out my book:

Roser, Christoph, 2016. *"Faster, Better, Cheaper" in the History of Manufacturing: From the Stone Age to Lean Manufacturing and Beyond*, 439 pages, 1st ed. Productivity Press.

7.7 Selected Source

Mass, W., Robertson, A., 1996. From Textiles to Automobiles: Mechanical and Organizational Innovation in the Toyoda Enterprises, 1895–1933. Business and Economic History 25.

8 The Lean Rabbit Chase in a U-Line

Christoph Roser, February 21, 2017, Original at *https://www.allaboutlean.com/rabbit-chase/*

Figure 57: Running Rabbit (Image alexanderoberst with permission)

There are different ways to manage workers in an manual U-line. One of these methods is known as the **"Rabbit Chase,"** also known as the "*Caravan Approach*" or "*Operators-in-Motion.*" The workers always move in a circle and handle all processes in sequence.

8.1 Introduction

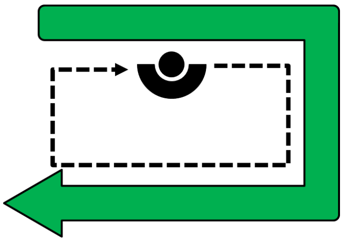


Figure 58: Cell with one person (Image Roser)

The Rabbit Chase is a possible approach to organize manual work in a flow line. The worker moves along the line with his part. When the worker reaches the end of the line, he picks up a new part and starts again. Naturally, this works best for U-shaped lines, or in general lines where the end is close to the beginning of the line.

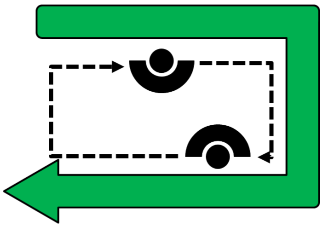


Figure 59: Two-person Rabbit Chase (Image Roser)

If there is only a single person working in the line, however, this would not (yet) be a rabbit chase. For a rabbit chase you need more than one person. The image here shows an example with two workers.

You probably can easily see where the name "Rabbit Chase" comes from. The faster worker will be "chasing" the slower worker.

This is also one of the possible drawbacks of this method. The system speed is limited to the speed of the slower worker, and the faster worker may have to wait for the slower worker.

8.2 Working Direction

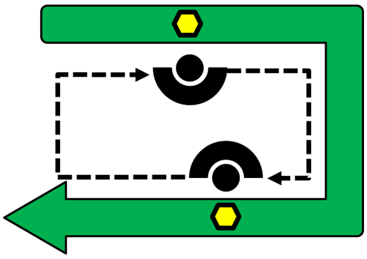


Figure 60: Forward: Good (Image Roser)

The direction in which the workers walk is very clear: **they should go forward with the part!** This way the worker processes one and only one part throughout the entire line. This has two advantages.

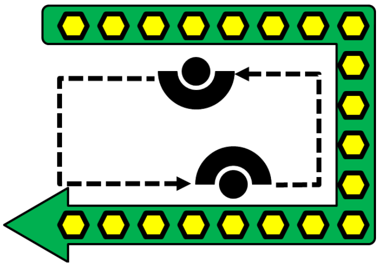


Figure 61: Backward: Bad (Image Roser)

First of all, you need less inventory. If the workers walk backward, they would need a new part waiting at every preceding process. The line would have many more parts. The lead time would increase, without a corresponding increase in line performance.

Second, if the worker is responsible for one part from beginning to end, then the quality is probably better. When walking backward, any quality issue in a part will soon be the problem of the other worker. While the size of this effect varies, there may be a tendency toward a "no longer my problem" attitude. When walking with the parts, however, the part is the worker's problem from beginning to end.

8.3 How Many Workers?

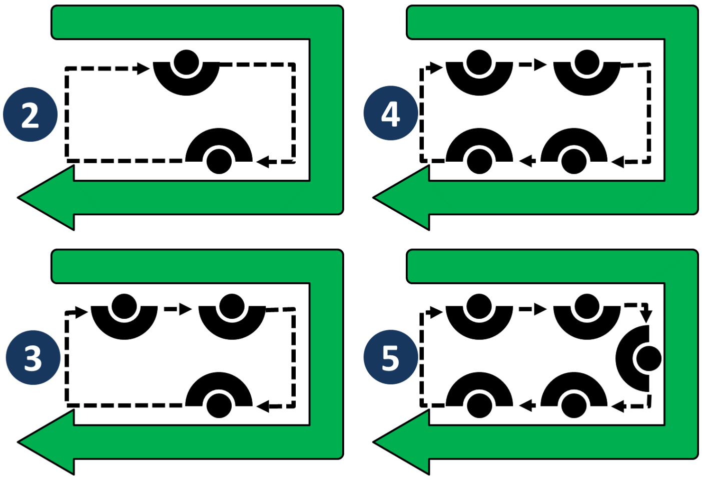


Figure 62: Multi-Person in U Loop Rabbit Chase (Image Roser)

How many workers can you put in the line? Well, theoretically as many as there are stations. However, adding too many workers can have quite a drawback.

The problem is that the workers have to wait for the slowest worker. The more workers you have in the line, the more workers have to wait. You end up with a manufacturing version of a traffic jam.

As for how many workers you want to add, it depends on the length of the line (or more precisely on the duration it takes for a worker to make a circle) and how much waiting time you are willing to accept. The exact relation is hard to determine.

8.3.1 Theoretical Model – Fixed Speed

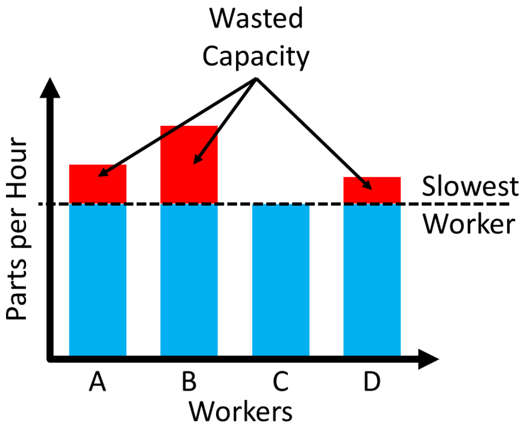


Figure 63: Wasted Capacity Constant Speed Rabbit Chase (Image Roser)

If you would (unrealistically) assume that all workers always have a constant speed, then the wasted capacity would be any capacity faster than the slowest worker.

The image shows this for an example, with four workers with different working speeds (indicated in parts per hour). Since the slowest worker C sets the speed, the other three will be trailing behind. Any excess speed of the other three workers is lost, since they cannot overtake the slowest worker. But, as I said, this is an unrealistic worst case assumption.

8.3.2 Realistic Model – Variable Speed

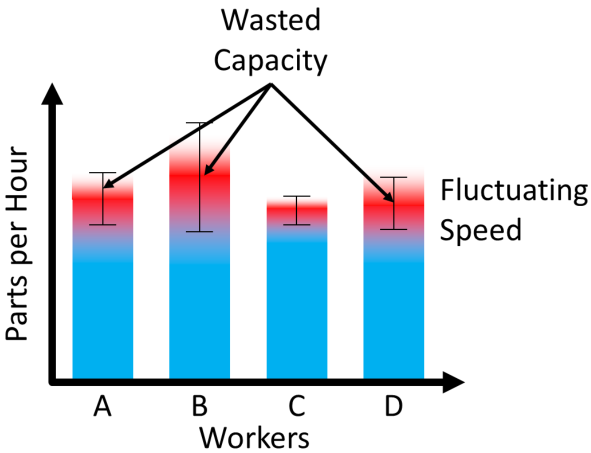


Figure 64: Wasted Capacity variable Speed Rabbit Chase (Image Roser)

In reality, the speed of the worker varies over time. Sometimes he can work the process faster, sometimes slower. This is a natural variation of the cycle time that happens in most manufacturing lines. In this case a worker may sometimes be the slowest worker, but later may speed up again.

Hence, the distance between the workers varies. The distance between the workers can act here as a buffer, allowing workers to catch up and fall back again as their speed changes over time.

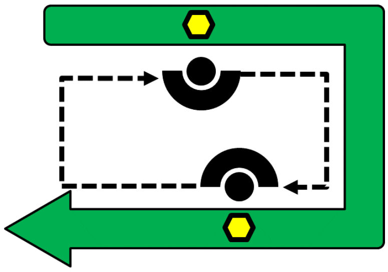


Figure 65: Animated Lean Rabbit Chase. Animated image can be found at https://www.allaboutlean.com/rabbit-chase/ (Image Roser)

While this will not completely cancel out the problems of wasted capacity and waiting times, it will probably be much less than the case assuming a constant speed. Unfortunately, the exact value is difficult to calculate. Overall: Do not put too many workers in a rabbit chase line, or the waiting time may become too much. Some sources actually recommend no more than two workers, although I can imagine cases where more than two workers may be possible.

8.4 Summary

Let me give you a brief run-down of the pros and cons of a rabbit chase.

8.4.1 Advantages

- Easy to set up and manage
- Low inventory
- Fast lead time
- Clear responsibility leading to better quality

8.4.2 Disadvantages

- Slowest worker sets the speed of the system (although this is found in many systems, excluding the bucket brigade).
- Possible mental pressure on slower worker due to the worker hindering everybody else.
- May cause a traffic jam behind the slowest worker.
- Significant walking distances. Each part requires a worker walking the entire line (but similar to many other systems where workers walk).
- Every worker needs to know all processes from the beginning, and training of new workers may be more difficult.
- Not very scaleable. Adding more workers will increase output, but not linear.

Overall, the Rabbit Chase style of managing a flow line may or may not be the best option for you. There are definitely situations where this may make sense, but in other cases there may be better ways to manage your line.

Anyway. As usual, I hope that this post was interesting to you. Now go out, chase some rabbits (or even better, improvement potentials), **and organize your industry!**

9 Lean Tales in Japan: The Japanese Supermarket Checkout

Christoph Roser, February 28, 2017, Original at https://www.allaboutlean.com/japanese-supermarket-checkout/

Figure 66: REWE Offenbach before Grand Opening (Image Roser)

Japan is a wonderland for anybody interested in lean. Of course there is the archetype of lean manufacturing, the Toyota group and its Toyota Production System. However, access to Toyota plants is restricted, and during their guided tours you can observe only so much. (See for example my post on Evolution of Toyota Assembly Line Layout – A Visit to the Motomachi Plant as the result of such a tour).

Fortunately, the goal to achieve perfection is also found in many other processes in Japan, many of which you can observe almost anytime, whenever you like and for how long you like. In the past I blogged about Lean in the Japanese Public Toilet and Japanese Standard Pointing and Calling on Japanese trains. This time I'm looking in more detail into the Japanese supermarket, in particular its checkout system.

9.1 Supermarkets in General

Figure 67: The original Piggly Wiggly supermarket (Image Clarence Saunders in public domain)

All modern supermarkets are based on the Piggly Wiggly store that opened in 1916. Besides the nowadays standard retail store, the name "checkout" was also given to the inventory management system based on kanbans (see Theory and Practice of Supermarkets for more).

One step in the supermarket is the checkout, where you pay for the goods. I'm sure you are familiar with this.

Now, supermarkets face quite a bit of volatility during the day. The busiest time for is usually late afternoon, between 5 p.m. and 6 p.m., when people stop by on their way home from work. Another busy time is weekend afternoons, especially Saturday afternoon. In contrast, weekend mornings are much less frequented, and weekdays at 8:00 a.m. you also have the store almost to yourself (because the working population is at work and the non-working population is still in bed).

Figure 68: Supermarket checkout (Image ed_davad in public domain)

During the day, the number of customers can increase six-fold and more. If manufacturing would face such a daily volatility, it would probably simply use a buffer inventory. However, unlike with parts, few customers would be happy to wait for four hours at checkout before their order is processed, merely to balance the workload for the supermarket.

Hence, supermarkets cannot decouple their fluctuations through inventory or waiting, but have to decouple mostly by adjusting the store capacity at checkout (see also The Three Fundamental Ways to Decouple Fluctuations).

Most supermarkets in the Western world simply have multiple checkout lines and add or remove staff according to the demands. If the lines at checkout are getting longer, another cashier comes and opens another register. If they get shorter, a cashier may close his register. So far probably no surprise to you.

9.2 Japan

Figure 69: Crowded supermarket in Nagoya (Image Roser)

The system is very similar in Japanese supermarkets, but there is much more attention to detail. First of all, Japanese supermarkets (and in fact, most places in Japan) are often much more crowded than Western supermarkets. While floor space in Japan is costly, it is not cheap in the West either.

The problem is more the intense competition among Japanese retailers. The profit margin in Japanese supermarkets is very thin (as quite a few foreign supermarkets had to find out). Hence, adding multiple checkout lanes just to cover peak demand is a waste of space.

9.2.1 One Person per Checkout

Figure 70: Japan Supermarket One Person Checkout (Image Roser)

Some supermarkets in Japan have a quite ingenious solution. But first let's look at the "normal" mode, similar to what we would find in a Western supermarket. If the demand increases, more and more checkout lanes are opened until all registers are operating with a cashier. The images here show such a cashier in detail. (Note that on all images I blurred the faces for privacy reasons).

Figure 71: Japan Supermarket One Person Checkout Overview (Image Roser)

For the entire supermarket (example from the southern island Kyushu), this would mean a total of seven checkout lanes. After all seven lanes are open, no additional lanes are available. So far everything is similar to a Western supermarket.

Each cashier does all the tasks a normal cashier has to do. They scan the items, then move the goods from one basket (which the customer brought) to the next basket (which the customer will take to a separate packing area). Finally, they complete the purchase with the payment of the goods.

Please note that the handling of the goods especially differs widely among supermarkets and countries. In America, the goods are often bagged into shopping bags at checkout, whereas when Walmart tried this service in Germany, the cashiers got yelled at.

9.2.2 Two People per Checkout

Figure 72: Japan Supermarket Two People Checkout (Image Roser)

Anyway, back to the Japanese supermarket. If the number of customers increases even more, these Japanese supermarkets use a trick that I have not (yet) seen in the Western world. They add a second cashier to each checkout lane. Overall **there will be not one but two people for each lane!** Please note that this second person is not the person bagging the items. While this is common in the USA, it is rare in Japan. The second person is also a cashier.

Figure 73: Japan Supermarket Two People Checkout Overview (Image Roser)

As seen in the pictures here, there are now two people at each checkout lane. The separation of work is roughly that the first person scans the items and puts them in the next basket, whereas the second person handles the payment of the goods.

Please note that this standard is not fixed, but the two workers help each other if one is faster than the other. I am pretty sure there are even more standards behind this that I don't even know.

Overall, even though the entire checkout lane is manned by two people, it feels like a seamless integration of the processes, and there is pretty much no difference for the customer – except that now two people can be serviced at the same time.

9.2.3 Checkout on Wheels

Figure 74: Japan Supermarket Checkout on Wheels (Image Roser)

Of course, to make this work, a lot of little things have to be taken care of. For example, the checkout lane must not mix up the order of the customer whose goods are being scanned, with the order of the other customer who is currently paying.

One additional detail that I noticed was that all registers were on wheels. If there is a change from one to two cashiers, they simply moved the register a few centimeters outward so that they have more space. If the staffing was reduced to one cashier per checkout lane, they simply rolled it back in a few centimeters so the distances were shorter. Overall, there are a lot of little details that not only make this system work, but also make it much more efficient!

9.2.4 Pros and Cons

This system has quite a few advantages. You can service (almost) twice the number of customers with one checkout lane. Or, if you will, you need less lanes, and hence less space, and hence have more area available for goods to sell. You can also maintain a good customer service level even at peak times. In the pictures above, the lines felt much shorter and faster than what I was used to in my native German supermarkets.

On the downside, there is not really much besides setting up the system and training the workers (and of course, continuously improving the system), although this effort also must not be underestimated.

9.3 Self-Service Checkout?

Figure 75: Cashier-Less Supermarket Self Checkout (Image CoCreatr under the CC-BY-SA 2.0 license)

Some supermarkets opt for self-service checkout registers, not only in Japan much in much of the advanced world. While this would reduce labor cost, the system still requires the customer to conform to the technology, and hence is more difficult for the customer.

Even I, as a computer-savvy guy, get a little bit more nervous with a self-service checkout register. I would still prefer a human cashier. For me, the technology is not yet quite good enough. However, Amazon recently opened its first supermarket in Seattle, Amazon Go. This store, according to its advertising, is much easier to use than any normal self-service checkout register. I am curious to see it for myself.

Overall, in Japan it is just amazing to see little tidbits of small but ingenius implementations of ideas and improvements. Every time I go there I see something new, and will of course blog about it. Hence, I hope this was interesting to you, and gives you ideas and analogies that you can use in your industry. Now, go out and organize your industry!

10 The Lean Mindset – Te & Kaffi in Iceland

Christoph Roser, March 07, 2017, Original at https://www.allaboutlean.com/te-kaffi-iceland/

Figure 76: Te & Kaffi Cup in Snow (Image Roser)

Lean is my life. Whenever I see someone working, I cannot help but to think about the work from a lean point of view. Every now and then I come across a little gem, where I am just thoroughly impressed with someone's approach to manage and improve their work. During my winter vacation in Iceland, I came across just such a gem with an excellent corporate culture for continuous improvement. Let me introduce Te & Kaffi and its lean mindset.

10.1 About Te & Kaffi

Figure 77: The Te & Kaffi in the Kringlan Mall in Reykjavik (Image Roser)

Te & Kaffi (which unsurprisingly means *Tea and Coffee* in Icelandic) is the largest coffeehouse chain in Iceland – which for a small nation of only 332,000 people means twelve coffee houses. And, in case you are wondering, even though Starbucks has 2000 times the number of shops worldwide, there are no Starbucks in Iceland.

Founded in 1984 by a coffee-loving couple, it now also roasts the coffee for many other coffee houses and stores, where it has 25% market share. They employ around 200 people, and plan to expand even more.

10.2 My Breakfast Observations

We had breakfast in the Te & Kaffi in the Kringlan Mall in Reykjavik. As usual, I observed the staff in their work to get inspirations for lean. First, everything went as expected. "*What would you like … I can recommend … For here or to go …*." In other words, the usual coffee house interaction. However, after the saleswoman took our order and typed it into the cash register, **she additionally wrote it down by hand on a small yellow Post-it note!**

Figure 78: The evidence … (Image Roser)

Alarm bells went off in my mind, screaming "*Waste!*" Why write it down by hand if you have it already in the computer? If it had to be done, couldn't you use a pre-printed sheet of paper where you merely mark the details of the order? To me it just looked like a total waste of time to write it down by hand again.

Being always curious (with an additional tendency of being a smart-ass), I inquired why she wrote it down on paper. "*It is the best way,*" she said. I inquired why they don't use a pre-printed sheet. They had tried that and it did not work. I inquired why they don't use a printout from the cash register, and they have tried that too, and it also did not work.

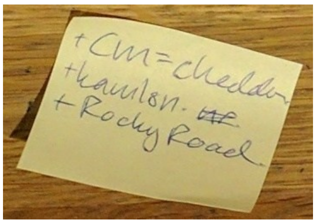


Figure 79: Te Kaffi Order Note Close Up (Image Roser)

While I had my (excellent) cinnamon roll, I pondered the responses. It totally went against my logic that writing by hand is better than the options I suggested. Not only does it take more time, there is also possibly a higher risk of mistakes, although her handwriting was much better than mine. I just did not get it!

I went back there the next morning for another breakfast, and – more importantly – for answers! Meeting the same woman again, I inquired why the alternative solutions did not work. The answer was quite unexpected. It had nothing to do with the time required for the paperwork, but with the space available.

Figure 80: The "production line" (Image Roser)

During peak hours, they have a long line of customers, resulting in a long line of papers for these customers' orders. They simply have not enough space to put all these papers. Only the yellow Post-its were small enough for the available space on the counter around the coffeemaker. They also have the additional benefit of being sticky, so they don't move out of place if someone walks past. After all, they should keep a FIFO (First in – First out) sequence so the first customer is served first.

Figure 81: Bill Spike (Image Rtimages with permission)

Again, my mind started working and I started suggesting ideas for improvement:

- *Can you use a box like for index cards, and add the printouts at one side and remove them from the other side?* Also already tried, did not work well.
- *How about a sort-of clothesline with hangers for receipts?* Another store already tried that, also without much success.
- *Can you use a receipt spike, and just pull out the bottom one for the next order?* Not sure if this works.
- *What about magnets? Could you use them to hold papers at the metal counter?* Also tried already, without much success.

While I still think that there must be a better solution for this problem, I noticed something else – the staff tried out many different things! And, in case you are wondering, the answers felt honest, and not the "*Leave me alone, I have to work*" type of conversation-enders. **They truly spent lots of time and effort testing different solutions.** I think I stumbled on a very nice example of a lean mindset for improvement.

10.3 The Lean Mindset for Improvement

It seems that Te & Kaffi managed to successfully involve their employees in their improvement efforts. The employees are actively working on Kaizen themselves. They also exchange improvement ideas with other shops. And, most importantly, **it is not a central lean coach that does the improvement, but the workers themselves!**

Figure 82: Hot chocolate! (Image Roser)

Continuing the conversation, I also found out that the owners not only permit this, but actively encourage the workers to change and adapt their workplace. Other changes initiated by the workers include, for example, a dedicated hot chocolate maker, which is much faster than making hot chocolate with the coffee maker.

This is employee empowerment! I usually try to avoid this word, since usually it is a buzzword in the corporate mission statement so managers feel good about themselves, but at Te & Kaffi the workers actually have the power to change their workplace. I also noticed lots of other little details that suggest creative solutions to little problems.

In my view, nobody knows the workplace as well as the people who work there. Properly managed, nobody will get as many good improvement ideas as the workers themselves. Let them experiment. Let them try to find a better way. Do not try to get the ideas from a Kaizen manager or Lean Change Agent, but have them empower the employees to create ideas and help them with implementing. From what I have seen, Te & Kaffi has managed this very well! Hats off to this Icelandic coffee chain!

10.4 Words from the CEO

The barista then recommended I get in contact with the CEO and the marketing manager, and gave me their emails (try that at Starbucks – hah!). Hence, I contacted them for a short interview. Here's the overview:

Figure 83: Te & Kaffi Tray Corner (Image Roser)

They put in a lot of effort in providing the right environment to allow this kind of improvement mindset, including frequent exchanges between the shops. They also do not hire external managers, but pretty much all managers start out as normal workers/baristas who got promoted.

This is very similar to the leadership at Toyota. Hence, they know the business from the bottom up and therefore most solutions to the different problems are homemade – and working!

Another improvement that the CEO was proud of was that their trays are "*missing*" a corner. While this makes the trays more expensive, it allows for easier cleaning and also easier drying while stacked. Overall, it improved the workflow. They also recently started to switch from the "call customer to pick up order" to "serve the customer at the table." While it is a bit more work, it makes a much nicer atmosphere and customer experience.

Overall, a nice example of a good improvement mindset involving the frontline workers. I hope this was a good inspiration for you. Now, **go out, start using not only the hands but also the brains of your people, and organize your industry!**

PS: next week I will be in Iceland again, presenting at the Lean Island Conference in Reykjavík!

11 Organize Your Production Sequence – 1: Project Shop

Christoph Roser, March 14, 2017, Original at https://www.allaboutlean.com/project-shop/

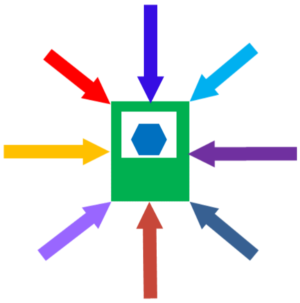


Figure 84: Project Shop (Image Roser)

There are different ways to organize your shop floor. You surely know the flow shop and the job shop. There is also a project shop (with many variants of names). While the flow shop is in many cases the ultimate goal, each shop has advantages and disadvantages. Let's look at them in more detail, starting with the project shop.

11.1 Project Shop

Figure 85: Hard to move around (Image Ricky Thompson in public domain)

The project shop has all manufacturing in one location. All material and information has to come to this location, and the finished product is then completed at this location.

This approach is most often used for very large and difficult to move products in small quantities. For example, if you build a large ship, it may be easier to move all parts to the ship and assemble it on-site rather than move the ship around for the different production steps. Another example for immobile products are … well … immovables, better known as real estate. Most houses are constructed on-site.

This is actually the least-known production method. Even the naming is a bit confusing. I like to call it the project shop, in line with the job shop and flow shop. Some sources simply call it "project," which is also technically correct, but to me a bit ambiguous. In German it is called "*baustellenfertigung,*" literally meaning "*construction site production*," which describes it well. Closely related is workbench manufacturing, where the part stays on the workbench until it is completed. Some sources also call it a "*fabrication shop*". If you have a better name, please let me know.

11.2 History of Project Shops

11.2.1 Early History

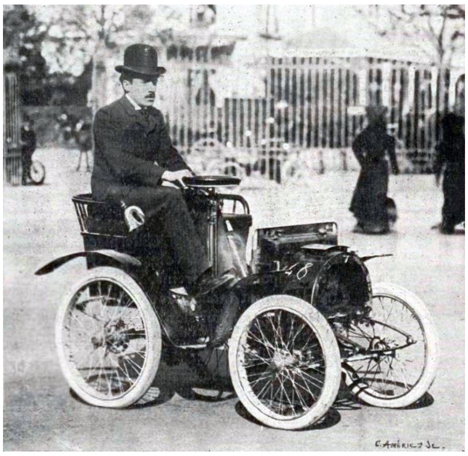


Figure 86: Not from an assembly line (Image unknown author in public domain)

Before 1920, project shops were actually quite common for anything that could not be carried around by hand. Even Henry Ford initially had teams of about fifteen people, with each team building a complete car at one location before starting the next car. This was the way to build products that were not easily movable.

Additionally, there were few or no interchangeable parts. Filing down parts to fit before assembly was a regular occurrence at that time.

Of course, that all changed with the introduction of the assembly line. While Henry Ford did not invent it, he used it to its finest. Soon pretty, most all car makers switched from these craft-type productions to assembly lines. This brought enormous improvements to cost, productivity, and quality. You would imagine that this would be the end of project shops in automotive. Well … no!

11.2.2 Revival(s)

Swedish car maker Volvo experimented with such project shops for automotive assembly again. Using such project shops, they opened a plant in Kalmar in 1984, and later in Uddevalla in 1990. Teams of around ten workers assembled a complete car in one location. Their goal was to make work better for the workers. Unfortunately, productivity went down, quality went down, material supply was a mess, and the workers were stressed about the same things as in an assembly line. Uddevalla was closed after three years, and Kalmar was changed to an assembly line after three years. The experiment did not work.

Figure 87: AGV at Audi (Image Audi with permission)

This didn't stop Audi from trying again. They are currently in the news for setting up a "*Smart Factory,*" a project shop and job shop crossover in Neckarsulm, Germany, and also in Györ, Hungary. Around two hundred assembly stations will work together to create new cars. While a station is not responsible for an entire car, they do larger parts of the work. The vehicles are moved around on autonomous vehicles, which will use the finest of Industry 4.0 technique to sort out where to go next … or maybe not.

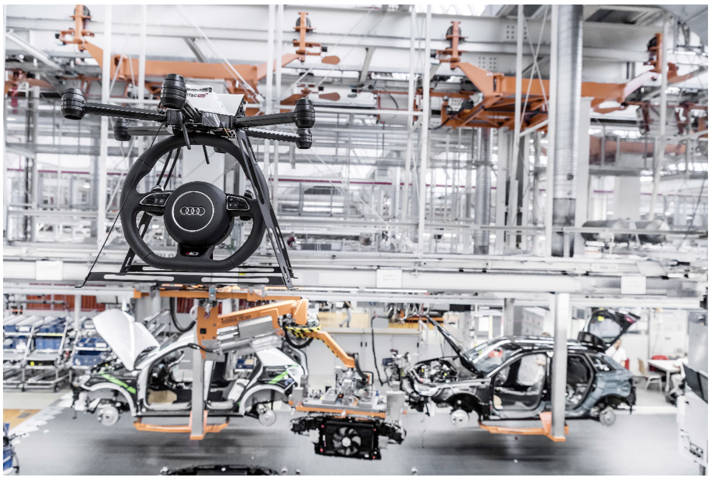


Figure 88: Hard to believe …. (Image Audi with permission)

On a side note: Their images and videos show drones flying around with steering wheels. From what I know, this is (like many Industry 4.0 things) merely an attempt to impress people with a staged demonstration, but definitely not a part of normal production.

Overall I am skeptical if this Audi smart factory will be successful or not. Chances are, five years from now we will not hear about it anymore.

11.3 The Problems with Project Shops

There are multiple difficulties when implementing a project shop. You have to get the material to the site, you have to get the information to the site, and you must not mix up the sequence.

11.3.1 Material and Information Flow

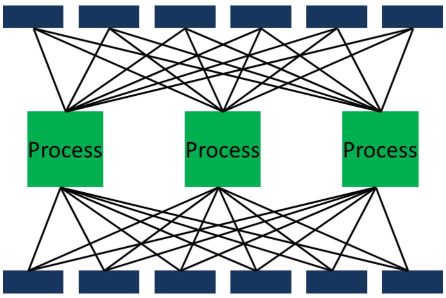


Figure 89: Process Shop Material Flow (Image Roser)

Let's start with the material and information flow. You have to bring the material to the workplace. If you have multiple workplaces, all material has to go to all workplaces. This will be a mess.

Ideally, you would provide a complete set of parts at the workplace before the worker starts working on a new product. Unfortunately, you would need quite a lot of space around the workplace to store all the parts. In all likelihood, you don't have that space. Hence, your material delivery needs to be timed to arrive before it is needed. Using lean philosophy, it should arrive exactly when it is needed, but I think we can just forget about this here.

In a flow shop (e.g. an assembly line), each material goes only to one process (or very few processes) in the line. Since there are few part types at the process, you can have more of each of them, as they are needed anyway. This makes it much easier for the material logistics. Each part has only one destination, and due to a small buffer it is usually not time critical.


Figure 90: Mixed up the parts (Image Kelly Bailey under the CC-BY-SA 2.0 license)

In contrast, for a project shop, the material needs to go to a different station each time, and if the supply is late, it is likely that work is interrupted. Even worse, it may be possible that the wrong part gets installed. Hence, it is much more demanding and complex for the material logistics, which is another way of saying that things will go wrong frequently. Such project shops are known for frequent missing materials, resulting in delays, rush orders, and overall inefficiencies.

11.3.2 Sequence


Figure 91: Mixed up the sequence! First sock, then shoe! (Image Roser)

In an assembly line, it is easy to keep production sequence. You simply order the processes in the sequence you want them. In a project shop, however, the workers have to make sure that the sequence is right. If multiple workers work on the same car, it is easy to attach parts out of sequence. If you install the door cover of a car, it will be no longer possible to install the wiring behind the door panel. You would have to remove the door panel again, install the wires, and attach the panel again. Such errors can happen way more than you want them to, resulting in lost time and potentially damaged products if you catch the problem, or a defective product if you don't.

11.3.3 Efficiency and Quality

Efficiency and quality will also suffer. Usually, a good workload for a factory worker is 30 to 120 seconds of work before the work is repeated. Such a small work content is easy to learn, and – even more importantly – quick to master. Workers will become experts soon, which makes them work more efficiently and produce better quality. Job rotation reduces boredom.

In contrast, a project shop may have hours or even days of work before the steps are repeated. It takes much longer to learn, even longer to master, and overall it will be less efficient with worse quality.

Since there are more materials and tools around, the worker also has to walk more to get the next part or tool. Walking time will increase, and hence waste will go up. Overall, the project shop will have a quite high variable cost compared to other options.

11.3.4 Standardization and Visualization

Finally, the mass of materials and tools and the long work sequences make it difficult to observe the process to find improvement ideas. You need to observe a process multiple times to see deviations from the standard, which is difficult if the work content may take hours before it repeats. Overall, optimization and improvement (*kaizen*) is very difficult to do.

The problem is similar when creating standards. Such a long work content would result in a very long standard, which is difficult both to create and to follow. In all likelihood, the standard will be only very basic, which again leads to inefficiencies and quality mistakes.

11.4 Some Advantages

This is not to say that the project shop does not have advantages. It is more flexible to change to different products. It probably requires less initial investment. If the product is difficult or impossible to move, it may be the only option (although even big jumbo jets are nowadays produced on an assembly line).

Overall, the project shop has limited use for modern production. There are cases where it is still useful, but most production is done using job shops or, even better, flow shops. I will talk about job shops next. In the meantime, go out and organize your industry!

12 Organize Your Production Sequence – 2: Job Shop

Christoph Roser, March 21, 2017, Original at https://www.allaboutlean.com/job-shop/

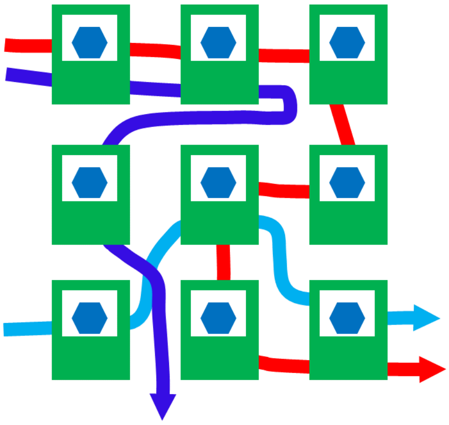


Figure 92: Job Shop (Image Roser)

Job shops are a manufacturing system where the machines are not arranged in the sequence of the work steps (as in a flow line). Rather, the flow of the part conforms to the arrangement of the machines.

This post looks in more detail at the job shop, its advantages and disadvantages, and where it may be useful.

12.1 The Job Shop

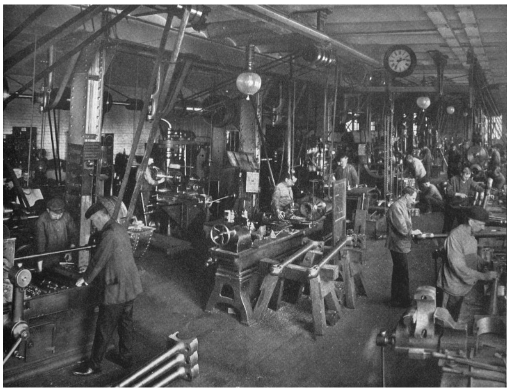


Figure 93: 1912 lathe department – a typical job shop (Image Waldemar Titzenthaler in public domain)

A job shop is a production system where the material flow is subject to the location of the machines. In other words, the parts go to wherever the machine for the next work step is. Often, the machines are arranged in functional groups (i.e., a lathe department, a milling department, a heat-treating oven, assembly stations, and so on).

This differs from a flow shop, where the machines are subject to the material flow, and are set up so the next adjacent machine is in most cases also the next process step (more on this in my next post). It also differs from the project shop, where the part does not move at all.

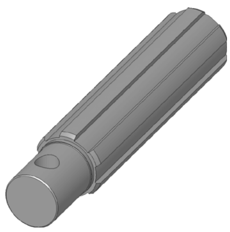


Figure 94: Spline Shaft (Image Silberwolf under the CC-BY-SA 2.5 license)

Each part has a sequence of production steps. These may be different for every part, although often there are groups of parts that have a similar sequence. Some steps have to be done before or after other steps, while other steps are more flexible and the sequence can be varied. For example, if you produce an axle as shown in the image, you probably use a lathe early on. However, if you first drill the hole or mill the grooves makes no difference. The grinding, however, should come at the end.

The part then has to be processed at different machines in line with the production sequence. Often, there is more than one machine available. For example, there may be more than one lathe where the part could be worked on.

A part may also visit a machine more than once. For example, for precision parts there may be multiple washing steps at different times, all done on the same washing machine. Or a metal part may be annealed in an oven multiple times throughout the production sequence.

Overall, the sequence of which part is processed at which machine is usually only loosely defined.

12.2 Planning a Job Shop

Figure 95: So what should we do today? (Image Schmiljun under the CC-BY-SA 3.0 Germany license)

If you are looking for a quick and easy way to effectively plan a job shop, **sorry … there is no such thing!** Job shops are almost always a chaotic mess if compared to flow lines. If they are not a chaotic mess, then a lot of effort is continuously put in to manage the system. Since it is hard to keep that effort up for longer periods, it usually ends up in a … well … chaotic mess.

Naturally, there are different software tools that make a plan for you and schedule which part is to be processed at which machine when and by whom. Unfortunately, these plans – which are difficult enough by themselves – are not dynamic. The problem is that a job shop is very sensitive to small changes. Even comparatively minor changes in the production system can change the sequence of parts at a machine, and hence can invalidate the entire plan. If a process due to some problems takes longer than planned, all subsequent parts on this machine are then delayed. Other machines waiting for the parts for further processing may be either idle, or – more likely – work on another part that is available. This creates a completely new sequence, which will invalidate the prior planning.

Figure 96: Your job shop? (Image ~Pyb under the CC-BY-SA 2.0 license)

Overall, material flow is difficult to predict. As a result, information flow is also difficult to handle. It is hard to say beforehand which machine needs what product information. Logistics is also more challenged to figure out what exactly has to be moved from where to where and when. Let's look at a few common and relevant KPIs in manufacturing, and how they behave in job shops:

- **Lead Time** (i.e., when the product will be ready for the customer): Hard to predict beforehand. Duration may fluctuate significantly between almost identical parts. Experienced shop floor managers will usually add quite a bit of safety, so they are late less often.
- **Machine Utilization and Capacity** (i.e., do I have enough machine capacity to satisfy the customer?): Same story. Due to the differences in product sequence, a lot of parts may arrive at one machine at the same time, exceeding capacity. Or there may be not enough parts, because the small changes lead to a different effect. Very hard to predict, high margin of error. It is hard to predict how many parts you can make in a certain time.
- **Worker Assignment** (i.e., which machine should be manned when): Closely related to machine utilization, hard to predict. Usually, the workers self-organize and keep themselves busy at whichever machine they can work on. Since some machines are often preferred by the workers over others, the utilization and lead time fluctuations may increase even more. Even if the worker has no preference, a "random" pick of the next task may often be the "wrong" one, since they do not have an overview of what is urgent and what not.
- **WIP Inventory** (i.e., the stuff on the shop floor): Here I can make you a prediction. **It will be a lot!** Much more than a comparable flow line. Exact numbers are hard to estimate, but I guess you are lucky if you have only twice the WIP than a flow line. If you have little WIP, then – due to the erratic nature of a job shop – it is likely that some of your machines run out of parts while others still have too much. Inventory is often an insurance against idle machines, and in job shops you will need it.

Figure 97: Inventory (Image Axisadman under the CC-BY-SA 3.0 license)

The timing of which part is processed when at which machine is highly sensitive to minor changes in the system! Any predictions have a high margin of error!

12.3 Advantages

Job shops are still found in industry, as they do have some advantages depending on your situation.

First of all, **job shops are easy to set up**. While a flow shop needs considerable planning and preparation to be done correctly, for a job shop you just get the machines and put them on the shop floor. Although, in practice, you save planning during set-up but get much more and harder planning problems during operations. Similarly, **expanding a job shop is also easier** since it means merely adding more machines of the required type, rather than setting up and balancing a new flow line. Same for reducing production capacity. Related to this, a job shop may also require a **lower investment than a comparable flow shop**.

Job shops are also very flexible with their product spectrum. While a flow line is restricted to certain part groups, a job shop can produce a much wider variety of goods.

Job shops are more robust: The failure of a single machine can completely stop a flow shop. A job shop, however, may have multiple machines, and can work "around" the broken machine.

12.4 Disadvantages

There are also quite a lot of disadvantages. I already described above in detail the **very difficult planning and scheduling issues**.

There is also a **lower productivity compared to flow lines**. Both workers and parts have to move around much more, resulting in waste through transport and walking, on top of waiting for parts.

The **workers also often have to be more skilled than at a flow line**. As a result, labor costs may be higher. Details depend on the particularities of the production system.

Figure 98: Low-hanging fruits? (Image andreas_fischler under the CC-BY 2.0 license)

Overall, **job shops are also very hard to improve**. Since a job shop is usually a mess, it is difficult to see how the standard works, if workers are deviating from the standard, and where you could start improving a job shop. Things like visual management, which normally would help you with this, are also more difficult. On the other hand, since most people shy away from improving job shops, there are often quite a few low-hanging fruits.

12.5 When to Use?

Figure 99: A really big assembly line (Image United States Army Air Forces in public domain)

The pros and cons make it quite clear when a job shop may be suitable. It works especially if you have a very high demand on flexibility, offsetting all the other disadvantages. In this case a job shop may be a possibility.

Nevertheless, you should still try to go for a flow shop whenever possible. There are many examples of industries that were once thought to be typical job shop products but now have arranged their production in a flow shop. Examples are Boeing and Airbus jumbo jets, MAN diesel engines, and Trumpf machine tools to name just a few (see my post [A Successful Example of Lean Implementation – Trumpf and its Synchro Manufacturing System]() for details on Trumpf).

I will talk about flow shops next. In the meantime, go out and organize your industry!

13 Organize Your Production Sequence – 3: Flow Shop

Christoph Roser, March 28, 2017, Original at https://www.allaboutlean.com/flow-shop/

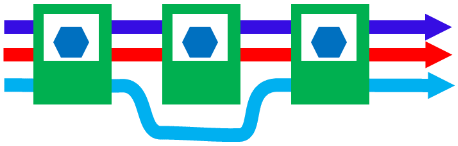


Figure 100: Flow Shop (Image Roser)

The flow shop is usually preferred for most lean production systems. In a flow shop, the processes are arranged in the sequence of the production steps. If you can manage to establish a flow shop, your production will be much more efficient than in a job shop or a project shop. In this post I want to talk in more detail about the flow shop. Be warned, this will be a bit of an ode to the flow shop ☺.

13.1 The Flow Shop

Figure 101: Automotive assembly line: A typical flow shop (Image Unterberg, Rolf under the CC-BY-SA 3.0 Germany license)

In a flow shop, the processes are arranged in the sequence that the parts are processed. The best known example is the assembly line, but there are many others.

This type of production system is usually the ultimate goal of any lean system. In fact, most of the writing in manufacturing and many of the lean methods concern the flow shop. The other methods, job shop and project shop, often feel even neglected to me. But then, it is just so much easier to perfect a flow shop than the other two.

13.2 Repeatability!

The big advantage of the flow shop is its repeatability! All work steps are repeated (ideally in identical form) over and over again within a short time period. One example would be an automotive assembly line, where the work content of every station is around one to three minutes before the process is completed and the cycle starts anew. Machine tool makers and aircraft assembly lines may have a cycle of a few hours (see Trumpf for an example), which is longer than a car maker but still much faster than the job shop or project stop alternatives. This repeatability gives a lot of enormous benefits.

Figure 102: Ford assembly line 1913 (Image unknown author in public domain)

Repetitive process cycles make optimization easier for humans! Human workers can learn one to three minutes of repeating work in an assembly line much easier than learn the always-different work in a job shop. For example, a lathe worker that is suited for job shops would need a long and costly education and years of practice to achieve mastery, and would command a higher salary. Teaching a worker a three-minute work content is done in a few days to achieve mastery (or even hours, but you should not cut it too short – see Operator Training at Toyota and Scania for an example). Labor cost is usually lower too, although the workers would prefer the higher salary, of course. To prevent boredom, the worker can work at different tasks at different times.

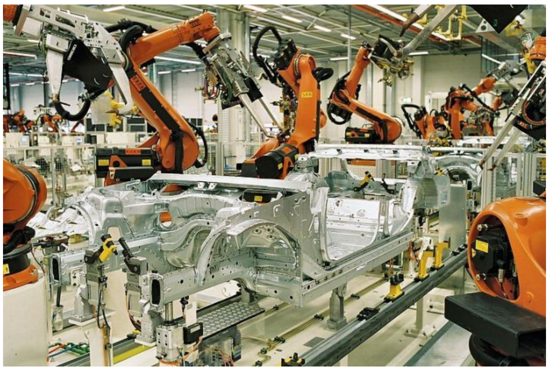


Figure 103: Robotic assembly line 2005 (Image BMW Werk Leipzig under the CC-BY-SA 2.0 license)

Repetitive process cycles make optimization easier for machines! Optimization is also easier for machines. If a work cell or robot always handles the same parts, it is much easier to mechanize and automate. Since the work content is much smaller, it is a lot easier to program a multipurpose machine. In fact, since the work content is (nearly) identical each time, it is also much easier to adapt the hardware. Rather than a (slower) multipurpose machine, you have a faster dedicated machine exactly for this process.

Figure 104: Just imagine doing this by hand… (Image ChristianBier under the CC-BY-SA 3.0 license)

Much easier logistics! The repeatability applies not only to the processes but also to the logistics. Since the steps are identical and always at the same spot, knowing what to bring where is so much easier. Part A always goes to process X, and Part B to process Y. Additionally, it is not only the same location but also the same frequency. Rather than a part per hour, day, or even less, the parts are needed by the minute or second. The material flow is not only with a clear source and destination, but also much higher frequency than job shops. This makes it much easier for human logistic workers to improve, be more efficient, and reduce errors. As above, this applies also to automation and mechanization. Since the material flow is now so constant, you can automate the material flow (for example, with a conveyor belt). In contrast, a conveyor belt usually makes no sense at all in a job shop.

13.3 Clarity!

Another big benefit of flow shops is clarity. This is a direct result of the repeatability from above, but since it is host to so many other advantages, I want to give it its own heading. As repeatability helps in making a fast and efficient system in the first place, clarity helps in improving it.

Easier to create standards! Since the work repeats in short cycles, it is so much easier to create good standards. There are (ideally) no exceptions and decisions in the standard, and the standard covers only a short period of time that repeats frequently.

Figure 105: You can see! (Image Lt. Wayne Miller in public domain)

Easier to see problems and potentials! This is a big one! Due to the repeating identical work, it is much easier to see problems. These may be deviation from the standard, recurring problems, or just potentials for improvement. A chalk circle exercise is much easier in a flow shop than in a job shop. Related to this, **visual management** is also much easier in a flow shop. Since the sequence is always the same, it is much easier to, for example, see if there is a lot or little inventory at a certain spot.

Easier to improve! Since it is so much easier to see problems, it is also so much easier to improve them. The implementation is also helped by the repeatability.

Easier to predict! Due to its repeatability and clarity, the behavior of the flow shop is also much easier to predict. Contrast this with the planning problems at the job shop. No matter which parameter, they are all much easier to estimate beforehand with much less fluctuations compared to a job shop or project shop. Take for example **Lead Time** (i.e., when the product will be ready for the customer), **Machine Utilization and Capacity** (i.e., do I have enough machine capacity to satisfy the customer?), **Worker Assignment** (i.e., which machine should be manned when), **WIP Inventory** (i.e., the stuff on the shop floor), and many more. Planning is, while still challenging, no longer a complete mess like in the job shop.

13.4 Gargantuan Benefits!

Figure 106: Stack of Dollar (Image aleciccotelli with permission)

When switching from a project shop or job shop to a flow shop, **the benefits can be gargantuan** (you know, I've always liked that word … *gargantuan* … so rarely have an opportunity to use it in a sentence). Any example I have seen where a job shop was converted into a flow shop resulted in gargantuan benefits.

While most examples I have are subject to a confidentiality agreement, I can talk about a few historic examples. An early example is James Bonsack and his cigarette-rolling machine in 1881. He transformed cigarettes from a luxury item to a commodity. Reducing production cost to 1/6th (even after including the price of the machine), he was able to supply all of America from two production lines. Another example: The first match sticks production line in 1880 improved productivity seven-fold. I could expand this list with canning, soap, sugar, toilet paper, and many more. Many of the famous brands you know started around that time: Diamond Matches, Quaker Oats, Campbell Soup, Procter & Gamble Ivory Soap, Heinz Tomato Ketchup; all had gargantuan growth due to the possibilities of a flow shop.

Figure 107: Henry and his Tin Lizzy (Image Ford Motor Co. in public domain)

Most famous, of course, is Henry Ford. Around 1913, Henry Ford switched from a project shop car assembly to the famous assembly line. For the magneto line (the generator), the labor time was reduced from 20 minutes to 5 minutes per part. For the axle line it was reduced from 150 to 26.5 minutes. Transmission assembly from 18 to 9 minutes. Engine assembly from 594 to 226 minutes. Final assembly from 12.5 hours per car to 93 minutes per car. Depending on the component, there was an improvement between 50% and 1000% for the labor cost. With improvements, over time, the Model T price was reduced from $850 in 1908 (around $20,000 nowadays) to $260 at its lowest in 1925 (or around $3,600 nowadays). Henry Ford became one of the richest men in America (net worth at his death over $180 **billion**).

This is not to say that a flow shop alone will give these benefits. But it makes it much easier! It allows easier mechanization, higher quantity production, and more importantly, it allows faster continuous improvement. The companies above utilized these possibilities and reaped gargantuan benefits.

13.5 Disadvantages

However, as usual, there are some disadvantages. Most importantly, **a flow shop usually has a much lower flexibility.** This is first for **product variants**. Since the processes are organized around the work sequence of a product group, it is difficult or impossible to adapt it to a different product group. Similarly, it is more difficult to adjust **capacity**. While in many cases multi-machine handling allows production rates below maximum capacity, it is difficult to increase capacity beyond the maximum. In a flow shop, you usually would need a complete new line. In a job shop, you simply add the machines you need. In a flow shop, if the line for product A needs more capacity, it does not help if the line for product B has excess available. In a job shop, other machines could be used.

Additionally, **setting up a flow shop is more work than a job shop**, but this is usually offset by the gargantuan benefits. The price is also often higher, but this is mostly due to the machines being more automated and hence faster. In a job shop, you could just rearrange the machines to a flow shop without additional cost. Yet to achieve the full benefit of a flow line, higher automation is often a good step.

13.6 Summary

Figure 108: Boeing assembly line 1944 (Image United States Army Air Forces in public domain)

Overall, a flow shop and its many variants (assembly line, transfer line, etc.) usually have gargantuan benefits. Hence, even products that are difficult to imagine as flow shops are converted to flow production. Examples include aircraft (Boeing, Airbus, etc.), large ships, huge ship engines, and many more.

As I have said before, the benefits can be gargantuan (which makes it now nine times I have used that word in this post. I'll stop now, I promise). Now, go out, see if you can change your production (or even parts of it) into a flow line, and **organize your industry!**

P.S.: If you want to know more about the history of the assembly line, check out my book "Faster, Better, Cheaper" in the History of Manufacturing: From the Stone Age to Lean Manufacturing and Beyond:

14 Lean Is Tough – The Phases of a Lean Transformation

Christoph Roser, April 04, 2017, Original at https://www.allaboutlean.com/lean-transformation-phases/

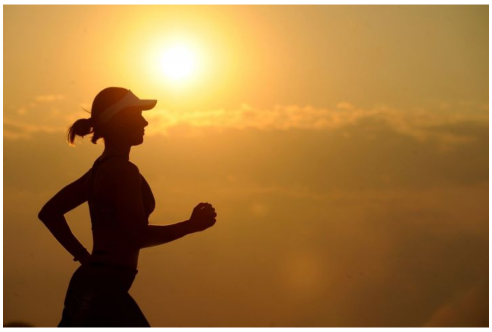


Figure 109: Woman Jogging (Image Jean Beaufort in public domain)

Sometimes, consultants sell lean as a quick and easy way to success that pays for itself. Unfortunately, this is usually not true, as many companies have found out the hard way. Getting lean in a company is similar to getting a lean body; it is usually neither quick nor easy. Let me show you the different phases of a lean transformation.

14.1 The Typical Phases of a Lean Transformation

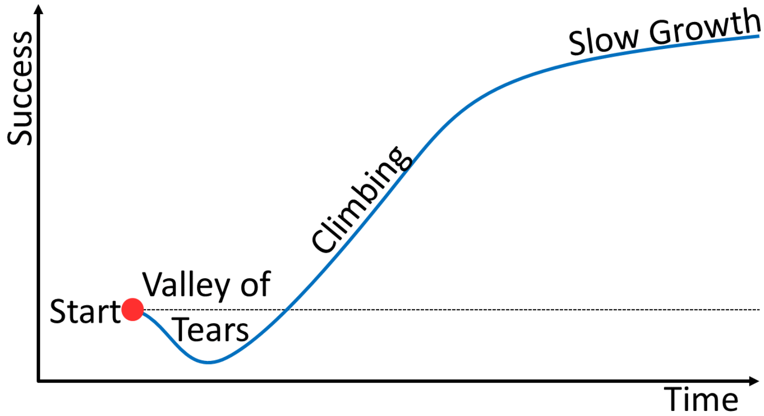


Figure 110: Lean Transformation Stages (Image Roser)

A lean transformation is a long-term strategic orientation of a company. It is more than just a lean project. In my experience, such a lean transformation goes through multiple stages. After the start, the company goes through the famous valley of tears before the performance starts to improve, first rapidly and eventually slowly.

14.1.1 The Valley of Tears

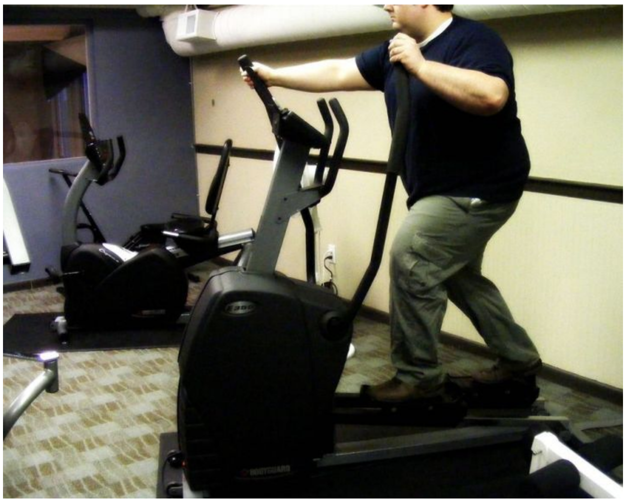


Figure 111: The start is the hardest! (Image Robert Anthony Provost under the CC-BY 2.0 license)

At the beginning of a lean project, there is usually (but not always) the valley of tears. If you try to lose weight, your body may feel uncomfortable with the exercise, and the weight loss is probably much slower than hoped for.

Lean manufacturing is similar. By changing the system, you may upset long-established traditions and customs. Some people may fight against the change, visibly or hidden. Others may have trouble adjusting.

Most often, however, the reason for the difficulty is that **the new system may still have some kinks and bugs in it**. These need to be sorted out (hint: This is the C&A of the PDCA!). If you do not sort out the many little details, you may be stuck with a system that is worse than before.

Also, for your transformation, you need manpower, definitely your own, and sometimes also additional (and more expensive) hired consultants. Your people will have less time for other things during the transformation, and you may have to spend initial money with a rather fuzzy outlook about when (and if) you will get the expected benefit (which is one of the reasons accountants often have problems with lean).

Furthermore, the learning curve cannot be underestimated. There is no way a lean project is guaranteed to work. In fact, in my experience, only 50% or less of the projects actually have a benefit (albeit the reporting to upper management often makes it look better than it is). Yet, without trying you will never improve. Overall, at the beginning there may be more mistakes than later on during the transformation.

In any case, the new system may not (yet) run as smoothly as intended, and actual performance may be worse than at the beginning. The duration of the valley of tears may be from a few months to years, depending on the details of the project. Of course, done wrongly you may never come out of the valley at all. But, more on this below.

14.1.2 Climbing: Rapid Improvement

Figure 112: Climbers (Image Savognin tourism under the CC-BY-SA 3.0 license)

If you do it right, you will eventually leave the valley of tears. If you keep up the effort, then you can expect rapid improvements. Your changes start to become effective. Done correctly, they may have a domino effect throughout your value chain.

In the Western world, lean is often seen as a reduction of waste (muda). In my view, however, the reduction of unevenness (Mura) is even more important! Reducing waste will usually only affect the spots where the waste is reduced. Reducing unevenness is tougher, but this will often have beneficial effects throughout the value stream. In any case, done correctly you can expect to improve rapidly.

As for the time scale, it depends on how far you are away from the top. Here, we are easily talking years.

14.1.3 Slow Growth: World Class Performance

Figure 113: Peak performance (Image unknown author in public domain)

Eventually, your improvements will start to slow down. While you still put in a lot of effort, your resulting performance is growing slower than before. Congratulations, you are now probably among the best companies in your industry! Further improvement is still possible, but it will become more difficult to improve.

For example, it is doable to go from 60% of the deliveries on time to 85% on time. It is more difficult to go from 85% to 95%. Getting from 95% to 98% will be even more difficult, as is 98% to 99%. The closer you get to 100%, the more effort is needed to improve further. Hence, your overall performance can still increase, but it will become harder and harder to improve. At one point it will take all your effort just to maintain the current situation.

No matter whether you exercise your body or transform your company, you are in peak performance. However, both in lean transformation and in personal exercise, if you stop, your performance will suffer. It takes a continuous effort to stay on the top.

14.1.4 The Way Back Down

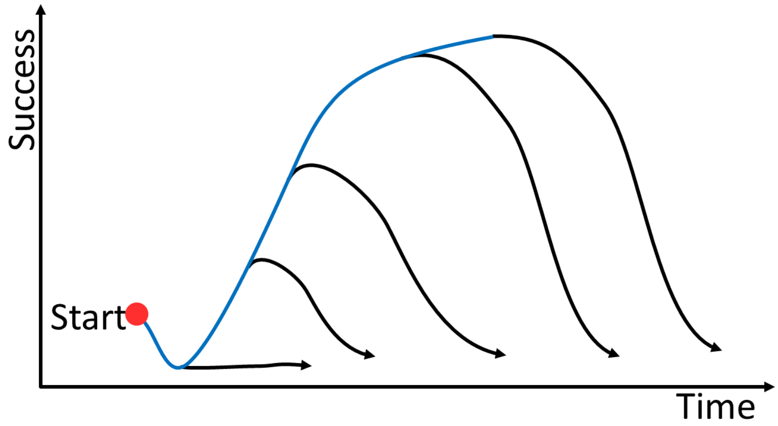


Figure 114: Lean Transformation Slide Back (Image Roser)

Like fitness, lean is a constant effort. The moment you stop, you will slide back down. The environment in industry is constantly changing. New products are introduced, old ones run out, suppliers and customers may change, laws may change too. Technology will both generate newer and better products as well as better and faster machines and tools. Just standing still will mean that you will fall behind.

14.2 Kaiaku, the Opposite of Kaizen

Even worse, depending on your situation, you may end up with worse performance than before. In Japanese, there is even a word for that: Kaiaku (改悪, changing for the worse). This is for situations where an ill-fated attempt at improvement results in a system that is worse than before. It is the opposite of Kaizen (改善, continuous improvement).

In my experience, this is not uncommon. A lean transformation often consists of multiple individual lean projects. These lean projects introduce changes. At least initially, not everything may work out as planned. This is where the C&A from the PDCA comes in. Check what is not (yet) working, and keep on improving it. In my experience, this debugging often takes more time than the initial implementation.

Unfortunately, in many Western companies, a nice presentation about improvements is all management ever wants, and the problems created on the shop floor are often ignored. I have seen way too many examples of this. From new ERP software that created chaos, to Industry 4.0 solutions that looked nice on paper but did not work, to make-believe kanban cards that were just another hassle for the shop floor with no positive effect. And, don’t even get me started on leveling!

14.3 The Low-Hanging Fruits

Figure 115: Low-hanging fruits… (Image andreas_fischler under the CC-BY 2.0 license)

Consultants often talk about low-hanging fruits (i.e., quick and easy projects with a high return on your effort). Yes, they do exist. Often, there are situations where you can find easy projects that quickly generate quite a bit of return.

In my experience, these are often associated with inventory reductions. In many plants I had good success with SMED (i.e., improving tool changeover speeds), which allowed us to reduce the lot sizes or produce more. At one plant I was able to give an extra month of production every year through a simple SMED. Overall, such win-win situations do exist.

Yet, in my experience, they cannot be taken for granted. Additionally, they are hard to repeat. You can "SMED" your way through your value stream only so often before further improvements become difficult.

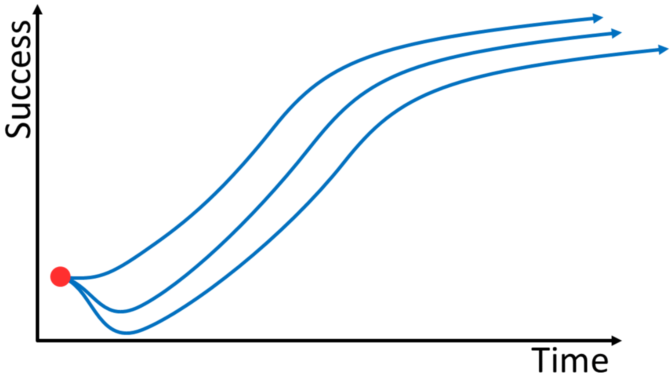


Figure 116: Lean Transformation Stages Variations (Image Roser)

However, many transformations do have a valley of tears. While every transformation is different, it is sometimes but not always possible to avoid this initial dip.

In any case, I hope your transformation will be successful, and that you reach peak performance with or without a valley of tears. Now, go out, climb that curve, do not slice back again, and **organize your industry!**

PS: My post inspired Juan Carlos Viela to write two posts (in Spanish) that include interesting data on the valley of tears: Medir es importante I/II and Echar a andar. Las curvas del cambio II/II. In case you don't speak Spanish, you can try Google Translate for Part 1 and Part 2.

15 Pacing of Flow Lines 1 – Unstructured and Pulse Line

Christoph Roser, April 11, 2017, Original at
https://www.allaboutlean.com/timing-of-flow-lines-1/

Figure 117: Spiral Clock (Image theTrueMikeBrown in public domain)

Flow lines are often the best and most organized approach to establish a value stream. Hence, for flow lines or flow shops you can organize the processes much more easily than for many other types of production systems.

In this series of posts I will look at and compare different ways to pace your production processes. Please note that this is not line balancing about the work content for each process, but rather different options on when to start the work for each process. In the first post I will look at unstructured pacing and pulse lines. In my next post I will go into detail for the continuously moving line.

15.1 Introduction

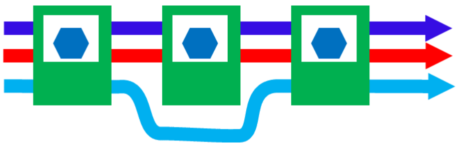


Figure 118: Flow Shop (Image Roser)

In this post we are dealing exclusively with flow lines or flow shops. In a flow shop, the processes are arranged in the sequence of the production steps. The highly linear and consistent value stream makes timing the production system much easier than, for example, a job shop or a project shop.

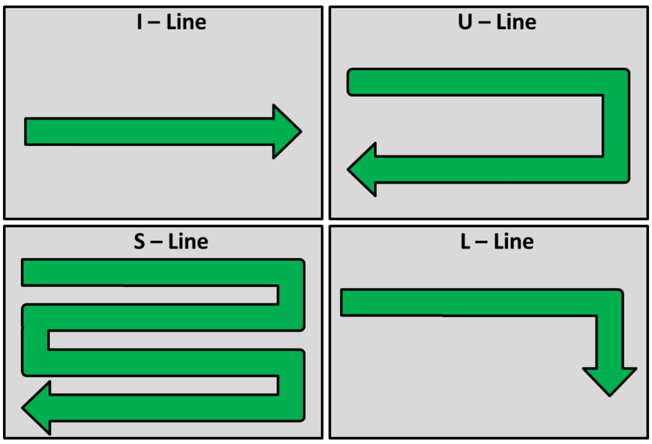


Figure 119: I, U, S, and L Line layouts (Image Roser)

I talked in detail before about possible layouts of the flow line. The most well known ones are the I, U, L, and S lines. Their advantages and disadvantages are discussed in my series of posts on Line Layout Strategies part 1, part 2, and part 3.

I also discussed in detail the process for line balancing in an extensive 6-post series. But please do not confuse line balancing with this post of timing a production line. In line balancing, you consider the work content for each process in the line. In this post on timing the line, you consider when a process should start. There are three different options on how to time the production lines.

15.2 Unstructured Timing

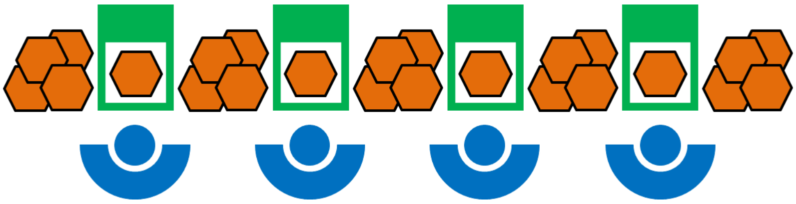


Figure 120: Animated Image of Untimed Line. The animated image can be found at https://www.allaboutlean.com/timing-of-flow-lines-1/ (Image Roser)

The "easiest" one is an unstructured approach. The processes are still arranged in sequence; however, there is no fixed signal when to start processing a part. Every process (both automated or manual) starts with the next part whenever it is done with the previous part. Even if at the beginning of the shift every process starts at the same time, minor variations will soon cause all processes to start at slightly different times. Sometimes a process will be faster, sometimes slower, but eventually the starting times will be independent of each other.

This has a couple of advantages and disadvantages.

15.2.1 Advantages

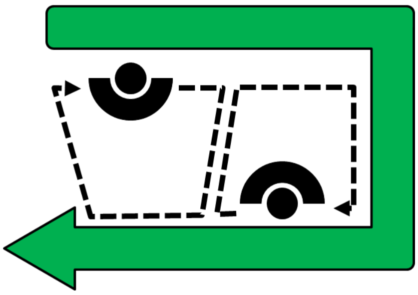


Figure 121: Baton touch line (Image Roser)

Overall, this line is **pretty easy to set up**. You do not have to worry about the timing of the processes. In other words, you do not have to set the speed of the conveyor belt (as for a continuously moving line below), but the speed of the system will organize itself. However, this can also be seen as a disadvantage, as you have less control over the speed of the system.

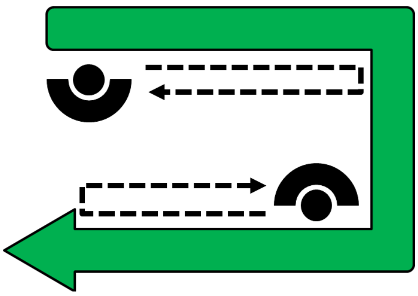


Figure 122: Bucket brigade (Image Roser)

Manual lines using this approach **can be partially staffed**. In other words, not every process needs a worker at the process all the time. Possible options here are the famous chaku chaku line, including bucket brigades, a rabbit chase approach, or a normal baton touch. This allows a more flexible use of the line for manual lines. If you face a high demand, you have the line fully staffed. If demand goes down, you reduce workers and hence output.

In this kind of system, it is also **easier to determine the** bottlenecks**.** Just look where the material starts to pile up.

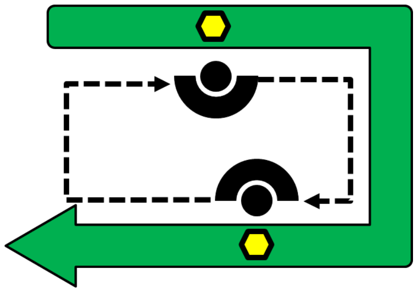


Figure 123: Rabbit Chase (Image Roser)

Finally, due to the buffers between processes, **small fluctuations in process time can be buffered through inventory**. If a process is temporarily faster than another process, the faster process does not have to wait for the other processes, but merely uses parts from the buffer until a fluctuation in the other direction slows it down again. It does not matter if these fluctuations are due to random variations in the process or due to slightly different products (where, for example, a two-door car has a faster door assembly than a four-door car).

15.2.2 Disadvantages

On the downside, this unstructured timing approach **needs buffers between processes** to buffer the fluctuations in process time. Hence, it will have a (slightly) higher inventory and a higher lead time.

Another disadvantage is that since all processes work at their own pace, **it is difficult to force a speed on the system**. Since there is no external time signal for completion, the parts are done whenever they are done.

Finally, it may be more **difficult to observe and understand the system**. Due to the fluctuations, it may be more difficult to identify improvement potentials. It is still possible; it may just take a bit more effort.

15.3 Pulse Line

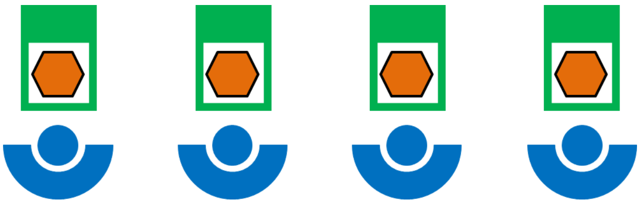


Figure 124: Pulsed Line. The animated image can be found at https://www.allaboutlean.com/timing-of-flow-lines-1/ (Image Roser)

The pulse line is also a flow line, but now all parts move at the same time. As shown in the animation above, all processes process their parts. When all processes are done, all parts move to the next process simultaneously. Hence, there would need to be an information system that triggers the move if all processes are done. You can also define a time for the move, but then have to check beforehand if all processes are completed or if one is lagging behind.

Figure 125: Junkers JU 87 pulse assembly line (Image Seuffert under the CC-BY-SA 3.0 Germany license)

One of the earliest uses of this system that I know dates back to the Junkers Aircraft plants in 1926. In Germany it was called "*Taktverfahren*," which by the way is the reason why lean uses the German word "*Takt*" time.

This type of pulse line is particularly well suited to longer cycle times. At Junkers, for example, they moved all aircraft to the next process simultaneously every few hours. German machine tool maker Trumpf uses a pulsed line with a cycle time of around 8 hours for its machine tool assembly. Another common example with a shorter takt time are automotive body welding lines.

15.3.1 Advantages

A pulse line **needs no buffer between processes**. Since all parts move at the same time, there is no need to buffer against random fluctuations in process time.

It **may be easier to identify potentials**. Since all parts move at the same time, any problem is immediately forced onto the entire line. While some see this as a disadvantage, it can help you to permanently fix problems.

It is **easier to define the speed of the line** by setting a target for the pulse time.

15.3.2 Disadvantages

Pulse lines usually need to be fully staffed. All processes need to be operating for a pulse line. Hence, adjusting capacity is possible only through overall work hours. There is one exception, however. Normally, when all parts move at the same time, the first process starts a new product. You can opt to occasionally NOT start a new part. This "empty slot" or "hole" is then also "pulsed" through the system. If, for example, every fifth slot is empty, your output is reduced by 1/5th or 20%. Of course, you would need to find something else to do for your workers. This is challenging but doable if the cycle time is multiple hours.

Since all processes need to be finished before all parts move one slot down, **operators may have some waiting time** until the last operator is done with his process. It **may also require slightly more effort to set up**.

In my next post I finally talk about the continuously moving line. Until then keep on moving forward, and **organize your industry!**

16 Pacing of Flow Lines 2 – Continuously Moving Line

Christoph Roser, April 18, 2017, Original at https://www.allaboutlean.com/timing-of-flow-lines-2/

Figure 126: Time Spiral (Image mipan on Fotolia with permission)

In my last post I described the pacing of pulse and unstructured flow lines. Another common way to structure the pacing of flow lines is the continuously moving line. In this type of line, the parts are always moving, and the processes and workers move along with the part until the process is completed.

16.1 Continuously Moving Line

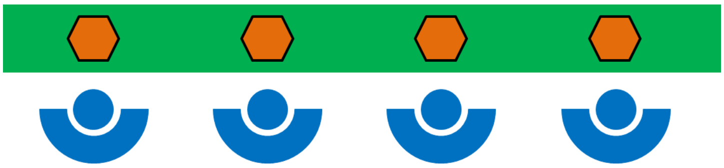


Figure 127: Continuous Moving Line. The animated image can be found at https://www.allaboutlean.com/timing-of-flow-lines-2/ https://www.allaboutlean.com/timing-of-flow-lines-1/ *(Image Roser)*

Figure 128: Continuously moving assembly line with hanging carriers (Image Siyuwj under the CC-BY-SA 3.0 license)

In the continuously moving line, the parts are – as the name says – continuously moving. This is usually an automatic transport system like a conveyor belt, a moving walkable platform, pulling by an underground chain, or moving hanging carriers, to name just a few.

These systems also have their advantages and disadvantages. They are, for example, very common for the final assembly of cars. Let's look into more detail in the set-up and operation of such a continuously moving line.

16.2 Speed of the Line

One very important aspect of the continuously moving line is the speed of the line. The speed is usually set through a central system. Adjusting the speed of the line requires some thoughts.

Figure 129: Modern Times (Image United Artists in public domain)

Henry Ford and his managers, around 1920, simply kept on increasing the speed of the line until the workers were no longer physically able to keep up with the speed. Luckily, these times are long gone (I hope). But seriously, don't just increase the speed until the workers can no longer take it! This is really bad practice and will demotivate workers. They will hate the company, and quality will suffer. In lean terms it would be one of the three evils in manufacturing: Muri, or overburden. See Charlie Chaplin in the afternoon scene of his famous movie *Modern Times* on how NOT to do it (Youtube link here, but copyright unclear).

16.2.1 Definition of Speed

At this time I have to be more precise in what I mean by speed. The speed is usually defined in meter (or feet) per second (or minute). However, when setting up a line, the speed is actually the time between one part and the next part. The distance between parts is important here. Every how many seconds does a part enter the space of a station. This is the time the station has to complete the part.

See, for example, the animation below. The parts in the top line move faster than the parts in the bottom line. On the other hand, the parts in the bottom line are much closer to each other than in the top line. Overall, the speed of the workers is the same in both lines, as is the number of parts produced. In the bottom line, however, the stations are much closer together, meaning that the workers have less space, but also that the overall floor space is better utilized.

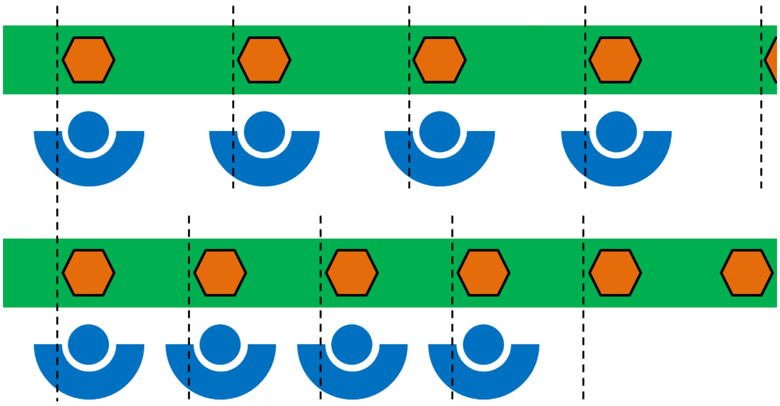


Figure 130: Continuous Moving Lines Different Speeds. The animated image can be found at https://www.allaboutlean.com/timing-of-flow-lines-2/ (Image Roser)

Hence, the actual line speed in meters per second also depends on the spacing of the parts. Therefore, it is often better to talk about the time between parts rather than the speed of the line. Of course, once the line is set up, the speed and the time between parts are directly related.

The time between parts should be based on two things: 1) The station or process with the highest workload (and of course, with line balancing, all stations should have a similar workload), and 2) the customer demand.

16.2.2 Not Faster than Slowest Station

Figure 131: VW Beetle assembly line with underground pulling system (Image Schaack, Lothar under the CC-BY-SA 3.0 Germany license)

The time between parts should not be faster than what the station with the highest workload can do. The slowest station should be able to complete the part within that time.

There is a little wiggle room if you alternate high-workload parts and low-workload parts. For example, for a car assembly, if you alternate two-door and four-door cars, then the door assembly has to do, on average, three doors. If the line is set up so that this team has a long-enough segment of the line to average this out, it may be a possibility to briefly have a higher workload if it is followed immediately by a lower workload. To determine the workload, you can use either time measurements of predetermined motion time systems like MTM.

16.2.3 Adjusted for Customer Demand

Figure 132: Hyundai assembly line with moving, walkable platform (Image Carol M. Highsmith in public domain)

The second influence for the time between parts is the customer demand. If your demand is lower than expected, you can reduce the speed of the line and give your workers more time. There are actually two schools of thought here. One is to reduce the speed and give the workers more time, the other is to reduce working hours and keep up the speed.

Toyota, for example, does reduce the speed of its assembly lines slightly if demand is lower. However, this is only a small reduction of 10% to 30%. For larger decreases in demand, they reduce the working time rather than the working speed. The danger of reducing the speed too much is that the workers have **too much** time, which will break their working rhythm and may worsen quality. They also have to find their rhythm again if the line speeds up again.

Also, from the view of the worker, working too slow is a pain and does feel uncomfortable and boring. If you don't believe it, try it out. The next e-mail you type, force yourself to slow down to one letter per second. Instead of enjoying the additional free time, it will feel *r-a-t-h-e-r u-n-c-o-m-f-o-r-t-a-b-l-e*. The same applies to manual work.

By the way, it should be obvious, but if the customer demand is higher than your line at top speed, then you need either more work hours or a second line or a significant improvement of efficiency of the stations.

16.2.4 Other Influences on Speed

There are additional influences, as for example that **the speed is significantly slower than walking speed** (i.e., significantly less than 1.4 meters per second). First of all, the workers have to keep up with the parts. Unless there is an entire moving platform, the workers may have to walk along with the part. The part should be slow enough so that the worker can not only walk along, but also work while walking along. This also would usually satisfy another requirement that a worker does not get injured if a part bumps into him.

16.3 Length, Spacing of Parts

Each station should have enough space so that it can do the work before another part arrives. Since we can play around with work space, speed of the line, and time between parts, we can influence the work space through the other parameters. In the interest of efficient usage of space, we should have the smallest work space possible that provides a safe and comfortable working environment. Also, the smaller the work space, the less walking and transport distances you have.

16.4 Advantages

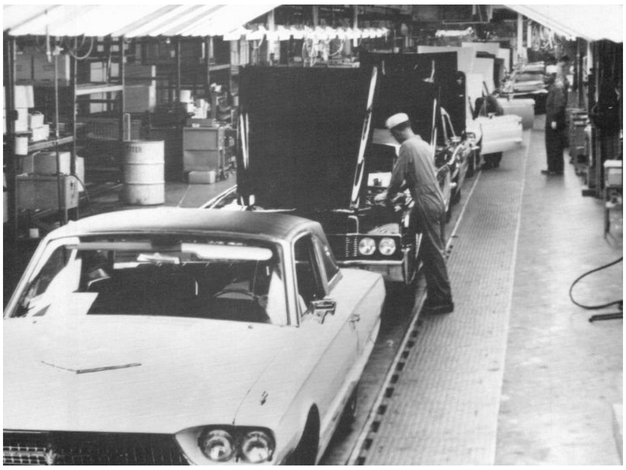


Figure 133: Ford Thunderbird assembly with pulling system (Image unknown author in public domain)

The moving assembly line has quite a few advantages.

First, **the production output can be defined through the line speed**. This makes it difficult for workers to slack off. While this is usually seen as an advantage, it can also be seen as a disadvantage, as the worker needs some short times to recuperate. However, due to the fixed speed, the work stations are often slightly faster than the speed, giving the worker some breathing room again.

It is also **easy to see delays and problems**. If there is a problem, the workers have to stop the line before their time runs out. Check my post on Andons for more about a good way to signal such problems and to stop the line.

The moving line also **needs no part buffers**. Since the speed is exactly the same everywhere, there are no extra buffers of parts needed to decouple fluctuations. Instead, your fluctuations are decoupled through waiting time of the workers for the next part.

16.5 Disadvantages

The moving line also has disadvantages. To operate, **the line has to be fully staffed**. Adjusting the capacity through the number of workers is usually more difficult.

The workers also **have more wasted as part of their work**. They have to walk along the part during production (unless it is a moving walkable platform where the workers can walk on the moving platform while it is moving), and they definitely have to walk back to the next part after finishing one part. Since the speed is also slower than the slowest station, their work may include waiting times for the next part.

The moving assembly line is also **difficult to automate**. For workers it is not a problem to walk back and forth along the line. However, this is more difficult for machines. While small handheld tools are often hanging from a movable overhead system, it is difficult to have a complex machine moving along the line. But then, the main advantage of defining the line speed is not needed for automated systems anyway, since you can set the machine speed directly, whereas the worker has to be influenced by the speed of the line.

The moving assembly line is also **less suited for long cycle times**, and is most commonly used for shorter cycle times. I have seen it most often in automotive, where a car is produced every 1 to 2 minutes.

Overall, if you have manual mass-produced parts with a short cycle time, a moving assembly line may be a possible solution. **Now go out, get things moving, and organize your industry!**

17 The Arsenal of Venice

Christoph Roser, April 25, 2017, Original at https://www.allaboutlean.com/arsenal-of-venice/

Figure 134: Land gate of the Arsenal of Venice (Image Roser)

The Arsenal of Venice was one of the the largest industrial sites in Europe in the 16th century. This was the hub of Venetian ship building, supporting the power of the Venetian republic. Both warships and merchant vessels were built there.

It is also known for the organization of its work. Sometimes it is listed as the world's first assembly line, although in my view this may be a bit of a stretch. While they achieved a lot, there was also a lot of chaos. In this post I present you with a bit about the Arsenal in general, as well as some detailed maps by Abbot Maffioletti from 1797 and 1798. In my next post I will go into much more detail on the material flow based on these maps.

17.1 The Significance of the Arsenal

Figure 135: Water gate of the Arsenal of Venice (Image Roser)

The Arsenal was the machine that powered the Venetian commercial and military fleet. Initially established around 1104, it reached its peak during the 16th century. It employed up to 16,000 workers at the same time. In preparation for the Ottoman–Venetian War, the Arsenal was able to outfit and launch 100 ships within two months, an astounding feat compared to all other Arsenals in Europe. In 1574, King Henry of France watched the outfitting of an entire ship during his lunch.

17.2 Engineering and Material Flow

Venice did change their shipbuilding technology. While Roman shipbuilders first created the hull and then added the frame for strength, the Venetians did it the other way round, building ships faster while using less wood at the same time.

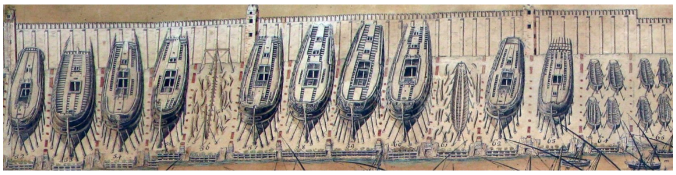


Figure 136: Arsenal of Venice hull construction (Image Gian Maria Maffioletti in public domain)

Probably most significant was that after the hull was completed, the hull was brought to the work rather than the other way round. They managed to change shipbuilding from a project shop to a flow shop, significantly improving efficiency. The hull was towed to different stations to be equipped with masts, cabins, rudders, sails, weapons, and so on. I will go into detail on this in my next post.

As part of this flow shop, they used proto-standardized parts. Most of the wood for benches, masts, and so on was already cut close to the final size, and required only minor adjustments during installation.

Quality was also tracked. For example, the rope makers added colored strands to the ropes. Each rope maker had its own combinations of colors, and if the rope broke on a ship, they were able to trace the issue back to the maker of the rope.

17.3 The Human Side

However, they did not yet have a good organization of the work. Modern management structures were not yet known, and the entire arsenal constantly faced challenges in dealing with its workers. While for its time it was groundbreaking and highly advanced, from our modern point of view it was a mess.

Figure 137: 1724 map of Venice by Joan Blaeu, the Arsenal is on the upper right. (Image Joan Blaeu in public domain)

Becoming a worker at the Arsenal, an *Arsenalotti*, meant lifetime employment. Since wages were paid simply for showing up once per day, many *Arsenalotti* did just that. Even the old, infirmed, or sick dragged themselves across the gate once per day to get paid. Able-bodied workers preferred to spend most of their time idling and chatting, working outside the arsenal for private profit, or even working inside the arsenal for private profit – often using material and tools provided by the arsenal.

Lots of material was also stolen. Despite attempts by the officials to establish a police force, the material and the equipment of the Arsenal often found its way outside into private hands.

Officials also tried to improve attendance, such as by offering benefits like additional pay and free wine. For example, in 1630 they consumed the equivalent of **two liters of wine per worker per day!** They also required attendance and tried to punish stealing. However, as most of these rules were not enforced strictly, the Arsenal remained a bit of a chaotic work environment.

17.4 The End of the Arsenal

Figure 138: Venice, with the Arsenal on the right (Image Robert Simmon in public domain)

The Arsenal supported the naval power of Venice. As the Venetian Republic declined, so did the Arsenal. With the fall of Venice to Napoleon in 1797, the Republic ended, as did the production in the Arsenal. Nowadays the Arsenal is used as a training location for the Italian Navy, and annually for the Venice Biennale.

17.5 The Beautiful Maps by Abbot Maffioletti

Abbot Gian Maria Maffioletti created a series of three maps of the Arsenal of Venice right around the fall of the Venetian Republic, although in all likelihood he did not draw them himself but arranged for the creation of the maps. One map shows the arsenal in 1797, the other one in 1798, and the third one shortly thereafter, labeled “After Napoleon.” All maps can be found in the Museo Storico Navale in Venice, which was once part of the Arsenal.

17.5.1 Arsenal of Venice 1797

The map of 1797 is probably the most interesting from a manufacturing point of view. It shows in great details the inner workings of the Arsenal of Venice. The roofs of most buildings are not shown, so you can see inside the building. Back then, such maps were also a simple approach to get an overview of the inventory. Hence, pretty much all buildings and areas are labeled, with a detailed legend for each entry (e.g., *33 Warehouse of softwoods and hickories* or *173 Blacksmiths’ workhouse for artillery*).

Figure 139: HighRes Map Arsenal of Venice 1797. The full resolution image can be found in the online article or at https://www.allaboutlean.com/wp-content/uploads/2017/03/HighRes-Map-Arsenal-of-Venice-1797.jpg (Image Gian Maria Maffioletti in public domain)

I encourage you to look at the map in greater detail and "wander around" in the Arsenal of 1797. Here is the link to the 12 MB full size with a resolution of a whopping 8388 x 6020 pixel at https://www.allaboutlean.com/wp-content/uploads/2017/03/HighRes-Map-Arsenal-of-Venice-1797.jpg. Please note that the map is stitched together from multiple individual images, hence there are a few stitching errors where the lines do not align. The map is in public domain due to its age, although I would love to get credit for the stitching of the images. The map is also enhanced for color; if you prefer the original, you can find the original color 8388 x 6020 23MB file here https://www.allaboutlean.com/wp-content/uploads/2017/04/HighRes-Map-Arsenal-of-Venice-1797-Original.jpg.

I also had the legend translated from late medieval Italian to English and German. The Excel file with the original Italian, English translation, and German translation for the three maps is available here, under the Creative Commons Attribution-Share Alike 4.0 license at https://www.allaboutlean.com/wp-content/uploads/2017/03/List-of-Entries-Map-Arsenal-of-Venice.xlsx.

17.5.2 Arsenal of Venice 1798

A second map shows the Arsenal in 1798. This one has no ships, and the roofs of all buildings are shown. Overall, it is much less detailed than the 1797 map.

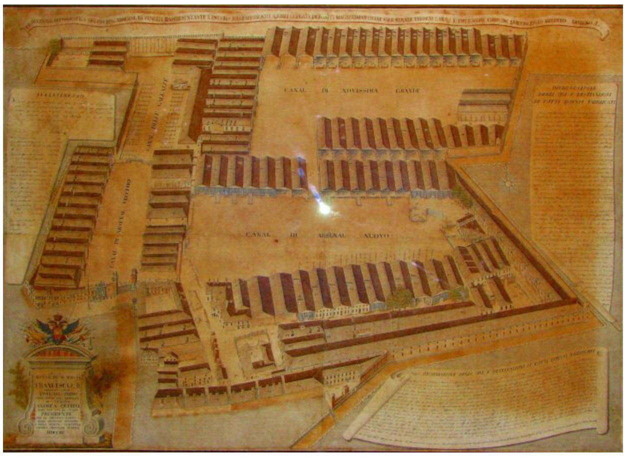


Figure 140: Arsenal of Venice Map 1798 (Image Gian Maria Maffioletti in public domain)

17.5.3 Arsenal of Venice "After Napoleon"

The final map of this series shows the state of the Arsenal after the sacking by the French. Most of the ships are gone, "*removed or sunk.*" The arsenal shows damage in many locations, although it is unclear how much artistic liberty was applied here.

Figure 141: Arsenal of Venice Map "After Napoleon" (Image Gian Maria Maffioletti in public domain)

I hope this brief introduction to the Arsenal of Venice was of interest to you. In my next post I will go into much more detail on the material flow. Until then, stay posted, and **go out and organize your industry!**

If you are interested in more manufacturing history, check out my book "Faster, Better, Cheaper" in the History of Manufacturing, which of course also includes a chapter on the Arsenal in Venice:

18 Material Flow in the Arsenal of Venice 1797

Christoph Roser, May 02, 2017, Original at https://www.allaboutlean.com/material-flow-arsenal-of-venice/

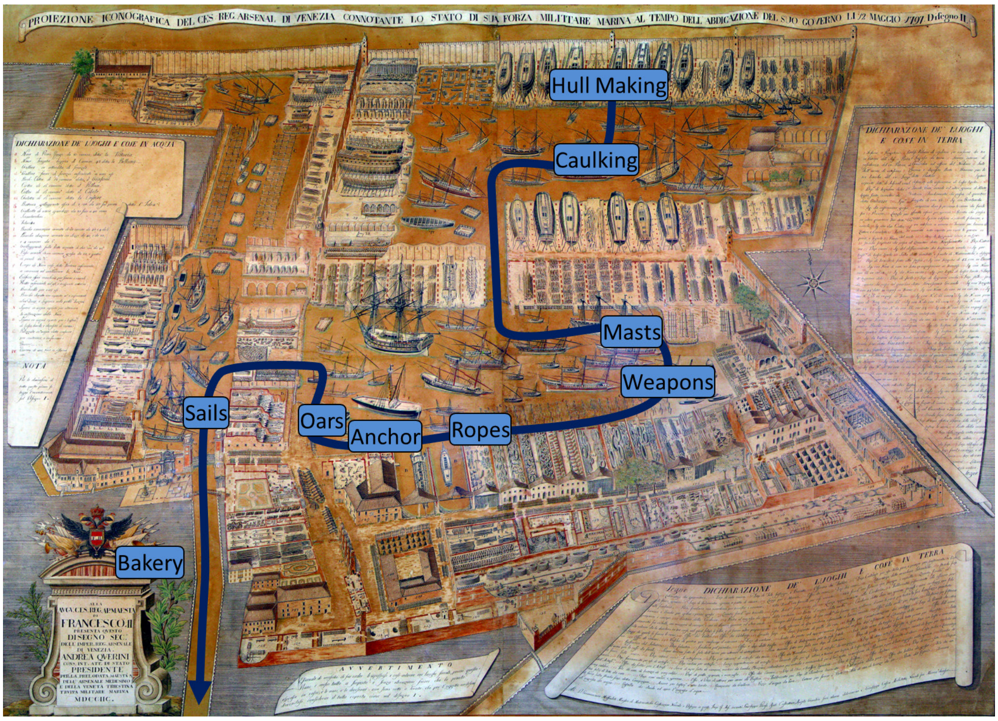


Figure 142: Arsenal of Venice Material Flow Overview (Image Roser)

Whenever I am in Venice, I try to visit the Museo Storico Navale, near the entrance to the Arsenal of Venice. This museum has a set of beautiful detailed maps by Abbot Maffioletti showing the Arsenal of Venice in 1797, 1798, and "After Napoleon." You can see in great detail the different steps needed to build and equip a sailing vessel. In this post, I will explain the material flow of the Arsenal of Venice, which was the largest industrial site in Europe and possibly in the world during its time. Be warned, this post is rich in images. The material flow is partially based on the master thesis of my student Maren-Linn Janka.

18.1 The Material Flow

The Arsenal of Venice had a quite elaborate material flow. Rather than assembling and equipping one ship at a time in one spot, only the hull was built in one spot. After that the hull was towed to the next location for the next step, until a completed ship left the Arsenal.

The material flow itself is shown in the map below. The blue markers show the likely locations of certain key steps in making and equipping a ship. All of them are explained in more detail below.

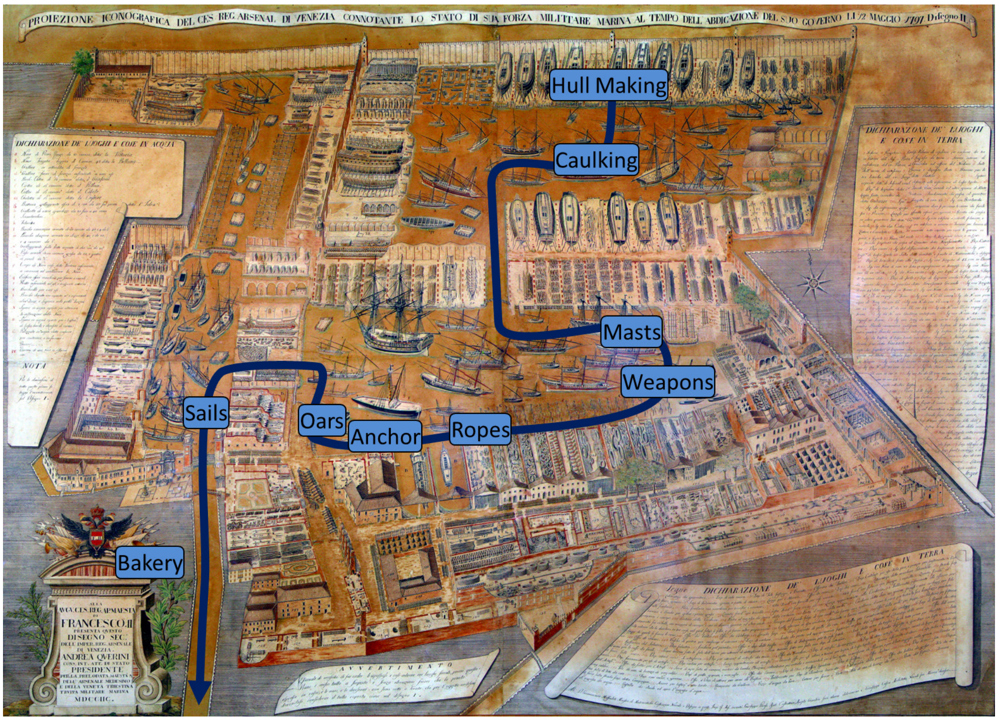


Figure 143: Arsenal of Venice Material Flow Overview (Image Roser)

The images and the descriptions are based on the map by Abbot Gian Maria Maffioletti. I described the maps in more detail in my last post. In any case, here are the files again:

- Stitched JPG 8388 x 6020 map (12 MB) color enhanced, in public domain, attribution appreciated, available at https://www.allaboutlean.com/wp-content/uploads/2017/03/HighRes-Map-Arsenal-of-Venice-1797.jpg
- Stitched JPG 8388 x 6020 map (12 MB) original color, in public domain, attribution appreciated, available at https://www.allaboutlean.com/wp-content/uploads/2017/04/HighRes-Map-Arsenal-of-Venice-1797-Original.jpg
- Excel file with the original Italian and English translation of the legend(s) available under the Creative Commons Attribution-Share Alike 4.0 license, available at https://www.allaboutlean.com/wp-content/uploads/2017/03/List-of-Entries-Map-Arsenal-of-Venice.xlsx

18.1.1 Hull Making

The first step in shipbuilding is the construction of the hull. The Venetian Arsenal introduced the frame-first technique, where first the frame is built, followed by the actual hull. This was both faster and cheaper than the traditional Roman approach of building the frame into an existing hull.

These hulls were often made years in advance. It seems that the Arsenal usually had a lot of hulls in storage and ready for use, and the average hull waited years before being completed into a ship.

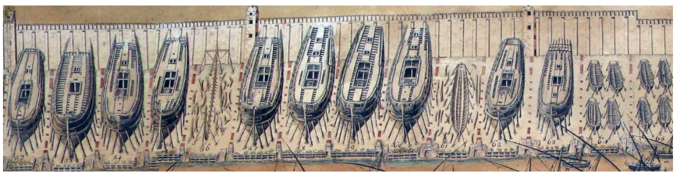


Figure 144: Arsenal of Venice Hulls (Image Gian Maria Maffioletti in public domain)

The image above is a detail of the map, showing the area around the northern wall of the Arsenal. To show the details, Maffioletti did not draw the roofs of the buildings, and indicated only where the walls would be. The panorama photo below shows how the area looks nowadays.

Figure 145: Panorama inside Arsenal of Venice (Image Roser)

18.1.2 Pitch and Tar for Caulking and Other Uses

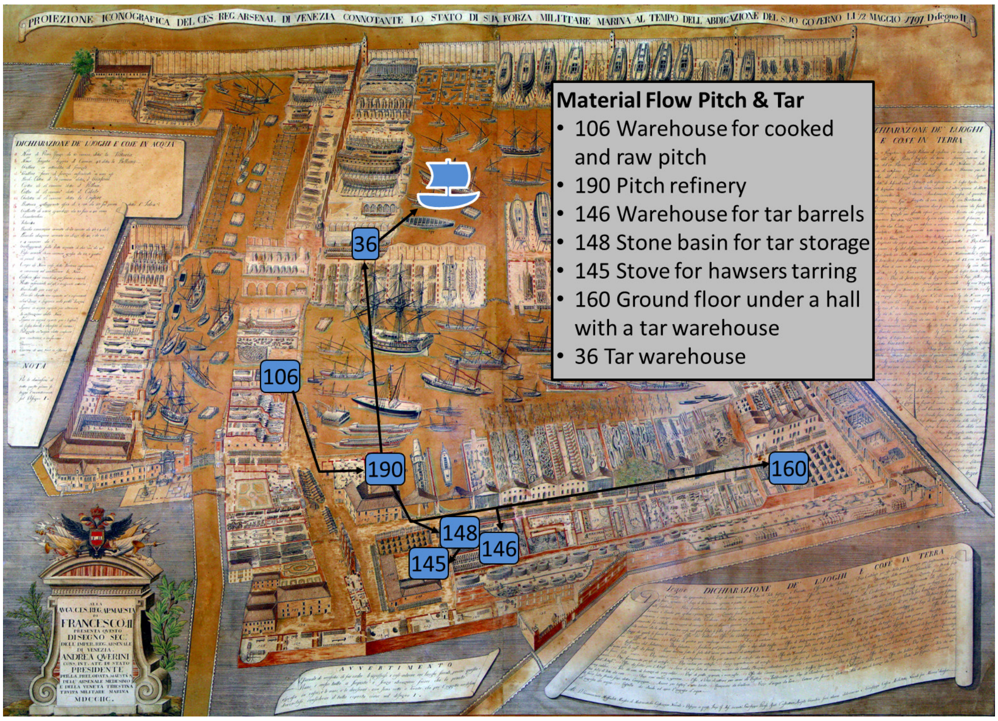


Figure 146: Arsenal of Venice Pitch Material Flow (Image Roser)

Pitch and tar was an important raw material for many different uses in ship making. Most importantly, the hulls were made watertight using pitch.

A completed hull was still rather leaky. To make the hull (more) waterproof, caulking was needed. For this, the ship was tilted to one side and then made watertight using fibers, tar, and other materials. From this point on, the ship was afloat, and towed from station to station. The image below shows the different stations from the map above in more detail. The index numbers match the numbers in the legend.

Figure 147: Model for caulking of the ships (Image Roser)

- 106 Warehouse for cooked and raw pitch
- 190 Pitch refinery
- 146 Warehouse for tar barrels
- 148 Stone basin for tar storage

- 145 Stove for hawsers tarring
- 160 Ground floor under a hall with a tar warehouse
- 36 Tar warehouse

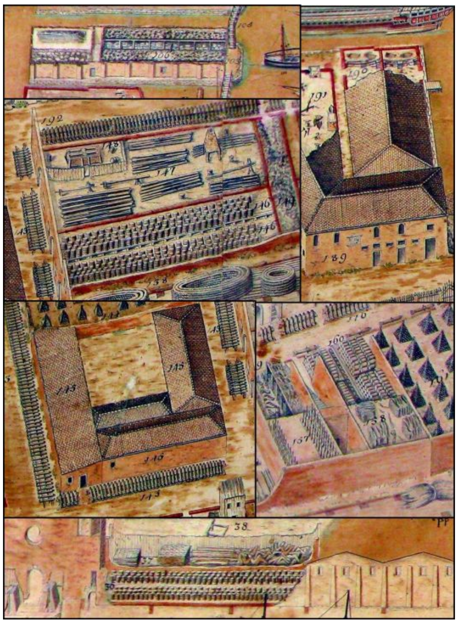


Figure 148: Arsenal of Venice Pitch Stations (Image Roser)

18.1.3 Installing of the Masts

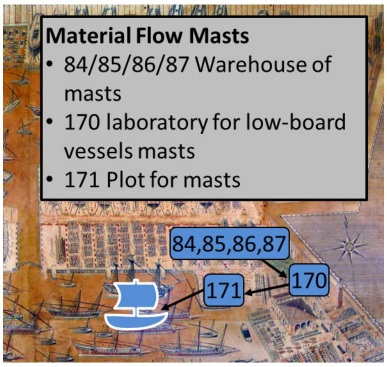


Figure 149: Arsenal of Venice Mast Material Flow (Image Roser)

The next stop was to install the masts onto the already floating ship. Masts were readily available in standard sizes. The labels on the map represent the following sites.

- 84/85/86/87 Warehouse of masts
- 170 Laboratory for low-board vessels masts
- 171 Plot for masts

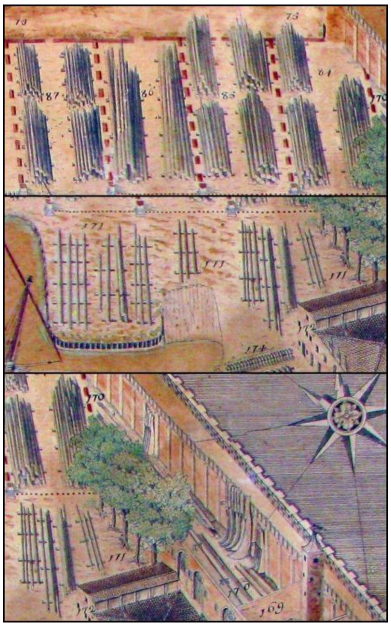


Figure 150: Arsenal of Venice Masts Stations (Image Roser)

18.1.4 Weapons

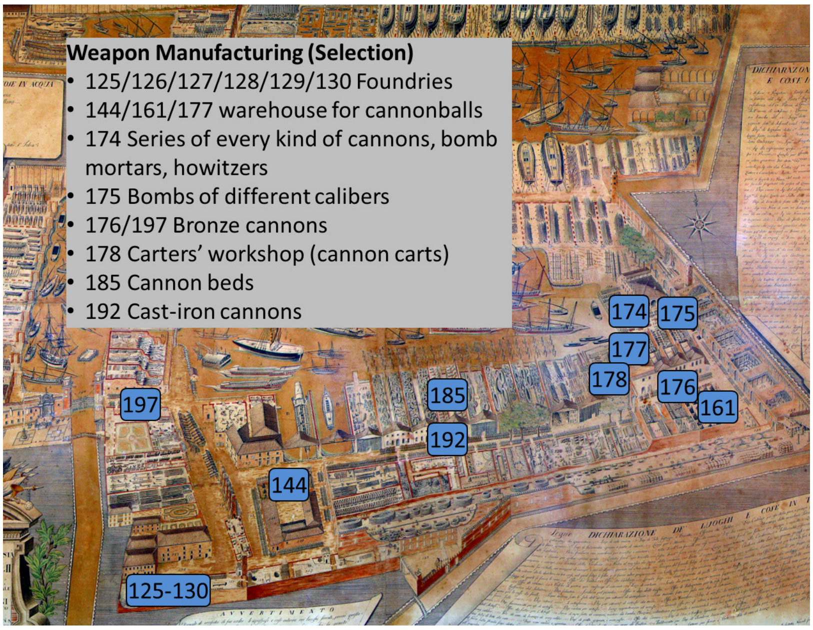


Figure 151: Arsenal of Venice Weapon Material Flow (Image Roser)

Naturally, a warship also needs cannons. The Arsenal had numerous cannons in storage to outfit warships. This area is also visible when visiting the Biennale. There is also a dedicated storage for cannon balls and gunpowder.

The material flow is not quite clear, and multiple material flow for cannons, carts, cannonballs, and gunpowder merge here. The list below shows a number of locations where cannons, cannon balls, and cannon carts were manufactured and stored. The photo below shows the area around the former cannon storage 192.

Figure 152: Cannon storage area in the Arsenal of Venice (Image Roser)

- 125/126/127/128/129/130 Foundries
- 144/161/177 Warehouse for cannonballs
- 174 Series of every kind of cannons, bomb mortars, howitzers
- 175 Bombs of different calibers
- 176/197 Bronze cannons
- 178 Carters' workshop (cannon carts)
- 185 Cannon beds
- 192 Cast-iron cannons

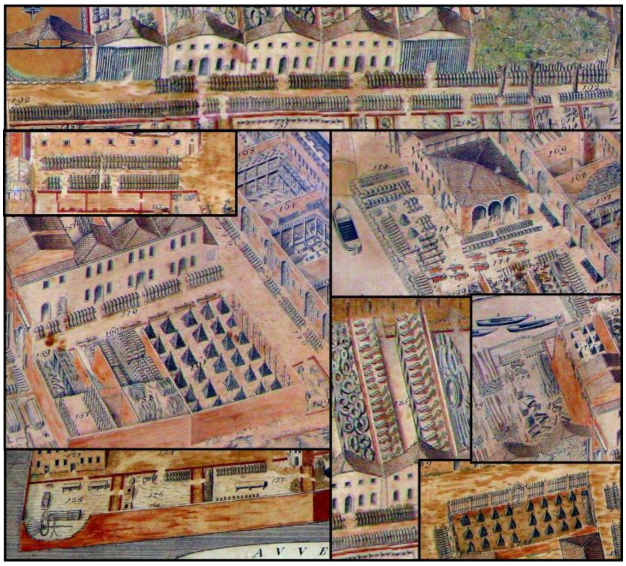


Figure 153: Arsenal of Venice Weapon Stations (Image Roser)

18.1.5 Rope Making

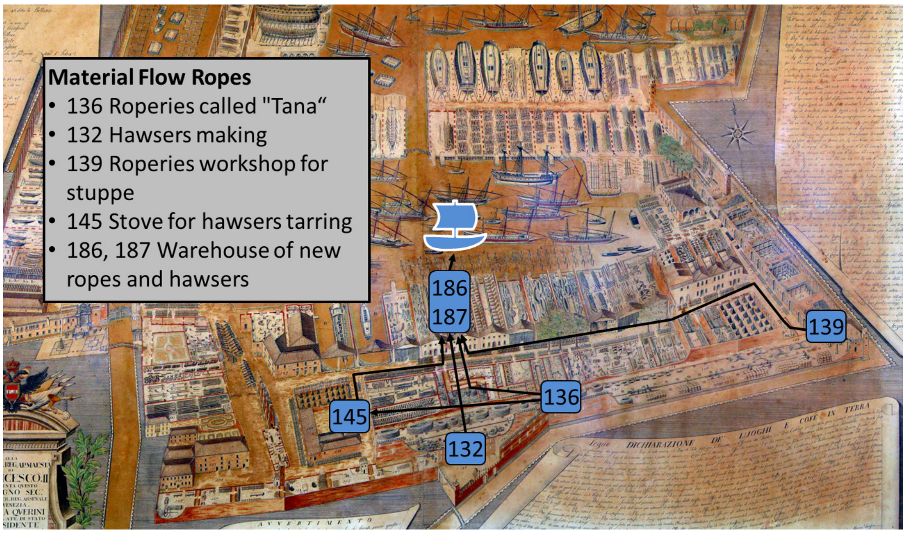


Figure 154: Arsenal of Venice Ropes Material Flow (Image Roser)

The Arsenal also had its own rope-making area. This building was very long and straight, and was the largest building within the arsenal. It still is a very long, straight building, now used for exhibitions like the Biennale in Venice, and it is pretty much your only chance to get inside unless you are a member of the Italian Navy. The photo below shows the view from inside toward the entrance. Unfortunately, when I visited, the length of the building was blocked with different installations, giving the feeling of multiple small rooms instead of one very long hall.

Figure 155: Door of the rope making area of the Arsenal of Venice (Image Roser)

- 136 Roperies called “Tana“
- 132 Hawsers making
- 139 Roperies workshop for stuppe
- 145 Stove for hawsers tarring
- 186, 187 Warehouse of new ropes and hawsers

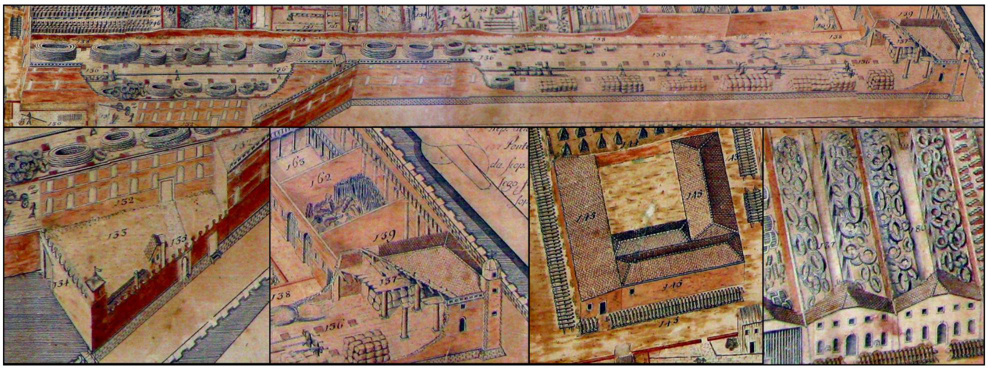


Figure 156: Arsenal of Venice Ropes Stations (Image Roser)

18.1.6 Anchors

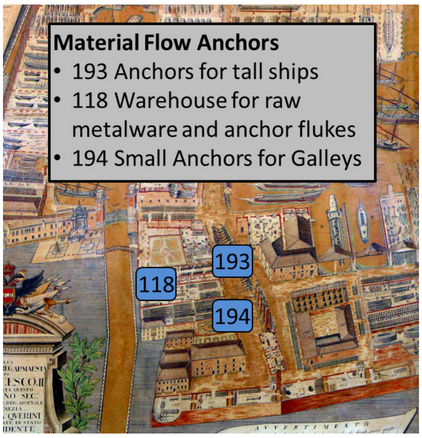


Figure 157: Arsenal of Venice Anchor Material Flow (Image Roser)

Almost completed, the ship was equipped with sails, anchors, oars, and rudders. These were also stored near the water gate.

- 193 Anchors for tall ships
- 118 Warehouse for raw metalware and anchor flukes
- 194 Small Anchors for galleys

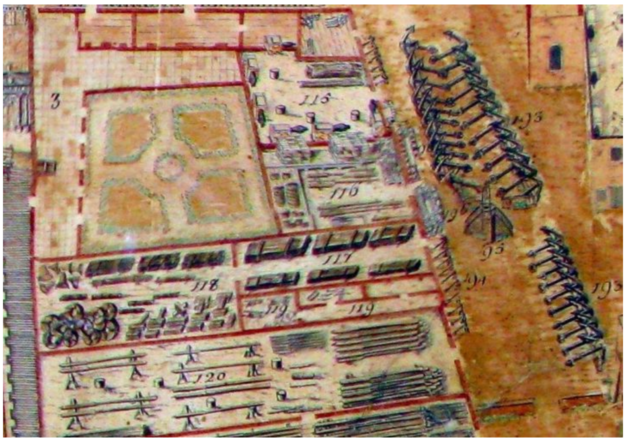


Figure 158: Arsenal of Venice Anchor Stations (Image Gian Maria Maffioletti in public domain)

18.1.7 9 Oars

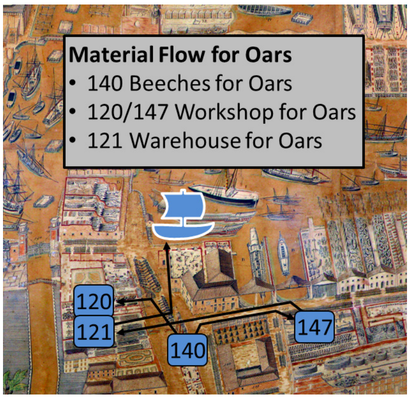


Figure 159: Arsenal of Venice Oars Material Flow (Image Roser)

The material flow for the oars was located in the southern part of the arsenal, near the entrance.

- 140 Beeches for oars
- 120/147 Workshop for oars

- 121 Warehouse for oars

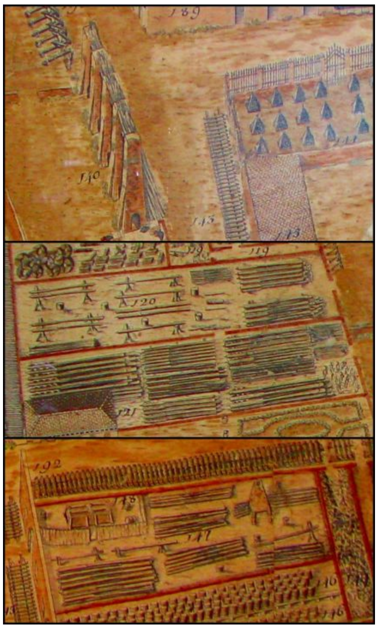


Figure 160: Arsenal of Venice Oars Stations (Image Roser)

18.1.8 Sails

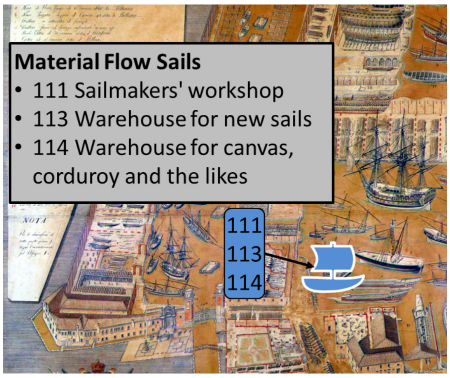


Figure 161: Arsenal of Venice Sails Material Flow (Image Roser)

The sail production and storage was also in the southern part, near the water gate. The sail-making area also received supplies from the roperies and the pitch storage.

- 111 Sailmakers’ workshop
- 113 Warehouse for new sails
- 114 Warehouse for canvas, corduroy, and the like

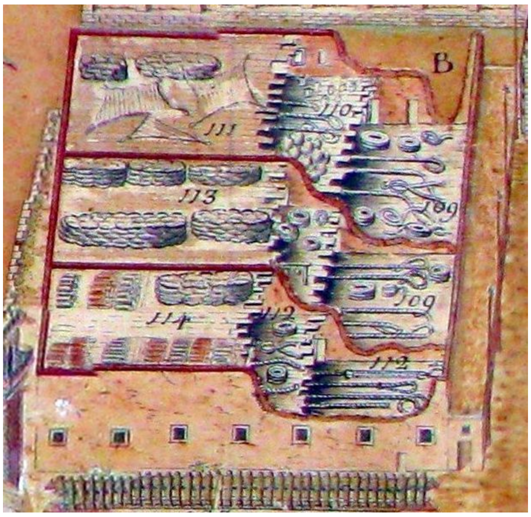


Figure 162: Arsenal of Venice Sails Stations (Image Gian Maria Maffioletti in public domain)

18.1.9 Bakery

The last step of the process was the bakery. This was already outside of the Arsenal area and in the canal to the Laguna of Venice. At that stop the crew also boarded the ship, and the vessel was ready to sail. Unfortunately, I have been unable to verify where exactly the bakery was or if it still exists.

18.2 Was This the First Assembly Line?

Indeed, the Arsenal of Venice did for its time have a quite advanced material flow. This helped increase its productivity in times of need, which in turn helped Venice to become one of the major powers in the Mediterranean Sea.

Due to this good material flow, it is sometimes claimed that the Arsenal of Venice is also the first assembly line. Here I strongly disagree. There was little to no automation or mechanization, there was no organized speed of production, and the workers were usually rather tumultuous. Theft of material, tools, and time was rampant. It was at the forefront of its time, but it was definitely not an assembly line.

In any case, the era of the Arsenal ended when Napoleon Bonaparte conquered Venice in 1797. Nowadays the Arsenal is an Italian Naval base for training officers.

I hope this look back in history was interesting to you. If you like these kind of stories, you should check out my book “Faster, Better, Cheaper” in the History of Manufacturing. Anyway, now **go out, control your material flow, and organize your industry!**

If you are interested in more manufacturing history, check out my book “Faster, Better, Cheaper” in the History of Manufacturing, which of course also includes a chapter on the Arsenal in Venice:

18.3 Selected Sources

A master student of mine looked in more detail of the material flow in the Arsenal of Venice. I also had a chapter on this in my book Faster, Better, Cheaper in the History of Manufacturing.

Janka, Maren-Linn, 2017. Optimierung des Materialflusses und des Fabriklayouts im Arsenal von Venedig von 1797 im Vergleich zur modernen Fertigung. (Master Thesis). Karlsruhe University of Applied Sciences, Karlsruhe, Germany.

19 Strategies for Mass Customization

Christoph Roser, May 09, 2017, Original at https://www.allaboutlean.com/mass-customization/

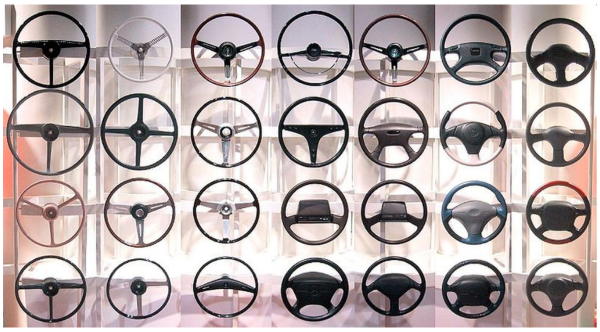


Figure 163: Steering wheels (Image Chris 73 under the CC-BY-SA 3.0 license)

Mass customization promises us individually customized products at the price of a mass-produced item. We get something that is customized to our needs but doesn't have the luxury price tag usually associated with custom-made products. While challenging, numerous different companies have managed to achieve customization with only marginally higher prices than standard products. In this post I want to look in more detail at how to achieve mass customization.

19.1 Mass Production

Figure 164: Suits on a rack (Image agcreativelab with permission)

Mass production has been able to provide us with inexpensive and affordable products. Since every product is identical, it is possible to standardize, mechanize, and automate the process. Both machines and workers are able to work much faster and more efficiently if every part is identical. They can use the more efficient flow production.

This also applies to the suppliers, who can provide many, many identical parts much cheaper than would be a variety of different products. The economy of scale brings benefits along the entire value stream.

With cars, Henry Ford and his Model T is the best example. Through mass production of identical cars, he was able to continuously lower prices until every worker in America could afford a Tin Lizzy.

On the downside, the customer had very few choices. Henry Ford famously said that, "*Any customer can have a car painted any color that he wants so long as it is black.*" This was because black paint dried faster and hence could be produced more efficiently. The needs of the producer took priority over the needs of the consumer.

19.2 Customization

Figure 165: Bespoke Tailoring (Image Rprakash1782 under the CC-BY-SA 3.0 license)

Customization is the opposite of mass production. The customer gets exactly what he wants, individually customized to his needs. Of course, this takes time and effort as well as significant expertise and hence raises the price tag significantly. For example, a mass-produced suit can be as low as $200, whereas a custom suit can easily cost ten times as much.

19.3 Mass Customization

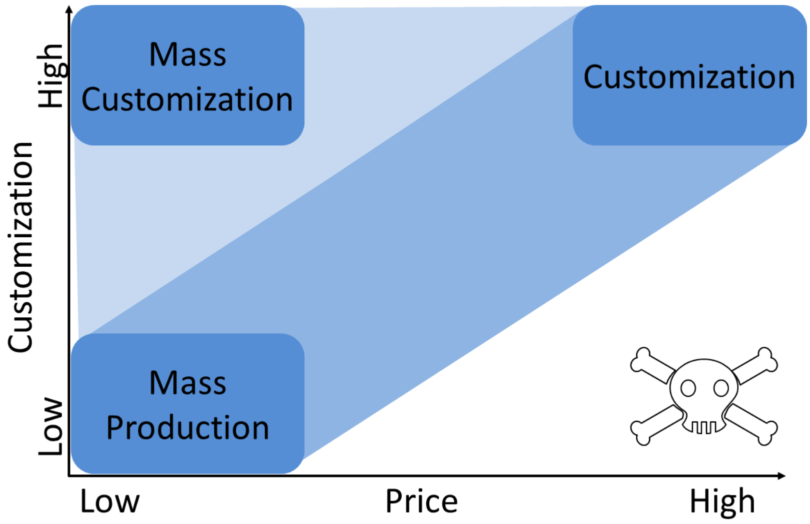


Figure 166: Mass Customization Chart (Image Roser)

Before talking more about mass customization, I first would like to note that there is a wide area between mass production and mass customization. Many companies make different trade-offs between price and customization, and still have a good business model. Hence, there are not only two corners of the playing field, but many in between.

The idea of mass customization aims for the third corner of both low prices and high customization. And again, there are many options in between. Already, many companies achieve a high level of customization at prices close to mass production.

For completeness sake, the fourth corner is the death of a company. If your products have less customization and higher prices than the competition, it will be very difficult to have a good business model. You have a significant risk of ruining the company because the competition is better. Unless you have another significant advantage (quality, brand image, monopoly, etc.), your company will shrivel and die.

19.4 How to Mass Customize

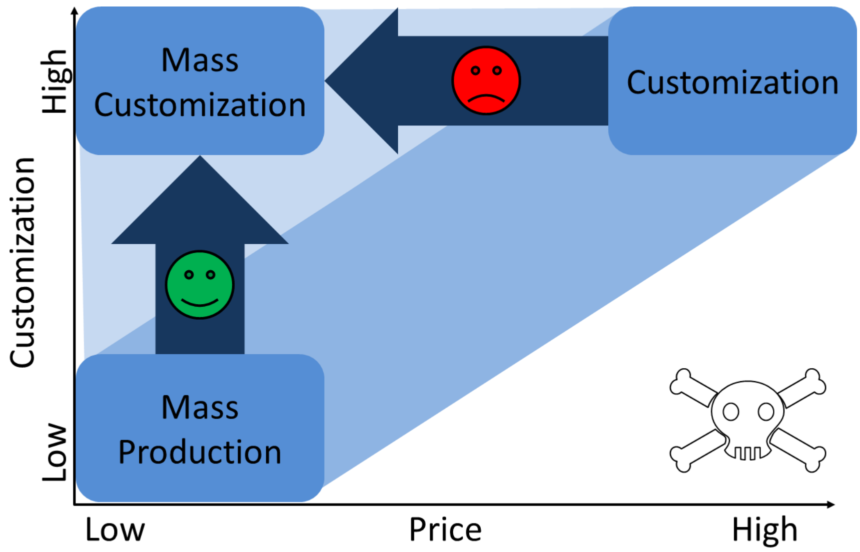


Figure 167: Mass Customization Chart Easy Hard (Image Roser)

For mass customization you need first and foremost … mass! It is much easier to move toward mass customization when you are already doing mass production. If you have little mass production but high customization, it is still possible to move toward mass customization, but it is more difficult. With mass customization, you aim to offer more variants and options to the customer. However, as you surely know, increasing the number of variants increases the cost. With mass customization you try to give more options while not increasing costs and prices too much. This will get you closer to the upper left corner in the graph.

To achieve low prices, you do need a **high level of automation**. I strongly believe that without automation, you cannot achieve the low prices of mass production. Often, however, automation reduces flexibility. For mass customization, you need automation that is flexible enough to support the options you want to give your customers. In any case, investing in automation makes only sense if you produce large quantities. The larger your output, the easier it is to move toward mass customization.

At the same time, **you cannot give the customer total freedom**. You have to limit the choices but also offer so many choices that it feels like customization. When selecting a car, you have different options for engines, seat covers, or entertainment systems, but you do not have complete freedom. If you really, really want your pink ostrich leather seat cover, you probably still can get it, but no longer at mass production prices.

19.4.1 Modular Strategy

One approach to mass customization is modularity. This is often used by car makers. Many modern car models share identical components among each other. Hence, each component or module is used more often. The modules then can be mass produced using conventional mass-production techniques. The development cost can also be spread over the larger quantity. Only during the final assembly is the final customized version of the car produced. Much effort goes into creating a flexible final assembly line that can handle such a wide variety of different products.

For example, it is estimated that BMW sells, on average, only two identical cars on of every variant per year. Toyota, Peugeot, and Citroën even share this across companies. The Toyota Aygo, Peugeot 107, and the Citroën C1 are all based on the same car, with only minor cosmetic modifications. In the image below, the cars are almost identical except for the front design, and they have mostly identical components under the hood.

Figure 168: Toyota Aygo Peugeot 107 Citroën C1 (Images Matthias93 in public domain)

19.4.2 Platform Strategy

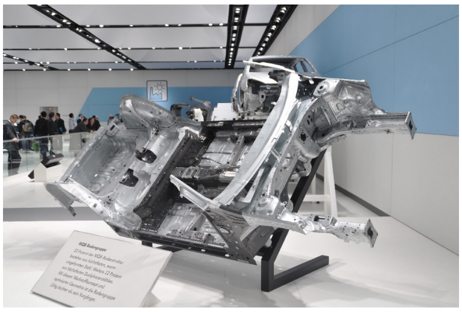


Figure 169: The Volkswagen platform (Image Ra Boe under the CC-BY-SA 3.0 Germany license)

Very similar to the modular strategy is the platform strategy, which is also used in the automotive industry. The company develops one platform and then modifies the platform for the development of different models. This also lowers development and production costs. The approach can also be combined with the modular strategy above.

This is used, for example, by Volkswagen, where they call it "*Modularer Querbaukasten.*" They are currently building or plan to build a wide range of vehicles always using the same modified base. However, rumors say that the benefits so far are below expectations. Here is the list of current and future models using this platform:

- Audi A1, Audi A3, Audi TT, Audi Q2, Audi Q3
- SEAT Arona, SEAT Ibiza, SEAT León, SEAT Ateca
- Škoda Octavia, Škoda Superb, Škoda Kodiaq
- Volkswagen Golf, Volkswagen Golf Sportsvan, Volkswagen Polo, Volkswagen Passat, Volkswagen Tiguan, Volkswagen Touran, Volkswagen Jetta, Volkswagen Arteon, Volkswagen Atlas/Teramont

19.4.3 Similarity

You can also mass customize products if there is much similarity. For example, when producing clothes, the basic pattern stays the same; you merely scale the clothes or parts of it up or down to conform to the body type of the customer. You still need automation, as hand crafting is either expensive or takes too long to ship. Since you need automation, you also need volume to make the automation worthwhile. The customer will get clothing that, while not quite custom, fits better than mass-produced clothing, but with a price tag closer to mass production than custom.

In general, if you have an automation system that can be programmed to flexibly adapt, you have the potential to automate the customization and therefore reduce the price of customization.

19.4.4 Soft Customization

There is also soft customization, where, instead of the product, the services around it are customized. Long-distance flights, for example, nowadays no longer offer the same movie for everybody, starting at the same time; now you can select from a library of options and start any movie any time.

Depending on how you do it, this may also be an option. On the other hand, if ill implemented, this can also backfire. For example, my bank recently contacted me and told me that as a loyal and valuable customer **I can now set the duration before my online banking logs me out due to inactivity**. For me, that is about as helpful as an eleventh toe.

19.5 Examples

mymuesli
custom-mixed cereals

Figure 170: Mymuesli Logo (Image mymuesli GmbH for editorial use)

There are many companies that move toward mass customization. Besides automotive (which has done it for decades), there are many other industries. For example, the German company Mymuesli sells a higher-end breakfast cereal mix, but also gives the customer the option to design their own muesli mix. From hundreds of potential ingredients you can choose which ones you like, at a price only marginally higher than the premixed cereals from the same company.

Figure 171: Custom-made NIKEiD sneakers (Image Christian H. under the CC-BY-SA 2.0 license)

Apparel companies are also starting to offer customization near mass-production prices. The customer either measures themselves or gets scanned in the store. The company then uses automation to tailor a custom-made piece of clothing that fits. Levi Strauss started this idea back in 1994. Today, a custom-made *NIKEiD* sport shoe costs only 20% more than a mass-produced one. Even printing your own photo or design on a T-shirt costs little more than a mass-produced T-shirt.

Yet another example of the modular strategies is desktop computers. Within the standard housing, you can mix and match a wide variety of components to get just the computer you want. This was for a long time the strategy of Dell.

There are many more examples in industry, and I am sure you know more too. Hopefully, this post helps you a bit if you want to move toward mass customization. Now **go out, satisfy your customer, and organize your industry!**

P.S.: This blog post was inspired by a question by Peter Meissner (name mentioned with permission)

P.S.S.: The structure of this article is intentionally different from the well-known and often-repeated Harvard Business Review article "The Four Faces of Mass Customization" by James H. Gilmore and B. Joseph Pine II, as I don't find their structure too helpful for the situations I encounter.

20 Where Lean Went Wrong – A Historical Perspective

Christoph Roser, May 16, 2017, Original at https://www.allaboutlean.com/where-lean-went-wrong/

Figure 172: Clueless Manager (Image Gandolfo Cannatella with permission)

The Toyota Production System is widely considered to be the best production system for any larger company. Achieving similar performance is the vision (or dream?) of many companies. Pretty much all of lean manufacturing is the attempt to copy the approach of Toyota in the hope of a similar stellar performance. Yet most lean transformations fall way short of the goal. In this blog post I would like to give some insights, from a historical perspective, on why lean so often fails.

20.1 Failure Rates of Lean

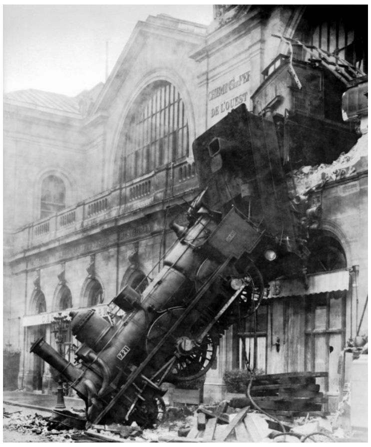


Figure 173: Train wreck Montparnasse 1895 (Image Levy & fils, Kuhn in public domain)

Lean is considered to be the best approach to improve your production system, or any other system for that matter (although as a lean expert you could call me biased on that point 🙂). Yet, by many accounts, lean projects usually have abysmal failure rates.

Richter claims failure rates well above 50%. Ignizio cites 70%, 90%, or even 95% failure rates. An *Industry Week* study in 2007 found that almost 70% of all US plants used lean, but only 2% achieved their objectives and a further 24% achieved significant results. Robert Miller from the Shingo Prize committee found that way too many of their past Shingo lean excellence prize winners lost ground and fell behind the competition. (Sources for numbers in this paragraph are at the end of the post.)

These numbers are also consistent with what I see in industry, somewhere around 70% failure rate. I define a failure as a project that did not improve the current situation. (Please note that if I would define failure as a project that failed to *impress management with nice numbers on fancy slides*, the failure rate would drop rapidly to around 10%–30%.)

Normally, if something fails 70%–90% of the time, we would throw it out and never look back. Unfortunately, the alternative options are usually worse. Much has been written on the reason for these failures, but I would like to look at it from a historical perspective to see where lean went wrong.

20.2 The Toyota Production System

Figure 174: Taiichi Ohno (Image unknown author in public domain)

Lean originates from the Toyota Production System, which was mostly developed somewhere between 1950 and 1970. The key driver for this was Taiichi Ohno, back then a middle manager responsible for a machine shop. (Read more on Ohno in my post Twenty-five Years after Ohno – A Look Back.)

Ohno had already realized the value of small lot sizes and flexibility earlier during his career. Yet it was in this machine shop where Ohno together with others developed some of the ideas of lean, like pull production, kanban, supermarkets, leveling, and multi-machine handling. Key points to recognize here are:

- Ohno was managing the same shop for years, and knew the details of the work and the workflow.
- Ohno knew the people on the shop floor, including their strength and weaknesses.
- Ohno was able to observe the impact of any changes on the shop floor directly.
- If something did not work, Ohno could not just walk away. Any problems on the shop floor remained his problems until they were solved.
- If a project did not improve the situation, Ohno was able to follow up and to fix the problems (think PDCA).

Through this, Ohno and his people were able to achieve a consistent improvement, and hence he helped to make Toyota the best-organized and most efficient large company in the world.

20.3 The United States Takes Notice

Figure 175: No gas in Portland, June 1973 (Image David Falconer in public domain)

After WW II, US car makers were happily producing like they always had, ignoring the Japanese competition. The US defeated Japan in the war anyway. However, during the 1973 oil shock, US car makers encountered big problems. Customers suddenly preferred more-fuel-efficient Japanese cars over the typical US gas-guzzlers. Even with declining sales, Japanese car makers seemed to handle the problem much better than the US makers, who quickly racked up large inventories of unsold cars.

A famous 1984 study by the Massachusetts Institute of Technology (and the subsequent book, The Machine that Changed the World, published 1990) found that the US needed twice the manpower to produce a car, much more floor space, inventory etc., while creating many more quality problems while doing so.

There was great interest in how the Japanese and especially Toyota managed their production. Unfortunately, there was no English-language information available on this. Of course, there was much information available in Japanese, but this may as well have been in ancient Egyptian hieroglyphs. The first English paper about lean appeared in 1977, and only from 1980 onward did written works appear in larger quantities. Yet, merely reading about the Toyota way did not help much. The US needed people with experience.

20.4 The First Lean Guru – Shigeo Shingo

Figure 176: Japanese Characters for Shigeo Shingo (Image Roser)

One of the first people to arrive in the US with experience at Toyota was Shigeo Shingo. With the help of a US promoter, Shingo soon achieved the status of a guru. However, Shingo was never really an insider at Toyota. To the best of my knowledge, he visited Toyota about once every three months to teach a 4 week workshop on industrial engineering basics called *P-Course*. He was the moderator for one of the last workshops on SMED (back then known as QDC for Quick Die Change), while the method was already firmly established at Toyota. He tried to learn from Ohno, but met a reluctant Ohno only very few times. Overall, Shingo was probably a small fish among the many people in Japan who worked with or contributed to the Toyota Production System.

Eventually he wrote a book on the "Toyota Production System" (later translated into English as the "Shingo System"). My friends at Toyota have read his books, not because he is famous in Japan (he is not), but only to learn what all the US fuzz about the great lean expert Shingo is about. They were quite disappointed and considered the book not very useful for implementing lean. Some Western lean experts I hold in high regard also agree with this.

Since this book was not authorized by Toyota, Toyota ended the twenty-year relationship, and Shingo moved to the US around 1980. There Shingo now was the one-eyed among the blind, and quickly propelled to guru status. This was helped by a tendency to boast and exaggerate on past achievements he may or may not have had (more on this in my post Shigeo Shingo and the Art of Self-Promotion. More sources also below). His view of lean manufacturing continues to shape what Westerners consider to be "lean," which is very different from the approach at Toyota.

20.5 Lean through External Consultants

Figure 177: Three Consultants (Image Traimak with permission)

Additionally, Shingo was only an external consultant, and hence he approached lean differently than Ohno could as a manager of his own area. While external consultants are needed to bring lean into companies, they face additional challenges compared to a home-grown production system.

Figure 178: Sneaky 5S Consultant (Image bramgino with permission)

External consultants usually neither know the process nor the people very well, at least initially. At the same time, they are often hired as know-it-alls. A consultant that shows uncertainty may not be hired again. This also leads to a proliferation of additional related approaches like, for example, Six Sigma, and adding some more mysticism into the approach.

Figure 179: Sneaky VSM Consultant (Image bramgino with permission)

Unfortunately, lean projects do have uncertainty, and often a lot of it. Contrary to their claims, not all external consultants really know lean very well. Some do, but I also experienced, as a client, completely clueless junior lean consultants who had no idea what they were doing, with little help from higher-ups.

Furthermore, US managers are usually pressured by quarterly reports, whereas Toyota managers can have a longer-term outlook. As a result, consultants are often expected to show results quickly.

Figure 180: Sneaky Consultant OEE (Image bramgino with permission)

If you don't know lean very well, don't know the process, and don't know the people, yet have to appear as the one guiding the people to the light, all the while being under time pressure, then you are in a pinch. The common "solution" is often to present a simple method with clearly defined easy steps, like 5S, SMED, or some data gathering like VSM or OEE. While these are powerful methods, on their own and used without context they do not help much. It seems that some lean literature and some consultants try to sell lean as a *simple recipe for success*, which it is not (see also my post "Lean is Tough" for more).

Often, management is also to blame for accepting a nice final presentation with good-looking numbers over actual performance on the shop floor. Modern managers in my view spend much too little time on the shop floor (Gemba), and way too much in meetings and presentations.

Figure 181: Sneaky Consultant SMED (Image bramgino with permission)

Finally, the consultant may not be around long enough to see the results of the changes, or even fix possible problems (think PDCA again). It is difficult to put a deadline on an improvement project, yet consulting contracts run only for a limited period of time, which is often estimated on the optimistic side.

In sum:

- A consultant has to impress the client in order to be hired (known as "beauty pageant" in consulting-speak), and appearing to know is often more important than actually knowing.
- Clients often expect quick results, and are unwilling or unprepared for the actual effort of a lean transformation.
- External consultants don't know people, processes, and products very well.
- Lean often relies overly much on simple methods rather than holistic views.
- Short-term engagements of external consultants make a good PDCA difficult.

There are good and bad consultants out there. But even a good consultant may have problems if the client expects too much in too little time. While I still strongly believe in lean as the best approach to manufacturing, these problems above cause the low performance of many lean implementations.

I hope my view on these historic developments was insightful to you. I also hope that you understand my view of Shingo, and if you disagree (which I would be perfectly fine with), that you are nice about it ☺. Finally, I hope that your projects are among the 5%, 10%, or 30% of the successful lean implementations. Now, **go out, do some good work, and organize your industry!**

P.S.: This post was inspired by a question by T. I.

20.6 Selected Sources

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21 What to Do with SMED: Reduce Lot Size or Increase Work Time?

Christoph Roser, May 23, 2017, Original at https://www.allaboutlean.com/smed-lot-size-or-work-time/

Figure 182: SMED Scales (Image Maksym Yemelyanov with permission)

SMED (Single Minute Exchange of Die) is a very useful tool to reduce changeover time. Reducing changeover time will free up time for other uses. Western management often wants to use this time to produce more goods. However, the rule of thumb at Toyota is to use this newly available time to do **more** changeovers rather than more products. This increase in changeover has the potential to significantly reduce the lot size, which often has much larger benefits than the additional work time. In this blog post I want to look in more detail at this relation between changeover duration, productivity, and lot size.

21.1 Quick Recap: SMED

Figure 183: Formula 1 Pit Stop (Image Francesco Crippa under the CC-BY-SA 2.0 license)

SMED (Single Minute Exchange of Die) is a structured approach to reduce changeover time. The seven steps are:

- Measure changeover times
- Identify internal and external elements
- Try to move as many elements as possible to external
- Shorten internal elements
- Shorten external elements
- Standardize and maintain new procedure

I have written a series of posts on how to do SMED, its history, and some SMED exercises, hence I won't go into more detail here.

21.2 A Simple Model

SMED can reduce your changeover time. You can use this time either to free up time or to do more changeovers (or anything in between). To illustrate the effects, I use a simple system with few parts. For simplicity, all parts have an equal share of the production time, and all changeovers take the same time. Production and consumption are also constant. I also assumed we need no safety stock. This is, of course, not quite realistic, but it makes the picture easier to understand, while still allowing valid conclusions for real-world situations.

21.2.1 Initial Situation, Two Parts

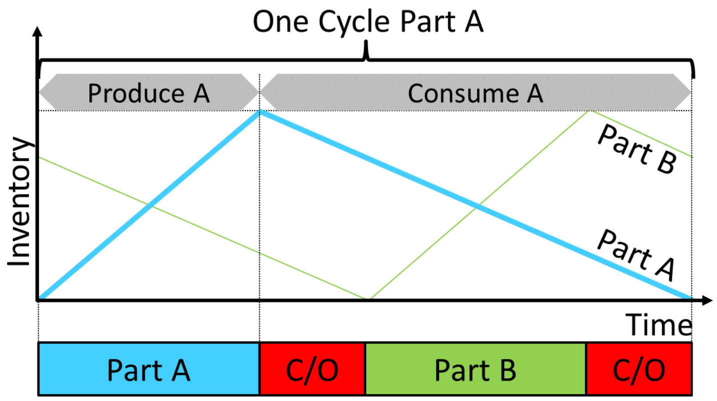


Figure 184: Inventory subject to Change Over Two Parts One Cycle (Image Roser)

In the first example I have two parts, part A and part B. As shown in the graph, we start to produce A, do a changeover, then produce B and do another changeover. After the second changeover, we again produce part A and repeat the cycle.

The inventory of parts A increases during production of A, and decreases during all other times. This is similar for part B. Hence, we need enough inventory to cover all other times. When the production run of part A has finished, we need to have enough parts to last us for two changeovers and the production run of part B before we get any more parts A.

21.2.2 Initial Situation, Three Parts

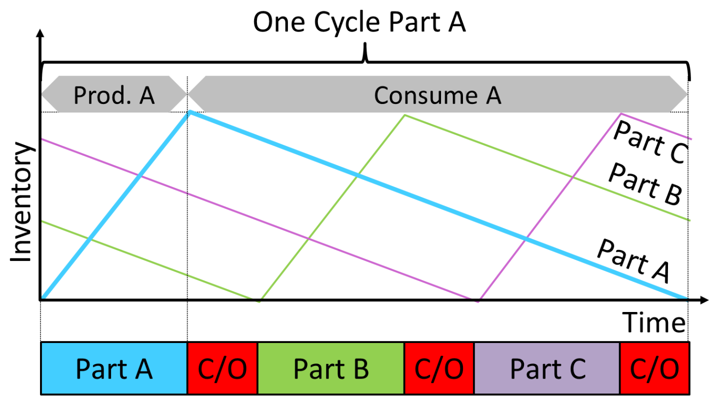


Figure 185: Inventory subject to Change Over Three Parts One Cycle (Image Roser)

A similar picture can be drawn for three parts. The production run of part A has to last until we produce more of part A again. This will be after three changeovers and the production runs of part B and part C. The behavior is again similar if you have four or more parts; you always have to cover the time until you produce part A again.

21.3 Half Changeover Time after SMED

Now assume we did a SMED workshop, and would have been able to reduce the changeover time by half. Now the changeover takes only half the time as it did before. This gives us two options.

21.3.1 Free Up Time

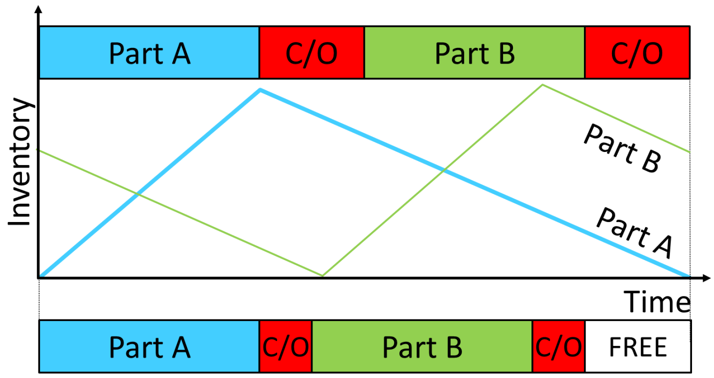


Figure 186: Inventory subject to Change Over Two Parts Free Time (Image Roser)

The first option is to free up time. The picture shows the initial sequence of production and changeovers on the top, and the new sequence with the changeover time reduced by half at the bottom. This would free up time equal to one initial or two current changeover times.

We could now use the time to produce more parts, or to send workers home, or to do maintenance, and so on. However, let's also look at the option recommended by Toyota, to do more changeovers.

21.3.2 Do More Changeovers

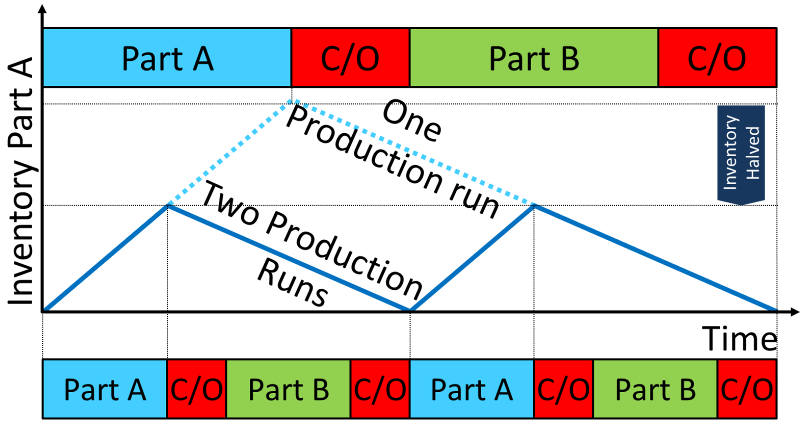


Figure 187: Inventory subject to Change Over Two Parts Two Cycles (Image Roser)

If we use more changeovers, we can do exactly twice as many changeovers as before since we reduced the changeover time by half. The picture again shows the initial situation on top, and the current situation with two production runs at the bottom. Each part is now produced twice during this period. For clarity I only show the inventory of product A over time.

The amazing thing here is the inventory! With the more frequent changeovers, you now need only half the inventory. The image shows the initial inventory with the dashed line, and the current inventory with the solid blue line. Both the peak inventory and the average inventory have been halved. As lean experts you surely know the value of reducing inventory, which quite often exceeds the value of the freed-up time.

21.4 A More Detailed Look

The above examples looked at specific examples. Putting this on a more general basis, there are two main variables that can be varied:

- What percentage of the total time is used for changeovers (i.e., the ratio of the sum of all changeovers divided by the total time). For example, if you have a 7-hour shift, and during that shift you had a total of 1 hour of changeovers, then you would have 1/7th or roughly 14% changeovers.

- How many different part types do you produce? This could vary from 2 to infinity (with 1 being a special case: if you have only one part, you will never have a changeover).

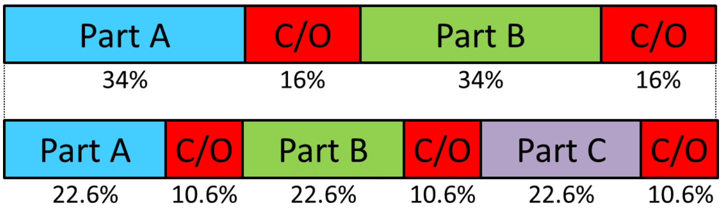


Figure 188: Change Over Percentages Example (Image Roser)

For simplicity I assumed that all changeovers and also all production runs for parts are of identical length. Looking again at the example from above, there are two parts A and B, with an equal production duration and two equal changeovers. The changeover time was 32% of the total time. Each change over took 16% of the total time, and each production run took 34% of the time. For the example with three parts, it was three times 22.6% production time and three times 10.6% changeover time.

21.4.1 Total of 10% Changeover Time

Let's start with the graph that shows the relation for an initial total of 10% changeover time (i.e., the sum of all changeovers is 10% of the time). Why 10%? Because Toyota believes their production lines should have changeovers for 10% of the time. However, while this works for Toyota, it does not mean that this works for everybody, so don't go rushing out telling your guys to do 10% changeovers.

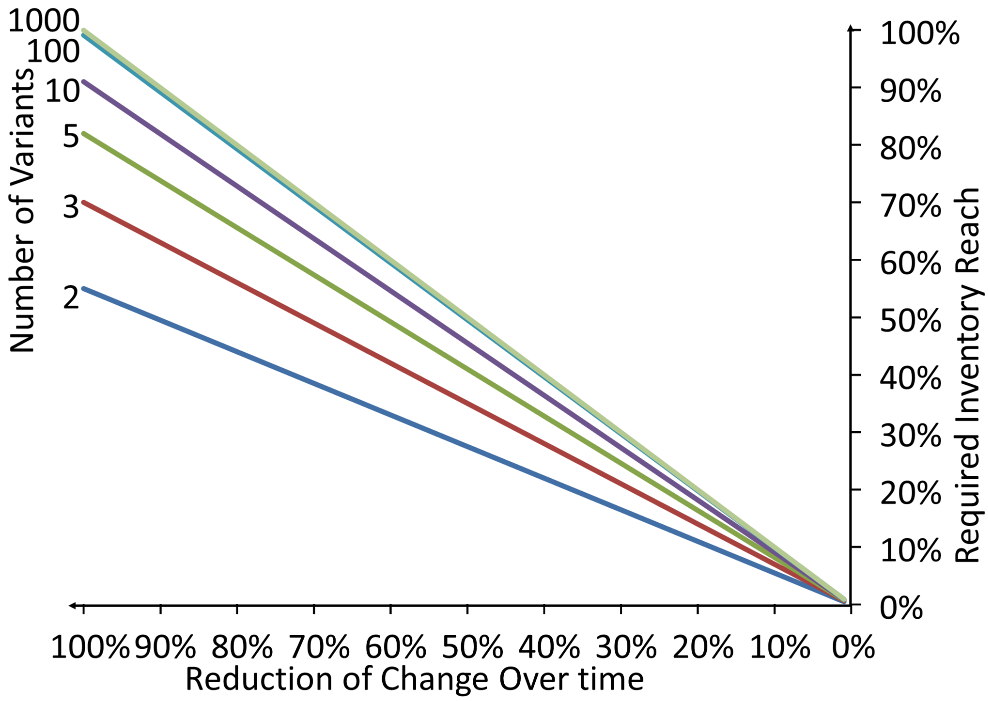


Figure 189: Change Over Impact with 10% total Change Over Time (Image Roser)

The graph is a bit more complex, so let me go through it in steps. Let's start with the blue line for 2 parts. If you have not done anything to your changeover, then you would need an maximum inventory reach of 55% of the time.

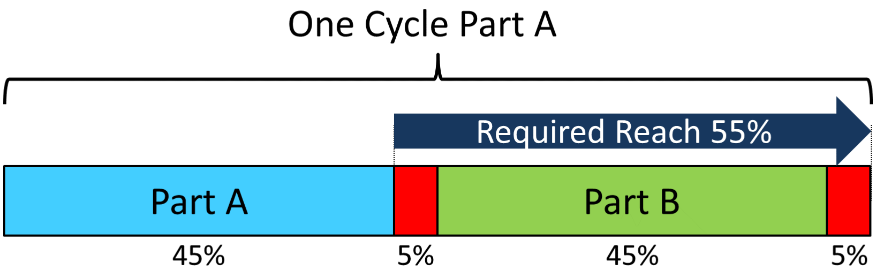


Figure 190: 10 % Change Over (Image Roser)

In other words, after producing part A for 45% of your cycle, you would need two changeovers with 5% of the time each plus the 45% time to produce part B. Hence, you would need to cover 55% of the time between the beginning of a production run for part A and the next beginning of a production run for part A. This increases if you have more part types, approaching a inventory reach of 100% of the time between the beginning of a production run for part A and the next beginning of a production run for part A.

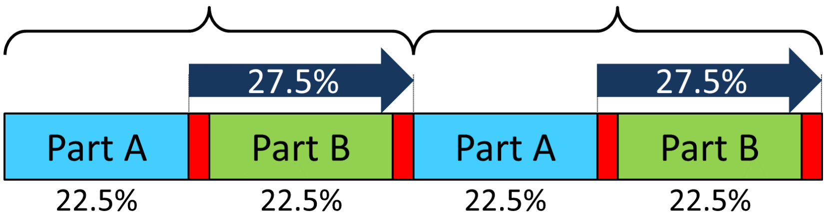


Figure 191: 10 % Change Over Two Runs (Image Roser)

If you now start to improve your changeover time, this inventory reach goes down. If for example you could reduce your changeover time by 50%, you would be able to have twice the number of changeovers, and hence every production run would need to be only half as long. The time you would need to cover would also be reduced by half. Instead of an inventory reach of 55%, you would need only an inventory reach of 27.5% of the time between the beginning of a production run for part A and the next beginning of a production run for part A.

21.4.2 30%, 50%, and 70% Total Changeover Time

I did this also with other percentages of total cycle time. The graphs below show the same data for 30%, 50%, and 70% changeover time, although these are unlikely to happen in industry (if you do 70% of the time changeovers, you have only 30% of the time left for production). These graphs also show a similar relation to the graph above.

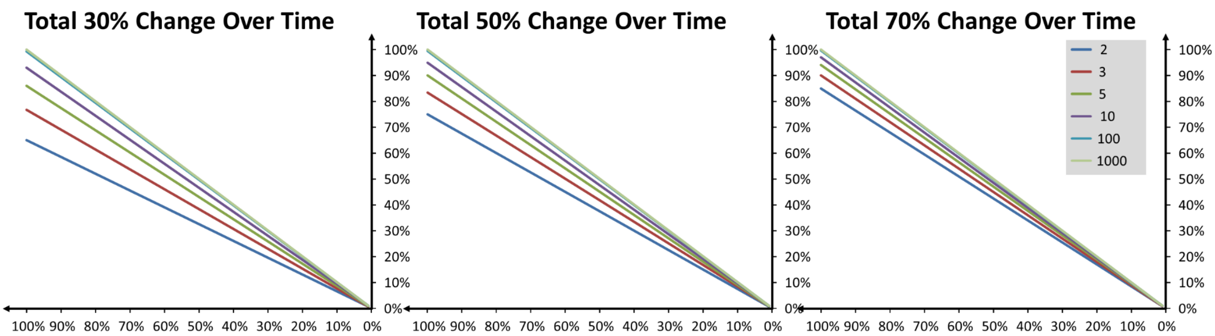


Figure 192: Change Over Impact with 30%, 50%, 70% total Change Over Time (Image Roser)

21.5 Summary

Overall, the picture is very clear. If you reduce your changeover duration and put the gained benefits in more changeovers, then your inventory needed to cover the changeovers can be reduced by the same percentage that you reduced your changeover time.

For example, if you reduce the change over duration by 50%, then you can reduce your inventory needed to cover these periods also by 50%. If you reduce changeover duration by 75%, then you need 75% less inventory. If you manage to reduce the changeover duration to zero, then you need no inventory at all to cover for changeovers.

Please note that you still need inventory for other purposes (e.g., to buffer other fluctuations, or as safety buffer). Yet a SMED workshop and the resulting reduction in changeover time can drastically reduce your inventory.

Of course, while it is generally recommended to put this gained time into more frequent changeovers, there are also cases where you may want to put it into more parts rather than more changeovers. For example, if your customer is screaming bloody murder because you lack the capacity to produce what he wants, then you better use the time to produce more rather than smaller lot sizes. You can also use a mixed approach and put part of the time toward producing more, and another part toward smaller lot sizes.

As always, there is no fixed rule, but it all depends on the situation you have on the shop floor. I hope this post was insightful to you. Now, go out, reduce your change over time, and organize your industry!

22 The Phases of a Changeover

Christoph Roser, May 30, 2017, Original at https://www.allaboutlean.com/changeover-phases/

Figure 193: Formula 1 Pit Stop (Image Francesco Crippa under the CC-BY-SA 2.0 license)

A changeover is changing the set-up of a process from one product to the next. Reducing changeover times is a common and popular way to decrease inventory or to increase available work time (see SMED). Ideally, the changeover time should be zero, allowing true one-piece flow. In reality, however, it is often not zero. This post looks in more detail at the different phases of a changeover to help you understand the process better and to reduce your changeover times.

22.1 Introduction

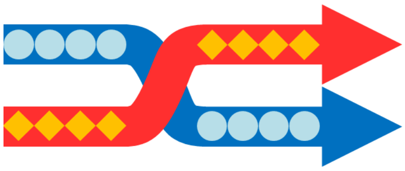


Figure 194: Change Over Arrows (Image Roser)

You may think that the duration of a changeover is simple. At one point you stop the process and the changeover starts. A bit later you start the process again, and your changeover ends. While there are processes that have such changeovers, there are also many more processes where the changeover is more complicated.

The changeover process is a disruption of your normal way of working. You could also call this unevenness (or Mura). This disruption can actually be seen from two angles: **First, you lose parts that could have been produced otherwise**. In other words, you produce less parts than if you would have had no changeover. Please resist the temptation to do less changeovers, as per my last post What to Do with SMED. Also, realize that you may lose parts not only during the full stop, but also before and afterward during the ramp up and ramp down. Generally speaking, **the changeover duration is from the last part at full quality and production speed to the first new part at full quality and production speed.**

Second, you spend additional work on the changeover that your people could have used otherwise. You have to prepare, do the actual changeover, wrap up afterward, and potentially do more work on quality checks after the changeover.

22.2 Loss of Production

Let's first look at the parts that could have been produced but were not due to the changeover. The image below shows the overview of these phases. Please note that not all processes and not all changeovers go through all of these phases. Please also note that I simplified the ramp down and ramp up as a linear change, whereas in reality the line may be more curved or even have erratic peaks and valleys.

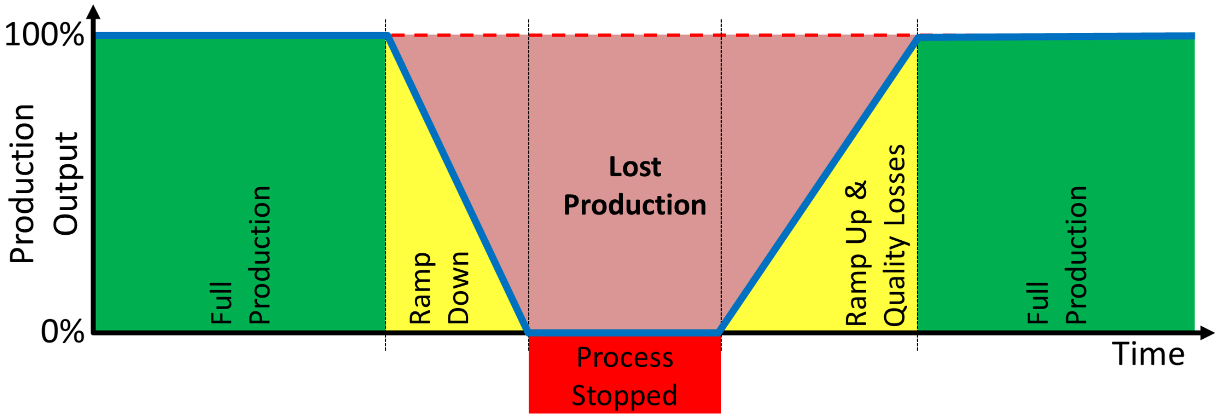


Figure 195: Change Over Phases Parts View (Image Roser)

22.2.1 Ramp Down

Initially, the process is running at full speed and quality. Depending on the details of the process, the changeover could start with a ramp down of the process. In most cases this will go rather quick. However, there are also situations where it could take more time. It is possible that the production rate decreases slowly. It is also possible that the quality problems may go up during the ramp down because the process is no longer operating at full capacity.

Examples are found in processing industries, where the process may run slower while emptying material. The produced goods may also be of inferior quality compared to normal production. It depends heavily on the process if there is actually a ramp down, how long it takes, and its impact on quality.

22.2.2 Stopped

The main part of the changeover is the time when the process is actually stopped. During this time, nothing is produced.

22.2.3 Ramp Up

The ramp up is more common than the ramp down. It often will take some time before the process produces good parts at full speed again. This may be for a number of different reasons.

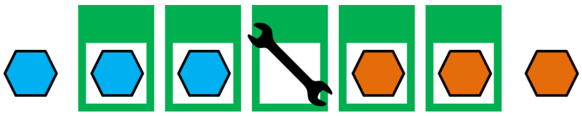


Figure 196: Ramp Up Down Change Over. The animated image can be found at https://www.allaboutlean.com/changeover-phases/ (Image Roser)

It is common, for example, for production lines to **need time to fill up again**. Hence, when the line starts working again, it will take some time until the first part exits the line again. (Note: This can sometimes be avoided with a running changeover, more on this in a subsequent post.)

Another cause is that after a changeover, **the settings of the process may have to be fine-tuned**. During this time, there may be more frequent quality checks, adjustments to the process, and also a higher likelihood of inferior or defective parts.

Overall, you produce fewer good parts than during normal production, hence this is part of the production losses due to changeover.

22.3 Work Spent on Changeover

You can also see the changeover from the point of view of the work needed for the changeover. As per the SMED approach, you should do as much as you can before or afterward so that the actual changeover and the actual number of non-produced parts is minimal. An overview of the different tasks is shown in the image below.

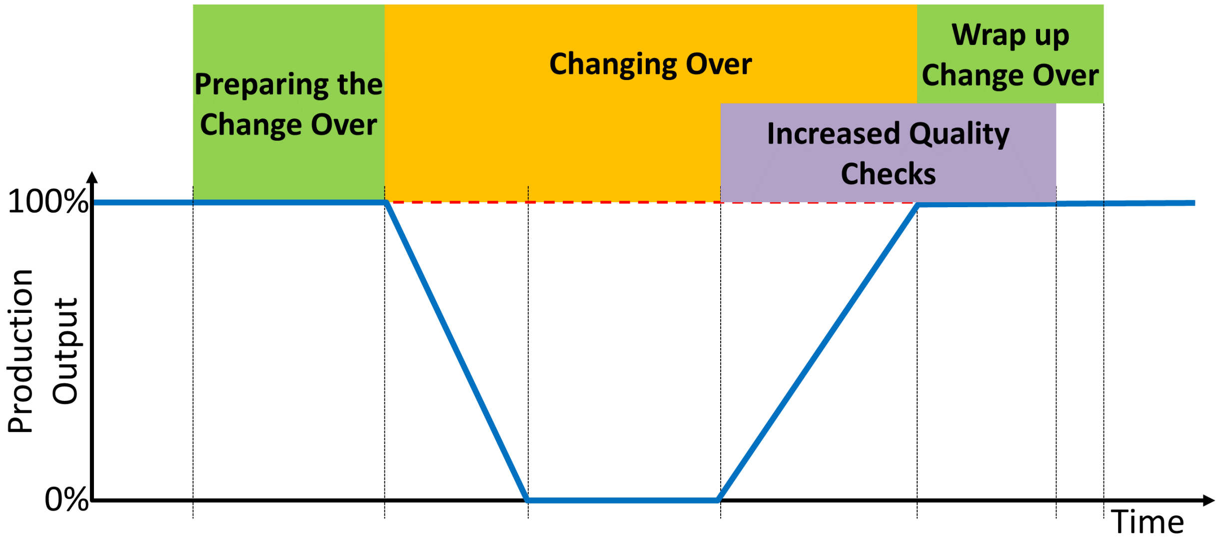


Figure 197: Change Over Phases Work View (Image Roser)

22.3.1 Preparation

During the preparation phase, the changeover is prepared. You should have all the tools, the equipment, and the needed manpower ready before you start to ramp down.

22.3.2 Changeover

The actual changeover is commonly measured as the time from the last part at full quality and production speed to the first new part at full quality and production speed. This includes the ramp downs and ramp ups.

22.3.3 Wrap Up Changeover

After the process is running good parts at full speed again, the changeover is completed, and we can now wrap up the changeover. Return tools and equipment to their storage places, maybe do the maintenance on them or set them up already for the next changeover – these are all things you can do after the machine is running again.

22.3.4 Quality Checks


Figure 198: Check quality! (Image Roser)

What many people often overlook, but what is also often necessary, is an increase in quality checks to make sure the process runs smoothly again and produces good parts. These quality efforts usually start when the machine is not yet at full speed, but when the machine just started to produce the first part. This actions often go hand in hand with the changeover to fine-tune the process settings. The increased quality checks may also extend beyond the duration of the changeover to catch quality problems caused by the changeover but happening infrequently. The details depend on your actual process, and again not all processes have this increased quality check phase.

22.4 Summary

Overall, there are quite a few steps during the changeover. To reduce waste and unevenness, you can look at all of them for improvement. The image below is the combination of the two graphs above, showing both the phases causing loss of parts and the work steps for the changeover. And again, not all changeovers go through all phases.

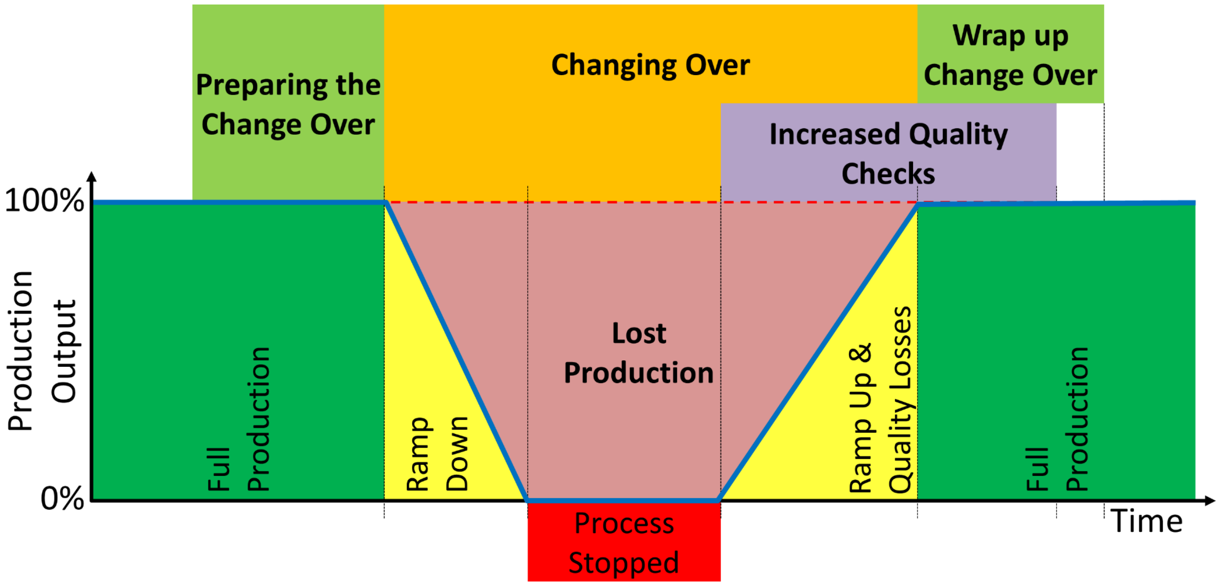


Figure 199: Change Over Phases Parts and Work View (Image Roser)

In any case, I hope this article helped you to understand your changeover better. Now, **go out, reduce changeover times, and organize your industry!**

P.S.: This post is based on a question by Agus Santoso.

23 On Running Changeovers

Christoph Roser, June 06, 2017, Original at https://www.allaboutlean.com/running-changeovers/

Figure 200: Women Relay Race (Image 22nd Asian Athletics Chapionships under the CC-BY-SA 4.0 license)

Changeover times and their reduction are popular topics in lean manufacturing. In this post I would like to introduce the idea of running changeovers for production lines. The idea behind it is simple, and probably many of you do it already. Nevertheless, I have found little info on it online. I also would like to go into more detail on the benefits of a running changeover in comparison to the alternatives.

23.1 A “Non-Running” Changeover

23.1.1 Parallel Changeovers

For a production-line changeover, the “easier” approach is to do all changeovers while the line is stopped. The sequence of steps is shown below and also animated in the image below.

- Empty the line of all products (i.e., the ramp down).
- Change over all machines.
- Fill the line with products again (i.e., the ramp up).

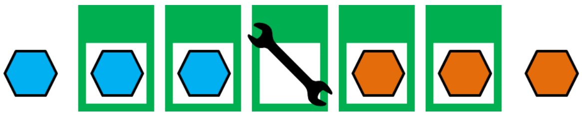


Figure 201: Parallel changeover while line is stopped. The animated image can be found at https://www.allaboutlean.com/running-changeovers/ (Image Roser)

The animation above changes all processes over to the new product at the same time. Unless the changeovers are fully automatic or nearly so, this may be a manpower problem. **You would need the people to change over all machines at the same time!**

23.1.2 Sequential Changeovers

More realistically, you may not have the manpower to change all machines simultaneously. Rather, you change the machines one by one as shown in the animation below.

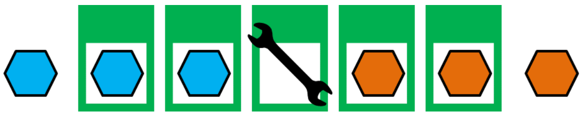


Figure 202: Sequential changeover while line is stopped. The animated image can be found at https://www.allaboutlean.com/running-changeovers/ (Image Roser)

Depending on your manpower or your level of automation, you can also imagine situations that are a mix of the two above. The changeovers could overlap without being fully parallel. For example, an oven could heat up on its own as part of the changeover while the mechanic is working on the changeover of the next process.

23.2 A Running Changeover

The improvement idea should be pretty obvious by now. You simply do the changeovers one machine after another while the line is running. This is called a running changeover and is shown in the animation below.

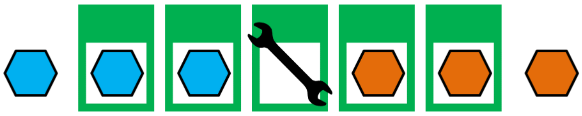


Figure 203: Sequential changeover while line running. The animated image can be found at https://www.allaboutlean.com/running-changeovers/ (Image Roser)

23.3 Functional Requirements

While this running changeover looks pretty neat, it is not suitable for all situations.

First of all, **it makes sense only in a flow line** (or flow shop). There has to be a clear sequence of processes that the parts follow. In comparison, in a job shop there is no clear sequence, and hence the changeover cannot "run" along the line.

A running changeover may also require the parts to stay in a process longer than normal. In other words, if the changeover takes longer than a process cycle, the parts in the previous process have to wait until the changeover is completed. This is often no problem for steps such as milling or assembly. It is, however, a problem for any kind of heat treatment (for example). If a changeover makes your bread wait in the oven three times the normal time, then you will not get nice bread but a burnt loaf of ugliness. Therefore, **the parts must be able to wait in the process longer than normal, or the changeover process must be reliably (!) faster than a cycle time.**

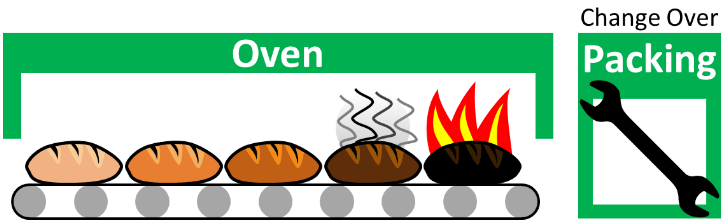


Figure 204: Burning Bread in Oven (Image Roser)

Overall, there is a **higher demand on the changeover timing** – which is actually not a bad thing! During a "normal" non-running change over, it usually makes no difference if you start the line ten minutes earlier or later. The waiting parts during a running changeover, however, do create a sense of urgency. Workers are then somewhat less likely to dawdle and may complete the changeovers faster.

23.4 Performance Comparison

23.4.1 Parallel Changeover while Line Is Stopped

Let's first look at the changeover where all processes are changed at the same time while the entire line is stopped. The total time lost consists of two parts: 1) The longest changeover time of the processes, and 2) the ramp-up time to fill the line until the first new part leaves the system again. For clarification I have here the animation again from above.

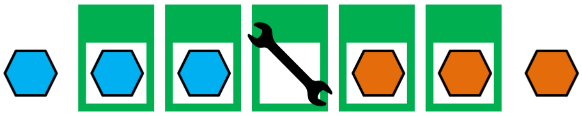


Figure 205: Parallel changeover while line is stopped. The animated image can be found at https://www.allaboutlean.com/running-changeovers/ (Image Roser)

Mathematically speaking, if we have *n* processes, all with a cycle time CT_i and a changeover time CO_i, then the total delay time *T* would be as follows (not including fine-tuning and adjusting while the line is running):

$$T = \mathrm{Max}(CO_1, \dots CO_i, \dots CO_n) + \sum_{i=1}^{n} CT_i$$

23.4.2 Sequential Changeover while Line Is Stopped

Of course, this differs when the changeover times are not parallel, but sequential. Here is the animation again for reference.

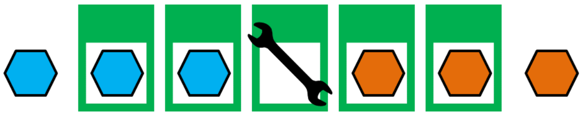


Figure 206: Sequential changeover while line is stopped. The animated image can be found at https://www.allaboutlean.com/running-changeovers/ (Image Roser)

Mathematically speaking, this would be the sum of all changeover times CO_i plus the sum of all cycle times CT_i for the ramp up.

$$T = \sum_{i=1}^{n} CO_i + \sum_{i=1}^{n} CT_i$$

23.4.3 Running Changeover

Finally, we look at the running changeover, where all processes are changed in sequence while the line is running.

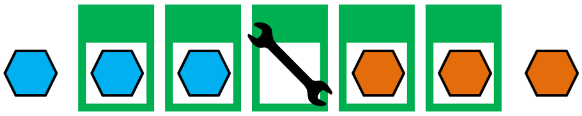


Figure 207: Sequential change over while line running. The animated image can be found at https://www.allaboutlean.com/running-changeovers/ (Image Roser)

Mathematically speaking, the total time between the last part and the first new part *T* is a bit more complex. It also depends on whether the line is a pulsed or continuously moving line, or a more flexible unstructured pacing system where the pieces move individually.

If the line is a pulsed or continuously moving line, then you lose at least one cycle time CT_{Pulse} due to one "empty slot" on the pulse line being used for the changeover. If all changeover times CO_i are faster than the CT_{Pulse}, you would not lose any additional time. Only if a changeover time CO_i is slower than the slowest cycle time CT_{Pulse} does this extend the "pulse" and slow down the line even more. In this case the additional time *T* is calculated as follows.

$$T = CT_{Pulse} + \sum_{i=1}^{n} \mathrm{Max}(CO_i - CT_{Pulse}; 0)$$

If the line has an unstructured pacing, the flow of the material through the system is very similar, except that the pulse speed is now the largest cycle time CT_{Max}.

$$CT_{Max} = Max(CT_1, \dots CT_i, \dots CT_n)$$

$$T = CT_{Max} + \sum_{i=1}^{n} Max(CO_i - CT_{Max}; 0)$$

Please be aware that these equations are an approximation, and may also depend on buffer sizes and random fluctuations.

Overall, at best you may lose only one cycle time CT_{Max} or CT_{Pulse} for the changeover. At worst you may lose one cycle plus the sum of all changeover times in excess of this one cycle. If your changeover times are very long, the total duration may even exceed the duration of a parallel changeover.

23.5 Summary

Depending on your situation, any of the above changeover approaches for production lines may be the best.

A **sequential changeover while the line is stopped** may be best if 1) you cannot do all changeovers at the same time (i.e., not enough manpower or not a fully automatic changeover), and 2) the changeover durations would cause unacceptable waiting times for the products in a running changeover. To improve this situation, it may be an idea to solve the issues that prevent you from a running changeover.

A **parallel changeover while the line is stopped** may be the best if you 1) can do all changeovers at the same time (either with manpower available or automatic changeover), and 2) this would be faster than a running changeover. To improve this situation, you may simply reduce changeover times, and possibly check if a running changeover may be better afterward.

A **running changeover while the line is running** may be the best if 1) additional delay from a longer changeover time would not cause problems for the products or processes or there is no additional delay; and 2) it is faster than the parallel changeover. To improve this situation, reduce changeover times, ideally starting with the longest changeover times that exceed your cycle time.

I hope this article was interesting to you, and I hope I did not dig too deep into small details, although these small details can often make a big difference in lean. Now, **go out, run your changeovers, and organize your industry!**

Figure 208: Curious Cat (Image Curious Cat for editorial use)

PS: The highly influential blog and website Curious Cat by John Hunter maintains a list of Curious Cat Top Management Improvement Blogs. This ranking is based on different metrics like MOZ page authority and page rank, traffic rank, number of subscribers, and so on. I am immensely thrilled that **AllAboutLean.com ranks number 4 out of 48** on this list, right after such long established and respected blogs like the Curious Cat, the Deming Institute Blog, and Mark Grabham's Lean Blog. Many thanks to John for the compliments ☺.

24 Changeover Sequencing – Part 1

Christoph Roser, June 13, 2017, Original at
https://www.allaboutlean.com/changeover-sequencing-part-1/

Figure 209: Ice Cream Flavor Selection (Image Roser)

The sequence of your changeover can have quite an impact on the duration of the changeover. In this series of posts I will show some approaches on how to improve your changeover durations by carefully sequencing the products. This was initially intended to be one post, but as so often happens, it turned out to be more complex than initially thought, and hence I have split it into two posts. The next post will appear next week.

24.1 Introduction

Figure 210: Ice Cream Sundae order (Image desertsolitaire with permission)

This is now my fourth post in sequence on SMED. After What to Do with SMED: Reduce Lot Size or Increase Work Time?, The Phases of a Changeover, and On Running Changeovers, I will now go into detail on the sequencing of changeovers (after doing a three-post series on SMED already in 2014). It was not planned that way, but I just happened to pick changeover-related topics for my next posts by chance. I am surprised myself by how much more detail there is on the topic of changeovers.

Anyway. Some machines have the same changeover time regardless of which product you change from and which product you change to. More commonly, however, is that at least some changeover durations vary depending on which product you come from and which product you go to. For this and the next post I will be using an (imaginary) example of ice cream manufacturing, hoping that you can enjoy some of the nice stuff too 🙂.

24.2 Reasons for Different Changeover Times

24.2.1 Material-Related Changeover Differences

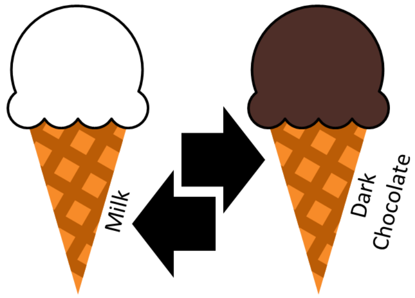


Figure 211: Ice Cream Change Over from Milk Ice Cream to Chocolate (Image Roser)

In some cases, the reason for a different changeover time is related to the material. Let's stick with the ice cream example.

If you are changing from dark chocolate ice cream to white milk ice cream, you have to make sure the system is very carefully cleaned. Any smudge of dark chocolate remaining will stand out in the white milk ice cream. The other way around, however, will not be as much of a problem. Even if there is a bit of milk ice cream left, it will not be noticeable in the mass of dark chocolate.

This is a very common approach to reduce changeover times (e.g., in polymer processing and injection molding). You always try to go from a light color to a darker color to reduce cleaning effort and to allow a faster changeover.

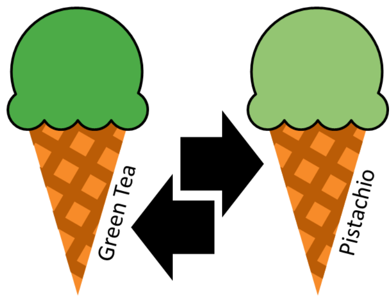


Figure 212: Ice Cream Change Over from Green Tea To Pistachio (Image Roser)

Color may be only one product-related aspect here, and – depending on your product – there may be many more. Again, let me use an ice cream example. If you change from green tea ice cream to pistachio, the color does not matter much.

However, pistachio is a nut, and many people are allergic to nuts. Hence, when changing from pistachio to green tea, you again have to clean extra carefully so as not to contaminate the green tea ice cream with nut allergens. The other way around is usually much less of a problem. While allergy to green tea exists, it is very rare. Of course, the machine is still cleaned, but a small oversight is unlikely to lead to a medical emergency.

In sum, depending on one or more of your material properties, it may be easier to change material in one direction than in another.

24.2.2 Machine-Related Changeover Differences

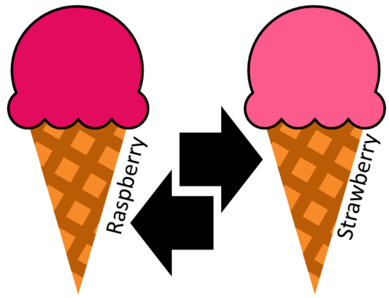


Figure 213: Ice Cream Change Over from Raspberry to Strawberry (Image Roser)

Probably more common than material-related changeover differences are machine- or tool-related changeover differences. For some very similar products, you may have to change few tools/adjust few settings, or none at all. In all likelihood, the more different the products are, the more tools have to be changed.

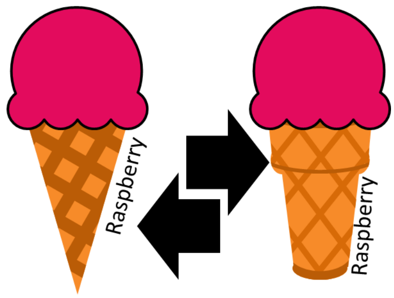


Figure 214: Raspberry Ice Cream Change Over from Cone to Cup (Image Roser)

Again, ice cream: Changing raspberry to strawberry or the other way round is usually very simple. Just flush out the remaining old berry ice cream, fill up with the new berry, ensure the product coming out at the end meets specifications, and you are done.

It is, however, probably more difficult to change the cone type. Even going from raspberry to raspberry, changing the cone may require a different tool as well as more extensive adjustments of the settings. Hence, this changeover may take longer due more to the tool change than to a simple change of the ice cream type.

24.3 A Note on Flexibility

Figure 215: Be flexible! (Image Kennguru under the CC-BY-SA 3.0 license)

Overall, you try to arrange your changeovers in a sequence that allows faster and easier changeovers. Using such a changeover-optimized production sequence will reduce your changeover time. However, **it will also reduce your flexibility!** You can no longer produce any product anytime, but you are constrained by this sequence.

Usually, this sequencing constraint may require slightly more inventory to cover the increased inflexibility (see my post Why Do We Have Inventory?). While this is not often talked about, having a fixed pattern usually requires slightly more inventory to cover any unforeseen circumstances.

On the other hand, however, shorter changeover times may allow you to changeover more often (See my post What to Do with SMED: Reduce Lot Size or Increase Work Time?). Details again depend on the situation on your shop floor, but my but feeling is that in many cases you may need slightly less material than before.

24.4 When Things Go Wrong: Firefighting!

Figure 216: It happens! (Image DVIDSHUB under the CC-BY 2.0 license)

If there is an urgent product needed out of your predetermined sequence, you either have to wait for this product to come up again in this sequence (or the next if it is too late already). Doing it out of sequence will potentially cause higher changeover durations when changing to the urgent product.

Additionally, you may have higher changeover durations afterward too, when you change back to the next product in normal sequence. Yet, this second longer changeover is usually better than completely rescheduling all the upcoming production to match the new point in the sequence. The details again depend on the situation on your shop floor.

24.5 Summary

Well, this was the first of this two-post series on changeover sequencing (out of a more or less accidental five-post series on changeovers). You should now understand why changeovers differ depending on the sequence, and their impact on flexibility. In my next post I will show you how to approach such an optimization. There will be the all-encompassing but unwieldy changeover matrix, which will give a much easier to use and practical changeover sequence or wheel. Until then, **stay tuned, enjoy some ice cream, and organize your industry!**

25 Changeover Sequencing – Part 2

Christoph Roser, June 20, 2017, Original at https://www.allaboutlean.com/changeover-sequencing-part-2/

Figure 217: Ice Cream (Image Jenifoto with permission)

This second post on changeover sequencing looks at the complexity of changeover options, how to optimize the sequence, and how to communicate it reliably to the shop floor planners. (First post here.)

25.1 The Changeover Matrix

To optimize your changeover sequence, you would first need to understand the relation between changeovers. This can be done in a changeover matrix – although in some cases this may be overkill, in other cases not enough.

The image below shows a simple example with three ice cream flavors – chocolate, raspberry, and milk. As discussed above, changing from light to dark is easier than the other way round. The longest changeover time is from chocolate to milk, and the shortest from milk to chocolate.

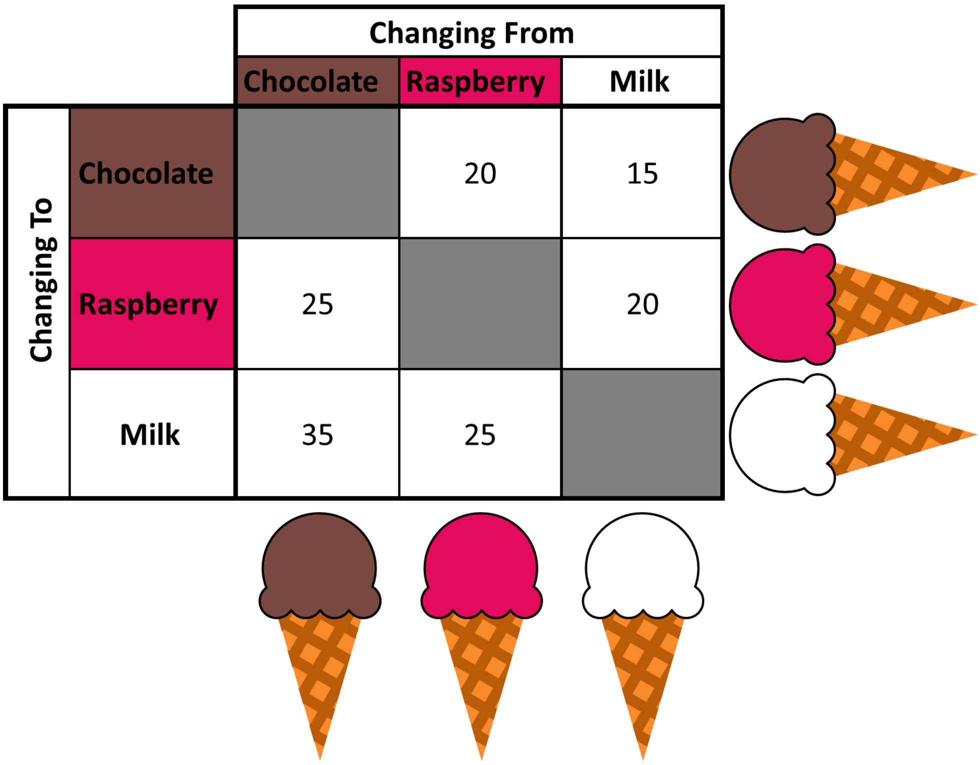


Figure 218: Ice Cream Change Over Matrix 3 Flavors (Image Roser)

If there are truly only three options, this gives us the full picture of the changeovers. But already, it may be difficult to decide what your best strategy is. For example, if you always change to the next flavor with the shortest changeover time, you may never get around to doing milk ice cream. It is easier to change from chocolate to raspberry and from raspberry to chocolate than from either to change to milk ice cream.

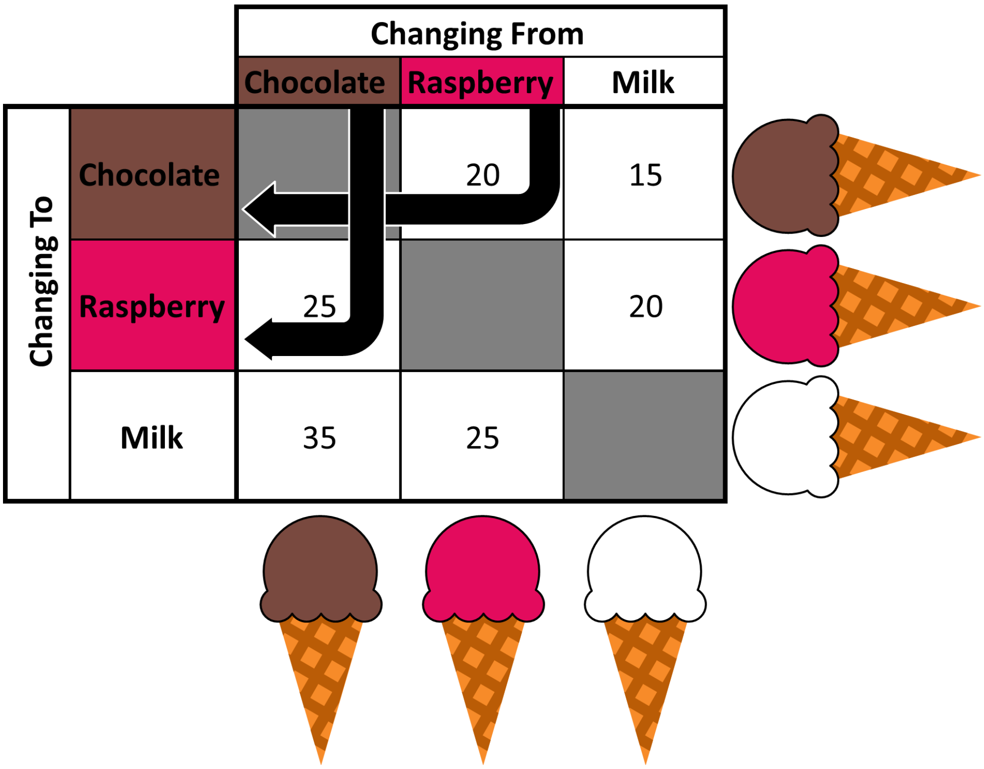


Figure 219: Ice Cream Change Over Matrix 3 Flavors Best Course (Image Roser)

Since this example above is very simple, it is easy to get a better solution: Always go from white to raspberry to chocolate and repeat. However, few changeovers are that simple. Below are the options if we add two types of cups (cone and cup), and we have now five times as many options, from 6 changeover options to 30. If we would have 10 flavors and 3 cups, there would be 870 changeover options. You can easily see how the number of follow-up products increases exponentially.

Changing To		Changing from: Cone			Cup		
		Chocolate	Raspberry	Milk	Chocolate	Raspberry	Milk
Cone	Chocolate		20	15	10	30	25
	Raspberry	25		20	35	10	30
	Milk	35	25		45	35	10
Cup	Chocolate	10	30	25		20	15
	Raspberry	35	10	30	25		20
	Milk	45	35	10	35	25	

Figure 220: Ice Cream Change Over Matrix 3 Flavors and 2 Cones (Image Roser)

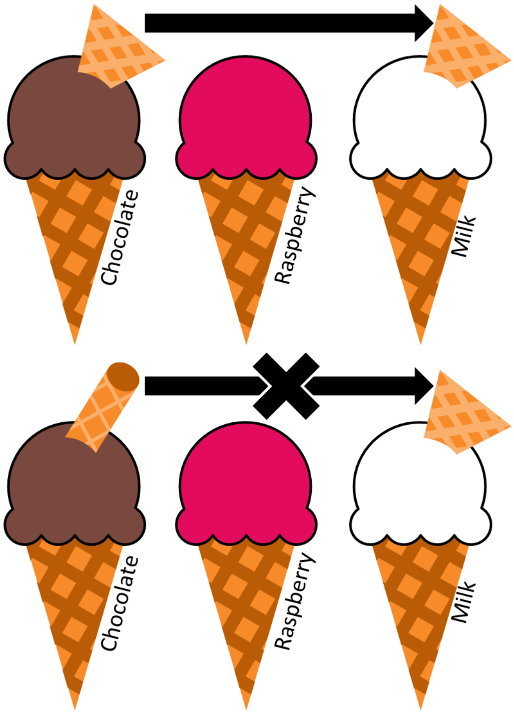


Figure 221: Ice Cream Change Over for Waffle on Top (Image Roser)

Additionally, you may not even catch all options with a changeover matrix. Assume you have chocolate ice cream with a either a round or a triangular waffle stuck on top, raspberry ice cream with no waffles on top, and milk ice cream with a triangular waffle on top.

When changing from chocolate to raspberry, you do not need to change the tool for the waffle on top. However, when you next change from raspberry to milk the tool change depends if the previous chocolate ice cream had a round or triangular waffle on top. Hence, the changeover may not only depend on the previous product, but also on the products before that (and potentially the products before that and even earlier).

Overall, for the complexity in both process and number of variants of a typical modern factory, this changeover matrix can quickly explode in a hugely complicated system that would require a doctoral thesis to optimize and many years of time for the data to accumulate.

25.2 KISS – Keep It Simple, Stupid!

Figure 222: Keep it simple stupid (Image Jantusla under the CC-BY-SA 3.0 license)

As so often in this blog, I recommend you to **go for an solution that may not be perfect but is quick and easy, good enough, and at least better than before.** There is no point in you spending a week on optimizing the changeover sequence for the plant to save only thirty minutes in changeovers per year.

As for the matrix above, try to group things. Which changeover steps take how long and where are they needed. In many cases it may be infeasible to consider every changeover possibility, but it may be good enough to merely have the big picture. Try to focus on the products that are produced frequently. Try to focus on the products whose changeover times depend heavily on the preceding product. In short: **Try to get the most bang for the buck!** (And, while you are at it, maybe you also have an idea to reduce changeover times through some technical or organizational changes.)

25.3 The Changeover Wheel

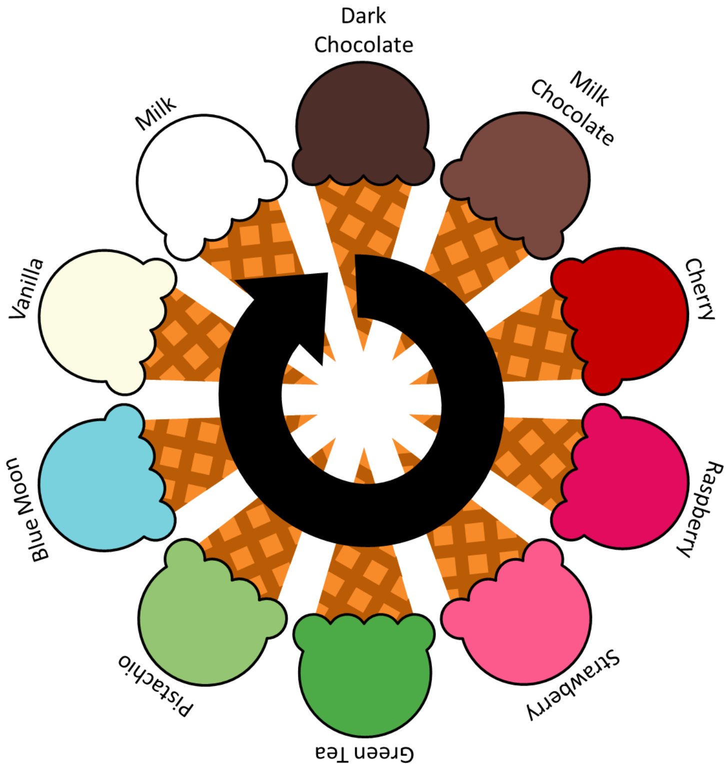


Figure 223: Ice Cream Change Over Wheel 10 Flavors (Image Roser)

We also have to convey these results to the shop floor. A matrix would be too complicated. There should be a simple set of instructions for the people planning the shop floor production. The most common solution is in my opinion also quite nice: **You create one set of changeover sequence!** This is also called changeover wheel. All the products that you could possibly produce at this process are listed in sequence. The sequence should be optimized to reduce the total changeover time, which may also be subject to the product mix. For complex systems it may be difficult to find the true optimum. As stated above, try to get the best result for the time and effort you put in.

Optionally, you can also do this as a sort of wheel as in the image on the left. This looks fancy, but is only suitable for a very small number of products. A simple sequence in the form of a list is usually easier to produce and maintain.

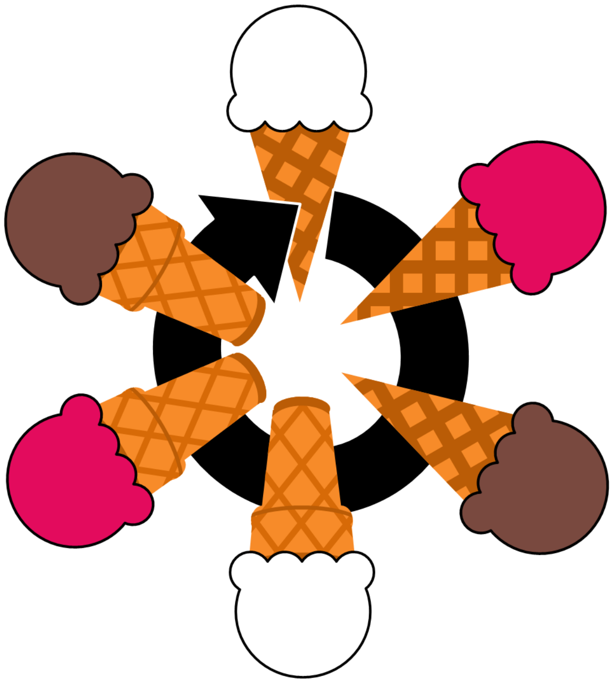


Figure 224: Ice Cream Change Over Wheel Three Flavors Two Cups (Image Roser)

The planner takes the products that have to be produced in the next period and simply arranges the products in this sequence. Any product that is not produced is simply skipped in the sequence. At the end of the period, the production sequence starts again. For our ice cream example, it would be *Milk Cone – Raspberry Cone – Chocolate Cone – Milk Cup – Raspberry Cup – Chocolate Cup*, and repeat.

You could now use different durations (or periods) for the sequence (or wheel) to repeat. You could have a new sequence every day, or every week, or every month, and anything in between. Some plant managers may prefer to have a duration as long as possible before the sequence repeats to reduce the overall changeover time. Don't do that! Instead, try to make the duration as short as you can get away with. As I have described in a previous post, What to Do with SMED: Reduce Lot Size or Increase Work Time? the benefits of a more frequent changeover usually outweigh the cost. Hence, shorter is better here!

Also, no matter how long your period is, you should start the next sequence only if the first sequence is completed. For example, if you always plan one day according to sequence, you should not force the plant to start a new sequence every day. Instead, whenever the current sequence of roughly one day is completed, start the next sequence. For example, if there is a minor problem in manufacturing, and the current sequence cannot be completed today, then you should first finish the current sequence on the next day before starting the next sequence.

25.4 Summary

Figure 225: Girls Eating Ice Cream (Image Tan Kian Khoon with permission)

So, now I am hungry for ice cream. Personally I am a fan of anything chocolate in combination with brownies, cookie dough, or similar mouthfeel enhancing stuff 🙂. But no matter which ice cream you like best, or even – shudder – if you like no ice cream at all, I hope this post gave you inspiration. As usual, it is not intended to be copied 1:1, but rather to give you ideas and suggestions for improvements that match the problems you have on the shop floor. **Now, go out, savor some good ice cream, arrange your changeovers, and organize your industry!**

26 Employee Motivation and Lean Implementation – Part 1: Carrot and Stick

Christoph Roser, June 27, 2017, Original at https://www.allaboutlean.com/employee-motivation-1/

Figure 226: Bored Employees (Image Farina3000 with permission)

All too often, good ideas for a lean implementation fail because workers won't use the new ideas. They simply stick to their old habits. And, no matter how good the ideas are, if they are not used, then the improvement project is a failure. In this post I want to talk about this common problem in industry. The solution is – in theory – easy: Get your people motivated! Doing this in reality, however, is an extremely challenging task with an often-unknown outcome.

26.1 Introduction

Figure 227: Management vs Worker (Image Paolese with permission)

You're working on a lean project. You analyzed the data thoroughly. You found a creative and usable solution. You got all the necessary items for implementation. And you changed the procedures. Yet your implementation fails because the workers simply don't do what you want them to do!

In theory, the solution is easy. You get your people so motivated that they do whatever you want them to do. In reality, achieving this is difficult and time consuming. This problem has existed since people started working together. Henry Ford is quoted, "*Why is it every time I ask for a pair of hands, they come with a brain attached?*" What most managers want is for the worker to behave like a machine made of flesh and blood. Yet your people are human too!

Below I will present a few ideas and suggestions that can help with these issues. But be warned, in all likelihood it is not only the worker that needs to change, but quite likely also you!

26.2 Mechanical Gadgetry

One easy way out is to set up a system that allows only one type of action, or at least makes one type of action much easier than anything else. This is very related to Poka Yoke, to make it idiot proof (although nowadays "mistake proofing" is the preferred term).

Figure 228: Don't forget your card! (Image 3Dman_eu in public domain)

Examples would be, for example, ATMs in Germany that give you your cash only after you take the bank card, thereby forcing you not to forget the bank card. Many ATMs in America still give you the money first and then the card, so you're more likely to forget to take the card (few people forget to take the money).

Other examples would be many types of plugs that fit only the matching socket. It is unlikely that a user puts a plug in the wrong socket, because either it does not fit at all or it is not intuitive.

If you can install such a system as your lean improvement, do it. It makes implementation much easier. Even a mechanical device that does not prevent something but only makes a correct action more likely is worthwhile. For example, I have used metal kanban cards to prevent them from being thrown out by accident.

Unfortunately, this approach does not always work. In the 1980s, GM CEO Roger Smith tried to robotize all GM factories so that they could set a standard simply with the flick of a switch. He invested $45 billion in robotics ($130 billion in today's money, or twice the annual federal US budget for schools). As it turned out, robots weren't ready yet, problems multiplied, and productivity halved. He also still needed people, and they were quite upset about his plans too. This is still considered one of the major business disasters in history.

26.3 The Big Fallacy: The Boss Is in Charge

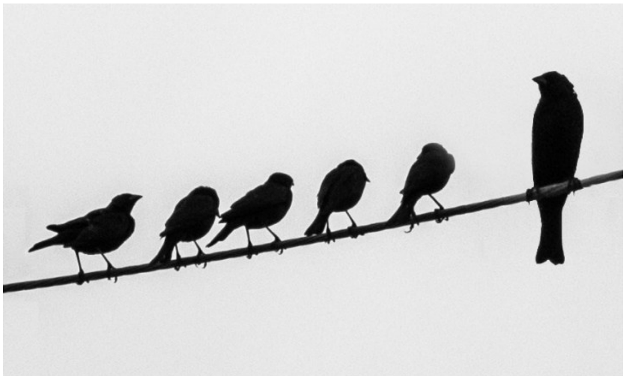


Figure 229: The boss and the bossed… (Image Tomascastelazo under the CC-BY-SA 3.0 license)

Most modern work contracts include that the firm (represented by the supervisor or manager) has the right to instruct the employee on their work. In short: The worker has to do what the manager says. This could lead you to believe that to implement any change in the work, the manager simply has to tell the worker about it. I can already hear the more experienced managers and workers chuckling about this. Nothing could be more wrong.

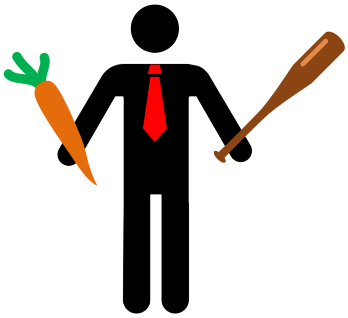


Figure 230: The carrot and the stick (Image Roser)

While officially this is true, in practice there is A LOT of leeway. Employees are very good at avoiding instructions. Often, this is actually necessary to avoid bad instructions and to keep the company running. One of the easiest ways to strike is work-to-rule. Employees follow precisely all safety and other regulations, and productivity and quality drops significantly. Employees should have leeway, and they do take it. In ancient times, slaves had pretty much no rights, not even to their own body, and still found ways to avoid management instructions. Nowadays – luckily – employees can at worst get fired and sued, but firms reserve such actions only for the gravest offenses.

This brings me to the next part: the carrot and the stick. Since the carrot is more important, let's first get the stick out of the way. The many different carrots will be in my next post.

26.4 The Stick

Figure 231: The Stick (Image Roser)

Obviously, management has ways to sanction employees. The details depend on your labor law code, but it usually includes the possibility of firing, or different levels of warnings and reprimands. Less regulated but still common are stern words, yelling, giving unpleasant tasks or undesirable work times, and so on.

The thing is, such negative actions rarely work. For example, terminating an employee contract is usually a last resort for grave offenses. If you fire everybody that does not do things to your liking, then you will soon run out of employees. Finding and training new employees is not easy, especially if the word gets around that firing is common.

Figure 232: Not very motivating… (Image Photographee.eu with permission)

Same goes for the other reprimands. Used sparingly and with just cause, they may have some effect. Yet, used indiscriminately for even minor oversights, they will quickly lose their effect.

On the contrary, the reputation of the responsible manager will suffer, and he will it find even harder to implement changes in the procedures.

Overall, you have to realize a simple truth: **You cannot force or threaten workers to do something against their will!** Okay, they will do it when you are around and observing, but as soon as you are gone, it is back to their ways. Any example in history that I looked at got very messy when management tried to force workers to do something against their will. Henry Ford initially had a turnover rate of up to 370%, meaning they had to rehire the entire shop floor staff every three months. The workers in the Arsenal of Venice mostly ignored official directives. Laid-off French workers threaten to blow up the factory (example from 2009). I am sure you have lots of examples from your own experience.

Hence, since the stick does not work very well, we will look at carrots in our next post. **Until then, stay tuned, be nice and fair to your employees, and organize your industry!**

P.S.: This series of posts is based on a question by Curtis Rosché (name mentioned with permission).

27 Employee Motivation and Lean Implementation – Part 2: Money

Christoph Roser, July 04, 2017, Original at https://www.allaboutlean.com/employee-motivation-2/

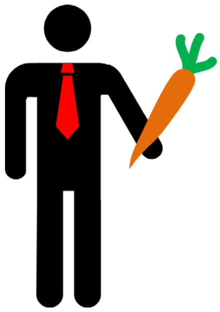


Figure 233: The Carrot (Image Roser)

Lean improvements often fail in implementation, meaning the employees do not follow the new standards. In my last post we already saw that pressure ("the stick") doesn't work very well. The second option is the carrot. In this post I will show different "carrots" that are sometimes used to get employees to follow the new standard. However, most of them won't work very well either. What often works best is actually simply treating people with respect – but I will talk about this in my next post.

27.1 Money, Money, Money …

Figure 234: Piggy Bank (Image Ken Teegardin under the CC-BY-SA 2.0 license)

Often, money is seen as the biggest motivator of them all. Give people cash, and they will work better and more. There is a bit of truth in it. Very few of us would work for free, and if our jobs would have no salary, we would probably be searching for a new one sooner rather than later. However, using money to actually change the behavior of the employees is very difficult.

27.1.1 How Much Money for Happiness

Figure 235: Happy Money (Image denisismagilov with permission)

One rule of salaries is that it is never enough. Surveys asked people about the salary they would like to get, and the answer is pretty consistent: 10% more! **Just 10% more salary, and they would be happy**. This is regardless of the salary level. A fast food worker earning $20,000 per year (one of the lowest-paying jobs in the US) believes he merely needs 10% more for happiness, as does an anesthesiologist making $270,000 per year (the highest-paying job category in the US) (Complete list of jobs here), or even CEOs earning millions per year. All of them believe that they would need only 10% more money to achieve satisfaction and happiness.

Oh well, 10% more labor expenses is a lot, but to achieve a truly happy workforce that may be considered. Unfortunately, there is a second set of research that shows that **this motivational effect from a raise lasts, on average, only three months** before the higher salary is now seen as the new normal. If you would pay your people 10% more, they would be happy for three months, then they would start dreaming again about 10% more. In effect you would need to raise the salary by 10% every three months. This would be 46% more money every year, doubling the salary in less than two years. Clearly this is not sustainable.

27.1.2 Performance-Related Pay

Figure 236: Usain Bolt doing his thing… (Image Fernando Frazo/Agncia Brasil under the CC-BY-SA 3.0 Brazil license)

Another option is performance-related payment. Work hard and get paid more. This is common in industry but also has its flaws. First of all, how do you measure performance? It is hard to have a measurable metric. Usain Bolt's performance can be measured easily based on how long he needs for 100 meters. But if your job does not consist of running 100 meters, it will be more difficult to measure performance.

For shop floor workers it may be possible to measure the number of pieces produced and to pay accordingly. But this is also flawed. First of all, the quantity produced rarely depends on the worker alone, but also on other factors like material availability, machine reliability, and so on, which the worker cannot influence directly.

Historically, payment per piece was tried, but the managers soon found out that the worker produced large quantities at low quality. In order to maximize his profit, the worker was prioritizing quantity over quality, and many of the produced parts were actually low quality or defective.

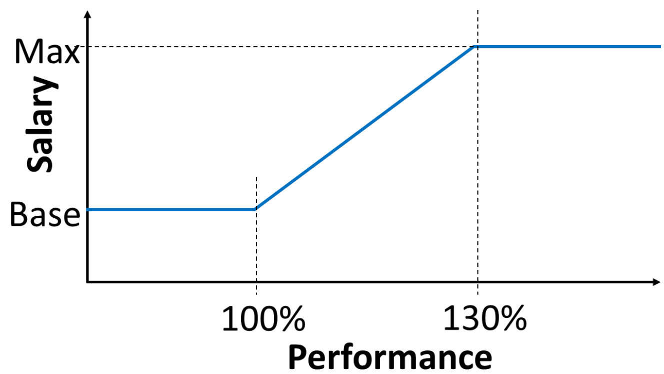


Figure 237: Performance-based salary (Image Roser)

Nowadays it is more common to actually cap the performance-related pay at a certain level. Often, this is at 130% of the target performance. Since the worker is not rewarded more for excessive speeds, quality will (hopefully) not degrade.

On a curious side note, for all such systems that I have encountered, the workers were able to work 130% consistently and without breaking a sweat. In effect, 130% was the norm, and the worker was punished if he fell below the 130% mark. I wrote a whole blog post on the psychological tricks going on with this: The Curious Case of 100% Work Performance.

Hence, with limitations it may be feasible to get more parts with more money, but it will be very hard to influence how these parts are made. If you pay by piece, you pay for the outcome, not for the following of a standard while making them. Achieving this with money will be very difficult.

Measuring performance will be even more difficult for indirect workers (office, admin, managers, and so on). While most companies try their best to make the performance evaluation as unbiased and measurable as possible, the results are often unsatisfactory. If you have ever received or given such a performance evaluation that influenced the bonus, you know how awkward these measures are, how little the worker can actually influence them, and how both sides (probably) feel that this is more of an ritual or dog-and-pony show than an actual evaluation.

And besides, similar to the desired 10% more salary above, this bonus is now expected and no longer motivational. On a side note: The higher up you are in the pay grade, the more you are able to negotiate getting your bonus regardless of your performance. There are countless CEOs that underperform but still are able to get the lion's share of their bonus despite the metric goals (e.g., stock market performance) that were set out initially.

27.1.3 Non-Monetary Goods

Figure 238: Keep the pitcher separate! (Image rades with permission)

There is one way that can to a certain degree avoid the trap of a bonus being "normal" after three months. You would have to keep the bonus somewhat separate from the regular pay. Think of your salary as a bathtub full of water. You don't really notice an additional pitcher to your monthly bathtub.

However, if you keep the pitcher separate from the rest of the tub, it will be more visible. Therefore, it may in some cases be better to give rewards not in the form of money that is transferred to the bank account and "no longer visible," but in some separate way. This could be gas vouchers, pizza coupons, gift cards, or other items that are not just money.

Figure 239: Mmmm … free pizza! (Image Scott Bauer in public domain)

To use the reward, the employee has to handle it separately from the rest of the salary. This can vastly extend the duration of the "motivation" above the three months for mere money. Additionally, depending on your jurisdiction, such rewards can sometimes be given tax free. And at least we Germans love to get things tax free!

But be aware that any such events can also horribly backfire. There are countless examples of motivational activities and offices or even company-wide events that horribly backfired. See my post Using Lots of Effort and Money to Demotivate Your People for a selection of ill-thought-out examples, including some cringe-worthy videos.

27.1.4 Never Ever Reduce Salary!

Figure 240: Money pulling (Image Szasz-Fabian Jozsef with permission)

In any case, whatever you do, never ever reduce the salary to nudge people toward doing what you want them to do. While additional money has only a short-term motivational effect, reducing money has a much, much stronger negative effect. If you cut the salary even by one dollar per year, the employee will be pissed for months and years to come. From the view of the employee, he has the right to his salary, and reducing it amounts (from his point of view) to stealing.

In academia, this is the so-called two-factor theory by Frederick Herzberg (1923–2000). He groups job satisfaction effects in two groups. The first one is called **hygiene factors**, and money is one of them. Having it does not really increase satisfaction very much, but reducing it will be extremely upsetting to the worker. Other hygiene factors are job status or prestige, job security, work conditions, vacation, and so on. Hence, you need them for your employees to be "not unhappy," but they will not make them happy either.

The second group actually motivates, and hence they are called **motivators**. And they have nothing to do with money, but everything to do with leadership and respect for people. Especially this respect for people is a very important aspect of the Toyota Production System, but unfortunately it all too often falls short in what we call lean nowadays. This is such a big topic that I will discuss respect in more detail in my next post. **Until then, go out, respect your own and other people, and organize your industry!**

P.S.: This series of posts is based on a question by Curtis Rosché (name mentioned with permission).

28 Employee Motivation and Lean Implementation – Part 3: Lack of Respect

Christoph Roser, July 11, 2017, Original at https://www.allaboutlean.com/employee-motivation-3/

Figure 241: Box on Head (Image Sergey Nivens with permission)

Motivating employees for change is tricky. What often helps is respect, but in reality the opposite is common. While managers claim that of course they respect their people, the employees feel very differently, and quite often there is a lack of respect. In this post I want to talk about this lack of respect and why it happens, before showing how to do it better in the next post.

28.1 Respect: Different Points of View

Figure 242: Workplace Handshake (Image Photocreo Bednarek with permission)

Please note that this lack of respect is not a black-and-white situation, but more of a gradual scale. Some people show more respect, other less. Naturally, there are managers and supervisors who give respect and therefore also receive it in return, but there are also lots of others who show a distinct lack of respect or even outright disdain.

Often, they don't even notice that they are disrespectful, but are wholly ignorant regarding their behavior and how it is received. Even your actions may have come across as disrespectful in the view of the people you lead. Oh my gosh, even I may have been disrespectful toward my people without noticing it … *<sarcasm> But no, no, that is completely unthinkable, and any perceptions of disrespect was clearly an error by the employees who misunderstood my noble intentions. It must be obviously their fault, not mine </sarcasm>.*

You get the idea. It is hard to judge yourself. After all, it does not matter if you think you are respectful, but only if the other side thinks so. If you are unsure, please try to get feedback, preferably anonymous feedback. Many companies even have structures – for example, a 360-degree feedback (meaning your boss, your subordinates, and your colleagues). If you have the chance to do this, do it! It may not always be pleasant, but it helps you to become a better leader.

28.2 Respect Is What You Do, Not What You Say!

Figure 243: The loyal subjects may now approach the manager … (Image В. Поляков in public domain)

If you ask any manager in any company if he respects his people, the answer will be almost always yes. If you then ask the subordinates, the answer will very often be quite different, especially if you ask blue-collar workers. Unfortunately, regarding respect for people, it does not matter what the manager thinks. **Respect for people only works if the people feel respected!**

In any case, actions speak louder than words. Employees are very good to observe these differences. If the manager talks about respect but cuts in the line at the cafeteria anytime (or even has his own management dining room), then there is no respect. If the manager takes credit for all successes but blames the subordinates for all failures, then there is no respect. If the manager observes processes or shows machines to visitors without saying hello or even acknowledging the workers, then there is no respect. If you think about the bosses you have worked with in the past, I'm sure you will have some colorful examples on your own.

28.3 Why "Respect" Often Fails: Hierarchy

Figure 244: Stepping on Person (Image ra2 studio with permission)

The curious thing is, such managers tend to be very respectful to their own peers. They are (often) nice, courteous, and well behaved. With superiors often they are even able to be outright humble. It is only with "lower" employees that they show a lack of respect. In my experience there are two main factors contributing to that discrepancy in behavior.

28.3.1 I Am Better than You!

Figure 245: I am better! (Image igorp17 with permission)

First, there can be a feeling of "being better" than the subordinate. Many people put in a lot of effort to argue to themselves or close friends that they are better than others. Inevitable, they pick aspects in which they believe to be good at. No matter if it is beauty, intelligence, money, religion, or power, the common believe is that "I *am prettier/smarter/richer/more religious/more powerful than you, so I am better.*" It doesn't even have to be true, the person merely has to believe it. Of course, it is rarely stated as such, but it is often an ingrained belief.

As for managers, they themselves rarely use the "pretty" or "religion" argument. More commonly it is "smart" (although this is often disputed by the employees), or rich or powerful (which is rarely disputed). Many people measure themselves and others simply by their salary level.

Figure 246: Narcissus by Caravaggio (Image Caravaggio in public domain)

As for the psychology behind this, there are different views (which may vary from person to person). Some people are truly narcissistic, and love themselves more than any other. They believe they are perfect and that nobody compares to them. They are often unable to connect to others, especially if these others don't flatter them. Having more money, power, or (perceived) intelligence will make them feel superior and better to others.

Others may feel inferior, and are in constant doubt and worry about themselves. To compensate for this inferiority complex, they may to overdo it on the superiority side. They may seek frequent validation that they are not inferior, resulting in disrespectful behavior toward subordinates.

28.3.2 Covering Insecurity by Trying to Dominate

Figure 247: Insecure Manager (Image STUDIO GRAND OUEST with permission)

Very related especially for managers is the handling of uncertainty and insecurity. Ideally, a manager is a leader, someone who has the answers and knows the path to the light. But let's be frank, in today's tumultuous business environment, nobody has all the answers. Modern business has risks, lots of it. Part of leadership is to be convincing even if you are not certain yourself. However, this includes the risk of being wrong.

Using hierarchy to distance yourself may be a preemptive defense mechanism against such uncertainties. Putting a divide between the manager and the employees makes it somewhat less likely for the employees to criticize him. In such examples, a command-and-control type of management style is common. Of course, employees will still criticize managers, but now more likely behind his back, and probably much more so than if open criticism is allowed.

28.3.3 Summary

Overall, there is often a lack of respect in industry. While open disdain is quite rare, there are a lot of subtle signs of perceived superiority, or neglect of etiquette and proper behavior. (See also my posts on Shop Floor Etiquette – Part 1 and Part 2.) Yet, if the worker feels disrespected, in turn he will also disrespect the supervisor or manager. This is actually quite common, and seems to be increasing with the more hierarchical levels there are in between. If the worker disrespects his superiors, it will be so much more difficult to change his behavior, and therefore be so much more difficult to change and improve the system.

After all this talk about motivation and respect, I will finally get to some ways on how to show respect in my next post. **Until then stay tuned, go out respect your people (really!), and organize your industry!**

P.S.: This series of posts is based on a question by Curtis Rosché (name mentioned with permission).

29 Employee Motivation and Lean Implementation – Part 4: Respect for People

Christoph Roser, July 18, 2017, Original at https://www.allaboutlean.com/employee-motivation-4/

Figure 248: Motivated Employees (Image Farina3000 with permission)

Motivating employees is not easy. In previous posts I described that the carrot and the stick approaches don't work very well. What in my experience works best to improve the system is **Respect for People!**

This is actually a very important aspect of the Toyota Production System, and Toyota puts in lots of effort to show respect to all people. This includes not only employees (the focus of this post), but also customers, suppliers, neighbors, and pretty much everybody else it comes in contact with. At Toyota, it is actually called **Respect for Humanity** (人間性尊重, ningenseisoncho). Unfortunately, all too often I find this lacking in Western lean implementations.

29.1 Respect for Humanity

Figure 249: Paper People Respect (Image Win Nondakowit from Fotolia with permission)

In my view, respecting your people is one of the key aspects of a successful lean implementation. In fact, respect is a large part of any successful leader or manager. Respect almost always works both ways. If the people you work with do not feel respected, they won't respect you either. Respect is all about what you do, and not about what you say you do. Most people can tell whether they are truly respected or if the manager just says it only because he has to say it. Even when the manager believes that he respects the worker, the worker's opinion may differ. And it is all about what the worker thinks.

29.2 How Do You Show Respect?

29.2.1 How NOT to Show Respect!

Figure 250: The miller, his son and the donkey (Image Darjac in public domain)

So, how do you show respect for others? First of all, let me get off my chest what respect is not. It is NOT always being nice to everybody. There is a fable of the miller, his son, and the donkey, where the miller tries to please everyone, eventually carries the donkey instead of riding it, and ends up pleasing no one while accidentally killing the donkey.

The moral is that you cannot please everyone. If you try to make everybody happy, then you will be the fool that is taken for a ride. As a leader you have to make decisions, which not everybody likes. But by making just and reasonable decisions, you can get the respect of (the majority of) your people, even if the decisions are sometimes (slightly) detrimental for the employee.

29.2.2 Respect the Opinions of Others

Figure 251: Respect (Image TN-Stock with permission)

In my experience, a large part of respect is shown by respecting and valuing the opinions of others. Just because someone has a different opinion doesn't automatically mean that he is wrong. Respecting that opinion is an important part of respecting the person.

On a side note, this would be good not only on the shop floor, but in general. We respect (rightfully so) different religions, ethnic backgrounds, sexual orientations, and so on. But it saddens me that as soon as it is about an opinion, all the respect and even tolerance goes out of the window. Republicans vs. Democrats, brexiteers vs. bremainers, military vs. peace movement, Anti-GMO vs. Biotech, and many more. It is not necessary to agree with others' opinions; but having a differing opinion does not automatically make a person bad or wrong.

In any case, back to manufacturing.

29.2.3 Value the Knowledge of Others

Figure 252: knowledge sharing (Image TN-Stock with permission)

Even more, respect is not only valuing the opinions of others, but also valuing their knowledge and experience. In fact, a lot of lean at Toyota is based on the experiences of the workers there. In many cases, the worker at the machine knows the machine better than anyone else. His knowledge can definitely contribute to a successful improvement. Of course, what the worker usually lacks is the view of the big picture. That's where management comes in. The goal is to combine the detailed knowledge of the worker with the (presumed) knowledge of the manager to get an overall well-rounded improvement.

Yet, in (many) Western companies, the approach is that the manager determines what is to be done, and the worker has to do it. The worker is simply a machine made of flesh and bones. To give you two quotes from history:

> *The Author believes that it would be possible to train an intelligent gorilla so as to become a more efficient [worker] than any man can be. (Frederick Taylor, speaking about himself)*
>
> *How come when I ask for a pair of hands, I get a human being as well? (Henry Ford)*

29.3 Enable Workers to Influence Their Workplace

Figure 253: Factory Workers (Image Cherie A. Thurlby in public domain)

Valuing the opinions and knowledge of others results in people being able to influence their workplace. I had the best acceptance with projects when the people on the shop floor were part of the improvement team and were able to contribute to the decision making.

Being part of the decision making gives the participants much more knowledge about the path to the decisions, about the alternatives discussed and the trade-offs made. Rather than seeing all the things that are lacking, they understand that the result is often a compromise among different goals.

There are two ways to do this. First of all – and that is a no-brainer – the knowledge of the workers should go into the decision making. But there is a second way, which in my experience gives even better acceptance by the workers. The workers not only give information, but are also part of the decision-making process. Some managers have a problem with that since management is no longer the only voice in the room. Managers have to give up some of their power to let workers be part of the decision making. If there is an approach that management prefers but the workers dislike very much, then it may be better to actually follow the workers' preference.

Figure 254: Me, me, me, … and me! Not good. (Image igorp17 with permission)

Of course, this can't be generalized. Sometimes the management overrules the workers, and sometimes workers can put their views through. It is a give-and-take. **If the manager is always right, then there is no respect and subsequently no buy-in by the workers!**

The details depend very much on the situation at hand, and it is hard to generalize. But please respect your workers' opinions and knowledge by sometimes accepting that they know more and by subsequently doing it their way. "Command and control" is not a respectful management style, and in lean manufacturing usually leads to inferior solutions.

29.4 Some Practical Tips

Here are some practical tips that help with the success of a lean project:

- Involve the different stakeholders. Depending on the project have, e.g., a manager/supervisor, a worker, someone from logistics, and someone from maintenance on the team.
- The team size should be 3 to 5 people. If it is larger, make subgroups.
- Try to get the "alpha males" on the team. The word of an experienced and respected worker holds so much more weight with his colleagues than that of a newbie, even though it may be easier to convince the newbie.
- It is unlikely that you will get everybody to agree. But try to have the majority of the people on board with your idea.
- Talk to people, and – even more important – listen to people! Show respect!

Hopefully this will improve your chances of a successful lean project. Now, go out, respect your people, and organize your industry!

P.S.: This series of posts is based on a question by Curtis Rosché (name mentioned with permission).

30 Visual Management

Christoph Roser, July 25, 2017, Original at *https://www.allaboutlean.com/visual-management/*

Figure 255: Eye (Image pixelaway from with permission)

Yet another hot topic in lean manufacturing is visual management. This can be very helpful in running a shop floor, but when done wrong it can also be quite wasteful and embarrassing. In this post I would like to show you the basic principles of visual management with a few examples. There is more to visual management than merely putting lines on the shop floor.

30.1 The Basic Idea

Figure 256: Prow lookout aboard USS NASSAU (Image Lt. Wayne Miller in public domain)

Visual management aims to make the situation easily understood merely by looking at it. The goal is to get as much information as possible with as little observation or time as possible. Visual management complements well with the idea of going to the real place (Genchi Genbutsu). It also intertwines closely with 5S.

Like most topics in lean, you can use the English phrase Visual Management, or you can use the Japanese term. While I prefer English when speaking to an English-speaking audience, the Japanese term is *Mieruka* (見える化 with 見える or *mieru* for being able to see and 化 or *ka* for the action of making something).

30.2 Four Approaches to Visual Management

In my view there are different directions you can go with visual management. I will discuss them here in order of preference, with the best one at the end.

30.2.1 Visual Management with Data Displays

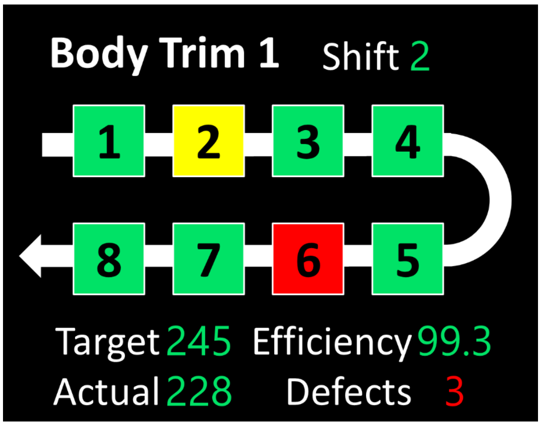


Figure 257: Andon Board (Image Roser)

Visual management can be done by putting data on display on the shop floor. It is usually my least-preferred way, but with some information it is difficult to do otherwise.

One common example is digital information displays, often called Andons (See also my post All About Andon and How to Use an Andon – and How Not To). On such information displays you can usually see the production rate, the quality defects, and the status of the machines.

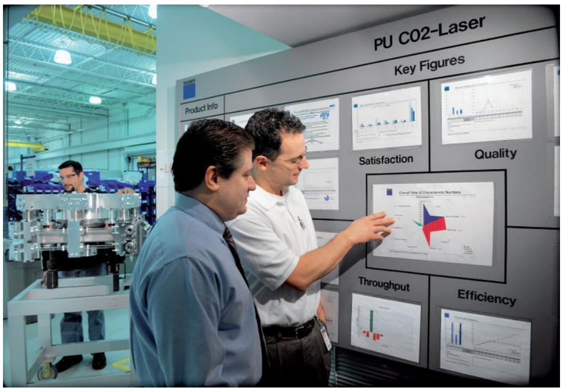


Figure 258: Trumpf team board (Image Trumpf Group with permission)

It is also possible to put data on paper. Often this is printed, although I prefer handwritten data due to the better involvement of the workers (see The Advantage of Handwritten Data on the Shop Floor). Ideally, this data is shown graphically and easy to understand, using graphs, tables, diagrams, and colors.

The idea is again that the data is right there on the shop floor. This is useful if there is no easier way to visualize the system.

30.2.2 Visual Management with Markings

Figure 259: 5S Cleaning Point (Image Tasma3197 under the CC-BY-SA 3.0 license)

Figure 260: Selection of Warning Labels (Image various authors in public domain)

Another approach is to mark and label locations on the shop floor. Using different colors you can mark what goes where, and label the places so that the items and tools go to the correct places.

A lot of such markings are actually government regulated. For example, all fire- and emergency-related markings are examples of visual management.

30.2.3 Visual Management with Tools and Parts

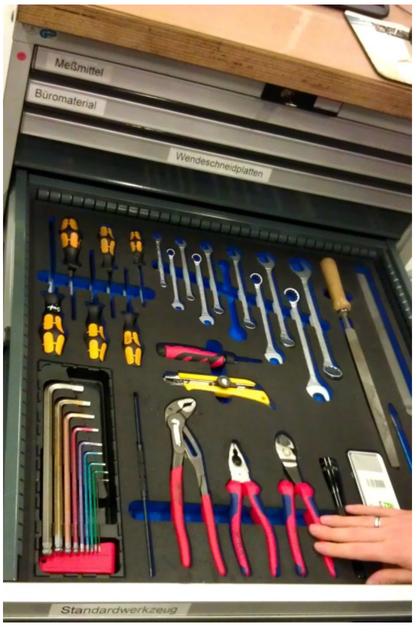


Figure 261: 5S tool drawer (Image Tasma3197 under the CC-BY-SA 3.0 license)

The best type of visual management is if the information about the system can be seen in the system directly. If you create a graph or a data display, there is a chance that it is outdated or simply wrong. Whereas if you see inventory on the shop floor or tools in a drawer directly, the information is up-to-date, and less likely to be incorrect.

Common examples are tool drawers where each tool has its own location. You can see immediately which tool goes where and which tool is missing.

Figure 262: Knives drawer on Alcatraz (Image Adam Kliczek under the CC-BY-SA 3.0 license)

A similar approach is a shadow board, where the *shadow* of each tool is outlined. The shadow board here was used at Alcatraz prison in San Francisco. At the end of the shift, the guards could see immediately if all knives were returned, or if an inmate was walking around with a potential weapon.

I have seen similar shadow boards for knives in the food industry. The managers there worry less about murders, but they don't want any tool to go missing and potentially end up in the products.

30.2.4 Visual Management using Layout

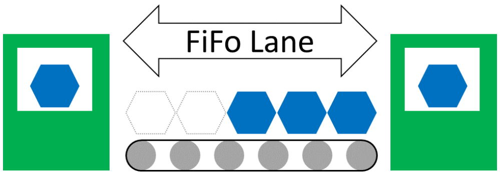


Figure 263: FiFo Lane (Image Roser)

This can also be done with material. A good FiFo lane not only manages inventory but also shows you where your material is, how much more work there is, and many other details on your process.

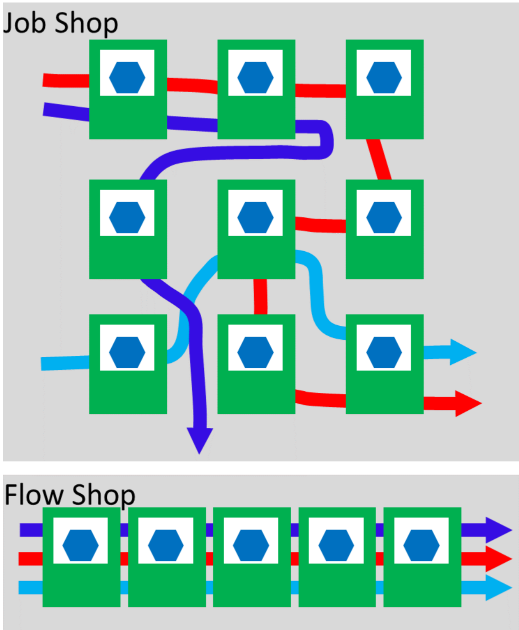


Figure 264: Flow Shop Job Shop Comparison (Image Roser)

Even the overall material flow can be visualized through the arrangement of the machines. A flow shop is so much easier to understand than a job shop, since the machines are arranged in the product flow. It is much easier to understand where the flow of material is hampered.

The image below is the shop floor at Trumpf, which I find particularly well organized and easy to understand.


Figure 265: Production at Trumpf (Image Trumpf Group with permission)

As a counterexample here is an old smithy. Even though it is a much smaller space, it is much more confusing.

Figure 266: Smithy in Finland (Image Wasapl under the CC-BY-SA 3.0 license)

Of course, I have also seen flow shops that were built like a maze, and even the workers that worked there every day had difficulty understanding the material flow. Clarity and structure are not only nice to the pedantic German engineer (me), but actually do have benefits for understanding the system.

Figure 267: Spices in a supermarket shelf (Image Blink in public domain)

Figure 268: Typical Full Warehouse (Image Axisadman under the CC-BY-SA 3.0 license)

Similarly, it is possible to structure your inventories. A supermarket has a dedicated lane for every product. You know immediately how much you have of which material. You can even mark the supermarket with green and red to show when you may get into a critical low-stock situation. This is so much easier than having an unstructured warehouse.

30.3 Some Not So Good Examples!

Figure 269: Not good… (Image Roser)

Figure 270: Ummm…. (Image Roser)

Like everything, visual management can be done badly too. It is particularly easy to overdo it with the markings. The image on the left is staged, but similar examples can be found proudly advertised on the web.

This is overkill. There is no advantage in visual management for individual pens and scissors, especially if it is the personal desk (it may be useful if it is a shared workspace, but even then it may also be too much).

Also, for illustration here is the cabling of two different computer racks. See the difference?

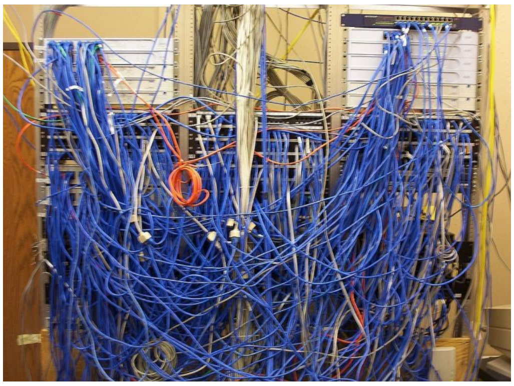


Figure 271: Tangled Cables (Image Bhankins in public domain)

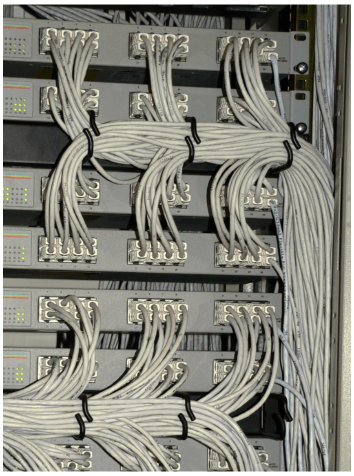


Figure 272: Organized Cables (Image Parkis, Zanaq under the CC-BY-SA 3.0 license)

30.4 Examples Outside of Manufacturing

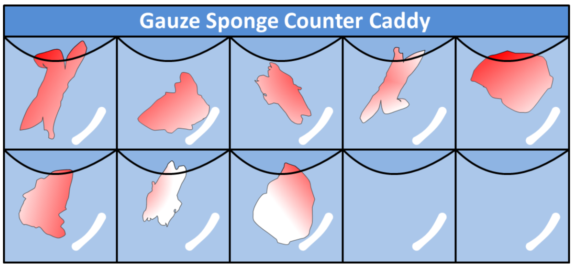


Figure 273: Gauze Counter Caddy (Image Roser)

There are also examples in other industries. For example, during surgery, used sponges and gauze are stored in an array of plastic bags or hung on hooks so it can be easily seen how many were returned. The number of surgical sponges after the surgery has to be the same as before, otherwise the surgeon has to go looking for the missing sponge. After all, you don't want the patient to wake up with something extra.

Figure 274: RAF Sector Fighter Control Room of the Lascaris War Rooms (Image unknown author in public domain)

For a more positive historic example, see my blog post on Visual Management during World War II – A Visit to the Lascaris War Rooms in Malta. You can find a lot of visual management ideas there before the use of computers. Quite nifty, and open to the public if you happen to be in Malta 🙂.

Again, the goal of visual management is to understand the situation as quickly as possible merely by looking at the shop floor (or, as a second choice, data displays on the shop floor). So go out, make your factory easier to understand, and organize your industry!

P.S.: This blog post is based on a question by Prashant.

31 Different Ways to Establish a Pull System – Part 1

Christoph Roser, August 01, 2017, Original at *https://www.allaboutlean.com/different-ways-to-pull-system-1/*

Figure 275: Rope pulling (Image Luis Louro with permission)

Pull production is one of the most important aspects of lean production. Its key feature is to have an upper limit on inventory that is not to be exceeded. The most well-known way to implement a pull system is by using kanban cards. However, there are many others. In this short series of two posts, I want to give you an overview of the different ways to implement pull systems, and discuss the pros and cons of them.

31.1 Key Feature: Limit the Inventory!

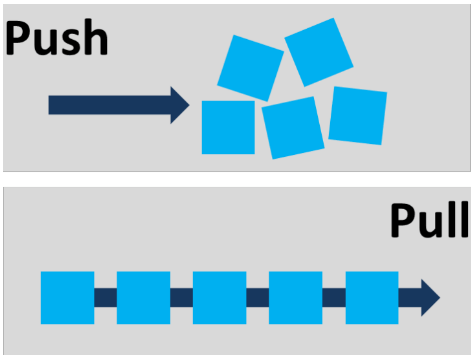


Figure 276: Common but misleading illustration of push and pull! (Image Roser)

Often, there is confusion on what makes a pull system a pull system. Many believe that a “signal” comes directly from the customer – but that is a pretty fuzzy and flawed definition. Instead, the key feature of a pull system is an upper limit on inventory! I wrote a whole blog post on this: The (True) Difference Between Push and Pull.

This key feature is also its advantage. If set up correctly, pull systems keep the system at the sweet spot with respect to inventory. It does not exceed the upper limit, but it should also not fall too low and cause a lack of material. Best of all, this does not require manual intervention, but should be automatically based on the rules of the pull system.

You can set an upper limit on inventory for every part separately, or for all parts combined. If you do this for every part separately, the system also automatically manages the production plan (if you take out one part, reproduce exactly this part type). Examples would be kanban, triangle kanban, two box systems, and reorder points or reorder periods. If you set an upper limit for all parts regardless of the part number, you do need to have a system in place that defines which parts to produce next once you fall below this limit. Examples would be CONWIP systems, drum-buffer-rope, or FIFO lanes. These combined upper limit, on the other hand, has the advantage of lower fluctuations in the total workload, whereas a limit-by-part-number approach can fluctuate more.

31.2 Where You Can Do Pull, and Where You Cannot

Figure 277: It only comes when you order it! (Image desertsolitaire with permission)

This makes pull systems overall very robust and stable, well suited for pretty much any production system. In fact, it can also be used outside normal industry (e.g., in healthcare, military, or data processing) (see also my post on Why Pull Is So Great!). There is, however, one requirement for it to work: **You need to be able to control the number of new parts or tasks arriving!**

This is usually the case in manufacturing. Parts arrive only when you explicitly order or produce them. Without a purchase or production order, you wont get any parts. Thus you can limit the maximum inventory simply by not ordering or producing more when you reach that limit.

However, not all systems have that ability. For example, if you work in retail, the customer comes whenever the customer damn well pleases! It is not practical to send customers away during the Christmas crazy shopping period just so you can limit your number of customers. I mean, of course you can, but it is usually not good business practice. If you cannot control your arrivals, then you have to be much more flexible with your capacity in handling these arrivals (see Lean Tales in Japan: The Japanese Supermarket Checkout for an example).

In any case, as long as you have control over the parts or tasks arriving, you can establish a pull system. There are different ways to do that.

31.3 Kanban

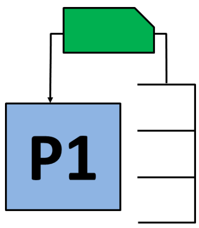


Figure 278: One Process Kanban Loop (Image Roser)

This is the most well-known approach to pull. All material in the kanban loop has a kanban attached. This kanban is used for that part type and that part type only. This kanban can be a simple card, a labeled box, or even a wireless RFID chip. Finished material is stored in a supermarket. Whenever a part is removed from the supermarket, the kanban goes back to the beginning of the loop for reproduction (if a kanban stands for more than one part, usually the kanban is returned when the first part is removed). Hence, the kanban card signals production (or generally delivery) of new parts. You can never have more material than indicated on all kanban cards.

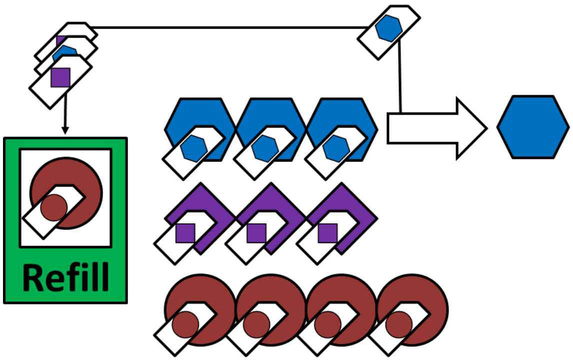


Figure 279: Kanban System (Image Roser)

A kanban system requires all kanbanized products to be available in stock, and hence this system is usually good for high-volume, low-mix production. However, it won't work for made-to-order production, and in general is not so good for low-volume, high-mix production.

31.4 Two-Box System

A variant of the kanban system is the two-box system. You have two kanban, often storage boxes, hence the name two-box system. Whenever a box is empty, the box is returned to be refilled. This is effectively a kanban system with two cards (boxes).

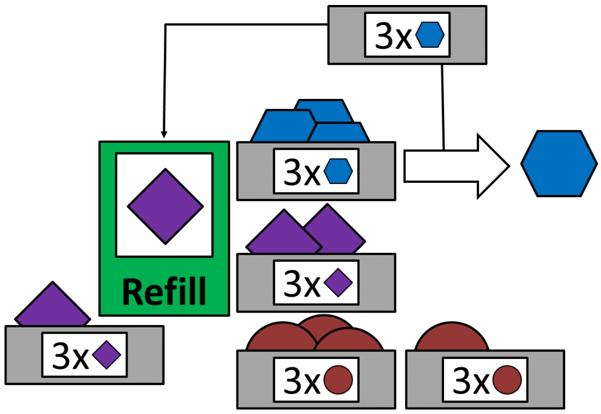


Figure 280: Two Box System (Image Roser)

This is used for parts where the replenishment time of a box is much shorter than the time to empty a box (i.e., the system can produce or order faster than the customer can consume). You need at least two kanban, otherwise you risk running out of parts if the single box happens to be empty when you need the part. This can be avoided with two boxes.

31.5 CONWIP

CONWIP stands for "constant work in progress." It is somewhat similar to kanban, but the CONWIP cards do not represent a specific part. Whenever a kanban comes back for replenishment, it needs to replenish exactly the part on the kanban and no other. When a part is removed from the CONWIP inventory, the CONWIP card is "blanked" (i.e., any part related information is removed). Hence, when a CONWIP card comes back, it merely has the information to produce whatever job is next in line. Therefore, a CONWIP system also needs a **backlog** list of open jobs to be completed, ideally arranged by priority. Whenever a free CONWIP card comes, the next job in the backlog merges with the card and enters the system.

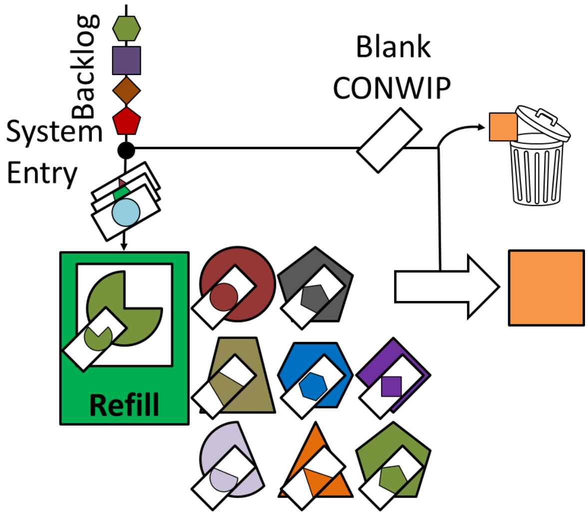


Figure 281: CONWIP system (Image Roser)

The advantage of the CONWIP system is that it can be used for low-volume, high-mix products. Hence, it is a system that is commonly used for made-to-order parts. It is possible but somewhat cumbersome to use it for high-volume, low-mix, as the backlog management becomes more complex. Hence, for made-to-stock products it is inferior to kanban. Luckily, kanban and CONWIP can be combined.

31.6 Kanban-CONWIP Mix

Due to its similarities, a kanban and a CONWIP system can easily be combined. You just have to take care on how to merge the kanban and CONWIP cards. There are different options. The easiest one is simply to have a joint queue (see Benefits and Flaws of CONWIP in Comparison to Kanban for more). However, you can also use a priority system. If you have less than 30% of the total workload as CONWIP, I recommend using a priority CONWIP lane, and, only if the CONWIP is empty, taking cards from the second-priority kanban lane. See my series on How to Prioritize Your Work Orders for more on prioritization.

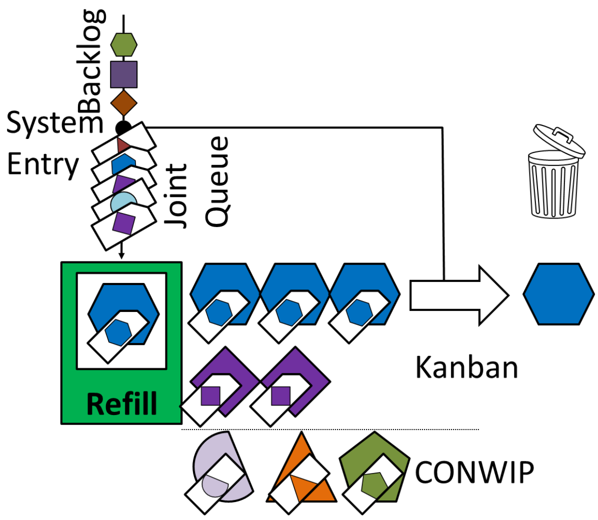


Figure 282: Kanban CONWIP Hybrid (Image Roser)

The obvious advantage of such a hybrid system is that it can handle both high-volume, low-mix (the kanban part) and low-volume, high-mix (the CONWIP part) – in other words, both made-to-stock and made-to-order parts.

In my next post I will discuss a few more, namely the triangle kanban, drum-buffer-rope, reorder point (surprise, yes, it is a pull system), reorder period (also a pull system), and FIFO lanes. Until then, stay tuned. Now, **go out and organize your industry!**

32 Different Ways to Establish a Pull System – Part 2

Christoph Roser, August 08, 2017, Original at https://www.allaboutlean.com/different-ways-to-pull-system-2/

Figure 283: Children Tug of War (Image Christian Schwier with permission)

This is the second post on different types of pull production. It features the less commonly known approaches of triangle kanban, drum-buffer-rope, reorder point (surprise, yes, it is a pull system), reorder period (also a pull system), and FIFO lanes. In my previous post I showed you the kanban system and its variant, the two-box system, as well as CONWIP and the kanban-CONWIP hybrid.

32.1 Triangle Kanban

Another variant of the kanban system is the triangle kanban. Instead of every part having a kanban card attached, only the last or second-to-last part in the pile has a kanban card attached. This is called a triangle kanban, since the card at Toyota was initially made from metal scrap and triangular. This triangle kanban gives the signal to reorder or reproduce multiple parts to refill the inventory. When the material arrives, the triangle card is then attached to the last or second-to-last part in the pile, and the process repeats. See Simple Triangle Kanban System for Office Supplies for more.

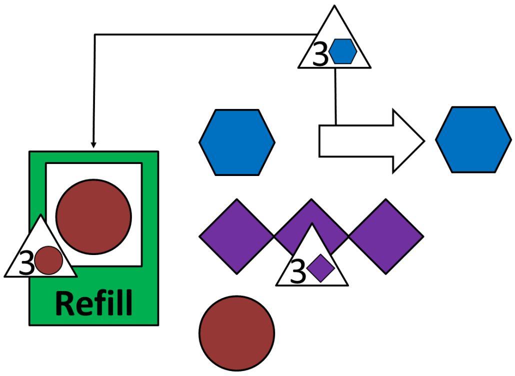


Figure 284: Triangle System (Image Roser)

A triangle kanban will order more parts in larger batches. Rather than one normal kanban per used part (or group of parts), you get one triangle kanban less frequently but with larger quantity. This goes against the basic idea of leveling (small quantities more frequently), but if there is little or no capacity constraint or if the unleveled ordering is not a problem, it can be done to reduce the effort on ordering.

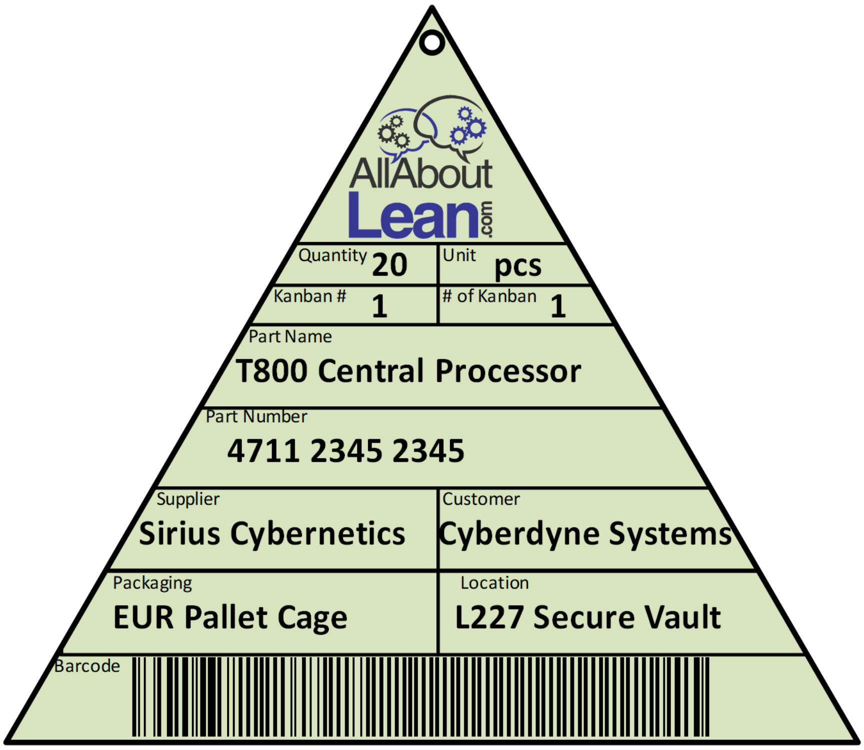


Figure 285: Example of a triangle kanban (Image Roser)

I have seen and used it frequently for office stationary supplies. You don't send out an order whenever someone takes a blue pen. Instead, when you open the last box of blue pens, you take the triangle kanban and reorder five more boxes of blue pens, which will last you for some time before you have to order again. There is also no problem when you, by coincidence, at the same time order five boxes each of blue, red, green, and black pens, as this "demand peak" won't overwhelm the capacity of the supplier to deliver.

32.2 Drum-Buffer-Rope

The drum-buffer-rope system was developed by Eliyahu Goldratt. It also is a pull system, but with some limitations. Goldratt is famous for his theory of constraints, and his drum-buffer-rope system is merely an extension to constantly provide the bottleneck with material. Hence he tries to manage the inventory in front of the bottleneck (or for a "*simplified drum-buffer-rope system,*" the bottleneck is automatically the customer, and the entire line is one big drum-buffer-rope loop).

It is probably most similar to CONWIP. Whenever a part is taken out of the inventory in front of the bottleneck, an information card (similar to a CONWIP card) goes back to the beginning of the line regarding the permission for the production of the next part.

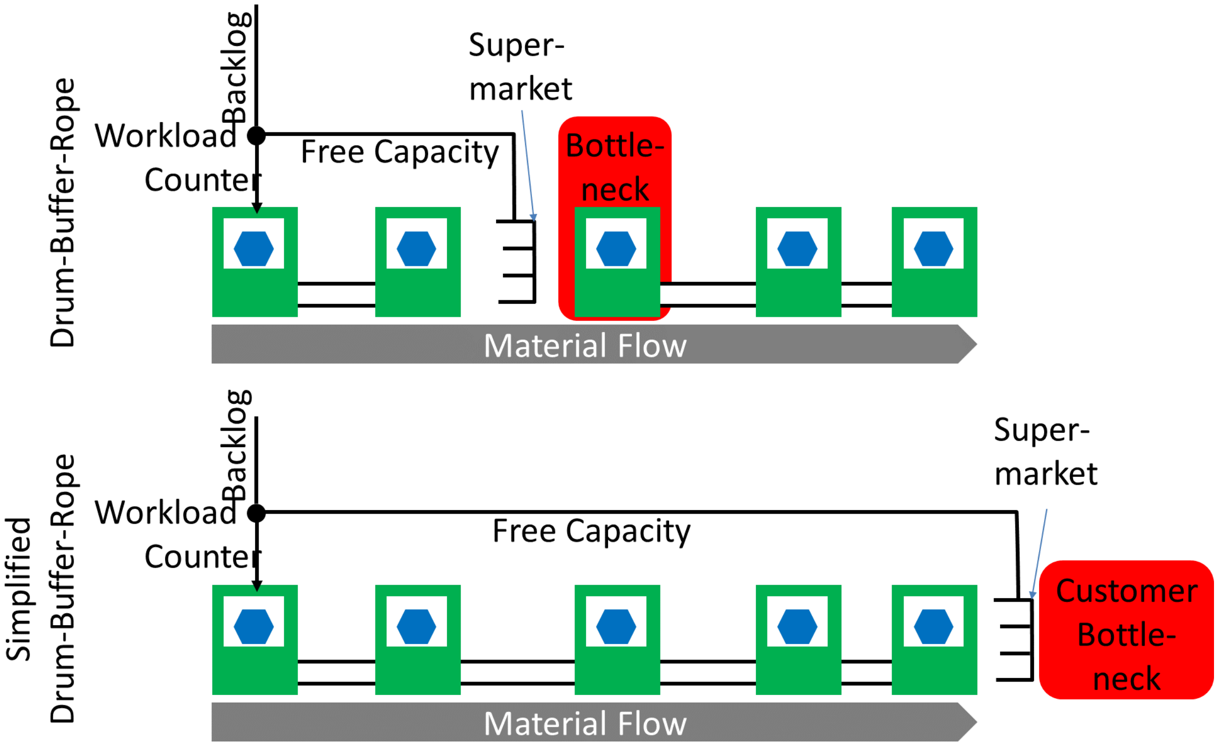


Figure 286: Drum Buffer Rope (Image Roser)

Besides the fixed location of the loop, the second main difference is that he does not count the parts (like kanban or CONWIP), but instead measures the workload. Rather than keeping the number of parts constant, drum-buffer-rope keeps the number of work hours in the system constant. This is beneficial if you have widely different workloads between different jobs (i.e., one order takes 1 hour, another 3 days to complete), but it is more effort. The effort may not be worth the benefit if your jobs are all of similar work content anyway. I wrote more about drum-buffer-rope in A Critical Look at Goldrath's Drum-Buffer-Rope Method.

Figure 287: A static bottleneck? (Image Nile in public domain)

While having similar features as CONWIP, it has one in my view major flaw: While managing the inventory in front of the bottleneck has marginal benefits, drum-buffer-rope assumes that the bottleneck does not move over time. However, it does, and frequently so (see About Shifting Bottlenecks). Hence, you have to set up your drum-buffer-rope system under an assumption that is simply not true in most cases.

32.3 Reorder Point

Yet another way to establish a pull system is a reorder point approach. Okay, now you may be surprised. You may have heard about reorder point before, but never in relation to lean manufacturing. Actually, it is not part of the lean toolset, but its effects make it practically a pull system.

The approach is simple. Whenever your inventory reaches a lower limit (the reorder point), you reorder to fill up the inventory again to the maximum. If your delivery time is zero, you could set the reorder point to zero parts too. However, since in most cases your delivery time is NOT zero, it would be wise to order more parts before you run out. Hence, in practical cases the reorder point is usually not zero.

Please note that the image below is simplified,as it does not include a reordering delay.

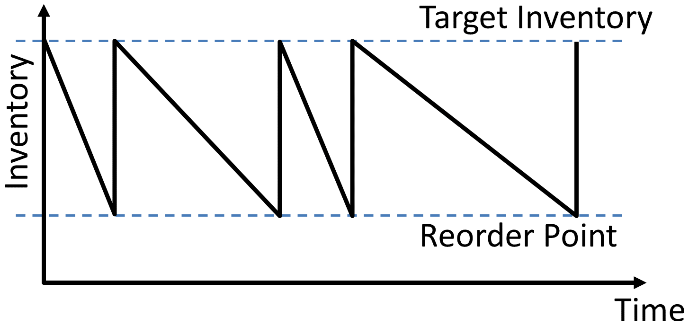


Figure 288: Reorder Point (Image Roser)

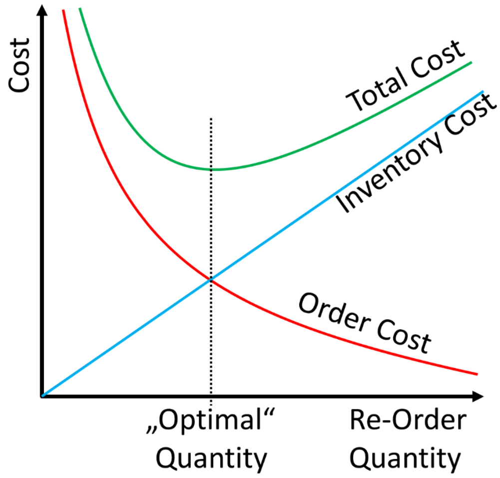


Figure 289: Optimal point … in theory … (Image Roser)

In economics this is often used together with economic order quantity, the quantity to order that supposedly gives you an optimal trade-off between order cost and inventory costs. However, in my experience these calculations usually include numerous assumptions, many of which are not true, and ignore other costs of inventories (see The Hidden and Not-So-Hidden Costs of Inventory). In effect, your supposedly optimal quantity will be too large. I personally avoid this economic order quantity approach and just go with as little inventory as I can get away with without breaking the system.

This system is very similar to a triangle kanban. You have less effort in ordering, but your orders come clumped together, which goes against the idea of leveling. It is doable if your supplier can handle your larger but less frequent orders. But, please note, just because your supplier can handle your order ups and downs doesn’t mean he can do it efficiently. Especially if you are a major customer of your supplier, you may cause your suppliers trouble, therefore you may cause your suppliers expenses, which he will probably forward to you in one way or another.

32.4 Reorder Periods

Similar to reorder points, it is possible to have reorder periods. With reorder points, you filled up your inventory to the upper limit when you reached a lower limit. With reorder periods, you do this every fixed time interval (e.g., every Friday you order to fill up your inventory). This makes ordering easier and more regular, but requires higher quantities of inventory to avoid a stock out. Otherwise it has the same disadvantages as the reorder point of clumping together your orders and going against the idea of leveling. Please note that the image below is simplified as it does not include a reordering delay.

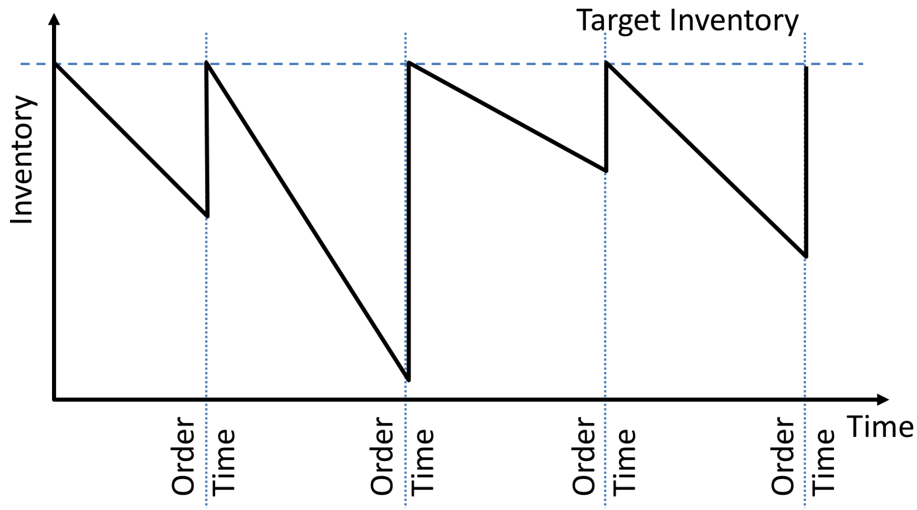


Figure 290: Reorder Period (Image Roser)

32.5 FIFO

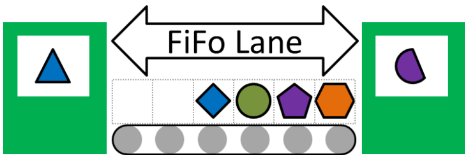


Figure 291: FIFO lane with different parts (Image Roser)

Yet another way to establish a rudimentary pull system is a FIFO lane. By default, a FIFO lane has an upper limit on the number of parts in the system, and hence it is a very rudimentary pull system.

However, it does need a system that supplies the first process with information on what to produce. Therefore, a FIFO on its own would work only if the system produces only one part type, and even then it is usually embedded in a larger system like kanban or CONWIP. Yet, within a larger control system it is an excellent way to even out the distribution of material between processes and to avoid getting a large pile of material in front of one bottleneck process. See Theory and Practice on FiFo Lanes – How Does FiFo Work in Lean Manufacturing? for more.

32.6 Others

In (academic) literature, you can find many more options for pull systems. And it is probably easy to come up with alternatives. For example, take the CONWIP system, but do not count jobs and instead measure the workload, as in a drum-buffer-rope system. Voila, your very own CONWIP-drum-buffer-rope hybrid. It will work, although I find the improvement marginal.

I am sure there are other methods out there that I have not yet heard of. Some of them may even work, but many others are academic ivory tower products and probably lacking practicality. I occasionally read about mixed pull-push systems, but I don't believe that. If you have the benefits of a pull system (i.e., limited inventory), you destroy it again if you introduce push-products. If some products do not have a limited inventory, then it is push for all, not pull. In any case, if I missed a pull system that you think works, let me know!

So, these eight systems are all I know to implement pull production. Surely, there must be one that works for you. Now, **go out, implement the pull system of your choice (since pull is really, really, good!), and organize your industry!**

33 Just in Sequence Part 1 – What Is It?

Christoph Roser, August 15, 2017, Original at https://www.allaboutlean.com/just-in-sequence-definition/

Figure 292: Ticket Dispenser (Image Richard Cote with permission)

"Just in Sequence" (JIS) is a good way to supply material to high-mix, low-volume production. It combines well with "Just in Time" (JIT) and "Ship to Line" (STL), but neither are a prerequisite for Just in Sequence. In this series of posts I would like to talk about what Just in Sequence is, how it works, and what to be aware of. This first post details the basics of Just in Sequence production.

33.1 What Is Just in Sequence?

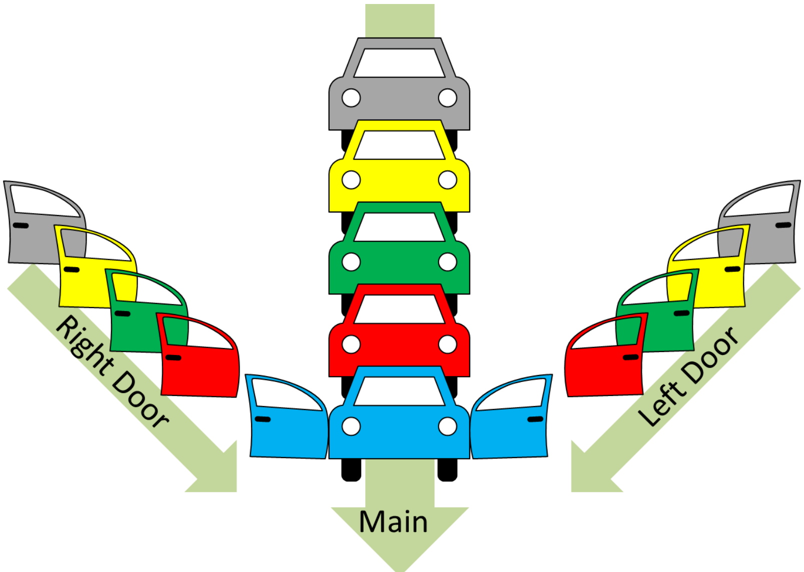


Figure 293: Just in Sequence Doors (Image Roser)

The basic idea is quite straightforward. Parts and components needed for production are delivered just in the sequence they are needed. Ideally, the person assembling the components does not have to choose from different parts, but merely picks the next part in the supply queue for assembly.

The prime example is (as often) in the automotive industry. Due to the large number of options in automotive, there is a low-volume, high-mix production where every car is different. Hence, the part type has to match the main product. This is commonly done for vehicle doors. Naturally, the color of the door has to match the color of the rest of the car. If the doors are supplied just in the right sequence, the worker simply has to mount the next door and everything will be fine.

You could in theory extend the sequence to sub-components. In other words, you have an initial sequence of the main car bodies, so you produce the doors just in sequence for the main body and then produce the door handles just in sequence to the doors that are in sequence to the main body. However, the longer such a sequence runs, the more complex it will be. Since Just in

Sequence is not easy to begin with, try to avoid this indirect sequencing until at least your direct sequencing runs reasonably trouble free.

On a side note, cars are usually painted together with their doors, but the doors are then removed again for ease of access for other assemblies. Only toward the end are the doors reinstalled. Hence, the doors in automotive merely have to maintain the sequence in which they are painted, which is together with the rest of the car body. Other examples of Just in Sequence are the seats, the dashboards, and many other parts of the car. In particular, the seats are often delivered from a nearby supplier just in sequence.

33.2 What Are the Alternatives?

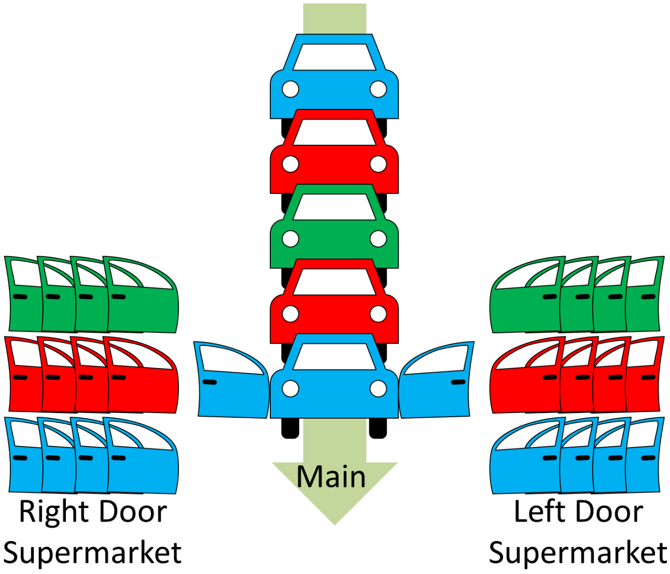


Figure 294: Door Assembly Supermarket (Image Roser)

There are two possible alternatives to Just in Sequence. You could use a supermarket instead of a just in sequence delivery. However, this would work only if you have a limited number of variants.

The more variants you have, the more cumbersome it will be to have them all in the supermarket. Take again the car doors. Sure, there are some standard colors that are common, but there are also lots of other rarer colors. You cannot keep all colors in stock in a supermarket. Hence, this option works only for a combination or small number of variants and small physical part size.

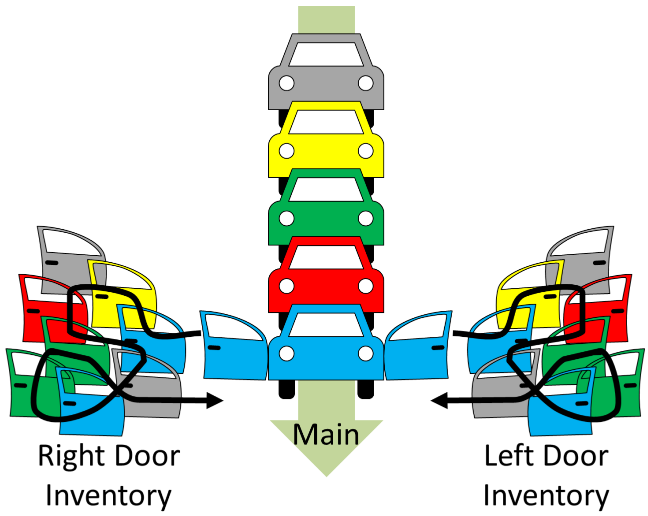


Figure 295: Door Assembly Inventory (Image Roser)

It is more common to have a larger (non-supermarket) inventory, and simply pick whatever part you need. This would work with both high-volume and low-volume components.

The inventory could have many parts of popular colors, and have the number of less popular colors that match the demand. On the downside, this approach may require quite a bit of walking and searching for the right part. But it works too.

33.3 Different Types of Just in Sequence

There are different ways to create a sequence.

33.3.1 Pick to Sequence

One option is pick to sequence. This is pretty much the same as the large inventory mentioned above. You have an inventory, and a worker (or a computer system) picks the required parts from the inventory and creates a sequence.

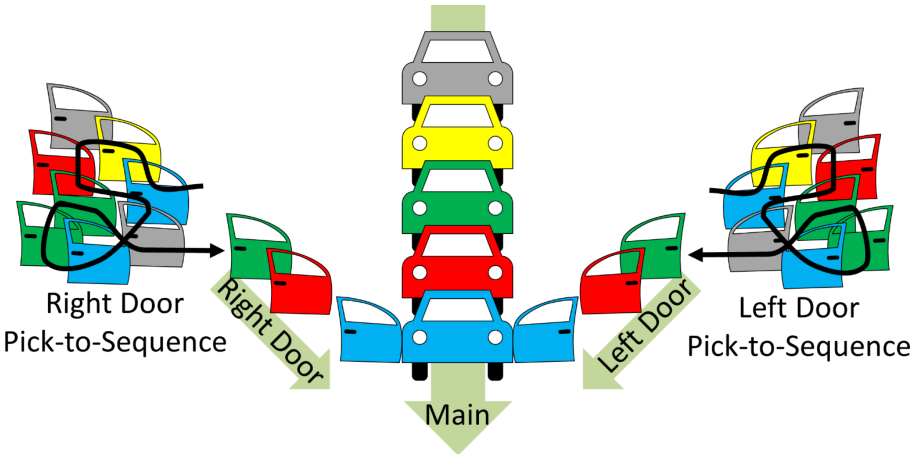


Figure 296: Pick to Sequence (Image Roser)

The worker (or computer) would need to know the sequence of production, and then simply select the matching parts for this sequence in the right order. Often, a small buffer is added between the picking and the actual assembly to reduce waiting times of both the pickers (if the main line is slower) and the main line (if the picker is slower). On the plus side, if you have the parts in the inventory, this approach is most flexible to adjust for short-term changes in the sequence.

33.3.2 Ship to Sequence and Receive to Sequence

It is also possible to have the products shipped in sequence. The supplier loads the part on the trucks in the right sequence, and drives the goods to the main line. There, the goods are unloaded and brought directly to the line, maintaining sequence all the way to the line.

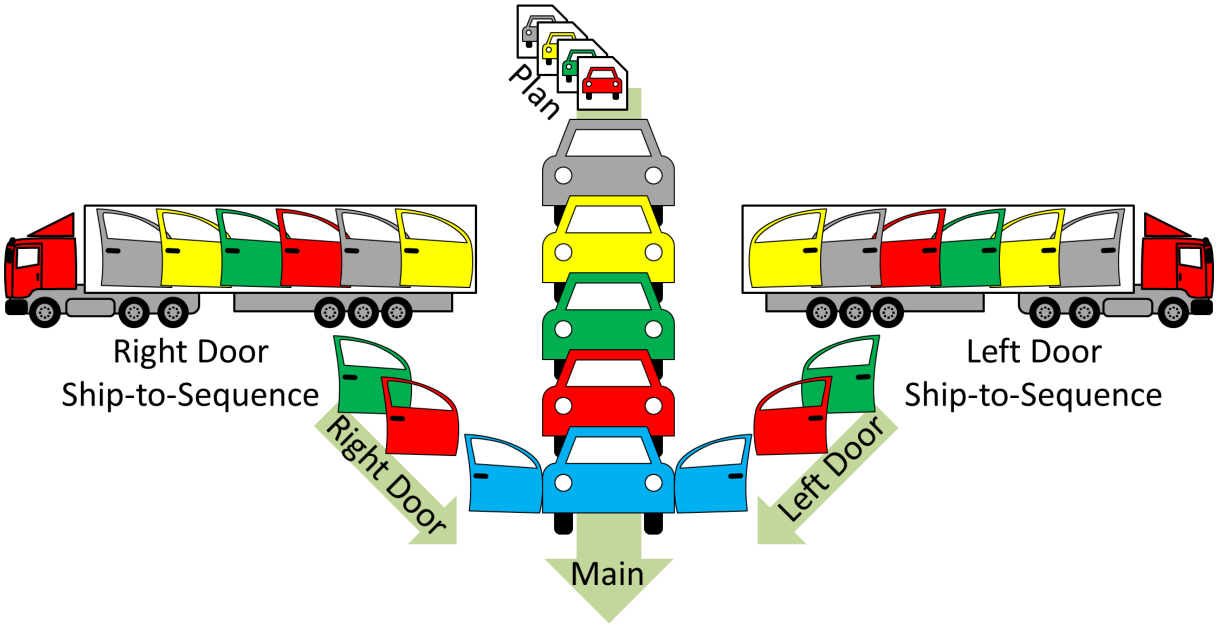


Figure 297: Ship to Sequence (Image Roser)

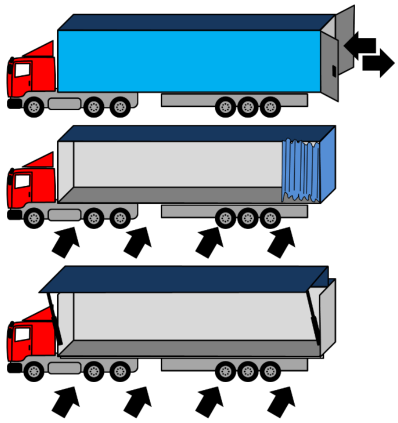


Figure 298: Different truck types: rear loading, side loading, and gullwing type (Image Roser)

Please note that depending on the truck type, you may have to load the truck in reverse order, so that the part needed last is loaded first and stored in the very back of the truck. This is easier if you load the truck from the side.

Toyota (and other manufacturers in Japan) usually does this for its Japanese plants, using trucks that with the flick of a switch can fold up an entire side of the truck, giving quick access to the entire inventory. These are called **gull wing trucks**, as they look like the wings of a gull when open. Since a lot of the structure is made from aluminum, they are usually a bit more expensive than normal trucks, but make unloading much faster and easier. The illustration shows a rear-loading truck, a side-loading curtain truck, and a side-loading truck where the entire side can flip open.

In all cases it is helpful if the parts that arrive are already in the packaging that is used within the plant. If you have to re-pack from, for example, standard pallets to blisters that are used at the line, you incur additional work that may not be needed.

33.3.3 Build to Sequence

Finally, there is Build to Sequence, also known as Make to Sequence, Assemble to Sequence, or Produce to Sequence. The preceding production processes produce parts exactly in the right sequence needed for the main line. This is regardless if the preceding process is right next to the line or if it is in another plant a few hours away. If it is on the other side of the earth, the effort may not be worth the benefits. You just have to maintain the sequence between the preceding production process and the use at the main line.

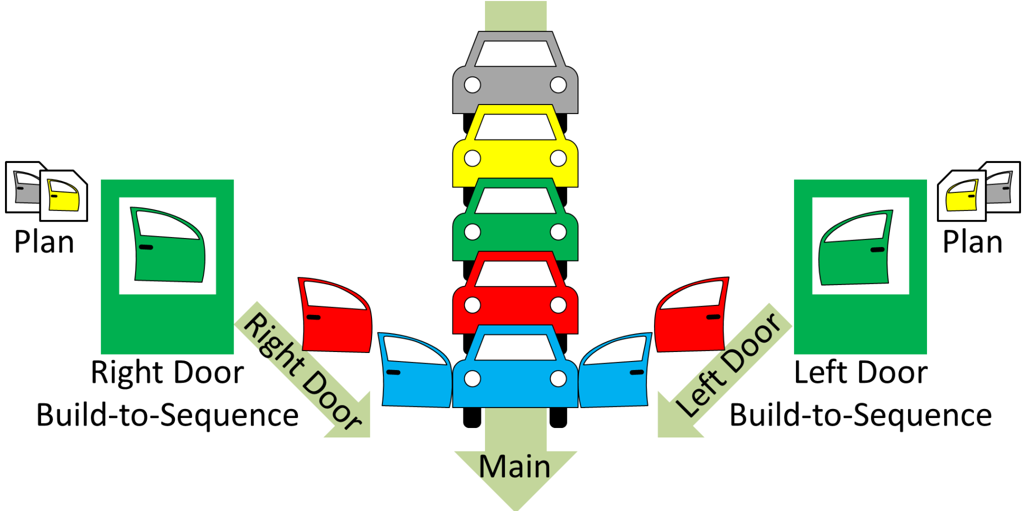


Figure 299: Build to Sequence (Image Roser)

33.4 What's the Benefit?

Figure 300: Where is my part? (Image WavebreakMediaMicro with permission)

If you check the Wikipedia article on Just in Sequence, they claim (at the time of writing, July 2017) that Just in Sequence helps you to reduce inventory. I respectfully disagree. You can keep a sequence even with loads of inventory; it will just be more difficult. Also, while Just in Sequence benefits from low inventories, it is not a primary cause of low inventories. Granted, you can reduce inventory a bit more, but this is a side effect of what I see as the main benefit.

In my view, the main benefit of Just in Sequence is a reduction on handling. From the point of the creation of the sequence, you (ideally) never ever have to search for the right part again; you merely have to take the next part in sequence. This has benefits if you build to sequence right from the preceding process, as the entire material flow in between could be a simple FIFO lane.

Even if you merely pick to sequence for the final assembly, it has the benefit of keeping different works separate. The worker at the assembly line should assemble, not look for parts. By having another worker look for the parts (the picking process), both can work more efficiently.

Overall, Just in Sequence reduces the time needed to rearrange and coordinate material. The further back in the supply chain you can maintain a sequence, the more you can reduce searching and rearranging along the entire material stream. This reduced handling time as a side effect allows for a further reduction of material that is needed to cover this (now avoided) handling time.

I hope this introduction to Just in Sequence was helpful. In subsequent posts I will discuss more details on how and when to sequence, as well as how to deal with problems in the sequence. Until then, stay tuned, go out, and organize your industry!

34 Just in Sequence Part 2 – How to Do It

Christoph Roser, August 22, 2017, Original at [*https://www.allaboutlean.com/just-in-sequence-how-to/*](https://www.allaboutlean.com/just-in-sequence-how-to/)

Figure 301: Waiting Room Ticket (Image damyz with permission)

In this second post on Just in Sequence, I would like to talk about some details on the actual sequencing of parts: when to use Just in Sequence in the first place, which parts to sequence, and how to define the sequence. These are all organizational details to make Just in Sequence work. In my next and last post of this series, I will describe how to handle problems with parts being out of sequence.

34.1 Prerequisites for Just in Sequence

34.1.1 Maintain Your Production Sequence!

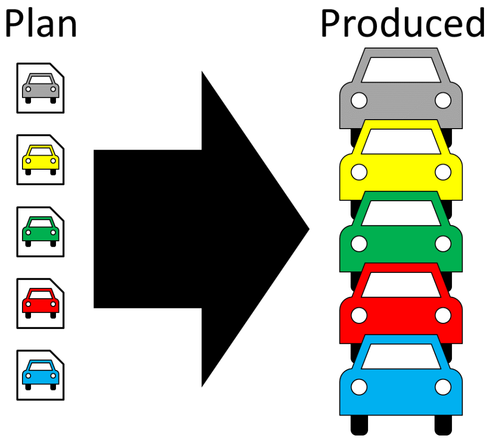


Figure 302: Just in Sequence Plan vs. Production (Image Roser)

For Just in Sequence to work, there are a few prerequisites. Most importantly, **you need to be able to define a sequence and stick with it.** Particular emphasis on "**stick with it**"! Pretty much all plants define a production sequence, but most plants I know won't be able to produce tomorrow without fail what they plan today. The more "hiccups" you have in your main production sequence, the more you have to scramble around to adjust the sequences of the depending parts. If 20% of your original sequence changes even a little bit, then the resulting scrambling around may not be worth the benefits of Just in Sequence.

On a side note, this in almost all cases means flow production rather than job shops. Since job shops are hell to manage anyway, you probably can forget about any sequence you would like to have at a process. For completeness' sake, it may work again for project shops like shipbuilding of large vessels, where all material has to go to one single construction site. Yet, since shipbuilding of large vessels usually is highly customized, it may or may not be worth the effort to create a Just in Sequence supply.

34.1.2 Assembly Process

Figure 303: Hyundai moving walkable platform assembly line (Image Carol M. Highsmith in public domain)

Just in Sequence is sequencing at least one other part to the sequence of a primary component. As such, you need at least two parts that are merged (i.e., you need an assembly process). If you are merely milling and shaping a part without attaching anything else, then you don't need and can't even do Just in Sequence.

34.1.3 Already Have a Lean Supply Chain

If you build your sequence very close to the main line (point of consumption), then your main sequence needs to be stable only for a short time. This would be the first example in the image below. The farther away you get, the longer you need to keep your sequence stable. This is directly related to the number of parts in the sequence. The more parts you have "in sequence" between the creation of the sequence and the consumption, the longer ahead you need to fix your sequence.

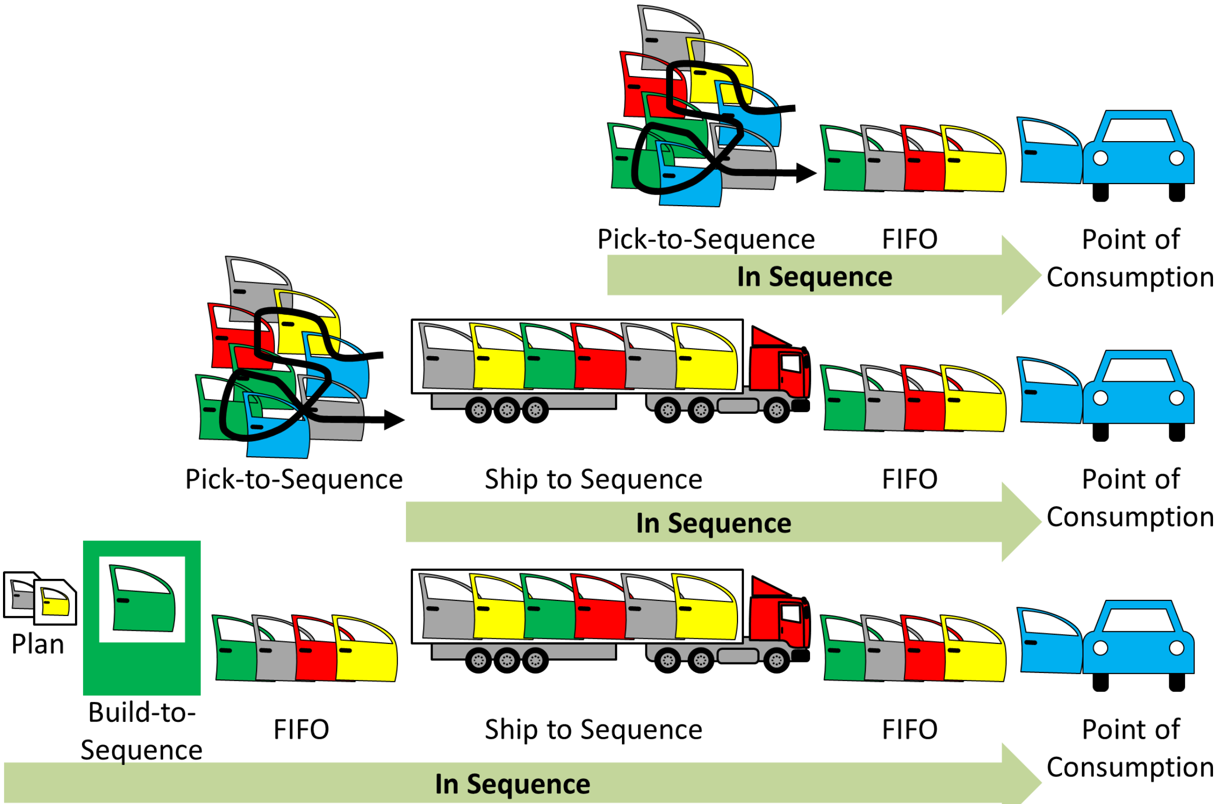


Figure 304: Just in Sequence Sequence Length (Image Roser)

For example, if you pick directly at the line, and do so around 30 minutes before the part is consumed, then your sequence needs to be unchanged for only 30 minutes. If, however, you produce in sequence a 4-hour drive away and need to plan this 6 hours before the parts are consumed, then your line needs to be stable for six hours. Don't forget that the production needs some time to prepare and schedule too!

If you are in a typical plant with 2 weeks' worth of inbound inventory, try to get your suppliers to not produce just in sequence, since you will never be able to hold the sequence for 2 weeks anyway! Hence, Just in Sequence benefits strongly from a lean supply chain, and therefore it benefits enormously from Just in Time and Ship to Line. If your supply line is clogged with weeks' worth of inventory, create sequences only very close to the point of consumption (e.g., pick to sequence or build to sequence if machines are nearby). In sum, **the longer the lead time from the sequence generation to the point of consumption, the longer you need to maintain sequence and the more difficult it will be.**

34.1.4 Small Lot Sizes

Figure 305: Quite a lot… (Image otsphoto with permission)

Strictly speaking, this is not a prerequisite but a factor that makes Just in Sequence worthwhile or not. If you have large lot sizes (e.g., building 400 red cars in sequence), of course you could prepare 400 red doors in sequence from the supplier. You would reduce handling and organizational effort in the value stream.

However, these doors are now organized and searched not individually but in batches of 500. Hence, instead of searching a door 500 times, you search 500 doors once. You still get a small benefit (of not searching 500 doors once), but it may or may not be worth the effort of Just in Sequence.

34.1.5 Low Defect and Rework Rates

Figure 306: Broken chain (Image Cigdem with permission)

For Just in Sequence to work, you would need to have low defect rates for the sequenced products and the main product. The more parts you need to rework, the more parts you may have to take out of the line or sequence, which will mess up your sequence. In fact, reworks of car bodies are one of the main reasons for sequencing problems in automotive.

34.2 What Parts to Sequence?

Your product is probably made from hundreds, if not thousands of parts. Theoretically, you could sequence them all. Practically, this will be a nightmare! If only one part of your hundreds of parts is out of order, your complete sequence for all other parts is shot to shreds. The much, MUCH better way is to sequence only a few parts. But which ones?

Figure 307: Car Seat Assembly (Image Ford Motor Co under the CC-BY-SA 2.0 license)

Sequencing is good for parts that are unique or nearly so. Any component that has a large number of variants could be a candidate for sequencing. Examples in automotive industry often include car doors (splitting off from the car after painting and maintaining sequence until reassembly, door components, and seats [often external suppliers], and wire harnesses [a surprisingly complex product for "just being a bunch of cables"]).

Vice versa, if you have parts that you use in large quantities, they benefit little from sequencing. Often, in this case the effort of Just in Sequence is not worth the benefit.

Just in Sequence can reduce the effort to find the matching part. This suggests high-variety parts. Additionally, this also suggests larger parts. Finding the matching seat out of a inventory of 20 seats takes longer than finding the matching plug out of 20 electric plugs.

Hence, while Just in Sequence is theoretically possible for all parts, you should start with the large, high-variety parts. Prioritize these based on the potential benefits and pick the part that benefits most from sequencing. Once you have successfully established just in sequence for one part, you can move to the next part (and we are talking not days but rather weeks and months until your sequence is stable and you can go to the next part).

The more parts you have sequenced, the more trouble you will have in correcting mistakes (see my next post). Hence, at one point the benefit of providing more parts just in sequence will no longer be worth the effort to sequence many different part groups due to the increasing effort to correct sequencing if things go wrong. That is, until you reduce such events of mis-sequence even more than before.

34.3 What Defines the Sequence?

Figure 308: Assembly Line (Image Siyuwj under the CC-BY-SA 3.0 license)

Just in Sequence always needs at least two components whose sequences match. You could, for example, coordinate the sequences of the trunk of the car and the body of the car (I would have used the door example again, but most cars have at least two doors, and here I would like to explain the minimum).

Now you have two options: Do you initially plan the sequence of the trunks and arrange the sequence of the bodies to match, or do you initially plan the sequence of the bodies and then arrange the sequence of the trunks to match? In this case it is easy. Since the car body is the larger component, it is more difficult to switch around and match its sequence to the trunk. Instead, most companies choose to initially plan the sequence of the car body, and then match the sequence of selected other products to the car body.

In fact, in most cases where you could use Just in Sequence, there is a main product that naturally defines the sequence, and then other smaller components that match the sequence of the main product.The sequence of the main product needs to be known beforehand. This main sequence can be defined any way you like (i.e., by customer priority, or to optimize changeovers, or to balance out the workload, etc.).

Nevertheless, for the off chance that your product does not have a main component, ask yourself what part defines the sequence and what other parts follow the sequence. In most cases the answer should be easy, but don't skip this question.

I hope this details on how to create Just in Sequence was helpful. In my last post I will discuss how to deal with problems in the sequence. Until then, stay tuned, go out, and organize your industry!

35 Just in Sequence Part 3 – What Can Go Wrong

Christoph Roser, August 29, 2017, Original at
https://www.allaboutlean.com/just-in-sequence-problems/

Figure 309: Pulling waiting ticket (Image Christopher R. Morales in public domain)

This third and last post on Just in Sequence details all the things that can go wrong, and talks about how to fix them. The biggest problem is if the sequence of your Just in Sequence part does not match the main component that it should be sequenced to. This happens especially due to defects and rework. I also describe common options to deal with these problems – but be warned: all of them suck. As usual in lean, it is so much easier not to have problems in the first place than it is to deal with them afterward.

35.1 Don't Break Sequence

One thing you have to watch out for in sequencing is that **you need to maintain sequence from the point where you create the sequence until the point of consumption.** If you break the sequence anywhere in between, then your effort is wasted and you have to pick the sequence again. This means that the entire material flow from the creation of the sequence has to be one big FIFO lane. In fact, FIFO is pretty much the only good way to store material for Just in Sequence. Don't use supermarkets or random inventory, as they will break the sequence again.

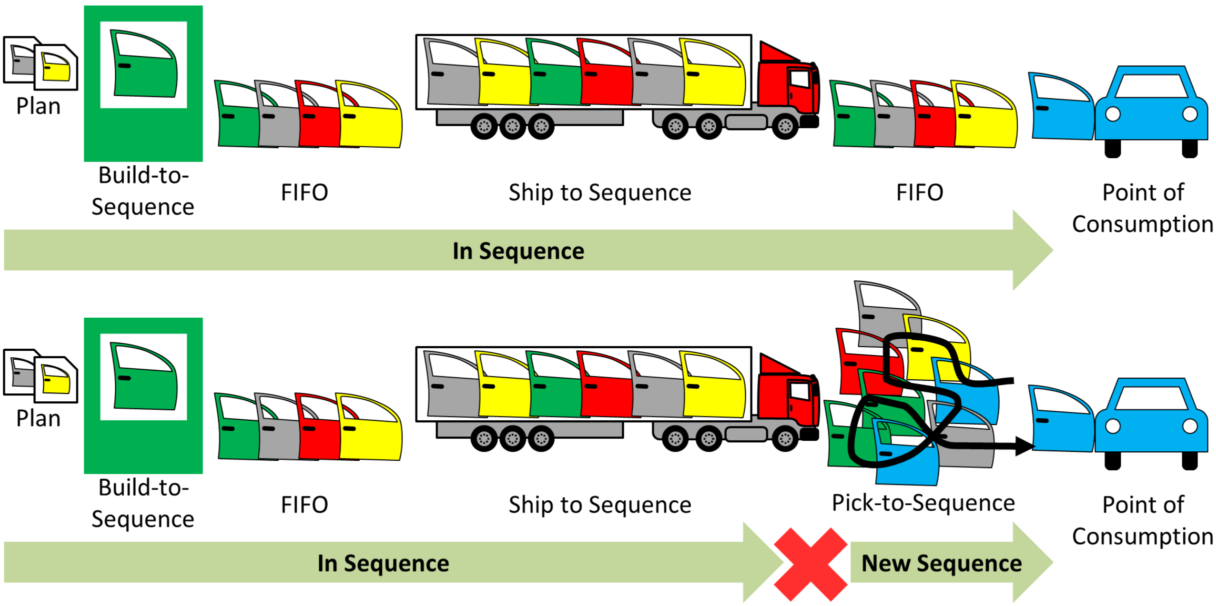


Figure 310: Just in Sequence Keep and Break Sequence (Image Roser)

35.2 Causes of Sequence Differences

Like anywhere, mistakes do happen. At one point you will find that the sequence of the component will no longer match the sequence of the main product. There are a few main causes of such a mismatch.

35.2.1 Wrong Part Sequenced

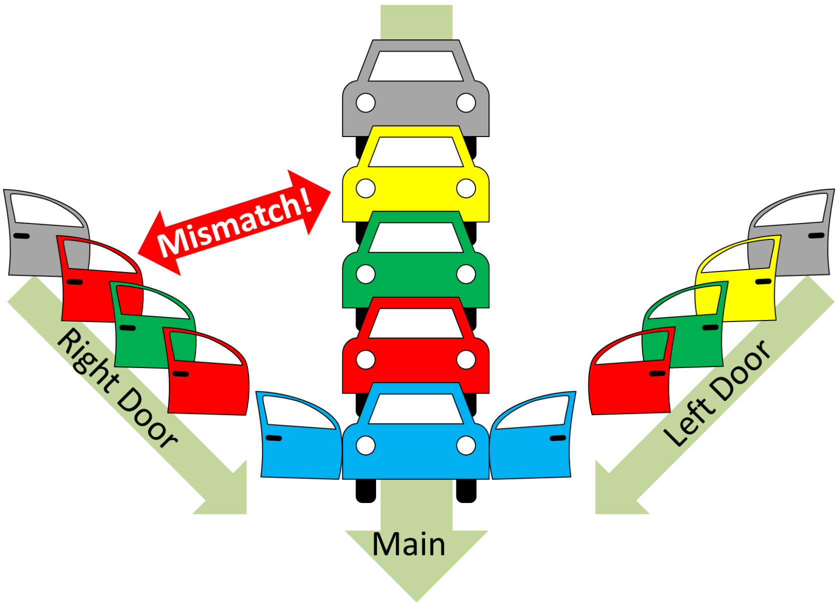


Figure 311: Just in Sequence Mismatch (Image Roser)

Less commonly, there is a mistake when creating the sequence. The image illustrates this by showing a red door for a yellow car. When creating the sequence, they picked/produced/delivered a red door where they needed to provide a yellow door.

35.2.2 Part Removed for Rework/Defect

More commonly, however, a part is taken out of the line due to defect or rework. This can happen for either the sub-component or the main component. As a result, the sequence of the other products is now out of line. Less commonly, there is a mistake in the sequence.

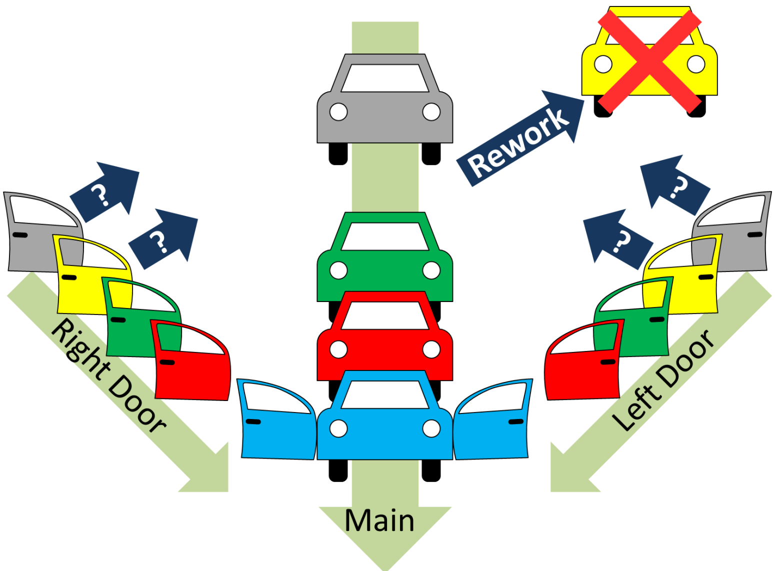


Figure 312: Just in Sequence and Rework (Image Roser)

Take, for example, this image. Assume the yellow car had a problem and had to be taken out of the line. Now, the sequence of the doors (and any other products in sequence) no longer fits.

The yellow doors have no matching car, and if you just follow the procedure, the next gray car will have yellow doors, whereas the gray doors intended for that car will be with whatever color the car has after the gray one.

35.2.3 Part Missing

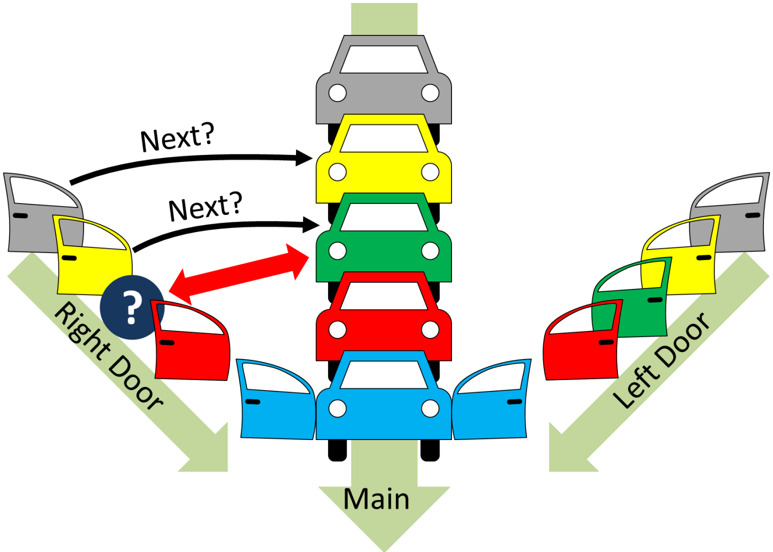


Figure 313: Just in Sequence missing part (Image Roser)

Yet another cause for a sequence mismatch is a missing part. This is particularly dangerous, because **if you do not catch that in time, all subsequent products will have a wrong part installed!**

In the example here, the green right door is missing. If that is not detected in time, the green car will get the next door in line, which happens to be yellow. The yellow car for which the door was intended will get the next door, which happens to be gray, and so on. Every subsequent car will have the wrong door until the problem is corrected.

35.3 What to Do with Sequence Differences

To remedy these sequencing issues, you have a number of options. All of them suck.

35.3.1 Replace Wrong Part

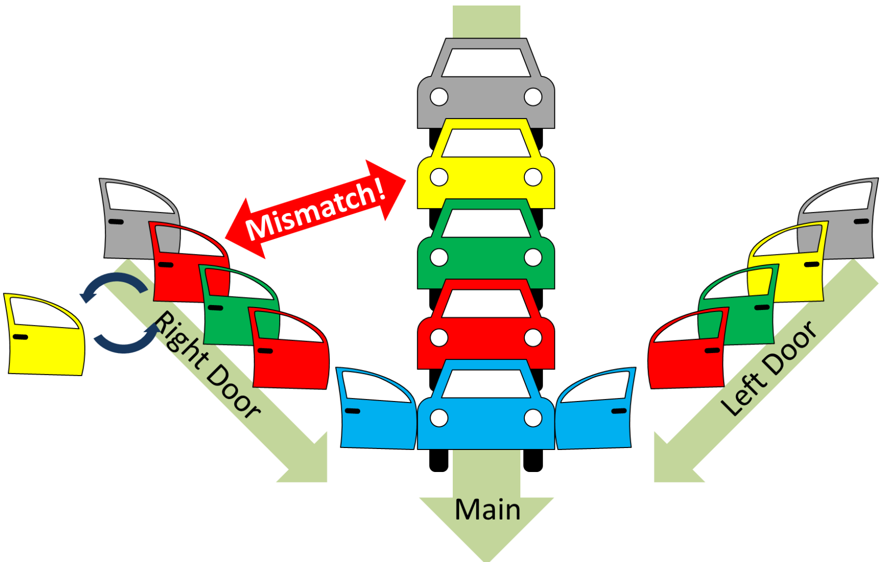


Figure 314: Just in Sequence Swap Parts (Image Roser)

Option one is to replace the one part that is wrong. For the two examples above, you could take out the red right door and add a yellow right door, or you could substitute another yellow car body for the one taken out for rework.

The problem is: Where do you get a right yellow door (or a yellow car body) on short notice? In all likelihood you won't have this part available, so this is usually not an option. Even if you have the part, it may be difficult to "pop it in" the line. How do you move a car body in and out of an assembly line except at its beginning and end? However, if you happen to have the part available, this may be the easiest option.

35.3.2 Remove All Parts in Wrong Sequence

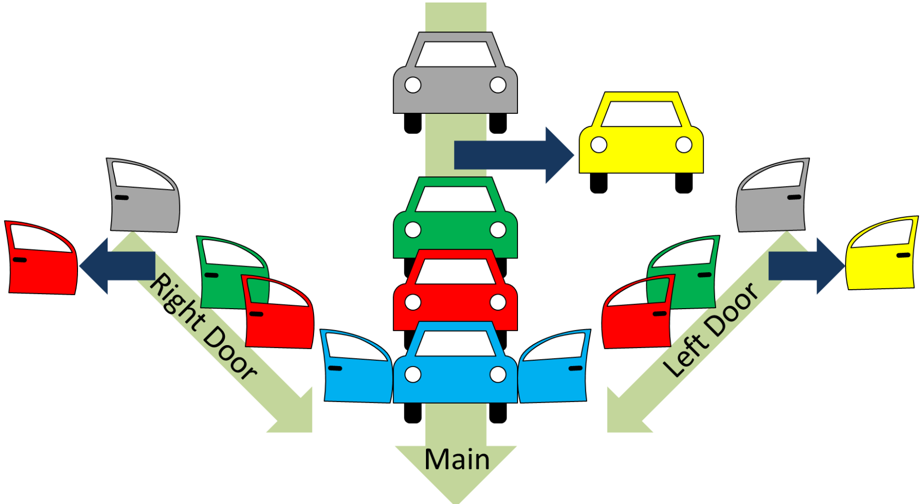


Figure 315: Just in Sequence Remove Parts (Image Roser)

The second option is to take out all parts related to the sequence difference. For the example above, you would remove the yellow car body and the yellow left door (all in correct sequence) as well as the mismatched right red door.

In effect, an entire product with its sequenced components is taken out of the line. Naturally, the more parts you have sequenced, the more hassle this is (think seats, dashboard, steering wheel, etc). And again, it may not be easy to remove these parts from the line. For example, to remove the main body, you probably would have to halt the main assembly line, idling hundreds of workers for 10 minutes at a cost possibly exceeding the value of the car in the first place. Usually not really a good option. And keep in mind, you not only have to do this physically, but also in your computer system! Any error, and you will just have produced even more mismatches for the near future.

35.3.3 Just Build It As Is

Figure 316: Bad sequencing … or bad design? (Image Analogue Kid under the CC-BY-SA 3.0 license)

The next option is to just build it as is. No matter what comes down the line, you build it. If you happen to have a red door for a yellow car, then by all means assemble the red door to the yellow car. This is the least disruption for the assembly process.

Obviously, you can't sell that to the customer. Instead, you have to fix the product afterward during rework. This means taking the product aside, obtaining a matching new part (i.e., a yellow right door), removing the mismatched part (the red right door), and attaching the yellow door. This is obviously not good for the doors or the cars. If it is a product deeper inside of the car, you may have to remove many other parts to get to it (e.g., you may have to remove the doors and seats to replace the dashboard). Again, a major hassle, but for many automotive companies that is the option they go for.

Of course, this works only if there is "only" a wrong part somewhere in the sequence. If a part is **completely missing** in the sequence, then all subsequent parts move one slot forward, and hence all products after the missing parts have a mismatch and would need rework.

35.3.4 Keep Things on the Line, But Don't Assemble

Figure 317: There was a sequencing issue … (Image Taco Ekkel under the CC-BY-SA 2.0 license)

A final option is to keep all parts in the line, but don't assemble mismatched parts. For example, the yellow car in the examples above would move along the line and get its yellow left door attached but not the erroneous right red door. The red door is put aside and you have a car moving along the line missing a door. Later, a correct door is installed during rework.

This sounds easiest, but it also has its problems. Any other part attached to this "non-attached" part has to remain unattached. There are a number of problems with this.

First, it confuses the people on the assembly line. If you job is it to attach door handles to the doors, and a car comes along without doors, then it will be confusing and break your rhythm (if it happens so often that you are used to it, then that is not good either 😜).

Second, you also have the problem of what to do with the parts at hand. Eventually they have to go to the rework area and find their matching car again. Hence, you have to create a separate material flow on the fly for just this one car. Since there is probably no standard for it, it depends on the worker's ability if this handling of the unused part works well or not. The worker has to find a place for the part(s), inform someone from logistics, who has to bring it to the rework area, find the matching car, and find a place to store it there. What could go wrong?

Finally, you need to keep track of what has been assembled and what is missing. For rework, you need to obtain all the missing parts (which you hopefully somehow got from the worker that had it in excess). There is also the risk of forgetting something, resulting in a potentially incomplete car being shipped to the customer. Overall, it is a possibility, but it also sucks. Often, the "just build it as is" could be the best option. Of course, not making any mistakes in the first place would be even better.

This concludes this three-post series on Just in Sequence. As all so often, I wanted to write a brief one-post article on Just in Sequence, but with all the details involved I ended up again with a three-post series and over 4,000 words. Thanks for staying with me in this lengthy process. Now, go out, see if your plant is suitable for sequencing, if so do it, and organize your industry!

36 Happy 4th Birthday AllAboutLean.com

Christoph Roser, September 01, 2017, Original at https://www.allaboutlean.com/4th-birthday/

Figure 318: 4th Birthday (Image Gvictoria with permission)

Aaaand another year is over. AllAboutLean is now a whopping four years old. Since I started on September 1, 2013, I've managed to write 213 posts on lean manufacturing, and my glossary now contains 375 terms related to lean manufacturing. Time to celebrate and to look back.

36.1 Ten Most Popular Posts

Figure 319: Top 10 (Image Roser)

Here are the ten most clicked posts in the last twelve months. All of them describe elements from the lean toolbox that help you to improve your production system.

- 10. Line Layout Strategies – Part 2: I-, U-, S-, and L-Lines 4,899 Clicks
- 9. Evolution of Toyota Assembly Line Layout – A Visit to the Motomachi Plant 4,933 Clicks
- 8. Ten Rules When to Use a FIFO, When a Supermarket – Introduction 5,134 Clicks
- 7. The Key to Lean – Plan, Do, Check, Act! 5,523 Clicks
- 6. Theory of Every Part Every Interval (EPEI) Leveling & Heijunka 6,092 Clicks
- 5. All About Swim Lane Diagrams 6,931 Clicks
- 4. Overview of Value Stream Mapping Symbols 7,994 Clicks
- 3. How to Measure Cycle Times – Part 1 9,525 Clicks
- 2. How Many Kanbans? – The Kanban Formula, Part 1 10,426 Clicks
- 1. The (True) Difference Between Push and Pull 22,106 Clicks

36.2 Recognition

Figure 320: First Place Ribbon (Image Ruby.W. under the CC-BY-SA 2.0 license)

It seems AllAboutLean.com is spreading, and I have received a few awards and top rankings. Here are the lists and prizes that I know of.

Additionally, many other bloggers have translated my posts into other languages, like Czech, Spanish, Russian, Chinese, and Arabic. For me, this is also a compliment! (Still, if you want to translate, please ask me for permission beforehand).

36.2.1 BTOES Insights: Top 10 (Top 1) Operational Excellence Blog

BTOES insights

Figure 321: BTOES Insights (Image BTOES Insights for editorial use)

The people from BTOES Insights made a survey of their readers for the best blogs on operational excellence. Out of over 100 blogs, AllAboutLean.com made it not only into their lists of Top 10 OpEx Blogs, but **they told me that my blog was the #1 Blog** according to the preference of their readers 🙂 ! Many thanks to BTOES insight for the honors!

36.2.2 Curious Cat: Top 10 Out of 48 Management Blogs

Curious Cat

Figure 322: Curious Cat (Image Curious Cat for editorial use)

The highly influential blog and website Curious Cat by John Hunter maintains a list of Curious Cat Top Management Improvement Blogs. This ranking is based on different metrics like MOZ page authority and page rank, traffic rank, number of subscribers, and so on. I am immensely thrilled that **AllAboutLean.com ranks number 10 out of 48** on this list, right after such long-established and respected blogs like the Curious Cat, the Deming Institute Blog, and Mark Graban's Lean Blog. Many thanks to John for the compliments 🙂 (when John told me about the list initially, I ranked #4, but since have fallen back a few notches; I will redouble my efforts to move up again 🙂).

36.3 Feedback

Many of you were also nice enough to leave comments and give feedback. The #1 commented-on post by the way was When to Do Value Stream Maps (and When Not!), followed by The (True) Difference Between Push and Pull. Many thanks for the input.

I also received praise for my website. Here are a few selected comments – again, many thanks to the commenters 🙂.

- I discovered your website through a simple Google search and bookmarked it later that day. I cannot express how helpful your posts are to my everyday duties and how much I refer to your real-world expertise when planning changes to make our manufacturing process more Lean & efficient. Thank yo for all you do! (By email from *J. F.)*
- Brilliant and enjoyable website. Thanks. (Comment by Ernst Swanepoel on my post The Tale of Taylor and Gilbreth)
- Great overview, Christoph! Thank you. Nice example of historical visual management. (Comment by Greg McCarthy on my post on Visual Management)
- Thanks, Christoph, for explaining clearly and giving lots of examples so it is easier to understand. (Comment by Wilson Sitanggang on my post on Visual Management)

36.4 Translations

You may have noticed that I recently added the "Google Translate" button on the upper right of the webpage (or very bottom for mobiles). Of course, Google Translate is still rather flawed. Therefore I am happy to tell you that people all over the world have asked me for permission to translate my work into other languages.

Figure 323: Průmyslového Inženýrství Logo (Image Průmyslového Inženýrství for editorial use)

I would like to point out especially the Czech lean blog Průmyslového Inženýrství (which means Industrial Engineering). They aim to bring lean to the Czech-speaking world and have translated with permission quite a few posts from my blog, as well as other famous lean blogs.

Omar Carrera translated my series on Employee Motivation and Lean Implementation from English into Spanish on LinkedIn: here's Part 1, Part 2, Part 3, and Part 4.

Valery Kazarin also translated some of my posts into Russian on his site WKazarin.ru about lean production and continuous improvements.

By the way, if you would like to translate my work, there are a few requirements (e.g., back-linking and acknowledging me), but usually I am pretty open to such requests. But please, do ask for permission first 🙂.

Overall, it was a fun year, I learned a lot writing my blog, and I gained lots of good contacts all over the world (and even a few consulting leads 🙂). So, dear readers, keep on reading, let me know what you like (and what not), and most of all, go out and organize your industry!

37 Ship to Line

Christoph Roser, September 12, 2017, Original at https://www.allaboutlean.com/ship-to-line/

Figure 324: Pizza Delivery (Image nullplus with permission)

Ship to Line (STL) is yet another technique in lean to optimize your material flow. The idea's gist is that instead of bringing material to the warehouse, you deliver it directly to the line or to the point of consumption. Like a freshly delivered pizza, you don't put it on the shelf and eat it two days later. However, for Ship to Line to work, there are a few things to be aware of and to take care of. Let me explain:

37.1 The Conventional Approach

The conventional not-ship-to-line approach is for arriving material to be stored in a warehouse until it is needed for production. When needed, it is taken out of the warehouse again and brought to a usually much smaller inventory next to the production processes.

Figure 325: NOT ship to line (Image Roser)

As you can easily see, the material is handled at least twice, once when it is stored in the warehouse and once when it is moved to the actual process. In reality, for organizational reasons, there are often even more handling steps included (e.g., unloading of the truck into a buffer space, and moving it from the buffer to the warehouse, then from the warehouse to a buffer again and finally to the process).

37.2 Ship to Line

Ship to Line aims to reduce these steps. Rather than storing the material in a warehouse, the material is brought directly to the point of consumption (the process) and used. Hence, one of the advantages is less material handling, which frees up worker capacity for other tasks.

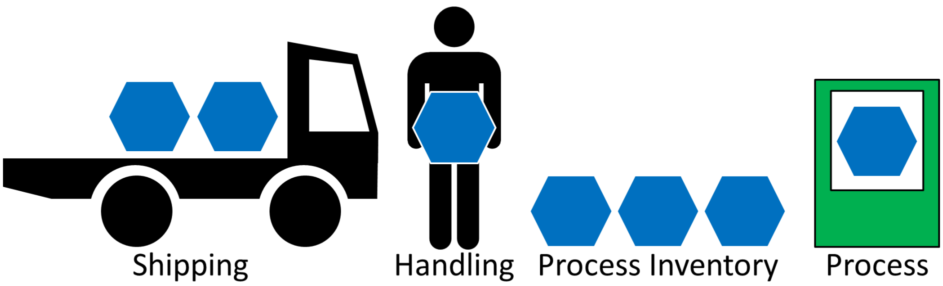


Figure 326: Ship to Line Illustration (Image Roser)

The above image is a slight simplification. The "handling" above consists of different steps. The process starts with a truck of material arriving. This truck is unloaded. When unloaded, the material is usually put in a short-term storage area. At Toyota, the unloaded material is put on a small carriage that is moved to this short-term storage area.

At this short-term storage area, rather than moving the material to the warehouse, the material supply for the processes takes the material. At Toyota this is done using small electric trailer. The worker creates a small train with matching material in the right sequence, and then uses this trailer to pull the carriages to the processes. There the material is unloaded and stored directly at the process.

37.3 Prerequisite: Low Inventory

For Ship to Line to work, there are a few requirements. **The biggest and most important requirement is a lean and low inventory.** All the material that arrives has to be stored very close to the process. Yet, space at or around your processes is always in short supply. The closer you can move your processes together, the more efficient your production will be. Processes that are close to each other require less transport, less walking, and have a much faster information flow, especially in case of problems. Hence, there is always a shortage of storage space at the processes, as this floor space comes at a hefty premium in efficiency. This limitation in floor space causes almost all the other requirements on Ship to Line.

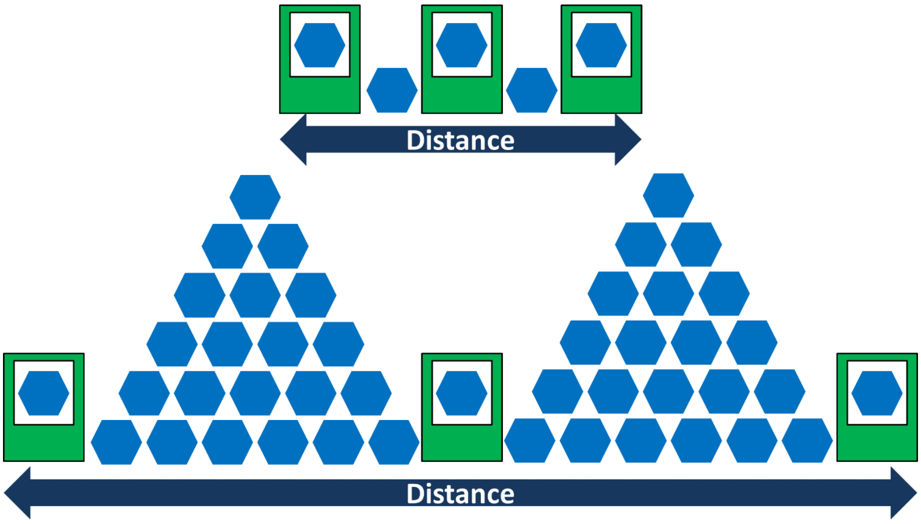


Figure 327: Material and Process Distance (Image Roser)

Subsequently, Ship to Line requires very small inventories. Any non-lean plant that has two weeks' worth of inventory will be unable to store all the inventory at the line directly. At Toyota, they have very few hours' worth of inventory, which they can store at the line directly.

This low inventory causes most of the other requirements. You need **more frequent but smaller deliveries**. If you get a big truck once per week, you cannot store it at the line. Instead, you need a smaller truck more frequently to make Ship to Line work. With so little inventory, it has to arrive only when it is needed.

Figure 328: Relay Race Hand Over (Image tableatny under the CC-BY-SA 2.0 license)

Hence, **Just in Time is a big prerequisite for Ship to Line**. In fact, if you don't have a (good and working) Just in Time approach, you should not be thinking about Ship to Line (unless you have extremely small parts where even two weeks' worth of inventory does not use much space). For more on Just in Time (or JIT), see my series of posts starting with [What Is "Just in Time"?](#).

As Ship to Line requires Just in Time, it does have the potential problems of Just in Time. If you change your production plan on short notice, or if you need the parts earlier or later than planned, your system will run into trouble. Hence, like Just in Time, Ship to Line is possible only for a very stable production system.

37.4 Helpful Concepts

37.4.1 Smaller Parts

Due to this space requirement, Ship to Line (and Just in Time) is much easier for smaller parts. Large, bulky materials need more space, and hence you can only afford an even smaller inventory. A large box of O-rings may last you quite some time, whereas the same volume of engine blocks will be used up in the blink of an eye. It can be done, but it is more difficult. On the other hand, the reward is bigger since you can reduce the more expensive materials.

37.4.2 Packaging Suitable for the Process

Another thing to consider is the packaging of the materials. While this is not an absolute requirement, it does help your efficiency. Ideally, **the packaging the material arrives in and the packaging that is used at the line should be identical**. Hence, if you use plastic boxes at the line, you should have the goods shipped in plastic boxes, not cardboard boxes. Similar for blisters and other packaging. Otherwise you have to repack the goods from one container to another container, which is a waste.

In most cases, I have seen the packaging of the supplier is adjusted to match the packaging at the line. Less commonly, the packaging at the line is changed to match the packaging of the supplier.

37.4.3 Flow Line

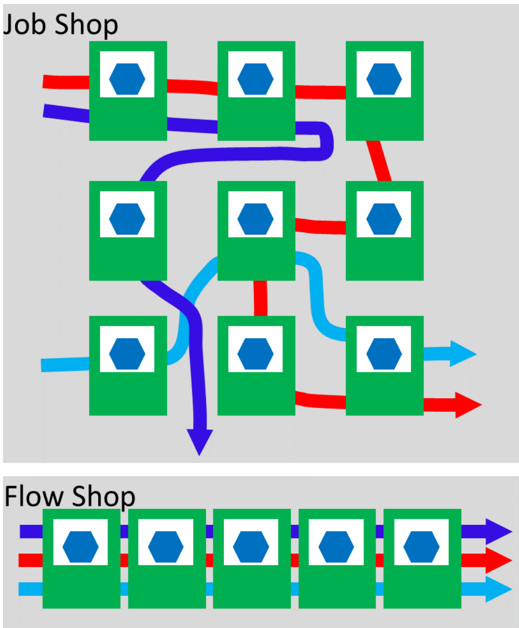


Figure 329: Flow Shop Job Shop Comparison (Image Roser)

Yet another requirement is that your production system is a flow line. The issue with job shops is that they are much more difficult to plan, and the timing of their material demand is much harder to predict.

Flow lines are much easier to plan, and you know much better which material is needed when and where. On a side note, Ship to Line would also work with a project shop.

37.4.4 Just in Sequence

Ship to Line combines very well with Just in Sequence. If your parts arrive already in sequence, you have less work getting them to the line. For more on this, see my series of posts on Just in Sequence.

37.5 Advantages

The main advantage is to be able to reduce your handling of material. Rather than storing the goods in the warehouse and taking them out again, you bring them directly to the line.

A side effect is that you can then reduce your material even more, since your lead time from truck to machine no longer needs these handling steps. While some see it as a tool primarily for material reduction, I believe the material reduction comes with Just in Time and is a prerequisite for Ship to Line. Ship to Line just squeezes a little bit more water out of an already dry towel.

I hope this brief overview of Ship to Line was of interest to you. Now, go out, see if this approach would help you, or if it at least inspired you to reduce your inventory a little bit more, and organize your industry!

38 The Kingman Formula – Variation, Utilization, and Lead Time

Christoph Roser, September 19, 2017, Original at https://www.allaboutlean.com/kingman-formula/

Figure 330: Traffic Jam (Image B137 under the CC-BY-SA 4.0 license)

The lead time of a system is heavily influenced by both the utilization and the variation. There are approximations available to estimate this relation, and one of them is the Kingman formula. In this post I would like to introduce you to this equation and describe the fundamental understanding of it. Luckily, you don't really need the formula for your daily dose of lean. The equation itself has little practical use. However, this relationship is important for understanding the behavior of your production system. While you won't use the Kingman formula to evaluate your production system, understanding the equation will help you in tweaking your system in the right direction.

38.1 Lead Time

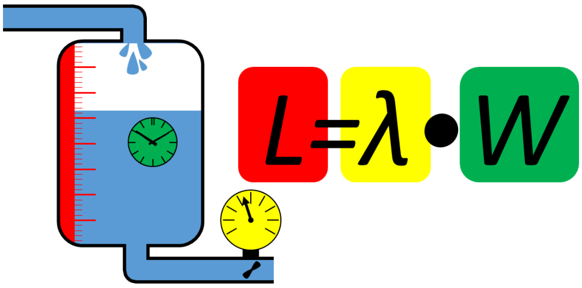


Figure 331: Water Tank Littles Law (Image Roser)

The lead time is the time it takes for a single part to go through the entire process or system. This is an important measure of the speed at which the system can react to changes. If you introduce new products or product changes, the lead time is (on average) the time until these changes come out at the other end. If your customer orders a custom made-to-order product, this is the (average) time your customer has to wait.

Hence, a lean production system aims to reduce the lead time. It is easy to determine the lead time for an existing system. You simply use Little's Law. There are three variables, often labeled as follows:

- L – Inventory, measured, for example, in units or quantity
- λ – Throughput, measured in units or quantity per time
- W – Lead time, measured in time

Little's Law is then the simple relation shown below:

$$L = \lambda \cdot W$$

While Little's Law tells you the lead time, it does not tell you much about how to influence it. Obviously, the main lever is to reduce your inventory (if you are active in lean manufacturing, you may have come across this idea ☺). Yet, in most cases this inventory is there for a reason, mainly to buffer fluctuations (but also others, see my post Why Do We Have Inventory?).

38.2 The Kingman Equation

The Kingman equation (also known as *Kingman formula* or *Kingman approximation*) gives you an approximation of the waiting time of the parts for a single process based on its utilization and variance. It was developed by British mathematician Sir John Kingman in 1961. As shown in the image, the parts arrive randomly, with a mean time μa between arrivals and a standard deviation σa. The parts then wait in the queue until they are processed (i.e., serviced). The service time has an average duration of μs and a standard deviation of σs. The equation determines an estimation of the waiting time (excluding the part in the process).

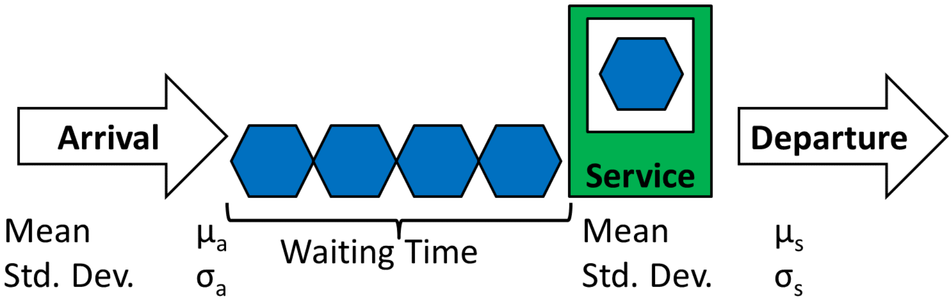


Figure 332: Kingman Equation Example System (Image Roser)

The equation includes the following variables, commonly written as:

- E(W): The expected waiting time W.
- μ_a and σ_a:Mean and standard deviation of the time between arrival of parts. This includes the losses. I.e. it would be NOT the cycle time, but rather the arrival takt time.
- μ_s and σs:Mean and standard deviation of the time to process one part. Please note that this usage is not standardized, and some equations use the symbol μ for the service rate, which would be the inverse of the mean time to process one part. Similar to the arrivals, this would also include the losses and hence be the mean and standard deviation of the process takt time.
- p: Utilization (i.e., the percentage of the time a machine is working). It is calculated by dividing the mean time for service μs by the mean time between arrival μa. If the arrival is faster than the service, you would have an utilization above 100%, which is not possible. Hence μa has to be smaller than μs. Therefore, p can range from 0 to 1. (Note: If the parts arrive faster than they can be processed, then the waiting time will go toward infinity. Even if the arrival is exactly equal to the service, the waiting time will still go toward infinity.)
- c_a: The coefficient of variation for the arrival (i.e., the standard deviation σa divided by the mean μa for the time between arrivals).
- c_s: The coefficient of variation for the service (i.e., the standard deviation σs divided by the mean μs for the average duration of a service).

$$E(W) = \left(\frac{p}{1-p}\right) \cdot \left(\frac{C_a^2 + C_S^2}{2}\right) \cdot \mu_s$$

Please note that the Kingman equation requires independently distributed arrival and service times (which is usually valid for most manufacturing systems), and is **valid only for higher utilizations** (which is also often true in manufacturing). Please note that this is also only an approximation, not a precise formula. And finally, it is only for a single arrival with a single process, which is quite rare in practice.

38.3 An Example

Let's look at an example. We have an arrival process with an average of 10 minutes between parts and a standard deviation of 8 minutes. Our service needs, on average, 8 minutes per part, with a standard deviation of 7 minutes. We have an utilization of 8/10 or 80%. Or coefficient of variations are: ca = 8/10 = 0.8 and cs = 7/8 = 0.875. Hence the equation is as follows, giving an expected waiting time of 22.49 minutes:

$$E(W) = \left(\frac{0.8}{1-0.8}\right) \cdot \left(\frac{0.8^2 + 0.875^2}{2}\right) \cdot 8 = 22.49\ Minutes$$

Again, this is only an approximation. The results depend heavily on the type of distribution. Using simulation for verification, actual waiting times were 20.8 minutes for Lognormal distributions, 21.19 minutes for Weibull distributions, and 18.16 minutes for the Pearson Type V distribution. Especially the Pearson Type V had a larger error, presumably because this distribution is heavy tailed compared to the others.

38.4 Interpreting the Formula

This equation (or more precisely, this *approximation*) shows us the two factors that influence your lead time and your queue length. One important factor is the utilization. The higher your utilization, the longer your queue. Eventually your queue will approach infinity as your utilization approaches 100%. This would be the first bracket of the equation above. The graph below shows the waiting time for different utilization for the example above. The closer you get to 100% utilization, the closer you will get to an infinite queue length.

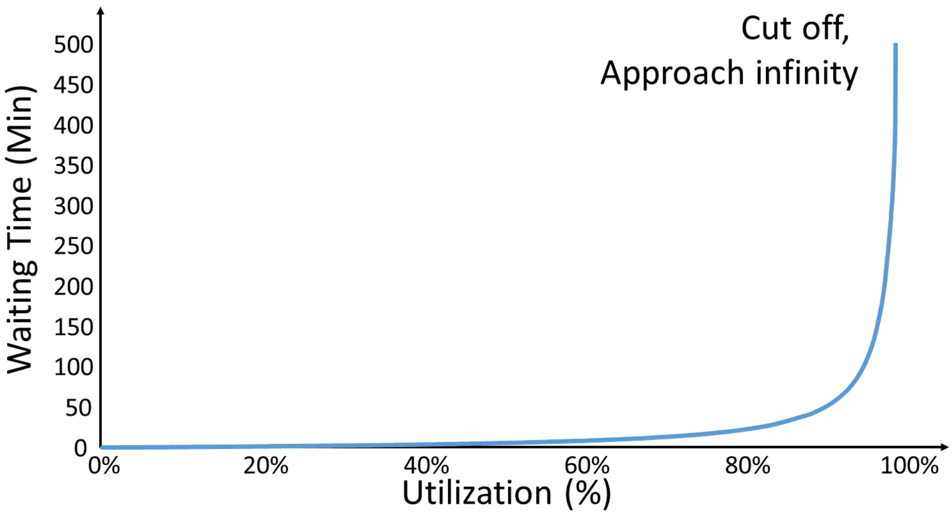


Figure 333: Utilization and Waiting Time according to Kingman (Image Roser)

The second factor is the variation. The higher your variation, the longer your queue. This would be represented by the right bracket in the equation above. The image below shows this relation again for our example above. The standard deviation was varied from 0% of the mean to 300% of the mean. You can see clearly how the waiting time increases.

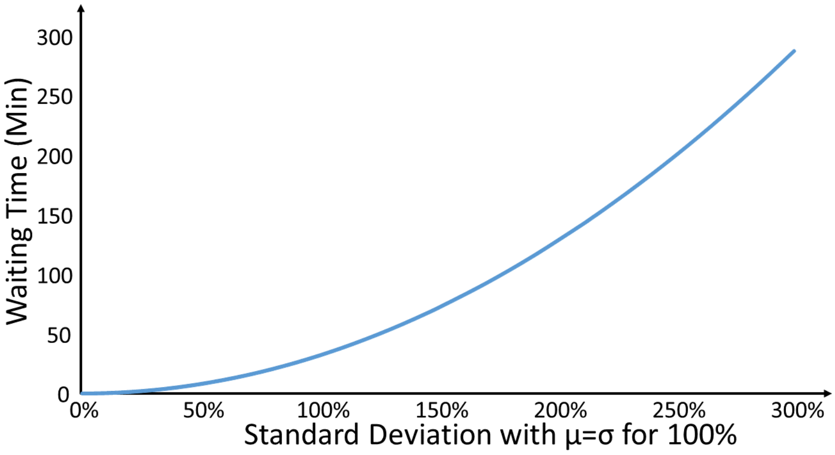


Figure 334: Standard Deviation and Waiting Time according to Kingman (Image Roser)

Finally, these two parts are not added but multiplied with each other. Hence, while a high value in each is not good, a combination thereof is even worse. This is visualized in the chart below.

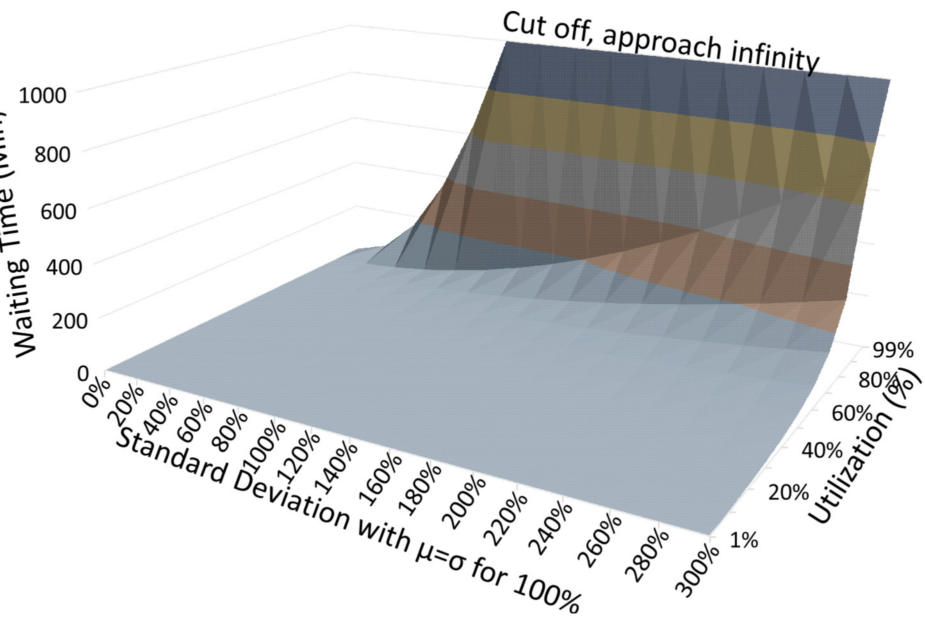


Figure 335: Utilization, Standard Deviation, and Waiting Time according to Kingman (Image Roser)

38.5 What Does This Mean?

This means, most of all, two things if you want to have a reasonable lead time or queue length:

- **Stay away from 100% utilization.** The lower your utilization, the shorter your lead time. Of course, a higher utilization also means a better use of the invested capital. Here you have to make a trade-off between a good usage of your machines with high utilization and a low lead time with low utilization.
- **Try to reduce variation**. Lower variation allows you to get away with lower inventories. Of course, this is easier said than done. The idea of leveling in lean manufacturing aims to reduce this variation to obtain faster lead times and other benefits.
- **If you have high variability, try to use lower utilization**. If your workshop has a high demand on flexibility, you can ease the pressure by reducing the utilization.
- **If you have high utilization, try to reduce variability**. If your workshop has a very high utilization, it may help to reduce the variability, although this is often easier said than done.

38.6 Alternative Calculations

The Kingman formula is the best known version to estimate waiting time, but by far not the only one. In the 1960s, lots of researchers developed formulas, some of which were more precise but a bit more cumbersome to handle. (For sources, see below.) W. G. Marchal published the following formula in 1976:

$$E(W) = \left(\frac{p^2 \cdot (1 + C_s^2)}{1 + p^2 C_s^2}\right) \cdot \left(\frac{C_a^2 + p^2 C_s^2}{2(1 - p)}\right) \cdot \mu_s$$

Almost simultaneously, Kramer and Langenbach-Belz published the following formula also in 1976:

$$E(W) = \left(\frac{p^2 \cdot (C_a^2 + C_s^2) e^g}{2(1 - p)}\right) \cdot \mu_s$$

Where

$$g = \frac{-2 \cdot (1 - p)(1 - C_a^2)^2}{3p(C_a^2 + C_s^2)}$$

Both formulas are (reportedly) a bit more precise, but also not as nice to show the effects of variation for our purpose.

Of course, if both your arrival and your service distributions are exponentially distributed (known as a M/M/1 queue in the queuing theory), then the following equation is a precise calculation. Unfortunately, you cannot make this assumption in the real world.

$$E(W) = \frac{p^2}{1 - p} \cdot \mu_s$$

Anyway, this is all the math for today. Again, the formula is of little practical use, as it is only for a single arrival and a single process with an infinite queue, but the relationship it shows is important. The formula can also be used for single arrival and single process for batches of parts or job orders. In sum, stay away from very high utilizations, and from high variability if you can. Now, **go out, find your trade-offs to control your lead time, and organize your industry!**

38.7 Sources:

- Kingman, J. F. C.: “The single server queue in heavy traffic.” Mathematical Proceedings of the Cambridge Philosophical Society. 57 (4): 902. October 1961
- Marchat, W. G.: An approximate formula for waiting time in single server queues, AIIE Trans. 8(1976)473.
- Kramer, W. and Lagenbach-Belz: Approximate formulae for the delay in the queueing system GI/G/1, Congressbook, 8th Int. Teletraffic Congress, Melbourne, 1976, pp. 235.1-235.8.

39 How to Deal With Long Delivery Times

Christoph Roser, September 26, 2017, Original at https://www.allaboutlean.com/long-delivery-times/

Figure 336: Snail Mail (Image Photo-SD with permission)

Lean has a bunch of advanced but good tools for material delivery, like Just in Time, Just in Sequence, and Ship to Line. Using them is much easier on short distances and with short delivery times. Yet, sometimes you just don't have the option of short delivery times. This blog post deals with the issues related to long lead times and delivery times.

39.1 What Is the Issue?

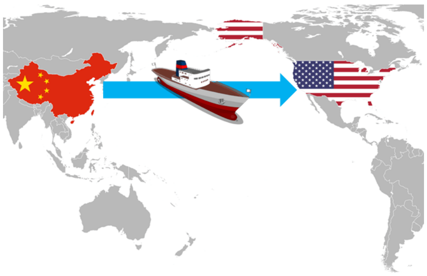


Figure 337: Shipping from China to the USA (Image Roser)

In many lean books (and also this lean blog), you read about the advantage of having the supplier nearby, having short lead times and delivery times, and having very local procurement. This makes it much easier for your material flow, especially with such tricky things as [Just in Time](), [Ship to Line](), or [Just in Sequence]().

Yet, often you do not have that luxury. If you go through your bill of materials, you may find quite a few that are shipped in from another country or another continent, either by air (which takes only a few days including customs but is expensive depending on weight) or by ship (which is stupendously cheap but can easily take months).

Sometimes this is simply because the only supplier just happens to be far away. Or it may be that the local suppliers are not up to scratch. A German high-level manager once told me that he opened a factory in the USA, and decided to buy as much of the equipment in the USA as possible to show his dedication to the new site. Yet, while he found suppliers for most of the machine tools in the USA, they were both more expensive and offered worse quality than what he could get in Germany and Japan. Hence he ended up buying the tools in Germany and Japan after all.

Figure 338: Angry businessman (Image Minerva Studio with permission)

More commonly, however, is that the supplier is simply cheaper. Of course, when I say cheaper, I mean merely the purchasing and shipping costs. Yet, most shop floor managers have a very different opinion of cheap machines, cheap parts, cheap quality, and cheap service. Overall, you may very well end up with a much higher bill from a distant but cheap supplier than a local but "*more expensive*" supplier. In any case, cost accounting and Lean are rarely good buddies.

39.2 What Are the Effects?

There are a lot of different effects of long delivery times. Here is an overview of the important ones.

39.2.1 Longer Lead Times

Figure 339: Global logistics network (Image Golden Sikorka with permission)

The first effect is obvious. Suppliers farther away usually have longer lead times. It just takes longer for the material to arrive. This means that you have to fix your production plan for longer in the future. If your material arrives four months after ordering, you need to fix your production four months ahead of time.

We all know that this does not really work. No plant in the world can fix its production four months ahead and stick to it. Hence, you need to cover eventualities. There are always three ways to decouple such issues: Often, additional inventory is used to buffer such fluctuations. You could also ramp capacity up and down. If these don't work, then you will default to the third way: your customer has to wait. All of these are cumbersome and may be expensive.

Some German car makers got hit quite hard by this during the 2007 economic crisis. They produced parts in Germany, sent them to China for cheap processing, and then shipped them back to Germany for assembly. Total time for the round trip: six months. When the crisis of 2007 hit and car sales dropped into the abyss, they were still getting enough parts for full production **for six months!** They had a hard time finding storage space for the goods, and had to rent additional warehouses to store all the stuff they didn't need.

Similar for quality issues or design changes, it takes months after the fix/change before you get parts that are actually fixed or the design is actually changed.

39.2.2 Higher Variance

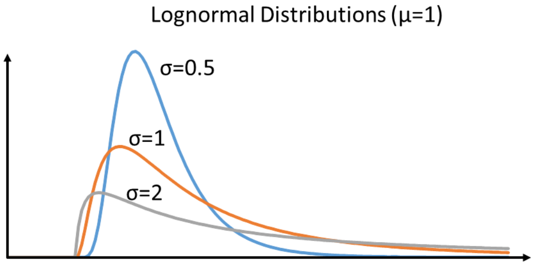


Figure 340: Examples of different Lognormal Distributions (Image Roser)

The second effect is no longer on everybody's radar, but it is still visible to many people. Not only does your delivery time go up, but your delivery time also fluctuates more. At Toyota in Japan, most goods arrive within two hours from the factory. Hence, a 25% fluctuation would mean a thirty-minute delay (being thirty minutes early is rare). This is still good enough for Just in Time.

However, if your goods come from abroad, your shipping time may be three months. A similar 25% fluctuation would mean a three-week delay. This three-week delay will throw any idea of JIT right out of the window. Even if you can get the fluctuations down to 10%, this would still be a week, so forget about Just in Time and other nice things; you can't have them.

Similar to the long lead time above, where you decouple the uncertainty in your planning with inventory or capacity or time, you can also decouple such lead time fluctuations with inventory (earlier delivery date and have the goods sit around), capacity (rush production when the goods finally arrive), or – if all else fails – with time by making your customer wait.

39.2.3 Worse Information Flow

That a distant supplier has long lead times and higher lead time fluctuations is pretty obvious. Less obvious is the worsening quality of the information flow. After all, there is not much time difference between a phone call or an email across the road and one across the globe.

Yet, longer distances worsen communication. For one thing, you are less likely to visit, and hence have less face-to-face communication. Even with phone calls there is often a time difference, and rather than calling your counterpart at 3:00 AM, you may not call at all.

Also do not underestimate the cultural differences. Even with best intentions, things can be misunderstood. There is the language ability, and not everybody speaks English well.

Figure 341: Nice Buns, Ma'am! (Image Roser)

Even for native English speakers there are some differences. If you compliment your female coworker on her *nice hot buns*, the British lady may take it as a compliment on her bakery, whereas the US woman will sue you for sexual harassment. Similarly, if you *knock her up*, you merely woke up the British woman, whereas the American lady … well … has some *a bun in her oven* now. (If you need an explanation, see the bottom of the page.)

This can get even worse if there is a lack of goodwill. Many may see people of other nations as inferior to their own. For example, in a German company in China, many (not all) of the Germans talked lowly of the local Chinese. A Chinese coworker ensured me that this is also true the other way round. This seems to be more common with larger differences in culture. Again, not everybody behaves that way, but enough people so it is a common problem. Without getting into the topic of racism, lets just say this was not good for the exchange of information.

Overall, the information flow becomes worse with distance for a multitude of reasons.

39.2.4 Worse Part Quality

Figure 342: Container Ship Wave (Image Peter Kaminski under the CC-BY-SA 2.0 license)

Also not to forget is the impact on the part quality, and to a lesser degree on the quantity. Shipping can be rough for the parts. They move around, may get banged into each other, may be exposed to salt water mist on ships, get hot, get cold, get dirty, may rust, and so on. Again, the longer the goods are en route, the more likely that some of them may be damaged and need rework or have to be scrapped.

Less common but also possible is that parts get lost. The ship may sink, or your goods may simply be stolen. Not that common, but sometimes a problem nevertheless, especially if you ship expensive consumer goods.

39.3 What to Do?

Figure 343: Question Mark (Image Horia Varlan under the CC-BY 2.0 license)

The big question now is how to deal with these effects of long delivery times. Maybe you are hoping for a quick, easy, and also cheap solution. If you know one, let me know, because I don’t (and please note that I don’t believe in magic software that solves all problems). The following ideas are all far from easy.

Of course you could pick a supplier closer to home. If that is possible, then that would be a good way, even if it may be a bit more expensive according to traditional cost accounting. Yet, in many cases there are no closer suppliers, or the powers in place prevent you from using them (i.e., your boss decided to go with the initial one regardless).

The next best course of action is then to mitigate these effects. You can buffer against fluctuations in the lead time and in your own production plan using inventory (or capacity or time). Of course this takes money and effort. Better but harder would be to reduce these fluctuations.

Make sure information flow is maintained, and even if the supplier is far away, try to visit them and have them visit you. Try to establish a good supplier-customer relation. Again, this takes money and effort.

Make sure the goods are packaged well and protected from movement and the elements (and theft if needed). Again, this takes time and money.

As for managing the flow: Here we have to distinguish if it is a mass-consumed part that you order regularly in large quantities, or if the parts are rarely ordered or even custom made. For rare orders or custom-made parts, there is no other way than to order them ahead of time. Adding a time buffer to the delivery date will increase the chances of the goods being there when you need them, but also the cost of paying earlier and having to store the items.

For mass ordered parts: You can use a pull system here like kanban, reorder point, or reorder period. Like all pull systems, you merely try to refill your inventory to the target level. Due to the higher fluctuations in the system, you may need some extra inventory, which again costs time and effort. Again you have to do a trade-off between the cost and the availability of your parts.

In sum, there are no easy answers to the problem. The general lean ideas still hold, but due to the long and fluctuating lead times, they just need more effort or inventory. Now, go out, get a closer supplier, and organize your industry!

P.S.: This post originated from a question by Guido.

P.S.S: Puns with buns: "*Buns*" mean round bread, often sweet, in the UK (such as in cinnamon buns), but it can mean sexy butt in the US. To "*knock you up*" means to knock at your door to wake you up in the UK, but to get you pregnant in the US. Having "*a bun in the oven*" is a metaphor for being pregnant.

P.S.S.S: Rob van Stekelenborg added some great points in the comments below. Use JIT, use small lot sizes. Have a (cheaper) supplier a distance away for the volume, and decouple fluctuations for the same parts with a more flexible local supplier (although Rob warns about quality and other issues popping up.) Having your supplier keep the parts in a local subsidiary until you need them does not solve the problem, but can push the expenses towards the supplier. Rob calls this very fittingly "financial games". You also have to agree on who owns the part, what happens if there are design changes, or who pays for scrapping of leftovers if you stop your production.

P.S.S.S.S: Michel Baudin also added that the material delivery could be outsourced to a specialized trading company. They could consolidate different materials in a warehouse near your plant, and deliver it from there to your plant as needed. While this won't decrease the needed buffer inventories, it outsources the trouble of taking care of them to another company. And, since this company specializes on logistics, it is (hopefully) better at it than your company, having both more focus and a larger economy of scale.

40 Industry 4.0 – What Works, What Doesn't

Christoph Roser, October 03, 2017, Original at https://www.allaboutlean.com/industry-4-0-potentials/

Figure 344: Robot holding Skull (Image koya979 with permission)

Industry 4.0 is (still) all the rage in manufacturing industry. I've already took A Critical Look at Industry 4.0. A lot of Industry 4.0 is hot air with a return on investment only far into the future. However, there are a few ideas that actually may work soon enough. In this post I would like to give my views of what works in Industry 4.0 and what doesn't.

40.1 Introduction

As explained in my previous post A Critical Look at Industry 4.0, Industry 4.0 is mostly a German government research program for computers in manufacturing. The topic is not well defined, and anything related to computers and industry may (or may not) be connected to Industry 4.0.

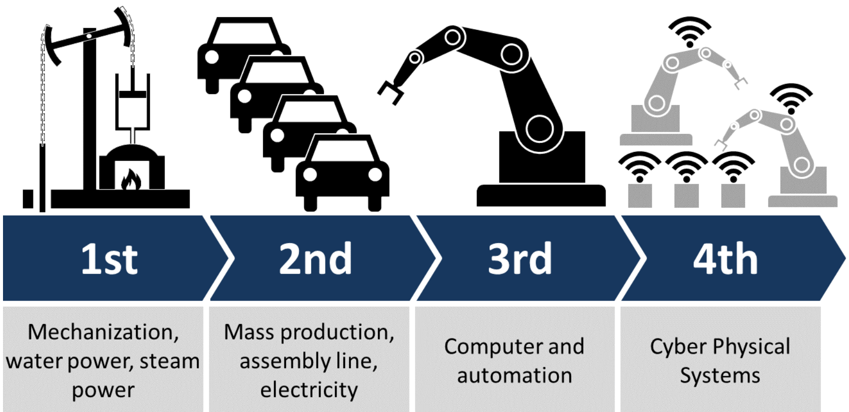


Figure 345: Industry 4.0 (Image Roser)

40.2 Manufacturing

Industry 4.0 is first and foremost a manufacturing topic. The Internet of Things or Cyber Physical Systems (to throw a few buzzwords around) will connect products and machines with each other. The vision usually is that the computer knows everything, and hence we will be able to improve control of the manufacturing system. Or, even better, the computer controls it and we don't have to do anything.

While this is possible in theory, the practical difficulties are vastly underestimated. I have seen highly networked Industry 4.0 examples in many different companies. In these production systems, every machine and every workpiece carrier was networked, and gazillions of data was available. Every part could move from one machine to any other machine depending on need and availability. These systems would be a wonderful Industry 4.0 showcase – except the people running it would rather go back to a plain old assembly line.

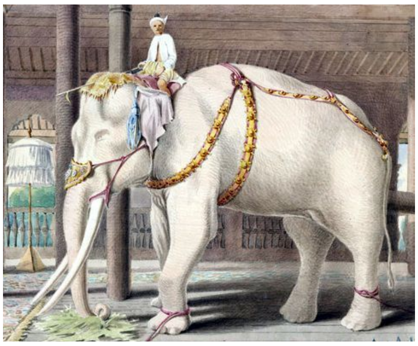


Figure 346: White Elephant (Image Colesworthey Grant in public domain)

Overall, these systems are white elephants. The expense to obtain and maintain the system vastly exceeds its usefulness.

In my view, there are a few reasons why such heavily computerized systems are suboptimal compared to a conventional system.

40.2.1 Complexity of Setting It Up

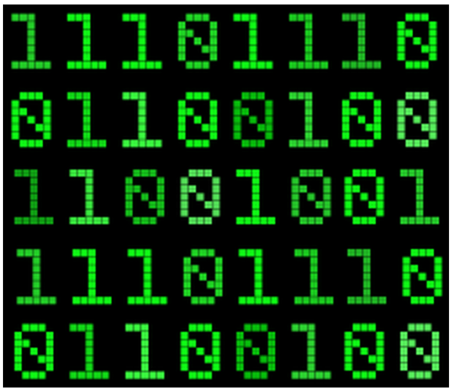


Figure 347: Binary Code Data Representation (Image MdeVicente in public domain)

Usually, people underestimate the cost and complexity of setting up the system. Having data requires sensors. Some may be already part of the purchased machines, in which case you often have to program (and debug) an interface between the machine software and your overarching software system. Other sensors have to be set up, which means data wiring, power supply, and inclusion in the software tools. Overall, a costly endeavor.

40.2.2 Complexity of Understanding the Data

Figure 348: Analyze Data (Image peshkov with permission)

But what data should be measured? This question is more difficult to answer than it seems. In industry, a common answer is that having a lot of data means that hopefully the right data is somehow in there too. However, a lot of data also makes it harder to filter out the right data. And the needed data may not even be included in the system.

Additionally, merely having the right data is only the first step. Now you have to make sense of it! Merely looking at when a sensor detects a passing part won't really help you much. Especially if you have thousands of such sensors. You need to aggregate and process the data to understand it. This also requires that you ask the right questions.

Again, this takes a lot of time and money to do right. It may be more expensive to process the data than to put the sensors there in the first place. Yet my gut feeling tells me that this *understanding the data* is often cut short due to time and budget reasons as well as the lack of awareness that this is actually necessary. By a recent McKinsey estimate, manufacturing generates significantly more data than any other industry. As one industry contact put it, **you have tons of data but no information!**

40.2.3 Complexity of Using the Data

Figure 349: Business hands holding tablet (Image ra2 studio with permission)

Running a factory is usually at least somewhat chaotic. Having good data available helps, but you also have to use it. This often seems to be much less than it could be, which may be due to tradition (*We have always done it this way*) or lack of training (*What data are you talking about?*) or, as explained above, not having the right data. In any case, the result is the same – the system is underutilized.

I often encounter the belief that all the problems in a factory will be solved simply by putting them into a computer. This is absolutely not true. The problems will still be there, except now they are much harder to understand, prevent, and fix.

40.2.4 Lack of Economy of Scale

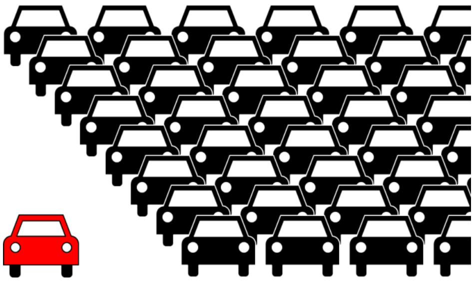


Figure 350: Many Cars vs One Car (Image Roser)

All of the above is not always done well. However, it could be done well. It is just a question of the time and effort put into it. And now we encounter probably the biggest obstacle: **This Industry 4.0 effort does not scale well!** If you manage to do it for one shop floor, you will have to do it almost completely again for another shop floor. It is difficult to recycle software tools without major rework to match the new and different sensor information in the new factory. Hence, for a new plant, this Industry 4.0 effort has to start almost from scratch.

An additional complication is that companies are very protective of their data. I have heard of a number of machine tool makers that implemented a remote sensing and maintenance diagnostics tool in their machines, only to have the customer demand that it be turned off. These companies do not want outside tool suppliers to access their production data for confidentiality reasons. Hence, this remote support tool is often not used at all.

40.2.5 Why Do It?

If there are so many negative effects of Industry 4.0, why do it in the first place? There are, in my view, two reasons, which may or may not apply to all companies.

First, it is to prepare for the future. While Industry 4.0 still has a lousy return on investment, eventually the problems will be sorted out and it may be beneficial (as a comparison, for CNC machines, this took a bit over twenty years). Hence, even if such a system may cost millions of euros, it may be worthwhile as a learning experience to stay on the cutting edge of technology.

Second, it helps to sell products. Such fancy flashy systems are well suited to impress the customers, and may lead to increased sales (or maybe not). But the overall business case to invest money for improved quality or cost is often not very good.

40.3 Economies of Scale – Logistics

However, there is one type of Industry 4.0 application that DOES have economy of scale: logistics! Pretty much all manufacturing companies have to move parts around. Commissioning from warehouses and bringing the goods to the point of consumption is standard for many firms. This is where the economy of scale can be beneficial!

Unsurprisingly, if the return on investment is good, people start doing it. The most famous example is Kiva Systems, purchased by Amazon and now called Amazon Robotics. These are little robots that move goods within the warehouse, typically from storage to picking and back. These robots reduced cost and allowed better use of the floor space, hence overall they seem to be good for the bottom line. They are also very scalable, and similar systems could be used by many companies. Below is one of many videos on the web on Amazon Robotics.

The Video by CNET is available on YouTube as "CNET News - Meet the robots making Amazon even faster" at https://youtu.be/UtBa9yVZBJM

These robots have been used by Gap, Walgreens, Staples, Gilt Groupe, Office Depot, Crate & Barrel, and Saks 5th Avenue, but after Amazon bought Kiva, they ended their contracts. Hence, this product is no longer available outside of Amazon, even though I believe many companies would benefit from it.

More proof that it works is that there is already a Chinese knock-off by a company called Geek+. I am not sure about the patent rights, but the company seems to be doing well, being used for example by Alibaba. Their promotion video is below.

The Video by Guo Yiran is available on YouTube as "Geek+ Logistics Robot and Picking System" at https://youtu.be/wxC6Sr78Ifg

A slightly different system developed by Shentong Express is also used in China to sort parcels for shipping. Below is one of a number of videos of their product.

The Video by New China TV is available on YouTube as "Army of robots sort out 200,000 packages a day" at https://youtu.be/XoQI-kLRrXA

Figure 351: Not self-driven, but me on top 🙂 (Image Roser)

This also works with the big toys. Large mining vehicles are starting to be driven by a computer; for example, in the Rio Tinto mine in Australia, they use seventy-three self-driven trucks. Self-driving is much easier to set up in a controlled mine environment where you can place markers, provide good WLan, laser sensors, and radar, as well as train all other human drivers on how to interact with self-driving 416-ton behemoths. This makes it not only faster and cheaper, but apparently also safer. Other mines are following that trend. The latest trucks don't even have a driver cabin as a back-up.

40.4 An Internet Allegory

Let's compare this to some Internet examples. There are tons of people out there creating content for Internet platforms like YouTube. Yet, creating this content is work intensive and difficult to scale up. Delivering the content, however, has excellent economies of scale.

If you want to invest money, you probably don't want to invest it in the next famous YouTuber, but rather in the next famous YouTube, since the benefit is so much larger due to the abilities to scale up for little extra cost. Same goes for manufacturing. Industry 4.0 is a low return for the making of the goods, but due to its better scalability, it has potentially a much higher return for the distribution of the goods.

40.5 Summary

Figure 352: 3D printed tower with internal staircase. (Image Roser)

For completeness' sake, I would also like to point out that I see lots of potential in 3D printing. If you see this as an Industry 4.0 topic, then this has potential too.

Overall, I believe that Industry 4.0 already has a strong benefit in logistics, compared to manufacturing where the benefit is more fuzzy and far in the future. Now, **go out and organize your industry!**

41 Introduction to Karakuri Kaizen

Christoph Roser, October 10, 2017, Original at https://www.allaboutlean.com/karakuri-introduction/

Figure 353: Karakuri Ningyo (Image PHGCOM under the CC-BY-SA 3.0 license)

Recently I visited the Karakuri Kaizen Exhibition 2017 in Nagoya. This was a very impressive exhibit, and I learned a lot about karakuri from the many different examples shown there by over one hundred exhibitors. Organized annually by the Japan Institute of Plant Maintenance, it is to my knowledge the biggest showcase of karakuri in the world. This was an exciting visit that I will process in a whole series of blog posts on karakuri (Fundamentals and Examples)

Karakuri is the use of mechanic gadgetry rather than electric, pneumatic, or hydraulic devices. Definitely no computers! Within lean, it stands for mechanical gadgets that improve your system. Time to look closer at what I learned from this karakuri exhibition.

41.1 Karakuri History

Figure 354: Inside of a Karakuri doll (Image World Imaging in public domain)

Karakuri is written in Japanese most commonly as からくり, but sometimes also as 絡繰り, 絡繰, 機巧, or 機関. It basically means gimmick, mechanism, machinery, trick, contrivance, or device. The key point here is some mechanical trickery.

It originated with mechanical dolls in Japan, called karakuri ningyo (からくり人形). These dolls are first mentioned around 1500 years ago, but were most popular around 200 years ago.

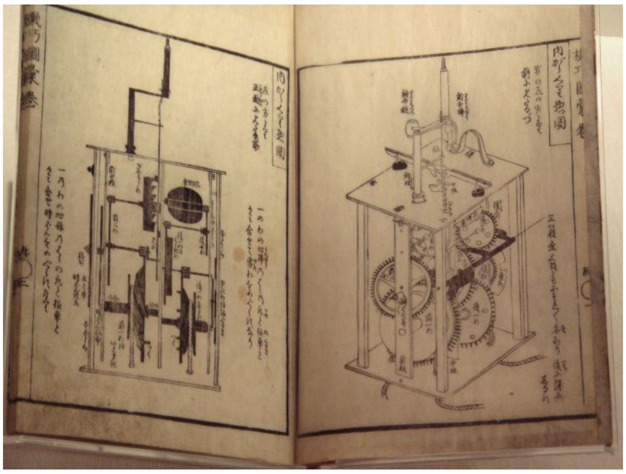


Figure 355: Karakuri doll mechanism (Image PHGCOM under the CC-BY-SA 3.0 license)

These dolls can be seen as the precursor to robots. One of the most well-known examples is the tea-carrying doll displayed at the top of the article. The weight of a bowl of tea put on the tray made the doll move forward a set distance while moving its feet (powered by a wound-up spring). After you remove the bowl and drink the tea, the empty bowl is placed on the tray again. This weight then made the doll turn around and move back to its original position.

Figure 356: Karakuri jitte weapon (Image Samuraiantiqueworld under the CC-BY-SA 3.0 license)

Besides such tea-carrying dolls, there are also dolls that shoot arrows, write, or dance. They were used in theaters, as (expensive) toys, or on festival floats.

Yet, karakuri was also used in other contexts. The image here shows a foldable weapon called *karakuri jitte*. Houses with hidden floors and hidings places were called *karakuri yashiki* (からくり屋敷 for karakuri mansion). There was and still is karakuri furniture and umbrellas.

Figure 357: Jaquet-Droz Writer Automata (Image Rama under the CC-BY-SA 2.0 France license)

Of course in terms of lean, it is most famous for karakuri kaizen (if you are here, you hopefully know that kaizen stands for continuous improvement [改善]).

But before I go deeper into that, I would like to point out that while the term *karakuri* is Japanese, the idea itself is not unique to Japan. The Western world also has many such dolls that can play music, draw, or write.

Similarly, many towns in Europe have a mechanical puppet gadgetry, often in the tower of the town hall combined with a carillon. Heck, even Rube Goldberg machines (deliberately complex mechanical contraptions) would fall into this category.

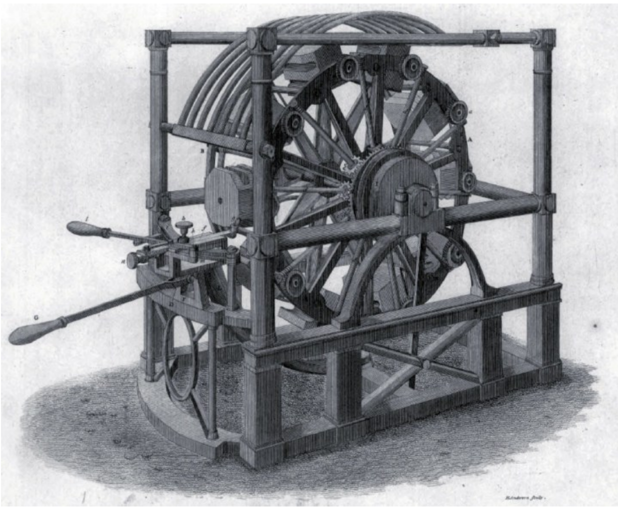


Figure 358: Bentham block-shaping machine (Image Edinburgh Encyclopædia in public domain)

Also, before electric motors and computers, similar mechanical gadgetry was also used in manufacturing to (mechanically) automate and improve the processes. Well-known examples are the Portsmouth block-shaping machines by Samuel Bentham that shaped ten wooden blocks unsupervised and stopped itself after completion, or the Jacquard loom where wooden boards "*programmed*" the pattern of the cloth in the mechanical loom.

41.2 What Is Karakuri Kaizen?

Figure 359: Karakuri shooting rack by ITEM (Image Roser)

Karakuri Kaizen is a mechanical device that generally improves work. The device uses only mechanical gadgetry, and shuns electric, hydraulic, or pneumatic power. It is also not controlled by a computer but rather by the design of the mechanics.

At the Karakuri Kaizen Exhibition 2017 in Nagoya, I saw lots of neat examples. However, some of them included a bit of pneumatics or electric. While you should aim for a purely mechanical solution, there is no karakuri police, and at the end you have to use a solution that is best for you.

I would have loved to take pictures at the exhibit, but unfortunately there was a strict no-photos policy. I even had to put a sticker on my rear-facing camera lens on my mobile phone to enforce this policy. Of course, me being me, I had to point out that my phone also has a forward-facing camera (for selfies), and I had to ask if I needed a sticker for this lens too. Well, it seems nobody ever asked that question before! After lots of discussion, the staff concluded that apparently a selfie camera poses no danger to the intellectual copyright of their karakuri gadgets, and hence does not need a sticker 🙂.

But fear not, I will show many of the ideas using diagrams and sketches, as well as photos and videos from other sources. Lets start with an example video from the Toyota Kaikan museum in Toyota City. It shows a little trolley that moves three items across a gap. Once three items are loaded, an (electrical) hook unhooks the trolley. The weight of the goods presses the platform downward. This gravity energy is converted into a forward movement through some gears below the cart. This will also wind up some springs inside of the cart.

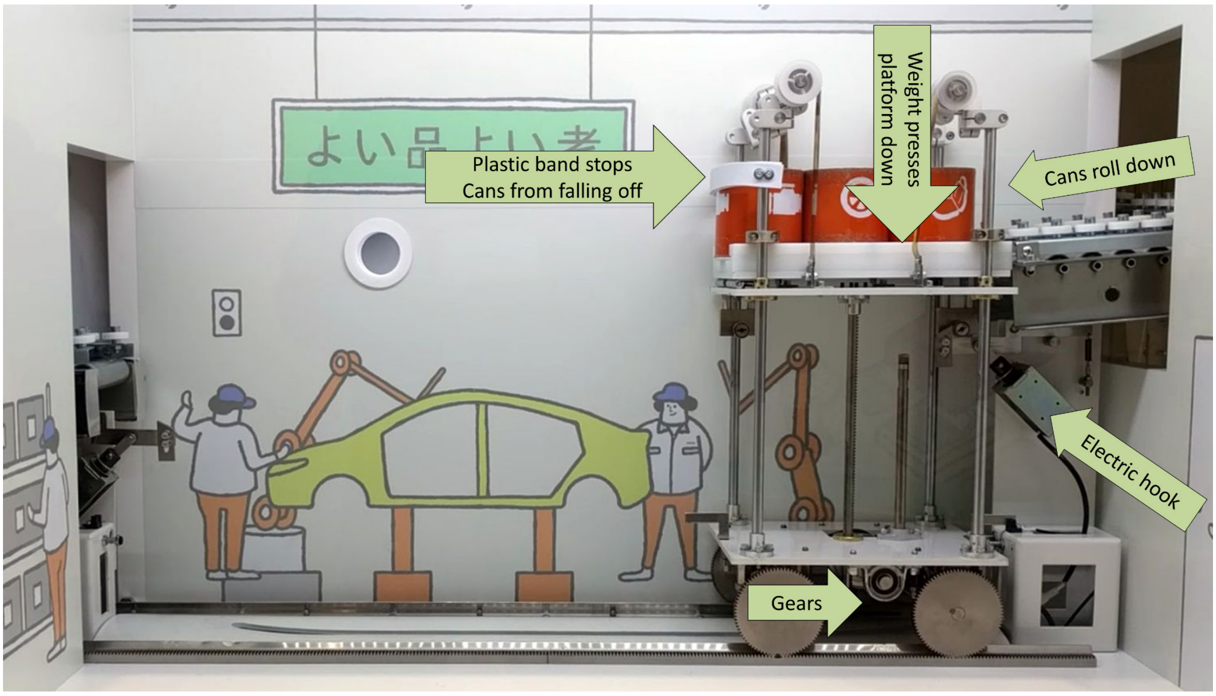


Figure 360: Toyota Karakuri Example Start Position (Image Roser)

Toward the end of the outbound trip, the platform will touch a pin on the right side of the cart, which will tilt the platform, and the cans will roll off. An electrical hook secures the cart while this happens. Afterward, the electrical hook unhooks the cart and the springs will release the stored energy to return the cart back to its original position.

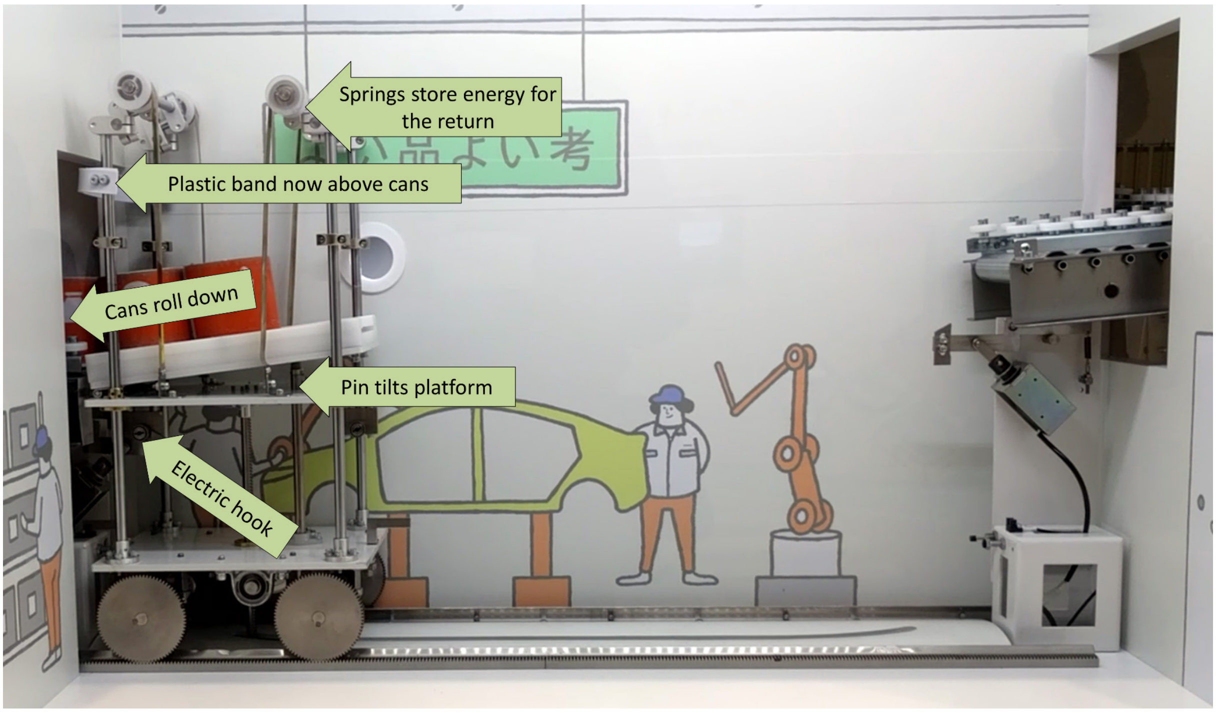


Figure 361: Toyota Karakuri Example End Position (Image Roser)

Here is the full video of the process.

The Video by AllAboutLean.com is available on YouTube as "Karakuri Kaizen Example from Toyota Kaikan Museum" at https://youtu.be/8_AY4IgADiI

41.3 Why Use Karakuri Instead of Computers?

Industry 4.0 is currently all the rage (maybe except on this blog here or there). Yet, karakuri kaizen with its focus on mechanical solutions is pretty much the opposite! These gadgets are not connected wirelessly, and not online as part of the internet of things or cyber physical systems. Heck, they don't even have a microchip! So why use them? After all, any of these actions can also be done using sensors, actuators, and processors. Yet, karakuri is often better. In my view, there are a few advantages.

41.3.1 Cheaper

A mechanical system can be much cheaper than a computerized system. One example I know avoided a $10,000 conventional expense by installing a $500 mechanical gadget, or a cost reduction of 95 percent. While not all karakuris have such potential, they are often cheaper than the competition.

Figure 362: Aluminum profile (Image frog with permission)

Many karakuris use aluminum profiles to construct the gadgets. If you've worked with aluminum profiles, you surely know that there are two price categories: **very expensive and even more expensive!** Yet it is often cheaper than computers. Some ways around expensive profiles are slightly less expensive aluminum pipes. Other solutions I have seen simply welded much-cheaper steel profiles together – although this is hard to change afterward and recommended only after you built a prototype using aluminum profiles.

41.3.2 Easier to Maintain

Often, maintenance of karakuri is also easier. If a computer system bugs out, it is really hard to figure out what went wrong. You need a mechanic, an electrician, and possibly also a programmer.

With a mechanical device, it is usually quite easy to see (even for the untrained eye) where the problem is. Hence, finding and fixing the problem is potentially much easier and may even be done by shop-floor personnel. However, no worker on the shop floor will touch a computer system to fix it, because it is so much harder to fix.

41.3.3 Much Easier to Improve

Figure 363: Chance and Change (Image Dreadlock with permission)

I kept the most important one for last. Karakuri is most often called karakuri **kaizen**. And kaizen is continuous improvement. Such improvement often requires trial and error, and usually requires the input from the workers.

Similar to the easier maintenance above, shop-floor workers can create and improve karakuri devices by themselves, whereas they will not install or change anything that includes computers and sensors.

Hence, karakuri devices allow for a grass-roots continuous improvement in lots of little steps. Computer systems are big steps, usually initiated by management when they notice the problem (often too late, and only the biggest ones), and implemented by engineers and programmers when they have the time (rarely). In sum: **Kaizen is so much easier with karakuri!**

Okay, so much for the introduction. In my next post I will go into some fundamentals. While I will not and cannot cover the vast topic of kinematics in one post, I would like to focus on the energy management of karakuri devices: Where does the power for its movement come from, where is it stored, and where does it go to. In my last post I will show you lots of examples for karakuri. Now, **go out, generate some solid mechanical links instead of computer gizmo-stuff, and organize your industry!**

41.4 Update June 17 2018:

Found a good Karakuri Video from Toyota. Many thanks to Cyril and to Michel Baudin for pointing that out to me.

The Video by Toyota Global is available on YouTube as "econohito season2 / The Toyota "Karakuri" meister leading our continuous improvements / Toyota" at https://youtu.be/Om2txc-Rq5s

42 Fundamentals of Karakuri Kaizen

Christoph Roser, October 17, 2017, Original at https://www.allaboutlean.com/karakuri-fundamentals/

Figure 364: Woman in Hamster Wheel (Image Sergey Nivens with permission)

Karakuri is the art of creating machines without an external power source. After an introduction to the topic in my last post, I would like to show you some fundamental techniques for karakuri.

I would like to pay particular attention to power management: Where do these machines get their power from, how do they store it, and where does it go? I will also (very !) briefly talk about kinematics, and even some karakuri ideas that go beyond kinematics. My next post will have lots of examples, mostly from the Karakuri Kaizen Exhibition 2017 in Nagoya.

42.1 Power Management

A karakuri device needs power to function, or, more generally speaking, it needs energy. Rather than using a dedicated power source like a motor, karakuri devices take their energy wherever they can get it from. Here are some examples of where to get energy, how to store it, and how to get rid of it.

42.1.1 Energy Sources

Figure 365: Athlete Exercise (Image Roser)

Often, the energy source is **human muscle**. Many karakuri devices are operated by hand, like a lever or a pair of custom pliers. This can also be in an indirect form (i.e., when the worker takes a power tool out of a holder or returns it, the movement of the power tool can power a mechanism). Many other karakuri devices are operated by stepping on a lever or pedal. This provides more power as the muscles in the leg are stronger. The biggest human energy source for the largest demands is created when the person steps with his full body weight on a platform. See the video below for an example of a lever operated karakuri by ITEM.

The Video by AllAboutLean.com is available on YouTube as "Karakuri Material Transport by ITEM" at https://youtu.be/h1H0joka0Ys

Another energy source is taking away a bit of **energy from another machine**. The movement of another machine is utilized to power the karakuri device. For example, a material supply cart driving by a storage rack may activate some levers within the rack.

Figure 366: No karakuri here … (Image NASA in public domain)

Closely related is the use of **gravitational energy**. A heavy object moves downward and powers the mechanism. This could be the part rolling down a slide and activating other mechanisms, as seen for example in the Toyota kaikan video above. Especially if you are moving your products using their own weight, you have to get as much usable movement as possible for the decrease in height, otherwise you soon have to make holes in the floor. I have also seen a heavy metal ball rolling downward to release stored energy and to move a cart forward where the object on the cart could not drop in height by itself.

I have also seen **water jets** as an energy source. The Suntory brewery directs a water jet at a small propeller to rotate a filter during cleaning, where lots of water jets are spraying on the filter anyway. Aisin Takagaoka is cleaning the inside of pipes using water jets from a nozzle that also propels the nozzle forward. Their problem was that this cleaned only the lower part of the pipe. After introducing an imbalance in the nozzle by making some jets larger than others, the nozzle now tumbles through the pipe and also cleans the upper part of the pipe.

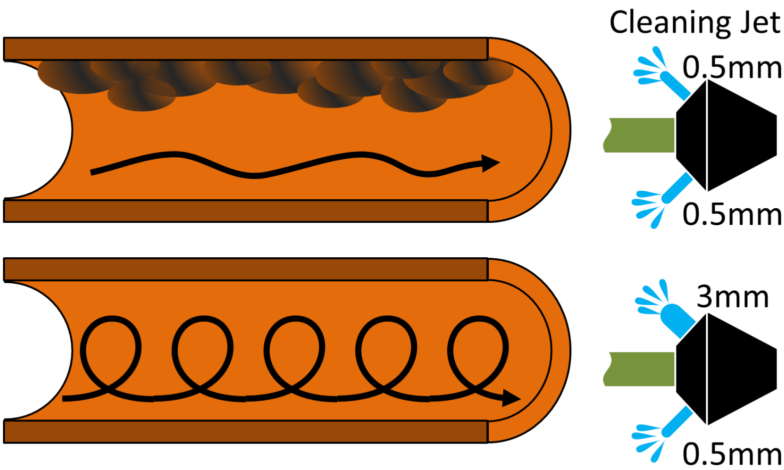


Figure 367: Karakuri Pipe Cleaning (Image Roser)

Similarly, **wind power** can also be used. A very easy and common example would be plastic strips at air vents. If the strip is moving, the vent is venting. If not, then not. However, this would be difficult for an intake vent, in which case I have seen small toy propellers installed at the vent. A rotating propeller indicates air flowing in.

42.1.2 Energy Storage

For many karakuri devices, you would have to store energy. Here too you can find a number of different ideas.

Figure 368: Storing and releasing energy … (Image Olesia Bilkei with permission)

Very common is a type of **seesaw**. One thing moves down (releases gravitational energy), while another thing moves up (stores gravitational energy). Later you can use this stored gravitational energy when the first thing has left the device.

Closely related are **weight on strings**. During a movement, this weight is pulled up. Later, this weight is released again to provide energy. Often, these weights were plastic bottles or canisters filled with water or sand, which allows easy fine-tuning of the weights.

Figure 369: Storing energy … (Image iloli with permission)

Yet another ingenious way of strong energy is a **pendulum**. One example I have seen used the removal of a power screwdriver from its holder to set a pendulum in motion. This was then converted into rotational movement that powered a magnetic disc that took screws out of a storage container, oriented them, and put them in a small buffer for the worker to use. The pendulum stored just enough energy to get five to six screws, which was all what the worker needed.

Figure 370: Springs (and unicorns)! (Image Monkey Business with permission)

Naturally, you can also wind up **springs**, as for example in the Toyota Kaikan video above. Rubber bands also work.

Besides weight, energy can also be stored as a **momentum**. An object rolling forward can activate a lever simply through its momentum. This momentum can be linear or angular. Such, a flywheel, sufficiently large, can power an entire bus.

42.1.3 Energy Dissipation

Not as common but still sometimes necessary are devices to get rid of excess energy. You simply convert the movement into heat through friction. These could be brakes, oil dampers, or similar. Usually this is not much of a challenge.

42.2 Principles of Movement

If you have ever taken a fundamental kinematics course and wondered when you will ever need those kind of contraptions, well, for karakuri you do! To cover all the things that are possible would by far exceed the scope of this blog (and would not really be my area of expertise either). Hence, here is only the briefest of introductions.

You convert movement from one form into other forms. Besides changing directions, this means converting back and forth between rotational movement, linear movement, swinging, and intermittent rotation. There will be all kinds of gears, ropes, pulleys, cams, cogs, bars, links, belts, and whatnot. For more inspiration, see the Wikipedia Category:Hardware (mechanical) or Category:Kinematics, or just pick up a good kinematics textbook.

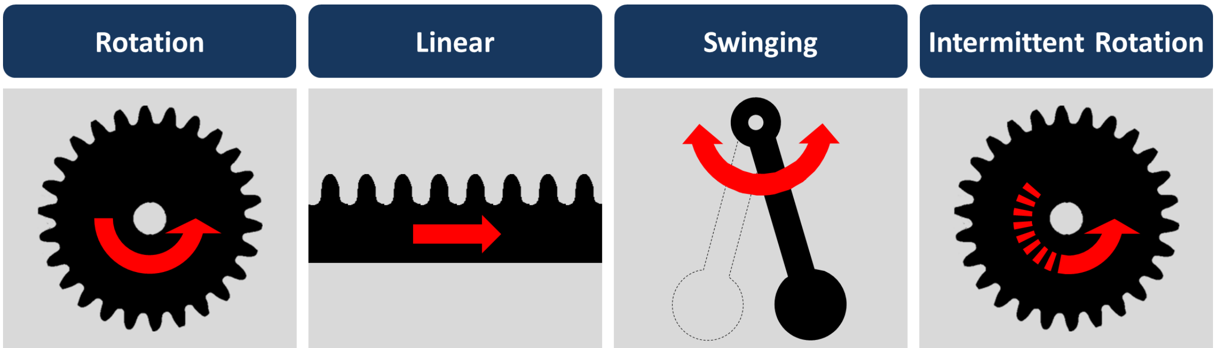


Figure 371: Fundamental Movement Types (Image Roser)

One particularly neat idea (at least to me) was a small set of four gears that converted omnidirectional rotation into unidirectional rotation as shown in the video below.

The Video by thang010146 is available on YouTube as "Mechanism for converting two-way to one-way rotation 2" at https://youtu.be/esVq6jfTigM

42.3 Beyond Kinematics

Of course, you are not limited by kinematics either. Many karakuri mechanisms use **magnets**. Others use **water jets** as described above. I have even seen an example by Denso where they used an karakuri mechanism to activate a syringe that created enough **vacuum suction** for a suction cup to transport a computer chip. I will write more about such examples in my next post. This is the right time to be creative! Now go out, think out of the box, get your gears moving, and **Organize your Industry!**

43 Karakuri Kaizen Examples

Christoph Roser, October 24, 2017, Original at https://www.allaboutlean.com/karakuri-examples/

Figure 372: Corkscrew (Image pbombaert with permission)

After an introduction and description of the fundamentals of karakuri kaizen, here are some different karakuri kaizen examples for a wide variety of uses. Most of them are from the 480 exhibits at the the Karakuri Kaizen Exhibition 2017 in Nagoya, Japan; others are from the 2017 OPEXCON in Stuttgart, Germany. Here is my attempt of a structured overview, even though some of the points below may be overlapping.

43.1 Improve Material Transport

There are a number of different uses for karakuri. In the West, it is most commonly associated with material transport, especially returning empty boxes in a rolling lane supermarket. Below is an example by ITEM displayed at the 2017 OPEXCON conference in Stuttgart.

The Video by AllAboutLean.com is available on YouTube as "Karakuri Shooting Rack by ITEM" at https://youtu.be/SGmNRZcbIlY

One of the most impressive examples I have seen was a video from BMW in South Africa. There an AGV moved material around. The material was stored on rolling lanes on the AGV. The AGV supplied a supermarket next to the assembly. Simply by driving slowly past the supermarket, different levers activated the material transport, and boxes with material moved from the AGV into the supermarket, while empty boxes moved back to the AGV. A rough sketch of the process is shown below.

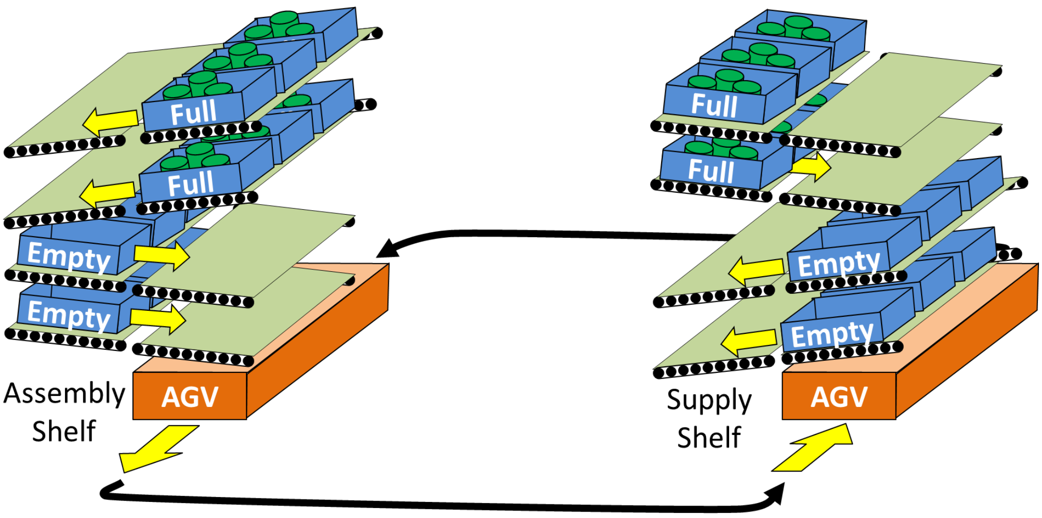


Figure 373: BMW South Africa Karakuri (Image Roser)

The AGV then returned to the supply supermarket, slowly driving along. Again, levers returned empty boxes to the supply supermarket, and other levers restocked the AGV with full boxes from the supply supermarket to be brought to the consumption area. The video showed different examples, including engine blocks with kits. Well-thought-out kinematics made sure no boxes dropped on the ground or tried to move into an already occupied spot. Again, all without computers, electronics, or electric motors (except for the movement of the AGV).

Since I wrote the post, Johannes Schuch showed me some good videos in his comment below. Here is one that matches closely the BMW example:

The Video by CREFORM Technik GmbH is available on YouTube as "Automated warehouse with CREFORM AGV" at https://youtu.be/nUf2EjXy-OI

43.2 Reduce Work Duration

Many of the karakuri exhibits aimed at reducing work duration. For example, on automotive assembly lines, operators often have a small cart with material and tools. These carts can be pushed along by hand, but it would be much easier if they move along the line by automatically. While this idea is not new, Toyota Motor Canada presented such a cart in a karakuri version for the mounting of the engine in the car. While moving forward, a weight is lifted. After one car is done, the weight is released and moves the cart back along the line to the next vehicle. They also incorporated a protective mechanism that covers the fender of the car while working and presents a tray with parts over the fender of the car within easier reach of the worker. Altogether they were able to eliminate eight steps per work cycle.

Another example helped with installing exhaust systems underneath cars. The device presented a new exhaust to the worker within easy reach, reducing both walking and lifting effort. This reduced the cycle time of the worker by four seconds, or roughly 7 percent overall, as well as eased the burden of the worker.

43.3 Reduces Workers Stress and Discomfort

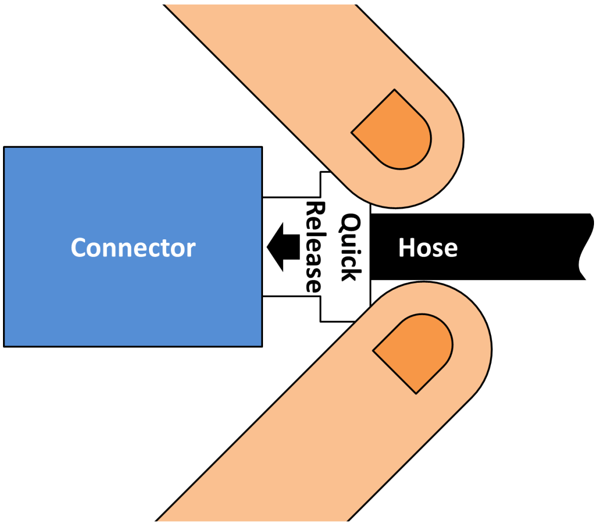


Figure 374: karakuri Quick Hose Release (Image Roser)

An exhibit by Aisin Takaoka simplified the removal of hoses. Thee plastic hoses were stuck in a connector. To remove them, the worker had to push a quick-release ring while pulling at the hose at the same time.

This happened in a cramped spot inside a larger machine, and the worker had to twist his fingers quite a bit to achieve that. Additionally, the small hose made it difficult to push the ring while pulling the hose.

After a few times, the fingers of the workers started to hurt (believe me, I tried it). To resolve this problem, the company created a special pair of pliers that fit into the tight spot. Simply by closing the pliers, a mechanism pushed onto the release ring while at the same time pulled the hose out. This special tool made it much easier and more comfortable to remove the hose, not to mention much faster.

Another example by Toyota Boshoshoku was during visual inspection of car bumpers. These bumpers were originally on a rotating rack. Before, this meant that the worker had to walk back and forth to be close to the bumper for inspection. This is shown below in a top down view on the left side. The new karakuri device had a pin in a peanut shaped slot. This moved the bumper not in a circle, but in a "peanut shape". As a result, the worker was always close to the bumper without moving back and forth.

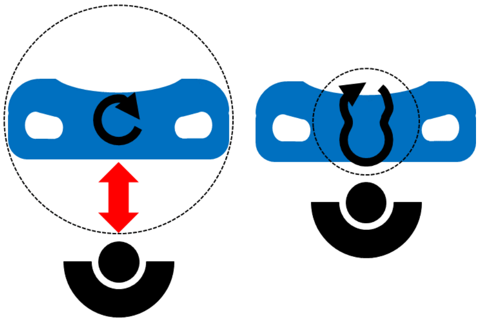


Figure 375: Karakuri Bumper Inspection (Image Roser)

Many more examples helped with lifting heavy loads or raising parts so that the operator can take them without bending over. Others helped to get parts into tight spots.

43.4 Orientation of Materials

Quite a few of the karakuri exhibits on display were used to arrange small parts for easier use by either machines or humans. The first example here is probably well known, being a popular example from Toyota.

During assembly, the worker needs to screw in two screws. Before, the worker had to pick them manually out of a box, which is cumbersome. Toyota attached two magnets to an movable arm. Whenever the worker returned the power drill to the power drill holder, the weight of the power drill pushed down the arm briefly. The magnets dipped into the box of screws and picked up just the right number of screws (in this example, two). This little unpowered mechanism saved the worker quite some time fumbling for the right number of screws.

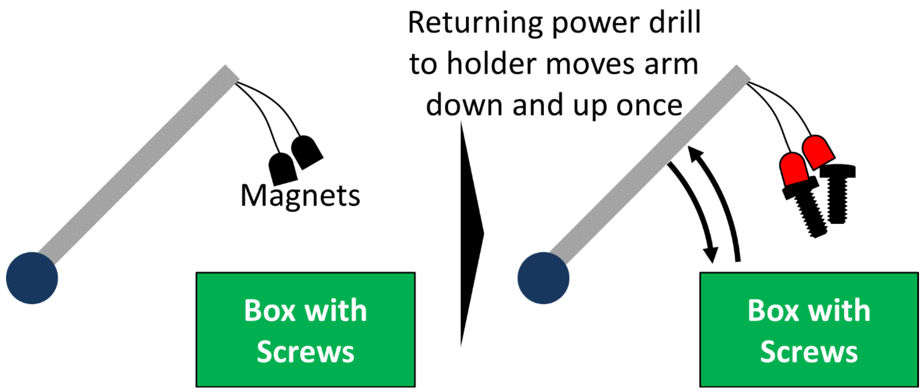


Figure 376: Karakuri Magnetic Screw Holder (Image Roser)

Another example is for feeding a machine with oriented parts. The mechanism is so simple that you could argue that it is no mechanism at all, since it has no moving parts. Yet, it was at the karakuri exhibit, and hence is "karakuri"-enough for me.

The goal was to orient bolts where both ends were of a similar diameter, with one side only slightly larger than the other one. Instead of using a complicated bowl feeder, they simply used a half-funnel-shaped metal slide. Since the larger diameter side of the bolt rolled faster, this end always came out first at the end of the funnel.

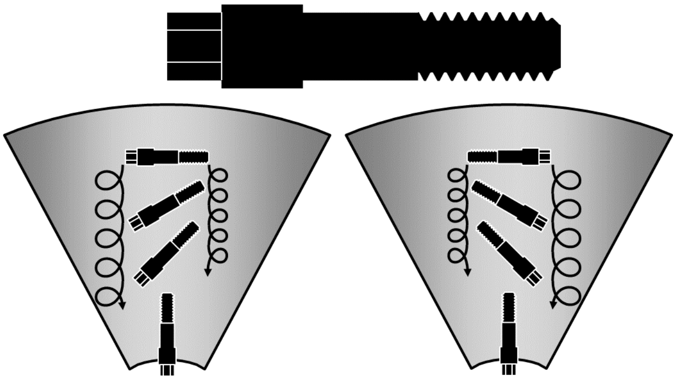


Figure 377: Karakuri Slide Part Orientation (Image Roser)

There were many more examples of bringing material in a good orientation for further use. In fact, this seems to have been one of the major uses at the karakuri exhibit.

43.5 Reduces Cost

Another advantage of a karakuri mechanism is that it can reduce the overall cost. A conventional machine with computers, sensors, and actuators can be rather expensive. Depending on the situation, a karakuri machine can be much cheaper.

Toyota Boshoku built a karakuri parts feeder that oriented the parts. They used a pendulum that stored power and allowed the mechanism to operate for a few seconds without additional power. This machine cost the company 50,000¥ (roughly US $500). They estimate that a conventional computer controlled machine would have cost them 1 million ¥ (roughly US $10,000).

43.6 Improves Quality

Denso showed an exhibit where they improved product quality. They transported a tray with around one hundred small and very delicate parts using an AGV. However, the route of the AGV was not perfectly smooth, and uneven surfaces like manhole covers bumped the AGV. This was enough to create an (occasional) issue for the parts, which got bumped too. Hence, they upgraded the pallet storage on top of the AGV to include a combination of suspension, x/y isolation, and damping system. As a result, even when the AGV ran over uneven surfaces, the parts did not shake. Not only did the quality of the parts improve afterward, but the AGV was also able to drive faster, reducing one minute of the turnaround time for the transport.

Another device by Toyota Motor Japan was a system that cleaned the rollers of a rolling lane automatically. This eliminated metal chips that sometimes scratched the parts. It saved around twelve hours of manual cleaning per month, as well as around US $500 in damage costs.

Another device by Daihatsu helped with inspection of valve seats, where an endoscope-style camera had to be inserted into around fifteen holes of a device. The karakuri gadget made sure no valve seat was forgotten, and also eased the use of inspection.

43.7 Improves Safety

Not many but a few of the exhibits improved safety. Toyota Motor Japan displayed a device that was incorporated in a winch hoisting forty-kilo items. They worried what would happen if the chain lifting the weight broke or otherwise failed. Hence they included a safety stop that actuates when the chain snaps. By itself nothing new (similar devices are long since standard in elevators), but in this application it was for a much smaller device.

Another example by Aisin Seiki provided pallet storage with a gate. The idea was that pallets won’t fall out during an earthquake. The weight of the pallet closes the gate when the forklift puts the pallet down. If the forklift lifts the pallet up again, the gate will swing open. (Side note:

Their video of the warehouse had only one such gated pallet storage, and upon my inquiry they commented that it may be a bit expensive. I guess this is not yet widely in use.)

43.8 Visual Management

Figure 378: The fan is ON! (Image apopium with permission)

Karakuri can also be used for visual management. Any type of gadget that visualizes the state of a device can help here. In its simplest case, this would be strips of plastic on a fan or air conditioner.

Other examples were a ball in a plastic tube to monitor flow, red and green coloring on dolly wheel locks, or a red sign that pops up when a valve is opened.

Wow, that blog post took me much longer to write than expected. It isn't easy going through almost five hundred examples with (mostly) Japanese descriptions to pick some interesting ones for you. In any case, I am confident that there was something in here that inspired you. But inspiration alone is not enough. Let the actions follow. Hence, **go out, use mechanics to make something easier, faster, safer, cheaper, or more visual, and organize your industry!**

44 The Challenges of Material Supply for Assembly

Christoph Roser, October 31, 2017, Original at https://www.allaboutlean.com/challenge-of-assembly/

Figure 379: Worker Assembly (Image naxaso with permission)

Assembly of multiple parts into one bigger part is a common process in manufacturing. It is also the most challenging one for supply logistics. If there is only one part that gets milled, drilled, coated, formed, or other wise processed, logistics is much easier. But if you have dozens or hundreds of parts that have to come together in different variants, it becomes much more of a challenge. In this post I will look at the challenges of supplying material for assembly. In subsequent posts I will show ways to address these challenges.

44.1 The Challenges of Assembly

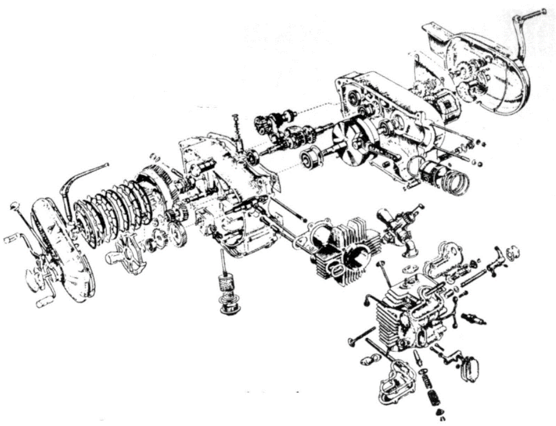


Figure 380: Engine Exploded View (Image unknown author in public domain)

By its nature, assembly is a process where many different parts come together. Depending on the product, there may be only a few small parts or a large number of bigger parts.

While robotic assembly is getting more common for mass production, most assembly is still done by human workers. After all, according to NASA, "*man is the lowest cost, 150 pound, nonlinear, all-purpose computer system which can be mass produced by unskilled labor.*" This post focuses on manual assembly, although many ideas can also be extrapolated to robotic assembly.

You need around 30,000 parts to make a car (more for upper-class vehicles, and much, much less for electric cars), compared with only around a dozen for a ballpoint pen. Obviously, all of these have to be supplied to the different assembly locations. There are a few challenges that arise from that process:

44.2 Minimize Usage of Space

Figure 381: Work in tight space (Image marcinmaslowski with permission)

Floor space costs money. Yet what many don't realize is that some space is more valuable than other space. In manufacturing, the space around the actual manufacturing process is usually most valuable. The closer you can put your processes together, the shorter the distances for material and information to flow across stations. Close processes also make it easier for one worker to help another one in case of problems. Last but not least, it can make visual management easier.

Hence, one challenge in assembly is to provide all the parts needed using as little space as possible.

44.3 Ensure Usage of Correct Part

Another challenge is to ensure that the worker uses the correct part. While for many parts it is obvious which one is to be used, many other parts look quite similar. One commonly confused part is screws of slightly different length, resulting in either not enough strength or damage to the parts below the screws. I once almost destroyed my new TV by picking the wrong (too long) bolt for the wall mount.

Figure 382: Don't mix 'em up! Different Thread standards from left to right Metric M12, M12x1.25, M12x1.5, 1/2' UNC, 1/2' UNF, 1/2' BSW (Image Roser)

Screws with the wrong diameter at least can't be assembled incorrectly, but have to be put back (unless you use not metric screws but US United Thread Standard screws where one screw sometimes can just barely be screwed into the next bigger nut).

I also once had a case where they used screws for two different products at the same assembly station that were identical except for the coatings, which were black and … black again. The workers were really good at distinguishing one black screw from an identical other one that was a tiny bit less shiny. Yet I presume many products still had the wrong screws.

There are many other examples of near-identical parts for different product variants that can be mixed up. Hence, you need to make sure that you **assemble the right parts in the right sequence**.

44.4 Comfortable for Operator

Figure 383: Tall and short person (Image xixinxing with permission)

The assembly operations also have to be comfortable for the operators. The parts should be easy to reach, without any twisting or bending of the body. They should also be comfortable to lift. Remember, they don't have to do it just once, but hundreds of times per day.

Also remember that not all workers are identical. Something easy to reach for a tall person with long arms may require a stepladder for a shorter person. Lifting a weight that is no problem repeatedly for a man may be a struggle for a woman. Or even more generally, people have different skills and abilities, and what may be easy for one may be not so easy for another. **The work has to be comfortable for all people working there.**

44.5 Not Monotonous

Figure 384: Bored Girl in Hard Hat (Image chajamp with permission)

Another challenge of an assembly line is similar to challenges in any kind of manufacturing line: There is a risk of boredom for the workers due to repetitive work. This is difficult to do in the assembly spot itself without risking productivity, but can be done by assigning the worker different tasks on different days.

That is of course if the worker wants it. Some people are happy just doing the same thing over and over again forever. But the possibility should be there! Or an even better idea: try to get your people thinking about improvements. What could they do to improve their workplace?

As an counterexample, the Chinese mobile phone assembler Foxconn had the problem that many of the workers were committing suicide. While this was not only an issue with monotonous work, this factor seems to have contributed to the issue. Hence, **try to keep your workers engaged and provide at least some mental challenges**.

44.6 Fast

Figure 385: Overworked worker (Image Roser)

Very related to the requirement of being comfortable is the requirement to be able to do it fast. Time is money! The faster the work can be done, the more work you can fit into a cycle. Please note that "fast" here does not mean that the worker is rushed, but that the work is arranged in a way that the worker can do more in the same time with the same effort! Your goal is to **fit as much work in the available time as comfortably possible for the operator**.

44.7 Inexpensive, But Not Cheap!

Figure 386: Calculator and Money (Image unknown author in public domain)

Finally, the gear and equipment should be not overly expensive. This is in my view a minor requirement. If the gear (shelves, tables, chairs, electronic aids, etc.) costs money, the benefits of being faster, more comfortable, better quality, and reduced use of space will usually be worth good equipment. **Don't buy shoddy stuff!** Get good gear for your people!

Overall, assembly is a particular challenge in the organization of manufacturing due to the large number of different parts needed at the same spot at the same time. (I am not saying that other manufacturing tasks are easier, as they do have technical challenges, but from an organizational point of view, assembly is not easy!). In subsequent posts I will talk about how to address these issues. Until then stay tuned and **organize your industry!**

45 Structured Approach to Material Supply for Assembly – Part 1

Christoph Roser, November 07, 2017, Original at https://www.allaboutlean.com/structure-assembly-1/

Figure 387: Kids playing with colorful plastic blocks (Image famveldman with permission)

Supplying material for assembly operations can be quite a challenge. After describing the challenges in the previous post, I would like to show you in two posts what you need to consider when you want to create an assembly location. This is a somewhat structured approach on how to set up a material supply for your assembly operations, although you will still need some iterations to achieve a good solution. After that I will have a post focused on what to do if you are running out of space at your assembly location.

45.1 Approaches to Assembly

Figure 388: Boy making Lego Tower (Image makistock with permission)

The following is a list of methods and ideas. Not all of them will work for your case, but do consider what is suitable for your situation. The task on how to distribute a more complex assembly among different stations would exceed the scope of this post. In previous posts I also already explained line layout strategies, pacing of flow lines, and different ways of organizing workers (bucket brigade, chaku chaku, rabbit chase). Now we will be looking at only one station.

Please note that this is unfortunately not a simple checklist that you have to go through, but rather an iterative process. I have sorted the steps by sequence as well as I can, but you will probably quite often have to go back to change a previous approach in order to make the assembly work.

45.2 What Parts Do You Need?

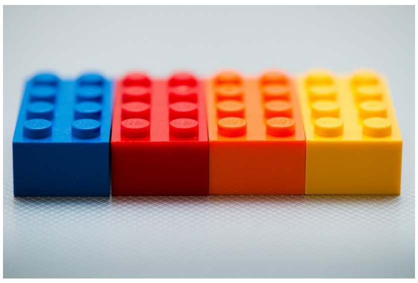


Figure 389: 4 Lego Bricks (Image Kenny Louie under the CC-BY-SA 2.0 license)

First you need to figure out what parts you need for your assembly. This list has to be complete. Be aware that this is not only the list for one product variant, but for all product variants that have to pass through this station, including packaging and other stuff. You will end up with a list of parts that have to be accessible for the operator to do his work. In all likelihood, a number of database queries will give you the (hopefully correct) data.

45.3 What Tools Do You Need?

Figure 390: Boy and Lego (Image katyspichal with permission)

Rarely does the worker assemble parts without tools. These also have to fit at and around the workspace. Especially for heavy or delicate parts, you may need special equipment. Do you have to install a crane or lifting device, or does the worker need tweezers?

45.4 How Many Parts Do You Need?

Figure 391: Lego Bricks (Image Alan Chia under the CC-BY-SA 2.0 license)

You should also know how much of these parts you need in a certain time frame. This is not only the number of parts that go into one product, but how many of these parts you need per hour of operation. It is important for the material supply to know how many parts to store at the assembly location to ensure an uninterrupted supply.

Important: This must not be the average, but the peak demand! If you need, on average, eight flux capacitors per day, it would be one per hour on average for an eight-hour workday. However, if you produce in batch sizes, all of these may be needed within one hour. Hence you have to plan for the peak demand on your parts, not the average.

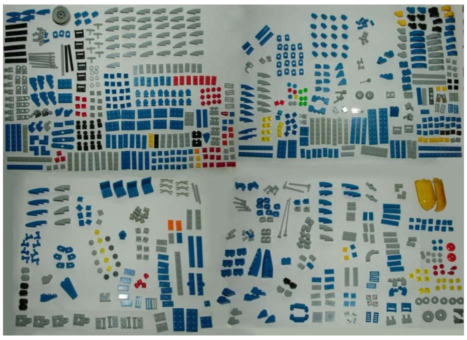


Figure 392: Lego Space Ship Package Content (Image granada_turnier under the CC-BY-SA 2.0 license)

Okay, now you know your average demand. This has to be combined with the frequency of your material supply. If you need ten parts of one type per hour, and your material supply comes along every thirty minutes, you need to keep five parts (plus some safety) at the assembly station for uninterrupted work. If you material supply comes along only every two hours, you now have to fit twenty parts at your station. You can see how a more frequent delivery reduces the number of parts required.

Figure 393: Lego Bits Box (Image Emily Walker under the CC-BY-SA 2.0 license)

Your delivery can also be regularly scheduled, often called a milk run, or it can be by demand. Please note that the on-demand supply works best if the person supplying is closely connected to the assembly line. If it is just one of your many forklift drivers, chances are that occasionally your assembly will be missing parts.

Overall, you have to make sure that the worker does not run out of parts even during peak load and even with a minor delay on the material supply (if the material supply is delayed more, eventually the worker will run out of parts).

45.5 What Are the Properties of Your Parts?

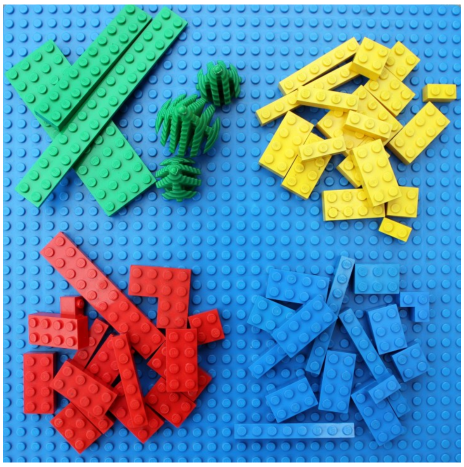


Figure 394: Lego Selected Bricks (Image Lesekreis in public domain)

For all parts needed, you have to figure out more details on the parts. Important aspects are, for example:

Packaging Type: What packages do your parts come in? Is it a plastic box that has to be returned? Is it a cardboard box that has to be scrapped afterward? Depending on the type of packaging, you may have to handle the part differently.

Packaging or Part Size: How big is the part or a set of parts including the packaging? This determines the size needed to store the parts.

Weight: How much does the part weigh? Light parts can usually be installed easier. Heavier parts are more difficult. Keep in mind that the worker does not only have to do it once, but many times. Also keep in mind that workers have different strengths, and what may be easy to life for a man may be more difficult for a woman. Here you should involve an ergonomic expert.

Handling issues: There are other things that may be relevant for assembly. Is the part spiky or does it have sharp edges? Your workers may need gloves to protect themselves. Is the part washed and fat-free? Your workers may need gloves to protect the part from fingerprints. Is the part sensitive to static charges? Your workers may need ESD clothing. Is the part very small? Your workers may need tweezers and magnifying glasses. There maybe more requirements, and it is probably best to involve shop floor people to find these things out. (You should involve shop floor people in the entire process, by the way. This will give you much better results.)

Due to the length of this post, I had to split it into two. In my next post I will continue on how to fit parts around your stations an touch briefly on ergonomics and how to provide material. We should also not forget the necessary information flow and safety aspects. Until then stay tuned, **go out and organize your industry!**

46 Structured Approach to Material Supply for Assembly – Part 2

Christoph Roser, November 14, 2017, Original at https://www.allaboutlean.com/structure-assembly-2/

Figure 395: Stacking Lego Tower (Image Gerisima with permission)

It is sometimes a challenge to provide material for assembly. In this second post I will continue with the different aspects and steps to consider when creating an assembly location. Enjoy!

46.1 Fit Your Parts around the Station

Now you can start to fit your parts around the workstation. Ideally, all parts are within easy reach of the operator.

Figure 396: Your unfinished product is usually the biggest part. (Image Ford Motor Co under the CC-BY-SA 2.0 license)

Most important is usually the unfinished product, since it is often the largest item that has to pass through the workstation. The worker will receive the unfinished product, work on it, and then move it to the next station or to storage. In an assembly line, this is for small products often a move from one side to the workspace to the other side, or for larger products something similar to an automotive assembly line.

All other parts go into these unfinished products (with few exceptions, as for example packaging material). There are two approaches that are commonly used to arrange these parts, and both are sensible. Usually it is best to do a combination of both, which requires some back and forth until you have a suitable solution.

Figure 397: Lego in boxes on shelves (Image Jacob Davies under the CC-BY-SA 2.0 license)

Start With the Bulky Parts First: One approach is to start with the biggest and heaviest parts. They need most of the space, and are also difficult to handle. Starting your material supply structure with these will give them the best spots, which makes it easier for the worker to assemble. If you need gear to lift heavy parts, it is easiest to fit in if nothing else is in the way (yet).

Start With the Most Frequently Used Parts First: The other approach starts with the most commonly used parts. Putting these "A" parts closest to the worker will make them easier to reach and will reduce overall work time.

Both the "bulky parts first" and the "most frequently used parts first" strategies are valid. Best is probably a combination of both. Get the really big parts out of the way, and then continue with the "A" parts.

46.2 Location of Parts and Ergonomics

Ergonomics likes to split the workspace into different zones. The easiest to reach **first zone** is around elbow height and in front of the worker, accessible by moving only your lower arms. This should be where most of the assembly work happens.

A **second zone** is accessible by moving the entire arm, giving the worker more reach. This can also be a bit higher or lower than elbow height. Everything is literally an arm's length away. This is the best spot for your material.

A **third zone** can be reached by not only stretching your arm but also bending your body. This could also be behind you, reachable by twisting your body.

The **fourth zone** is everything else. The worker now has to walk to access this zone. A simplified view is given below. Note that for the work table on the right, I kept some space for the part to move across the table.

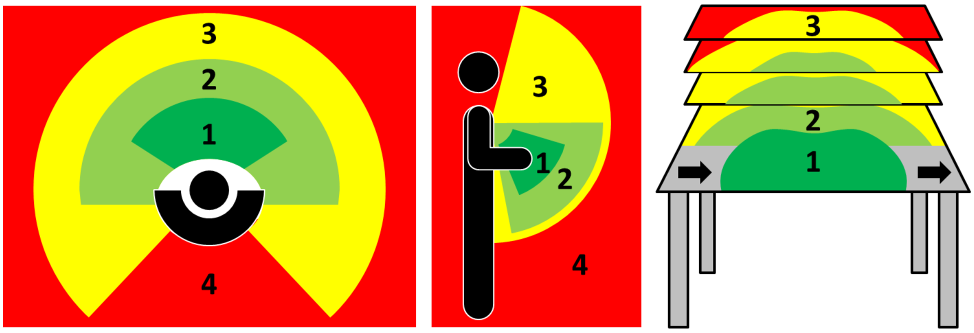


Figure 398: Ergonomic Zones (Image Roser)

It should be pretty clear that the closer you can get the parts to your worker, the easier and faster the assembly is. Ideally, parts are supplied in front of the worker above or next to his assembly space. Of course, this is not always possible. It is difficult to supply big parts across the assembly space.

46.3 How to Provide Parts

Figure 399: Pallet Scissor Lift (Image Edmolift AB under the CC-BY-SA 3.0 license)

No matter where you put the parts, they have to be somewhere. This could be as basic as a pallet on the floor, although this is, ergonomically speaking, not very good. An improvement may be a pallet on an small lift as shown in the adjacent image. Using such a device can reduce the stress for the worker by providing parts always at a suitable height.

Figure 400: Warehouse rolling rack (Image praethip with permission)

It could be simply a shelf with parts on it. However, here too it may be better to use rolling lanes that can be filled at one end and emptied at the other. This simplifies the filling and maintains FIFO. A full box is always behind the next box. This is common for supermarkets for small- and medium-sized parts.

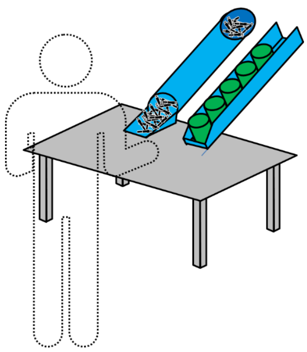


Figure 401: Material Supply over Table (Image Roser)

There are also options for chutes and slides to provide parts as shown in the adjacent image.

Chutes are often simply plastic tubes that are filled at one end and emptied at the other one. If you use a clear tube, it is easy to see how much material is in the tube. This is a form of visual management. Often, foam rubber at the end of the chute makes picking up small parts easier.

The exact way of delivering the material depends on your specific situation, but feel free to be creative. You should always make sure that the material is easy to add and easy to remove, and that the quantity available is easily visible. As mentioned earlier, you may also provide lifting devices for heavy parts or other tools for parts that require special gear.

46.4 Delivery of Information

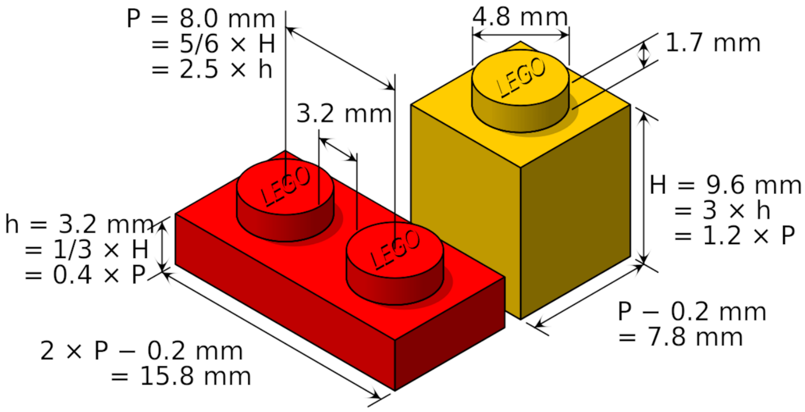


Figure 402: Lego Dimensions (Image Cmglee under the CC-BY-SA 3.0 license)

You should not forget that the worker needs not only parts but also information. There are generally two bits of information needed: what to produce, and how.

What to Produce: The worker needs the information on what product to produce. In an assembly line, this may simply be defined by the part that is handed down from the previous station, and often only the first station would need information on the product type. This information may also be needed along the line if the worker creates different variants from the same unfinished product.

If the products come in batches, it may be easier ("*in the morning we do A, in the afternoon B*"), but lot size one is usually better in lean. If your only reason for a batch size is the information flow, then don't, and do lot size one instead. Find a way to inform the worker what the current product is going to be. This could be, for example, a sheet of paper attached to the product or a digital display.

How to Produce: The worker also needs to know how to produce the product. This could be a simple work standard printout or a more fancy pick-by-light, where a light indicates which part to use next. This topic also deserves its own blog post, and due to the scope of this article, I won't go into details here.

46.5 Access and Escape Routes

Finally, you should also make sure your worker can get in and out of the workspace, and has the necessary escape routes. The place should be well ventilated, lit, and overall a safe and comfortable workplace. Usually not a big issue, but you should not forget.

So, this is an overview of the most important aspects to consider when creating an assembly workplace. It is no magic, but simply focused work and common sense. In my next post I will go into details about how to deal with space limitations. What can you do if you are running out of space at your assembly location? Until then, stay tuned! Now, **go out and organize your industry!**

47 Twelve Ways to Create Space around Your Assembly – Part 1

Christoph Roser, November 21, 2017, Original at https://www.allaboutlean.com/assembly-space-1/

Figure 403: Tight Office (Image marcinmaslowski with permission)

Assembly needs lots of parts. Especially if you have larger parts, you may find that you are running out of space to put them. Fear not, there are a number of things that you can do to solve this problem. This post will present you with all the solutions (that I know) to remedy a space shortage in assembly.

47.1 Introduction

Space around the assembly location is most precious. The closer you can put your stations together, the more efficient they will be (up to a limit, of course). A lack of space usually stems from too much material around the station. In this short series I will present you twelve ways to reduce space around your assembly. I would like to split the following remedies into two (related) groups, differentiating if you have **too much material overall** or if you **need more front space** for the operator. Remedies for the latter often improve overall floor space usage as well. Surely there must be one solution that helps you with your space problem.

For an initial situation, assume you have an assembly location as part of a larger assembly line as shown below. The station needs quite a bit of material, putting it quite a bit apart from the adjacent stations and maybe even causing space problems elsewhere (in the image, illustrated by a milk run that cannot pass due to the pile of material).

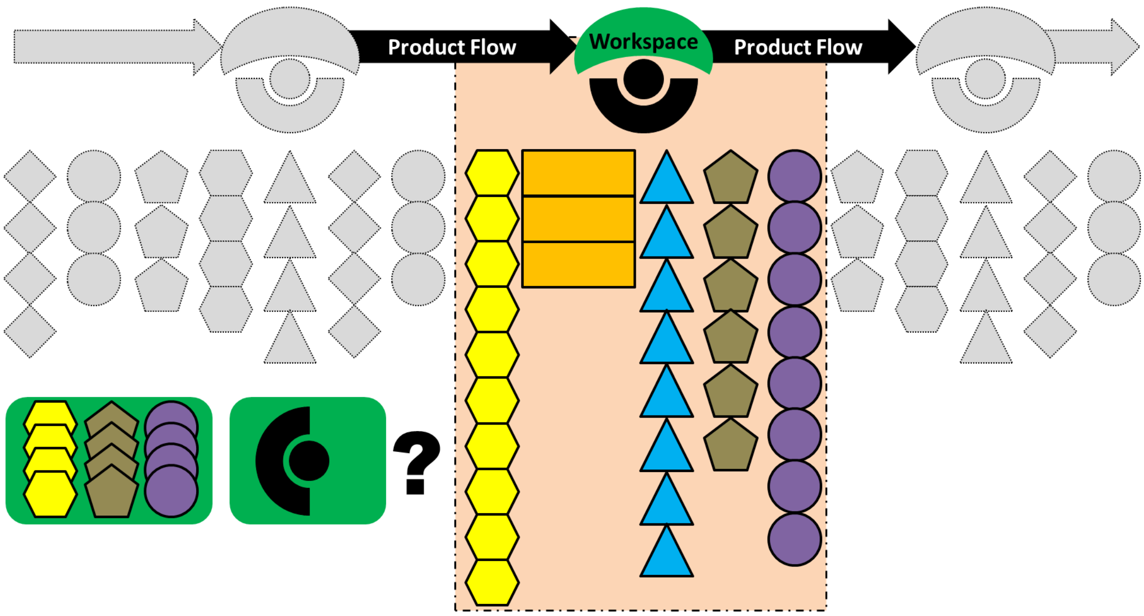


Figure 404: Assembly Space Original (Image Roser)

Let's first have a look at how to rearrange the overall pile of material, or even reduce the quantity of material. The first few ideas simply rearrange the material, but latter ideas reduce overall material.

47.2 Move Stations Farther Apart

The first solution is quite simple. If there is not enough space for the material at the station, move the stations farther apart as shown in the image below. Of course, this does not reduce the overall quantity of material, nor reduce overall use of space. It also puts the assembly stations even farther apart, making the material and information flow between the stations trickier. You simply exchange space in the back of the assembly station for space to the sides of the assembly station. Yet, the space to the sides of the station is usually more valuable than the space in the back. Therefore, this is usually not a good solution, but may help you in a pinch.

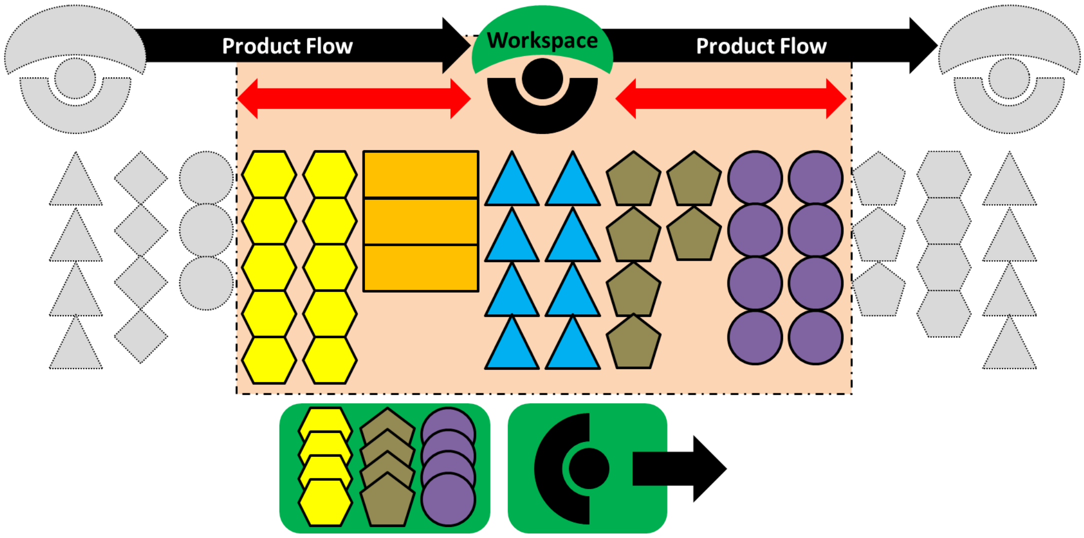


Figure 405: Assembly Space Expanded (Image Roser)

47.3 Store Material Elsewhere

Another option is to move material to another space where it is not in the way, as shown below. Yet this is also a less desirable solution because now the worker has to walk to get the material. Even if you put the least frequently used material elsewhere (which you should do), the worker will have additional walking distance and hence additional waste.

This additional work may even be outside of his normal cycle if he has to do it only for some products but not for others. In general, we try to split the work into cyclic work (happens for every product) and noncyclic work (happens occasionally). A worker should be doing either one or the other, but ideally not both.

This additional delay due to walking may also cause problems for the entire line if the worker now has more work than the line takt allows and other workers have to wait for the worker to complete his tasks. Hence, this is also not an ideal solution, as it does not reduce the material. But as the previous idea, it may help you in a pinch.

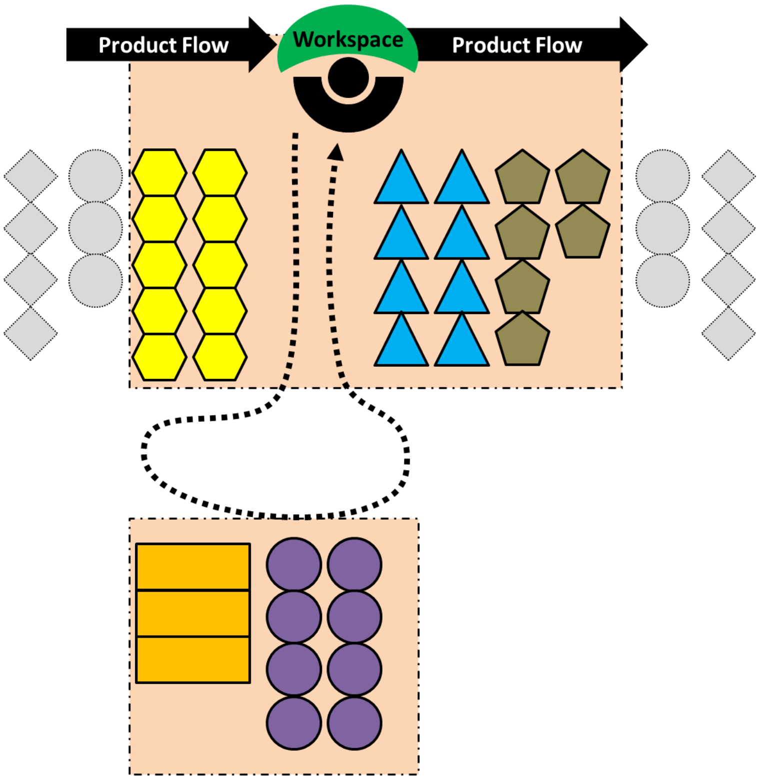


Figure 406: Assembly Space Elsewhere (Image Roser)

47.4 Point-of-Use Provider

As mentioned above, lean manufacturing aims to keep noncyclical work away from cyclical work. If the assembly worker does the cyclical assembly work, then someone else should do the noncyclical work. With respect to material supply, this is exactly the idea of a point-of-use provider (POU).

A point-of-use provider is a worker who does mostly the material support for other workers. It is noncyclic (hence not a milk run) and for short distances only (hence not a forklift). In practice, it is usually one worker assigned to an assembly cell that makes sure all of his assembly cell teammates have all the material they need. This is illustrated in the image below for a point-of-use provider supplying one worker, but in reality he would of course be supplying multiple workers.

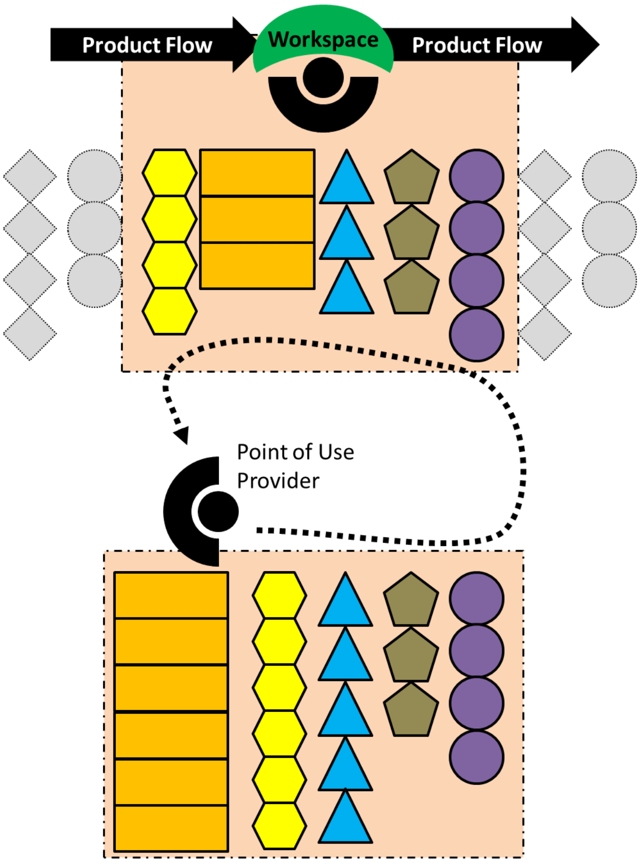


Figure 407: Assembly Space Point of Use Provider (Image Roser)

Usually, the point-of-use provider receives his material from an intermediate supermarket (often supplied from the central warehouse through a milk run) and distributes this as needed along the assembly cell. He is in close contact with his assembly cell teammates and part of their team. It is often a more experienced team supervisor that not only supplies materials but also helps in case of problems and other issues. He can also stand in for a worker if the worker needs to go to the toilet to keep the line running smoothly.

I have seen point-of-use providers used very effectively for many assembly cells and believe that this is a good way to take pressure off an assembly cell. Of course, you would need an extra worker, but the resulting gain in efficiency is often worth it.

47.5 Increase Delivery Frequency

You could also increase the delivery frequency of your material supply from the central warehouse. This is illustrated in the image below by a second milk run. If the assembly worker needs ten parts per hour, you could keep ten parts (plus safety) on site with a milk run every sixty minutes, or keep only five parts (plus safety) on site with a milk run every thirty minutes.

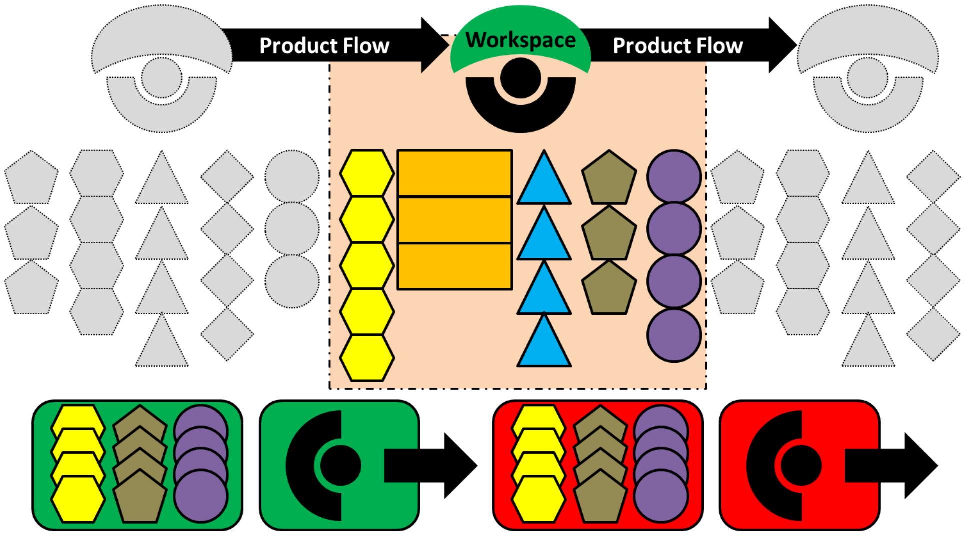


Figure 408: Assembly Space Increase Delivery Frequency (Image Roser)

Increasing delivery frequency not only rearranges the material around your workplace, but actually **reduces** the overall material quantity and hence the required space. You don't even merely push the material back to the central warehouse, but instead slightly reduce the quantity of material there too. Rather than keeping ten parts in the warehouse available for the hourly milk run, you need to have only five parts for the twice-hourly milk run. But this probably pales compared to the 1,680 parts you have sitting around due to the weekly truck from your supplier.

Overall, you buy your reduced material quantity on site with an increased delivery schedule, and a potentially slightly increased overall delivery workload. The work for delivering material won't be twice as much since every milk run now has only half the material, but it is an increase in work content. Yet often this is worth it. One vision in lean is, after all, a one-piece flow, and increasing delivery frequencies moves in that direction. For a nice example of one-piece flow in material supply for assembly, see my post Toyota's and Denso's Relentless Quest for Lot Size One!

47.6 Just in Time

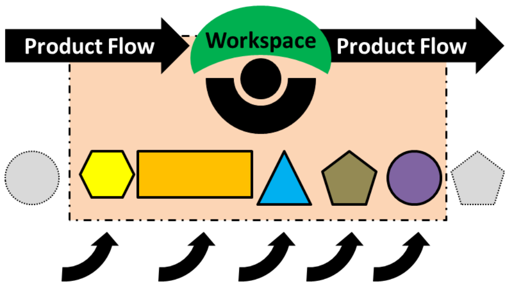


Figure 409: Assembly Space Just in Time (Image Roser)

This increase in delivery frequency can be pushed even one step further: Deliver Just in Time (JIT)! Bring the material from the central warehouse exactly when the worker needs it. This way you have (almost) no material at the actual work location.

Of course, this is easier said than done, as Just in Time is not easy. You would, among other things, have to reduce fluctuations in your value stream. Generally speaking, reducing fluctuations reduces your required buffer inventories, and hence you need for space around your workstation.

This post looked at how to rearrange or reduce the overall pile of material. In my next post I will continue by showing you ways to reduce the front space needed facing the worker. Most of these methods also rearrange or reduce the piles or material, but aim at using less space facing the worker. Now, **go out, reduce the material problem around your assembly stations, and organize your industry!**

48 Twelve Ways to Create Space around Your Assembly – Part 2

Christoph Roser, November 28, 2017, Original at https://www.allaboutlean.com/assembly-space-2/

Figure 410: Large Fish in Small Bowl (Image Mikael Damkier with permission)

The spaces around your assembly locations are most precious. In my previous post I explained how to relocate or reduce the overall material quantity. In this post I focus on how to better use the area facing the worker. Ideally, all material should be within easy reach of the worker.

48.1 Initial Situation

Let's briefly recap the initial situation from the previous post: You have too much material around your assembly location as shown below. Hence, you need to reduce or rearrange the material.

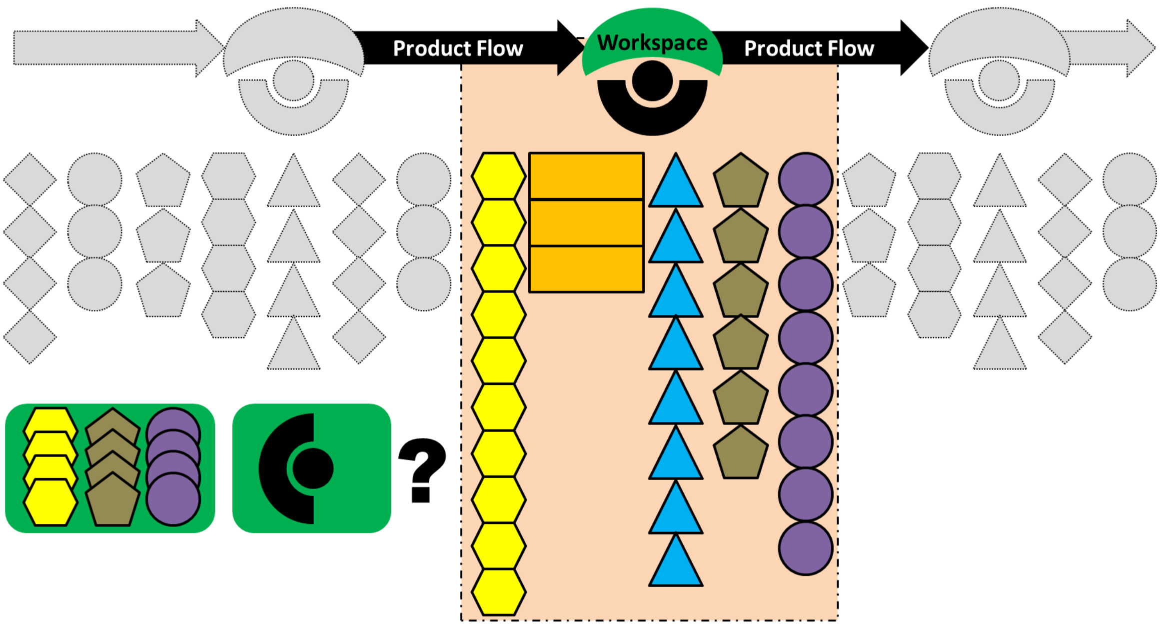


Figure 411: Assembly Space Original (Image Roser)

48.2 Use Full Space around Worker

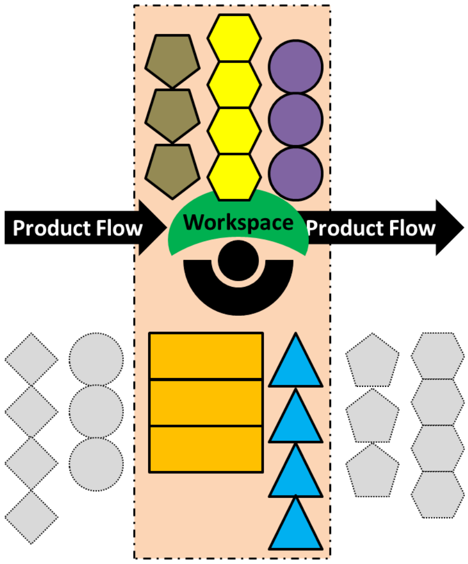


Figure 412: Assembly Space Use Full Space (Image Roser)

If the space around the assembly workstation is tight, try to use the entire space around it. Material can be provided not only from the back but also from the front.

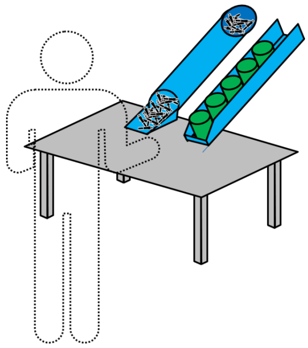


Figure 413: Material Supply over Table (Image Roser)

As explained in a previous post, this is often actually more ergonomic and easier for the operator. However, it is usually possible only for smaller parts. Larger parts simply don't fit across a table.

Hence the front and the back of the workspace are both very well suited for material supply. The sides are usually less useful, as this is where the main product normally comes along. Hence it may be difficult to use this space also for material supply, but this depends on the situation at your assembly line. It may work if there is little movement of the main product combined with long cycle times. A watchmaker, for example, can easily be surrounded by parts on three sides while twiddling with his product.

Just for completeness' sake, besides front, back, left, and right, there is also the top and the bottom. Yet I have never seen material supplied from above the worker, and please don't pull the floor away underneath of the worker!

48.3 Zentenatamadashi

Figure 414: Zentenatamadashi Dogs (Image Roser)

Next I would like to present you *Zentenatamadashi*. Now, in the mind of many people, if a method has a Japanese name, it must be superior to other methods that suffer from being known only in English. This is bollocks! I just couldn't find a good English name for Zentenatamadashi. As for the method, it is useful, but only a minor step in arranging material around your workspace.

Zentenatamadashi is written in Japanese as 全点 頭出し, and means something like "*only the heads sticking out.*" An English translation may be "*single-piece presentation.*" The idea is that when presenting parts to the operator, the smallest side of the part faces the operator so that the part takes up less area facing the operator. In the image below, I rotated the orange rectangle to use up less width. This allows you to fit more different parts within the operators reach. Of course, since the parts did not get smaller, you would need more space extending outward from the operator to fit in the parts. A small but sometimes useful method.

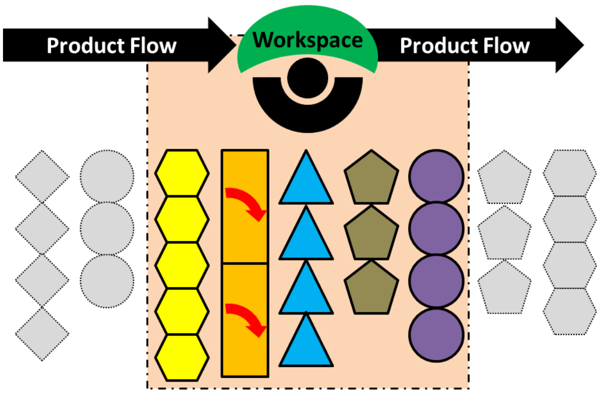


Figure 415: Assembly Space Zentenatamadashi (Image Roser)

48.4 Smaller Packages

If your parts are delivered from the supplier in larger packages, you may consider repacking them into smaller units. This is common if the material is delivered on pallets. Rather than putting the large pallet directly to your assembly line, you keep the pallet in the warehouse and take out only a few parts every time as needed for the assembly station. This could significantly reduce the space required at the assembly station.

On the downside, you now have to touch every part twice, and you also may have to provide suitable packaging for the leg between the warehouse and the assembly location. If you have some influence over your supplier, however, you could rethink the packaging delivered from the supplier. Can the supplier deliver in smaller packages? Can the supplier maybe make larger packages or a pallet that consists of multiple smaller packages? This may be beneficial overall.

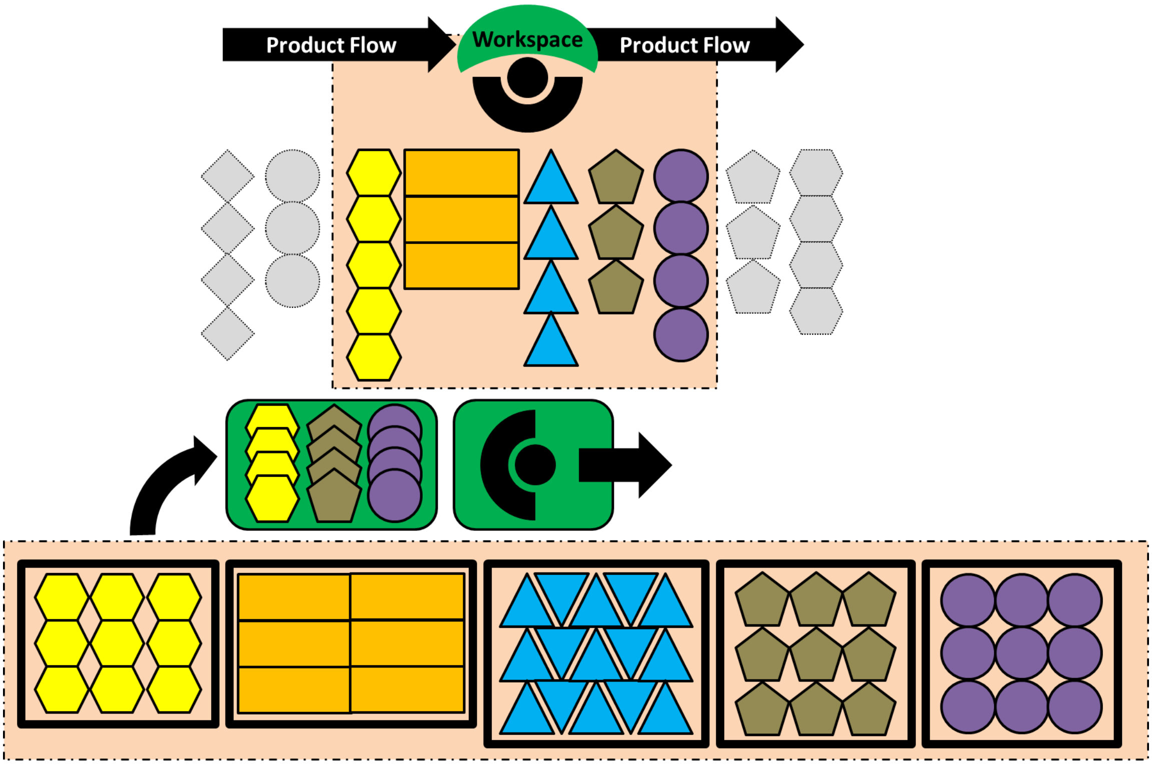


Figure 416: Assembly Space Smaller Packages (Image Roser)

48.5 Reduce Part Variety

If you have too many different parts, you may be able to reduce the number of different part types. Of course, this would mean involving construction to change the product design, which construction may or may not be fond of. But maybe they are open for some design for manufacturing (DFM), design for assembly (DFA), or design for manufacturing and assembly (DFMA) workshops.

However, this would among other things reduce the number of part types at your assembly. This not only frees up some space facing the worker but will also reduce the total number of items around the workstation since now you only need buffer stock for one part type instead of two. There are also lots of other side benefits, including reduced inventory along the entire part supply chain, reduced space for inventory, and reduced handling for inventory.

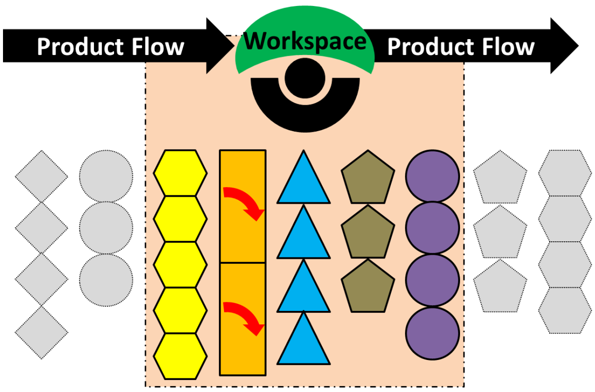


Figure 417: Assembly Space Reduce Part Variety (Image Roser)

48.6 Movable Shelves

The next option works only if you produce in batches: You create movable shelves containing the parts needed to produce a certain product, and depending on what product you make, you merely put the right shelf next to the assembly station. That shelf may contain all parts or only the parts specific to this product with the generic parts being stored on permanent shelves.

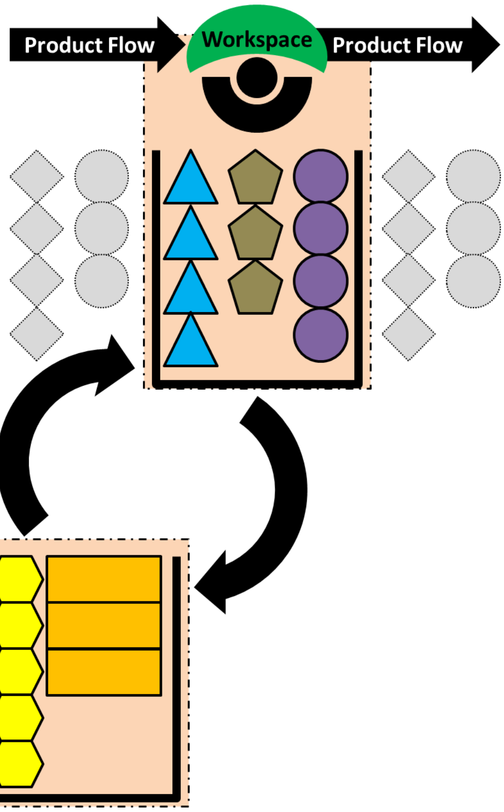


Figure 418: Assembly Space Movable Shelves (Image Roser)

I have used this approach, but it is not really a good approach. The extra work and the extra space needed for the shelves is one handicap. A potentially bigger issue is that this solution prevents you from moving toward one-piece flow, which is one of the main visions and goals in lean manufacturing. You reduce flexibility and are limited to larger batch sizes due to the effort of moving the shelves.

48.7 Kitting

This approach is similar to the movable shelves, but without many of the drawbacks. Rather than moving an entire shelf around, you prepare individual kits containing only the parts needed for one product at this station. The worker gets a kit, uses the parts, and returns the empty box or container back to the material supply. A kit may contain

- All the parts for the entire line if the kit moves with the product
- Only the parts for one assembly station
- Only the product variant-specific parts, with the generic parts stored in permanent shelves/storage locations
- Any combination of the above

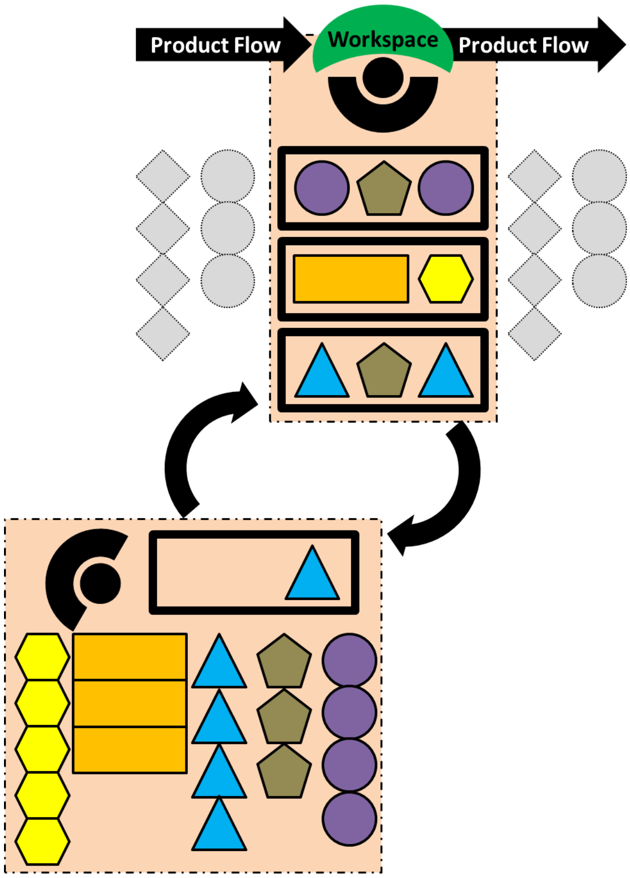


Figure 419: Assembly Space Kitting (Image Roser)

On the plus side, now you have much more flexibility and can move toward lot size one and one-piece flow. However, there are also some disadvantages. You need one worker preparing the kits. However, since the worker preparing the kits and the worker assembling can specialize in their respective tasks, you may become more efficient overall. A second challenge is to provide the right kits in the right sequence. The kit has to match the product that has to be assembled.

Kitting is frequently used for products that have larger parts and a large product variety. At Toyota they also call it SPS for Set Part Supply. It is a common approach in automotive assembly lines.

48.8 Just in Sequence

Finally, if you have a large product variety, you may provide parts Just in Sequence (JIS). The next part provided in the shelf is always the part variety needed for the product variety to be assembled. Again, common parts are always provided, but product variant specific parts can be delivered just in sequence.

A common example are seats in the automotive industry. They are rather large and come in many different varieties. Hence a seat supermarket would eat up too much space, and they are delivered just in sequence.

Providing material just in sequence is not easy. I have written about this in much more detail in my posts Just in Sequence Part 1 – What Is It?; Part 2 – How to Do It; and Part 3 – What Can Go Wrong. The main challenge is to make sure that the part provided matches the product to be assembled. A part–product mismatch causes lots of trouble.

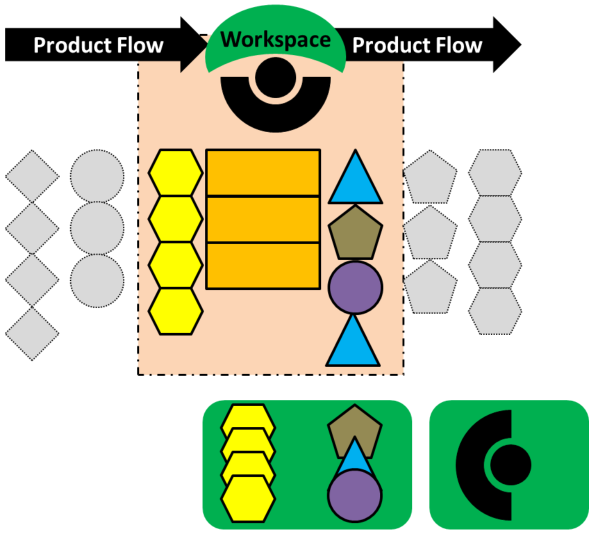


Figure 420: Assembly Space Just in Sequence (Image Roser)

So, the approaches above and in my previous post are the twelve options to rearrange or free up space around your assembly location. Some of them are better than others, some may be more effort than others, and some are merely a last-ditch-effort quick-fix solution. Yet these are all I know. If you have additional ideas, please share in the comments below. I hope at least one of these twelve will ease your assembly space issues. **No go out, optimize your assembly, and organize your industry!**

49 A Small Dice Game for the Kingman Formula

Christoph Roser, December 05, 2017, Original at
https://www.allaboutlean.com/dice-game-kingman-formula/

Figure 421: Kids with Dice (Image spass with permission)

In a previous post I wrote about the relation between utilization, fluctuation, and waiting time, and its approximation by the Kingman formula. Let me show you a quick and easy dice game where we simulate a supermarket checkout to let participants experience the effect of utilization, fluctuation, and the (worse) combined effect of both.

49.1 Introduction

Figure 422: A typical supermarket checkout (Image Robert Kneschke with permission)

Waiting time in front of a process is heavily influenced by two things: the **utilization** of a process (how busy is it?) and the **fluctuations** of the arrival and process times (how steady is the system – or not?). The Kingman equation and others show this nicely (check out my post The Kingman Formula – Variation, Utilization, and Lead Time for details on the equation). As the utilization approaches 100%, the waiting time approaches infinity. As the fluctuations of the arrival and process times increase, so does the waiting time. This game will demonstrate this effect.

$$E(W) = \left(\frac{p}{1-p}\right) \cdot \left(\frac{C_a^2 + C_s^2}{2}\right) \cdot \mu_s$$

49.2 Game Equipment

Figure 423: D4, D6, D8, D10, D12, and D20 dice (Image Roser)

What you need are dice! Many-different-sided dice! If you grew up before the internet like me, then you may be familiar with dice that are different from the common six-sided dice D6

(Dungeons and Dragons anyone?). In particular, you need three different types of dice – a small one (D4 or D6), a medium-sized one (D10 or D12), and a large one (D20 or D30).

Ideally you have one of each die for every player, but if you are short on dice you can have one die for every two players (we will make teams of two people shortly). It is best to have a large spread in the range of dice (i.e., using D4 as the smallest one and D30 as the largest one).

Dice Game Queue AllAboutLean

Round	1	2	3	4	5	6
Dice						
+Arriving						
+Check Out						
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
Sum						
Ø						

Figure 424: Blank Dice Game Sheet (Image Roser)

Then you would need to print out the data sheets (one for every two players, plus maybe a few for backup). There is also an overview sheet, but you can also use a whiteboard, blackboard, or a flip chart for a quick sketch. More on these below.

The game itself takes about one hour including some theory, and can handle a wide range of group sizes, although it does get cumbersome if you have more than thirty people.

49.3 The Game

You will create groups of two people, each simulating a supermarket checkout. One will determine the number of people arriving, the other the capacity of the checkout. They get one dice-game queue-length sheet as shown above. Each then gets a die, which will determine the number of customers arriving at the checkout and the number of customers processed at the checkout. They may have to share one die if you are short on dice. There will be six rounds in the game, and each round consists of twenty iterations. In the first three rounds we vary the utilization.

49.3.1 Varying Utilization

Round 1 – D4 with Offset 2: In the first round, each player gets a four-sided die. For the number of people arriving, we throw the die and **add 13**. For the capacity of the checkout, we also throw a die, but this time **add 15**. Therefore the checkout has on average two more capacity than the number of people arriving. This information would also be the first three empty rows on the data sheet, where we write 4 (for the sides of the die), 13 (for the customer), and 15 (for the supplier). This could also be printed on the sheet, but I prefer to keep the players in the dark on the future rounds so that they can focus on the current round.

Both throw the die and add to determine the arrivals and capacity. If the capacity matches or exceeds the demand, the two players write a zero in the next cell below. If the arrivals exceed the capacity, the number of people waiting is noted down. These people waiting in the queue have to be processed in the next iteration. They repeat this for twenty iterations, always keeping track of the number of people waiting in line. Afterward they calculate the total and average queue length by summing up the twenty entries and dividing by 20. This is written in the last two rows of the sheet.

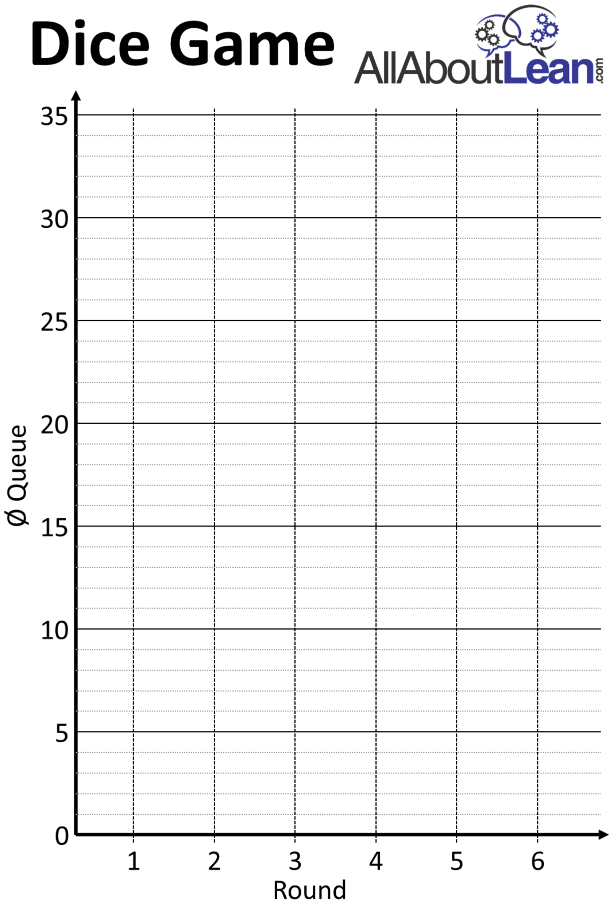


Figure 425: Dice Game Overview Sheet (Image Roser)

The results are added to an overview statistic for all teams. A blank sheet is shown here, which could be printed or simply drawn on a whiteboard, blackboard, or flip chart. You write down the average queue length for each team in round 1. In all likelihood there will be no queue, as the expected outcome is 0.07 people waiting in line with a standard deviation of 0.08 people.

Round 2 – D4 with Offset 1: The next round we reduce the offset. The arrivals keep on adding 13 to the die, but the checkout now adds 14 (instead of 15) to his throw. Therefore the first three rows of round 2 are 4, 13, and 14. Again they play for twenty iterations and then determine the average queue length. These results will be added to the overview statistics for all teams.

The expected outcome is now an average queue of 0.5 people with a standard deviation of 0.4 people, so there will be more people waiting in line.

Round 3 – D4 with Offset 0: The next round we eliminate the difference between the arrivals and checkouts. Both can add only 13 to their die throw. Now the queue starts to heat up. The expected outcome is an average queue length of 3.1 people with a standard deviation of 2.3 people.

49.3.2 Theory on Utilization

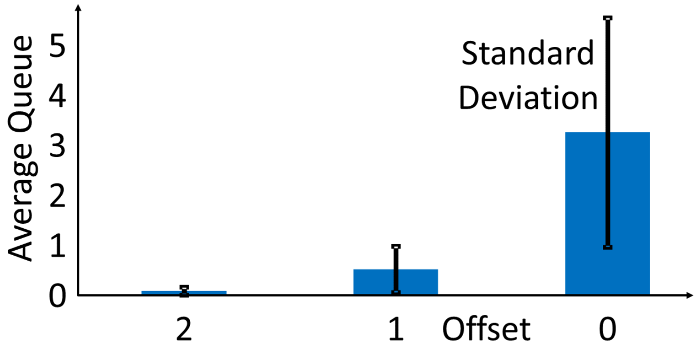


Figure 426: D4 Offset Chart (Image Roser)

At this point, we should discuss with the participants what happened. By reducing the overcapacity per iteration from 2 to 1 to 0, we in effect increased the utilization of the checkout. When the checkout had on average two more capacity than the people arriving, he had in effect a utilization of 88.57%. With an offset of 1, the utilization was 93.945%. Without any offset, the utilization was 100%. In the long run, an utilization of 100% means a queue length of infinity, but since we did only twenty iterations, we did not get that far. The graphs shows the expected average outcomes with the standard deviations for a D4 with different offsets.

49.3.3 Varying Fluctuation

In the next two rounds, we vary the fluctuations while keeping the offset constant. This means the utilization will always be at 88.57%.

Round 4 – D12 with Offset 2: Now we use a twelve-sided die. The arrivals add 9 to his throw, and the checkout adds 11 to his throw. Again, after twenty iterations, we add the averages to the overview sheet. The expected outcome is an average queue length of 3.0 people, with a standard deviation of 2.4.

Round 5 – D30 with Offset 2: Finally, we get to use the thirty-sided die. To maintain the same utilization and offset, the arrivals add nothing to his die throw, while the checkout adds 2 to every die throw. The expected outcome is an average queue length of 14.7 people, with a standard deviation of 11.0.

49.3.4 Theory on Fluctuation

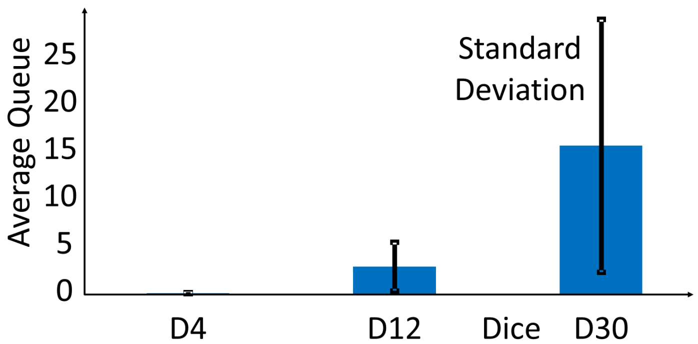
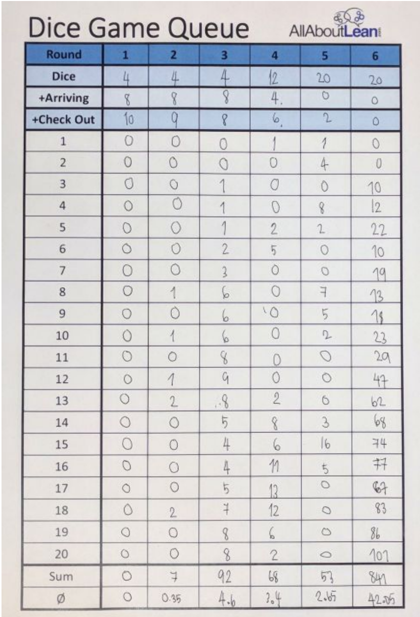


Figure 427: D4 D12 D30 Chart (Image Roser)

By changing the die from a D4 to a D12 to a D30 while keeping the average arrivals and checkout capacity constant, we in effect increased the fluctuation. The D4 +13 arrivals meant that the number of arrivals fluctuated between 14 and 17 with an average of 15.5. A D12 +9 keeps the same average of 15.5, but now with a fluctuation from 10 to 21. A D30 plus nothing again has the same average of 15.5, but this fluctuates now between 1 and 30.

Hence, we increased the utilization. Similar to the utilization, increasing the fluctuation also increased the average backlog as shown in the chart above.

49.3.5 Varying Utilization And Fluctuation


Dice Game Queue

AllAboutLean

Round	1	2	3	4	5	6
Dice	4	4	4	12	20	20
+Arriving	8	8	8	4	0	0
+Check Out	10	9	8	6	2	0
1	0	0	0	1	1	0
2	0	0	0	0	4	0
3	0	0	1	0	0	10
4	0	0	1	0	8	12
5	0	0	1	2	2	22
6	0	0	2	5	0	10
7	0	0	3	0	0	19
8	0	1	6	0	7	13
9	0	0	6	0	5	18
10	0	1	6	0	2	23
11	0	0	8	0	0	29
12	0	1	9	0	0	47
13	0	2	8	2	0	62
14	0	0	5	8	3	68
15	0	0	4	6	16	74
16	0	0	4	11	5	77
17	0	0	5	13	0	67
18	0	2	7	12	0	83
19	0	0	8	6	0	86
20	0	0	8	2	0	107
Sum	0	7	92	68	53	841
Ø	0	0.35	4.6	3.4	2.65	42.05

Figure 428: Example game data sheet (for largest dice D20) (Image Roser)

Round 6 – D30 with Offset 0: For the next round we increase both fluctuation and utilization. Both the arrivals and the checkout get a thirty-sided die, and neither gets to add anything to the die throw. Important: Before we do this round, ask the participants about their guess on how long the queue will be! In all likelihood they will probably add the two effects together and expect a queue length of around 18. However, what they do not (yet) know is that these effects are not additive but more multiplicative! Let's do the sixth round.

The expected queue length is not 18, but 24.2 people, with a standard deviation of 17.6. Hence it is much bigger than expected. Emphasize that this is not additive but multiplicative as per the Kingman equation above.

49.4 Simulation of Expected Outcomes

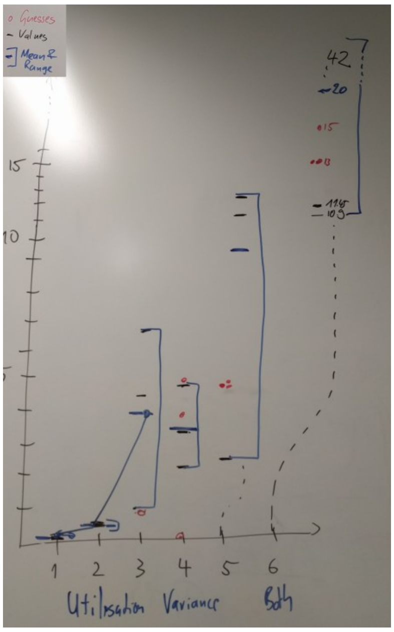


Figure 429: Example results graph … the ceiling turned out to be too low … (Image Roser)

For your convenience, here is a table of the expected outcomes for offsets 2, 1, and 0 and for dice from two sides (a coin flip) to thirty sides in steps of two based on two hundred games each. Naturally, I did this in Excel rather than throwing a die eighteen thousand times. Besides, I don't have a twenty-six-sided die, which according to Wikipedia wouldn't really be a good die anyway. In any case, here is the mean and the standard deviation of the queue length for different situations.

	Mean Queue Length			**Standard Deviation of Queue Length**		
Dice	**Offset 2**	**Offset 1**	**Offset 0**	**Offset 2**	**Offset 1**	**Offset 0**
2	0,00	0,00	1,21	0,00	0,00	0,88
4	0,07	0,49	3,07	0,08	0,42	2,28
6	0,47	1,35	4,80	0,39	1,11	3,59
8	1,01	2,89	5,80	0,79	2,99	4,03
10	1,88	3,86	7,70	1,50	3,35	5,48
12	2,98	5,39	10,26	2,44	4,45	7,25
14	3,91	6,83	11,71	3,33	5,75	7,90
16	5,49	7,33	13,24	4,88	5,32	8,60
18	6,04	9,56	14,62	4,93	7,42	10,35
20	8,22	11,99	15,67	6,95	9,26	11,83
22	9,85	12,33	19,17	8,23	9,19	13,67
24	10,92	14,19	20,51	9,39	10,56	14,30
26	12,44	16,99	23,02	10,92	11,70	16,17

28	11,89	18,65	22,83	9,13	13,44	15,75
30	14,70	20,36	24,18	11,02	14,49	17,64

49.5 Different Dice

Figure 430: D30 Dice (Image Traitor under the CC-BY-SA 3.0 license)

If you don't have a thirty-sided die, you can also use a twenty-sided die. If your largest die has only twelve sides, then it may be difficult to see a good effect. The numbers added to the arrivals for different dice above would work for any die up to 30, but if you have smaller dice, you can also use smaller add-ons. The table below shows you the quantity to add to the arrivals for different dice depending on your largest die. The numbers in any row would also work for any smaller dice. The checkout has to add 2, 1, or 0 on top depending on your desired utilization.

Dice	D4	D6	D8	D10	D12	D20	D30
Max D30	13	12	11	10	9	5	0
Max D20	8	7	6	5	4	0	n/a
Max D12	4	3	2	1	0	n/a	n/a

So, there it is, a quick and easy game with which you can demonstrate the effect on the backlog or waiting time of utilization and fluctuation, and the much-worse combined effect of utilization and fluctuation! I believe everybody can share that feeling if they are waiting at the supermarket checkout.

This game was inspired by the dice game in The Lean Games and Simulations Book by John Bicheno, which uses D6 to show the effect of utilization. I expanded this using different dice to also show the effect of fluctuation and the even-worse combined effect. Now, **go out, throw a dice (not at your coworker, boss, or customer!), reduce fluctuation, get utilization under control, and organize your industry!**

50 Monozukuri – Japanese Work Ethics

Christoph Roser, December 12, 2017, Original at https://www.allaboutlean.com/monozukuri/

Figure 431: Japanese Carpenter (Image National Museum of Denmark in public domain)

Perhaps you've heard of the Japanese word *monozukuri* (sometimes written as 物作り, but most often written as ものづくり). Literally translated, it means to make (zukuri) things (mono). Yet, there is so much meaning lost in translation. A better translation would be "manufacturing; craftsmanship; or making things by hand." However, this translation also does not give justice to the weight and influence this idea has in Japan. Let me take you on a tour of the Japanese culture of monozukuri.

50.1 The Spirit of Monozukuri

Figure 432: Japanese Tea Bowl (Image Philrogers under the CC-BY-SA 3.0 license)

Monozukuri is so much more than creating products. If monozukuri was simply creation, then music would be nothing more than nice sounds, and a picture would be only a bunch of pretty colors.

When Japanese talk about monozukuri, they mean much more than mere manufacturing. If they want to talk only about manufacturing, they would use *Seizo* (製造) or *Seizan* (生産) for *manufacturing* and *production*.

No, monozukuri is more than just crafting; it is a mindset, a spirit, a philosophy. It is the Japanese work ethic and the drive toward perfection. I apologize for all these fuzzy words, but it's really difficult to explain this concept without sounding bombastic. Later on, I will give you examples on how this monozukuri establishes itself in everyday Japanese society.

The word itself is quite old and considered to be an original Japanese (i.e., not Chinese or Western-origin) word. Historically, it was used in connection with an individual artisan and craftsman who took pride in his or her products.

Figure 433: (One of multiple) monozukuri displays at the Suzuki Plaza, Hamamatsu (Image Suzuki with permission)

Over time, however, it also started to be used in industrial production. Factory work in Japan was often undesired and was considered to be **3K** for *kiken* (危険, dangerous), *kitsui* (きつい, difficult), and *kitanai* (汚い, dirty). The use of monozukuri improved the image, standing, and self-value of industrial production. Suzuki, for example, probably used it from at least 1970 onward to describe its production.

The word got another boost in 1999, when the Japanese government created a law for the *Promotion of Monozukuri: Basic Technology Promotion (ものづくり基盤技術振興基本法)*. This significantly improved the image of factory work and managed to bring the historically significant value of craftsmanship and artisans into modern manufacturing technology.

Below I will give a few examples for this spirit of manufacturing, both in the traditional craftsman style and in modern manufacturing industry.

50.2 Living National Treasures

Figure 434: Shoji Hamada, (no longer) Living National Treasure in Pottery (Image unknown author in public domain)

You probably know of famous artists like Shakespeare, Michelangelo, Picasso, Kahlo, and many more. Now do you know a famous potter? No? How about a famous smith? A carpenter? How about a weaver? I'd be surprised if you do. At least I didn't.

Japan also has its share of famous Japanese artists. Many of them are officially recognized as Living National Treasures (人間国宝 Ningen Kokuhō) of Japan. They include performing artists like musicians, dancers, and actors in traditional Japanese arts.

Figure 435: Shimura Fukumi, Living National Treasure in Dyeing and Weaving (Image 小松菜もぐもぐ under the CC-BY-SA 3.0 license)

These Living National Treasures, however, have a second group of categories in crafts. There, Japan recognizes skilled artists and artisans in pottery, textiles, dying, lacquerware, metalworking, swordmaking, dollmaking, woodworking, and papermaking. Japan values such craftsmen on an similar level to traditional artists.

Even though these names are not household names, they do get recognition and respect for their skills. While monozukuri values craftsmanship, it also values the artisan. This applies not only to famous living (or dead) National Treasures; value of working with the hands extends to all craftsmen and artisans.

Update: Michel Baudin pointed out the similar Meilleur Ouvrier de France.

50.3 Value of Work

Figure 436: Shoe Repair Japan (Image Kusakabe Kimbei in public domain)

Yet another subtle way in which the Japanese express their value for work is in their greetings. At the end of the workday when the workers leave the factory, office, or general workplace, the custom greeting to the departing colleague is *gokurosama* (ご苦労さま), meaning thank you for your effort.

Yet, digging deeper into the Japanese character, this greeting implies more than just effort, directly connecting to hard and physical labor. The first kanji 苦 stands for *pain, trouble,* *difficulty, hardship;* and the second kanji 労 stands for *labor, toil, work, effort.* Overall, this common message thanks the departing colleague for his *hard and demanding physical work*, even if the person is only an office worker. This is another example in how the value of physical work is deeply ingrained into the Japanese society.

50.4 Evaluation of Toyota Employees

Figure 437: Checklist (Image ClkerFreeVectorImages in public domain)

Recently I got access to a Toyota employee evaluation form (more in a later post). Employees at Toyota up to the plant manager level are evaluated every year on twenty factors. While the form contains some of the standard aspects, it also includes a lot of surprising elements.

The very first entry in this list: Skills in manufacturing on the shop floor. Can the employees handle the standards within the allotted time frame? Again, this is for evaluations up to the level of plant manager! Second point: Can the employee maintain good product quality at work? Again, this is up to the plant manager.

It seems to me that Toyota puts an enormous focus on actual physical work in its evaluation. This is also reflected on the shop floor. Everybody at Toyota starts out assembling cars. No matter if you are a manager or a designer, your first job after entering Toyota is producing cars on the shop floor.

At Toyota they also have master craftsmen called **Takumi** (匠, master craftsman or artisan). These are highly specialized expert craftsmen with a deep focus on one particular manufacturing technique (e.g., painting, electronic welding, sewing, or automotive body quality). They do a major part of their work by hand rather than with robots, to get a deeper understanding of the process. They are used to train others, solve problems, and help program robots and machines worldwide. Reportedly, around five hundred takumi exist at Toyota. While *takumi* is not an official job title, Toyota invests significant time and effort in training these takumi.

50.5 Monozukuri Spin-offs

A spin-off of monozukuri is **hitozukuri** (人作り, making people) for developing people. This includes the lifelong education, training, and coaching of people, not only in the classroom but especially at work.

At Nissan they are also **kotozukuri** (事作り, making stories) for "brand storytelling," with the goal of entering into dialogue with the customer. However, this is little used outside of Nissan.

50.6 Watching Japanese People Work

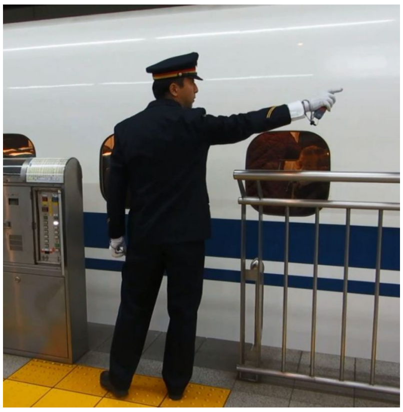


Figure 438: Point and call! (Image Roser)

Whenever I am in Japan, I enjoy watching the Japanese work. In most cases their work methods and standards are much better and more focused than in the Western world. This seems to be not only training, but part of the Japanese culture. (Note that office work, however, does not always have this *crisp* feeling, and a lot of time in the office is wasted away. But then, with twelve-hour workdays, it is impossible to be efficient all the time. There is huge potential for Japan to reduce office work hours while becoming more efficient and increasing their usually poor work-life balance.)

Figure 439: Japan supermarket checkout (Image Roser)

While monozukuri focuses on the manufacturing aspect, it also strongly influences the service part of Japan.

In previous posts I showed examples of Japanese Standard Pointing and Calling and The Japanese Supermarket Checkout.

Overall, every time I am in Japan, I am amazed at the Japanese work ethic and their spirit in making things. Of course, like in any country, the people are not all identical, and you surely can find slackers and good-for-nothings in Japan too. Yet, overall I feel that the Japanese people take much more pride in their work, and are much more respected for it. This applies not only to individual artisans, but also to people like factory workers who are only a minor cog in a large system. They, too, get much more respect than what a Westerner would consider appropriate based on their salary level.

50.7 A Story of a Shampoo Refill Bottle

Figure 440: Shampoo Refill Bottle (Image Roser)

Let me give you another example how deeply ingrained this culture of monozukuri is in Japan. A while ago I was on a domestic flight within Japan, and the plane had no video monitors in the seat (only big ones for everybody). In the US, they would be probably showing a cartoon of a robot talking of peace while beating the bad guys to a pulp, or a video of the Kardashians doing … whatever it is the Kardashians are doing (I haven't figured that one out yet).

But on this domestic Japanese flight, they entertained the guests with a twenty-minute documentary on **how to optimize a shampoo refill pack!** It wasn't even a real shampoo bottle, only the refill pack, but for twenty minutes they described in detail design features to maximize customer experience to reduce waste and increase comfort and safety. They coated the inside of the foil pack and used a special origami folding to minimize the wasted shampoo stuck in the container. They described how they optimized the opening with a smaller hole in a bigger one so less shampoo gets stuck in the hole. As a safety feature they added a jagged outer edge to the outlet so nobody accidentally mistakes it for a jelly drink (that is a thing in Japan). The designers were visibly proud of their work, and this was the video for all three hundred people on the flight in economy.

Figure 441: Notice the zagged edge and the slightly smaller opening at the bottom (Image Roser)

If a US airline media manager would select this for the audience, he probably would be fired. The product would even be too much of a fringe product for the special interest "How It's Made" series on Discovery Channel. Yet in Japan it is absolutely acceptable to go into great detail on the design aspects of a bloody shampoo refill bottle! I find this amazing, and a great example of the culture of monozukuri. (I also bought the refill pack to take it apart and see it myself. However, lacking a proper container to fill it in, I now have a soft drink pet bottle filled with shampoo. I hope you appreciate my efforts ☺)

I hope this post was interesting to you. Now, go out, be proud of what you do and try to do it well, be even more appreciative of what your people do for you, and organize your industry!

51 Anatomy of the Toyota Kanban

Christoph Roser, December 19, 2017, Original at https://www.allaboutlean.com/toyota-kanban/

Figure 442: Toyota Kanban Card (Image Roser)

While Toyota did not invent the pull system, they did invent kanban, the genius idea of using cards of paper (and later other forms of information) to create a pull system for mass-produced goods. I recently was able to take pictures of Toyota kanbans, and would like to show and explain them to you.

51.1 Introduction

Figure 443: Kanban on Store in Ginza (Image Roser)

The word *kanban* (看板) is nowadays usually translated as "card," but originally it meant the signboard with the name of the place (e.g., the name of a store). The image here shows a kanban on a fancy store in Ginza, Tokyo.

In lean manufacturing, however, *kanban* now means the bit of information attached to a part or product that initiates its replenishment after the part is used. Since it is a major part of lean production, I have written a lot on kanbans (see my [tag for Kanban](#)). This post goes into the details of Toyota kanbans as an illustrated example. Content-wise it probably comes closest to my post on Kanban Card Design.

51.2 Modern Toyota Kanban

Here is a photo of a Toyota kanban. I got permission to take the image during one of Toyota's plant tours. The paper is about 210 mm wide and around 100 mm high, like an A4 paper cut into three parts. The card here is laminated, but in the factory they are usually simple printouts attached to boxes using clips or added into folders attached to the material. Especially for supplier shipments, these cards are printed new each time they are used. Let's dig deeper into the card.

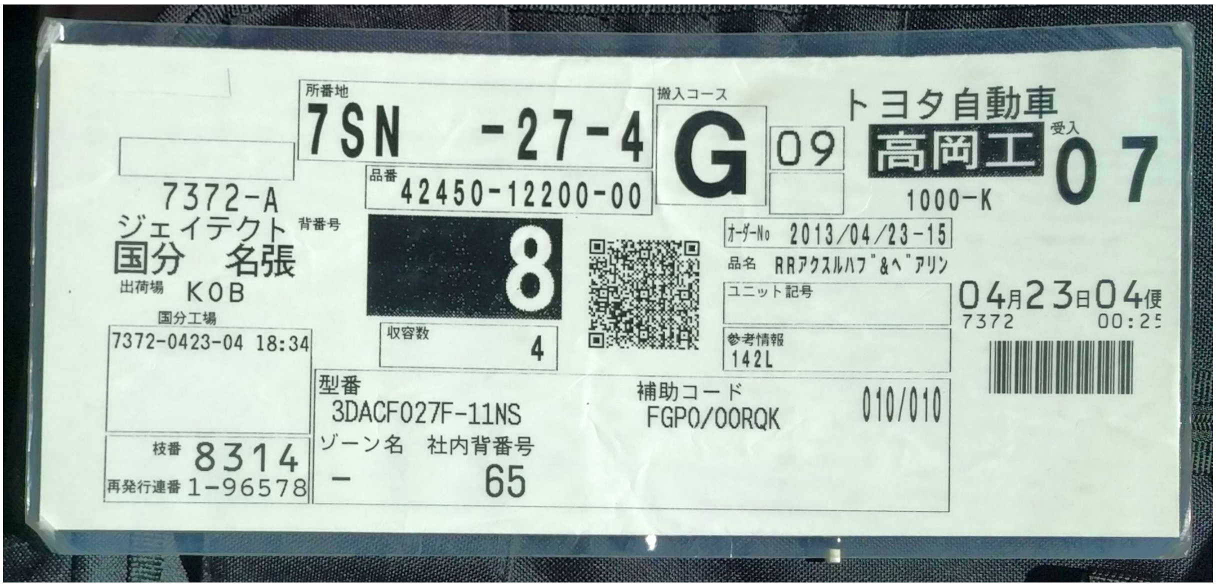


Figure 444: Toyota Kanban Card (Image Roser)

The card contains a number of elements. I have translated the different areas of the card and explained them (although some internal codes are still a mystery to me). The image below shows the general areas, with the detailed explanation following below.

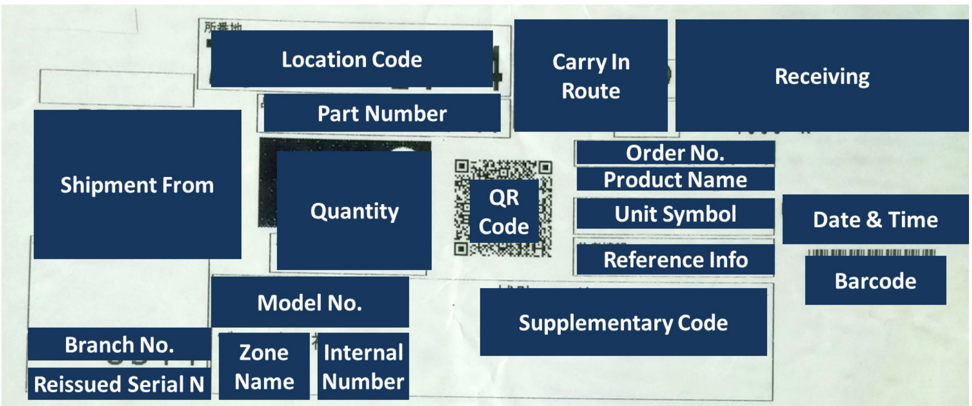


Figure 445: Toyota Kanban Card Annotated (Image Roser)

51.2.1 Product Related Information

Figure 446: Wheel Hub Assembly (Image Cschirp under the CC-BY-SA 3.0 license)

- **Part Number** (品番 *hinban*): The part number of the product, here 42450-12200-0, which stands for a Toyota rear wheel hub. This is a similar product as shown here, although this image is for an Opel Vectra.
- **Product Name** (品名 RR アクスルハブ&ベアリン *hinmei akusuruhabu&bearin*): The product represented by this kanban is an axle hub and bearing.
- **Unit Symbol** (ユニット記号 *unitto kigo*): Place to add a unit (e.g., liter or kilogram). This is left blank here, since the kanban quantity is in pieces.

Figure 447: Toyota ZR engine (Image Ypy31 in public domain)

- **Reference Information** (参考情報 *sankō jōhō*): Additional information on the product, here 142L. This seems to be a Toyota internal code for a Toyota ZR engine used in the Toytoa Auris, Yaris, Corolla, and others.
- **Model No.** (型番 *kataban*): The model number is 3DACF027F-11NS, which is the model number for the angular contact ball bearings. Hub units. Complete.

51.2.2 Source Information

JTEKT

株式会社ジェイテクト

Figure 448: JTEKT Logo (Image JTEKT for editorial use)

- **Shipment from** (出荷場: 7372-A ジェイテクト国分名張 *JTEKT Kokubu Nabari*): The items seem to be shipped from the Kokubu plant of the automotive supplier JTEKT, part of the Toyota Keiretsu (conglomerate). They provide, for example, in-steering systems and driveline components. The Kokubu plant is near Osaka, which means it is at least a three-hour drive to the Takaoka plant. This is quite far away by Toyota standards. The code underneath the shipment, 7372-0423-04 18:34, contains the date April 23, which matches the date on the right hand side of the card.
- **Branch Number** (枝番 *edaban*): 8314, probably an internal code for the location within the JTEKT plant.

51.2.3 Destination Information

- **Receiving**(受入:トヨタ自動車 07 *ukei: Toyotajidōsha, Takaoka Ko 1000-K 07*): The destination of the card is the Takaoka plant of the Toyota Motor Corporation, location1000-K 07.
- **Carry In Route** (搬入コース *Han'nyū kōsu*): Here G 09, an Toyota internal route code.
- **Location Code** (所番地 *tokoro banchi*): In this case 7SN-27-4.

51.2.4 Kanban-Related Information

- **Quantity (**収容数 *Shūyō-sū*): Eight containers, each including four parts.
- **Reissued Serial Number** (再発行連番 *Sai hakkō renban*): Probably the serial number of the kanban, 1-96578.
- **Order Number** (オーダーNo order No.): The order number is 2013/04/23-15, indicating that it was ordered on April 23 in 2013, and probably was the 15th order on that day for the supplier JTEKT.
- **Date and Time** (4 月 23 日 04 便 *7372 00:25 4 gatsu 23 nichi 04 ben*): The date and time for the card, stating April 23rd, 00:25 AM. There are additional service numbers 04 and 7372, which I am not sure of what they mean.

51.2.5 Additional Information

- **QR Code**: Internal code for scanning within Toyota. If anyone is interested, the code here contains 152 bytes and says "*JT7372AKOB 1000K07 100423040920130423 15 Z5760 84245012200000000040FTP342 83147SN -27-4 2*." You can find a lot of the other information again here in this QR code. The QR code was developed in 1994 by Denso, a company of the Toyota group. It was designed to be resistant to dirt. It also helped Toyota with storing all the information on a kanban in a machine-readable form, since at the end they needed nine different normal bar codes on a kanban before they switched to a QR code.
- **Barcode**: The barcode, strangely enough, does not seem to contain any information. Maybe a historic "leftover"?
- **Zone Name** (ゾーン名 *Zōn-mei*): Unsure what this is for, but it is not used anyway.
- **Company Internal Number** (社内背番号 *Shanai sebangō*): More information to be used within Toyota. The internal number is 65.
- **Supplementary Code** (補助コード *Hojo kōdo*): Again, not sure what this *FGPO/OORQK 010/010* stands for.

51.3 Old Toyota Triangle Kanban

Here is a Toyota triangle kanban in situ at a stamping press and also as a close up. This is an older model, having no barcode, and on display in the Toyota Commemorative Museum of Industry and Technology. It contains less information but still works as a kanban. Let's go through it from top to bottom:

Figure 449: Toyota Triangle Kanban (Image Roser)

- **Part Number** (品番 *hinban*): The part number of the product, here 13261-74040. (The first character of the text is not visible in the image, as the kanban hangs behind a pipe, but it is the same as in the modern kanban above).
- **Quantity** (収容数 *Shūyō-sū*): There are to be 500 pieces produced.
- **Reference Number** (基準数 *Kijun-sū*): Reference number 2.
- **Lot** (ロット *Rotto*): Lot number 4000 (not the quantity!).
- **Line** (ライン *rain*): This kanban is for the machine ER2500.

In the image below, you can see the kanban again at the bottom left, and the two receiving material supplies in the back for two different part types (13261-74040 for 500 connecting rods and 41314-20020 for 60 flanges), both to be made in the ER2500 machine.

Figure 450: Toyota Triangle Kanban Overview (Image Roser)

Okay, now that was quite a lot of detail on the Toyota kanban cards. For actual kanban card design, I would like to refer you to my previous post on Kanban Card Design, but I hope this post helped to satisfy your curiosity on how it is done on Toyota. Now, **go out, get your parts flowing, and organize your industry!**

52 The Toyota Employee Evaluation System

Christoph Roser, December 26, 2017, Original at [*https://www.allaboutlean.com/toyota-employee-evaluation/*](https://www.allaboutlean.com/toyota-employee-evaluation/)

Figure 451: Toyota Logo (Image Toyota for editorial use)

Like most companies, Toyota conducts an annual evaluation of the performance of their employees. Recently I got a chance to look at these evaluation sheets and take notes. There are some surprising differences in the evaluation by Toyota in comparison to the evaluation by most other companies.

52.1 Introduction

Figure 452: Checklist (Image ClkerFreeVectorImages in public domain)

Toyota evaluates its employees annually. When Toyota reorganized its evaluation system, it was one of the few instances where Toyota sought the help of outside consultants, working with them for three years to come up with this process. I do like the resulting sheets, although (as always) I advise you against simply copying whatever Toyota does. Instead, use this as inspiration for your own evaluation process.

At Toyota, an employee up to and including plant manager is measured on twenty different aspects. Actually, the evaluation is done three times. The employee evaluates himself independently of the evaluation of his supervisor. When discussing the evaluations, both have to agree on a joint evaluation, and only this joint evaluation is then used for the promotion of the employee.

These twenty aspects are split into two groups of ten aspects each. The first group is the more important one, with each aspect having up to 10 points. The aspects in the second group can each get a maximum of 5 points. Additional points can be given if the employee completed a training during the previous year.

52.2 First Group of Aspects: Genba, Kaizen, Quality

Each skill in the first group is graded on a scale from 0 to 10. The possible options, however, are only 0, 2, 6, and 10, to avoid too much clustering in the neutral, comfortable middle.

- **Physical Skills on the Shop Floor**: Can the employee handle the work with respect to takt time and quality? This also includes if the worker calls for help without delay if he needs help. Again, please note that this is used even for plant managers, hence plant managers are also evaluated on how well they work with their hands. Although it may very well be that for higher-ups, past evaluations were recycled without verifying if the plant manager still can assemble cars. However, since every person at Toyota starts out with a few months of

assembling cars, the plant manager at Toyota probably knows the work better than most comparable plant managers in Europe and the USA.
- **Quality on the Shop Floor**: Can the employee maintain quality? Does he see if the quality differs? Is his hand movement suitable for quality? Again, even the plant manager is evaluated on this.
- **Kaizen**: Is the employee actively involved in the continuous improvement process (kaizen)? Does he generate ideas and are these useful?
- **Documentation**: Is the employee good at documentation? Does he know the documentation sheets, and does he fill them out properly? Toyota uses many sheets to track quality, productivity, safety, kaizen, and other things, and almost all of these sheets are filled out by the employees by hand to be verified and commented on by the managers, also by hand.
- **Big Picture View**: Does the employee know how the targets for his work are derived from the higher level targets? How do his targets contribute to the higher-level targets?
- **Leadership**: Can the employee make the most out of the different skills of his team? Can he help his subordinates and his team to grow? Can he help to foster the generation of improvement ideas?
- **Problem Solving**: Is the employee good at problem solving? Does he contribute to quality circles, etc.?
- **Cooperation with Support**: Does the employee work together well with support functions that help him in his work?
- **Cooperation with Management**: Does the employee work together well with management?
- **Outside-the-Box Thinking**: Does the employee look beyond the scope of his own assignments? Does he get ideas from outside of his own workplace? Is he interested in or aware of benchmarks? Does he read news or articles (e.g., on IT, robotics, or other topics)?

52.3 Second Group of Aspects: Performance, Behavior

The ten aspects in the second group rank lower than in the first group. While the aspects in the first group could get up to 10 points each, the second group has a maximum of 5 points for each aspect. These, too, are not evenly distributed, but can be 0, 1, 3, or 5, again avoiding the comfortable middle ground. These ten criteria are:

- **Performance**: Can the employee reach his targets?
- **Teamwork**: Is the employee a good team worker? Does he cooperate with others? This also includes if he is satisfied with his job or if he is here just for the money.
- **Manners**: Is the employee well behaved, and does he interact properly with others?
- **Self-Awareness**: Is the employee self-aware of his personal development? Is he aware of his contributions? Does he evaluate himself regularly, and has he the ability for self-reflection?
- **Health**: Does the employee get regular health check-ups? Does he do sports or exercise on or off the job?
- **Forward Looking**: Is the employee looking forward and eager for new experiences, or is he complaining and stuck in previous grievances?
- **Focus**: Can the employee focus? Can he separate the important from the unimportant? Does he understand the essence of problems and focus on the correct things?
- **Unbiased**: Can the employee keep his personal feelings separate from the factual aspects? Do his personal dis-/affections impact his evaluation of others?
- **Wide View** (literally “wide eyes”): Does the employee get ideas and inspiration from outside of Toyota?

- **Team Organization**: Can the employee organize a team? Can he lead a team, or does he just want to be a member?

52.4 Joint Results

Altogether, the employee can get up to 150 points, plus additional points for completed trainings. This determines the maximum rank he can achieve within Toyota.

Toyota has different salary levels, ranking up from Level D-VIII for the common worker up through C, B, and eventually A1. For a promotion, the employee has to achieve both a minimum number of points in his evaluation, as well as a minimum number of points on certain questions in the evaluation. For example, if you cannot work well on the shop floor, you will never make it to plant manager, even with a perfect score on all other aspects and exceeding the required minimum of 130 points.

A raise in the ranking corresponds with an increase in salary. However, a worker cannot move up more than two levels every year. It still takes time to move up, and it usually takes ten to fifteen years to become a supervisor, and fifteen to twenty years to become a group leader.

52.5 Summary

Like in most companies, some employees see this system as a challenge, whereas others see it as a drag. Usually, the employees that do well like it, and those that don't, don't.

What struck me as surprising is the value Toyota puts on working with your hands, on continuous improvement, and on teamwork. Elsewhere, I have never seen an employee being evaluated on how well he fills out forms, nor on his ability to assemble products. Again, this system is used up to the level of plant managers! There are a lot of surprises in this system, but to me these are good surprises! I don't know if this evaluation only affects promotion (and hence salary) or also the bonus.

Regarding bonuses, I do like the Bosch way. Bosch recently scrapped its performance-based salary bonus, and bases the bonus only on the performance of the division and company overall. This avoids a lot of bad blood if the employee sees himself better than the manager does (a common problem, as you surely know).

Anyway, I hope this post helped you to improve your "out-of-the-box thinking" score ☺. Now, **go out, think a bit more outside of the box, and organize your industry!**

PS: Before you ask: No, I don't have a copy of the documents, only my own notes. Sorry! But I do recommend the C2U Lean Leadership Training in Japan, at which I saw this Toyota employee evaluation form (and learned also many other things on Toyota).

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54 Author

Figure 453: Christoph Roser (Image Roser)

Prof. Dr. Christoph Roser is an expert for lean production and a professor for production management at the University of Applied Sciences in Karlsruhe, Germany. He studied automation engineering at the University of Applied Sciences in Ulm, Germany, and completed his Ph.D. in mechanical engineering at the University of Massachusetts, researching flexible design methodologies. Afterward he worked for five years at the Toyota Central Research and Development Laboratories in Nagoya, Japan, studying the Toyota Production System and developing bottleneck detection and buffer allocation methods. Following Toyota, he joined McKinsey & Company in Munich, Germany, specializing in lean manufacturing and driving numerous projects in all segments of industry. Before becoming a professor, he worked for the Robert Bosch GmbH, Germany, first as a lean expert for research and training, then using his expertise as a production logistics manager in the Bosch Thermotechnik Division. In 2013, he was appointed professor for production management at the University of Applied Sciences in Karlsruhe to continue his research and teaching on lean manufacturing.

Throughout his career Dr. Roser has worked on lean projects in almost two hundred different plants, including automotive, machine construction, solar cells, chip manufacturing, gas turbine industry, paper making, logistics, power tools, heating, packaging, food processing, white goods, security technology, finance, and many more. He is an award-winning author of over fifty academic publications. Besides research, teaching, and consulting on lean manufacturing, he is very interested in different approaches to manufacturing organization, both historical and current. He blogs about his experiences and research on AllAboutLean.com. He also published his first book, “Faster, Better, Cheaper,” on the history of manufacturing.

Prof. Dr. Christoph Roser is an expert for lean production; Toyota, McKinsey, and Bosch Alumni, and professor for Production Management at the Karlsruhe University of Applied Sciences. He is interested in everything related to lean manufacturing, bottleneck detection and management, as well as historic developments of manufacturing. His first book is “Faster, Better, Cheaper” on the history of manufacturing.

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