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Other Books by Christoph Roser

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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

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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 Introduction to One-Piece Flow Leveling – Part 1 Theory

Christoph Roser, January 04, 2015, Original at
https://www.allaboutlean.com/one-piece-flow-leveling1/

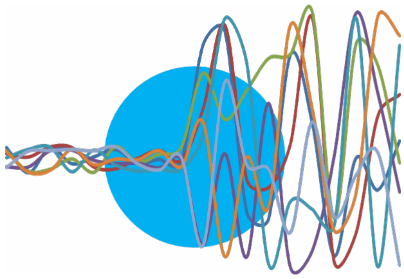

Figure 1: Leveling (Image Roser)

One successful approach to leveling is one-piece flow leveling, which I would like to talk about today. Another successful approach is capacity leveling. These can also be combined. (But please do yourself a favor and stay a way from a longer fixed repeating schedule EPEI leveling.) As the name already says, you should drive your lot size toward one. In addition to **one-piece flow,** this approach is also known as **single-piece flow** or **continuous flow**.

1.1 The Basics: Lot Size One

1.1.1 The Traditional Approach – Large Lot Sizes

The traditional thinking in manufacturing systems is that changeover times are a waste. This is correct, they are a waste. However, the traditional conclusion is to do as few changeovers as possible, resulting in large lot sizes. Unfortunately, this will lead to an even bigger waste: excess inventory! Additionally, it will work against smoothing the production and all its associated benefits. Hence, the example shown below is not very lean.

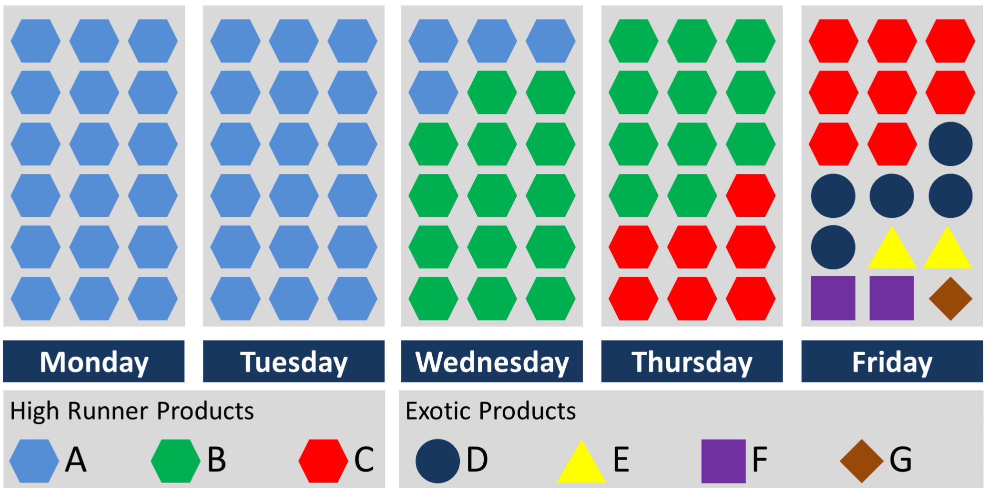

Figure 2: Example with Large Lot Sizes (Image Roser)

1.1.2 The Wrong Way: Fixed-Sequence EPEI Leveling

One approach often used to change this is to create a repeating pattern. I have explained the details of this approach in my post on the Theory of Every Part Every Interval (EPEI) Leveling, Also Known as Heijunka. However, I have explained even more why this usually fails (The Folly of EPEI Leveling in Practice – Part 1 and Part 2). Overall, I would like to strongly advise you against it. Nevertheless, for completeness sake, a possible solution is shown below, even if they rarely work in practice.

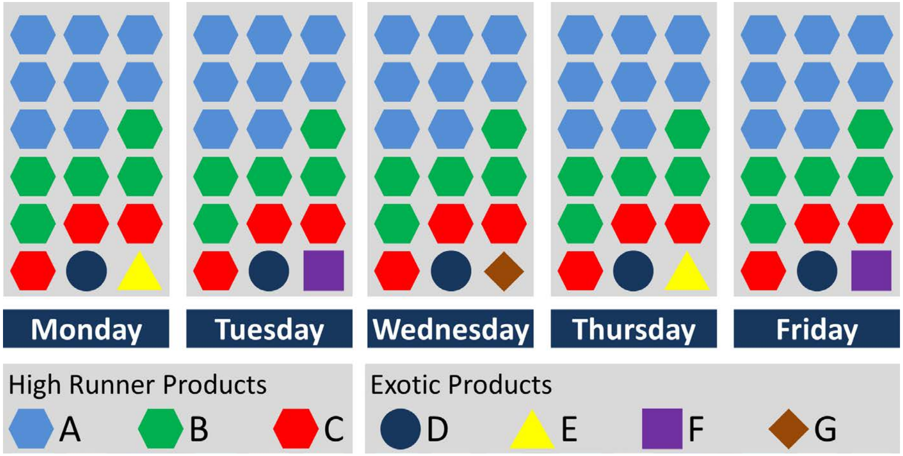

Figure 3: Better only in Theory: EPEI Fixed Sequence Leveling (Image Roser)

1.1.3 A Better Approach: Lot Sizes for Daily Demand

A much better approach is to reduce lot sizes so you produce every day what you need that day. Just to make sure: You do NOT take the daily average of your weekly/bi-weekly/monthly demand. It is truly what you need to produce today based on the best available data, forecasts, and demands you have today. This includes effects like:

- Rush orders
- Canceled orders
- Changes in demand forecasts
- Suppliers that did not deliver
- Raw material that turned out to be defective/wrong/missing
- Completed products that turned out to be defective/wrong/missing
- Customers begging/threatening/yelling for urgent parts
- Higher-up managers telling you what you must produce right now
- and many more.

Of course, the fewer of these effects you have, the smoother your production will be. But let's be realistic, you will have at least some of these effects. Based on this best available data (if you can call it that), you should produce every day what is most urgent.

Assuming you cannot yet do one-piece flow, your resulting production plan may look like the image below. Produce whatever is most urgent today, where the lot size is the daily demand of this product.

Figure 4: (Not) one piece flow (Image Roser)

Of course, for practical reasons, you may still want to pool your exotic parts in larger lot sizes and make them, for example, once per week. The violet square and the brown diamond in the example above have a lot size one. Depending on your system, you may want to pool these together across multiple days and make, for example, three of them once per week. It all depends on the ability of your system.

1.1.4 The Lean Approach – Lot Size One, Well Mixed

However, your goal should be to have lot sizes as small as possible, ideally a lot size of one. Furthermore, you should mix your lot sizes as much as possible. **One-piece flow leveling does not mean only the ability to do lot size one, but also the mixing of the production sequence so that there are no two similar parts produced together. Hence, it is not the ability to do lot size one, but actually doing only one product before changing to a new product.**

Using the daily schedule from above, the result may look like the schedule below. The total quantities of the parts are still the same, but the sequence is intentionally well mixed.

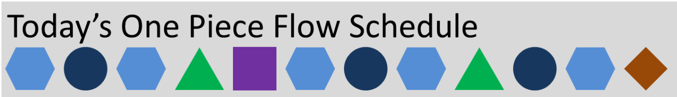

Figure 5: One Piece Flow (Image Roser)

1.1.5 How to Create the Mix with Lot Size One

I have seen some Excel tools to make a sequence as mixed as possible. If you have one of these (or can make one yourself), it may help in your scheduling. However, in my opinion, it is not strictly necessary. The difference between a perfectly leveled sequence and a nearly perfect sequence is, in my opinion, very small. Even in the example above, you could imagine different patterns that are also similarly leveled. Just try to mix up the sequence as much as possible.

However, here is a basic structured approach to create a good mix that works for products with few common parts (Alternative approaches are available for products that have common parts, which I may cover in another post). Let’s assume that the total production quantity looks like below, producing a total of twelve parts within the planned period (e.g., one day):

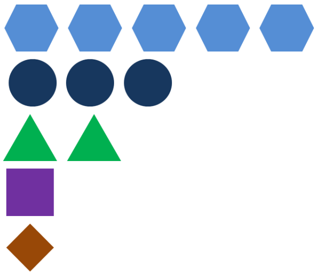

Figure 6: One Piece Flow Example (Image Roser)

We start with the largest volume (the blue hexagons). We want to produce five and have a total of twelve slots. Hence, dividing 12 by 5 results in every 2.4th slot being a blue hexagon. Starting with the first empty slot, this would put a blue hexagon in the 1st, 3.4th (rounded to 3rd), 5.8th (rounded to 6th), 8.2nd (rounded to 8th), and 10.6 (rounded to 11th) slot. The full pattern can be seen further below.

Next we take the dark blue circles. Dividing 12 by 3 circles gives us a circle every 4th slot. Starting with the first empty slot (number 2), we get blue circles in slot number 2, 6, and 10, except that 6 is already taken by a blue hexagon. Hence, instead of in the occupied slot 6, we put the circle in the nearest free slot, in this case slot 7 (although slot 5 would also have been possible).

Similar with the green triangles. Dividing 12 by 2 triangles gives 6 slots between triangles. The first empty slot is 4, hence there is a triangle in slot 4 and 10 – except that slot 10 is occupied. The nearest free slot is number 9, hence the triangles go into slots 4 and 9. The last two exotic pieces then take up the remaining free slots. This gives step by step the one-piece flow pattern as shown below.

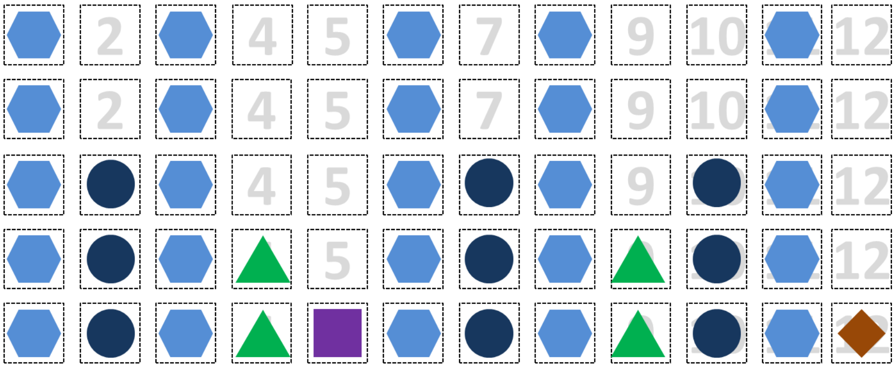

Figure 7: How a One-Piece Flow Pattern is established (Image Roser)

Similar calculations can easily be done for other production quantities, and can also easily be implemented in Excel or a similar program.

1.2 More Next Week

This post describes how one-piece flow leveling works. Please note that one-piece flow also often refers to a zero (or at least low) WIP approach. In the next post I will discuss how to best implement this one-piece flow leveling, and also what else there is in leveling. In the meantime, **go out and organize your industry!**

Also, Michel Baudin wrote a post on [Theories of Lean and Leveling/Heijunka]() on his blog with a review of my series on Leveling. Some of his comments helped me to update and improve the above post. Check his post out for further details on Leveling.

2 Introduction to One-Piece Flow Leveling – Part 2 Implementation

Christoph Roser, January 11, 2015, Original at https://www.allaboutlean.com/one-piece-flow-leveling2/

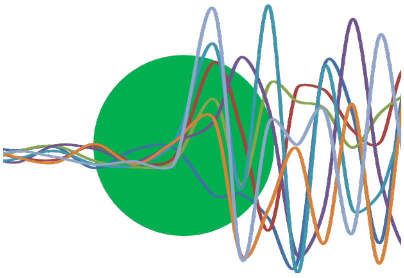

Figure 8: Leveling (Image Roser)

One successful approach to leveling is **one-piece flow leveling** (also known as **single-piece flow** or **continuous flow**). Last week I described the theory. This week I talk about implementation, and its combination with capacity leveling. I also look at what else there is in leveling.

2.1 It is not EPEI with a Daily Cycle

As described in earlier posts, EPEI leveling depends on a repeated fixed pattern, but it does not work. One piece flow leveling has no larger repeating pattern. Instead, you try to make your lot sizes a s small as possible and well mixed within the time-frame that you plan your production. You do not aim to produce *every part*, only the parts you need within that time frame.

Assuming you have a change over time of zero and are able to do one piece flow. If you create a production plan every day for the fourth day in the future, then you should mix this production for the fourth day as much as possible as described in the last post.

If you are close to one piece flow, but not yet there, one piece flow leveling is still possible. Assume your minimum lot size is 100, and you can produce 10.000 pieces per day. You still can mix up to 100 different lots or part types within one day.

If your minimum lot size is more than half a day or so, mixing within a daily planning cycle for one piece flow leveling becomes difficult or impossible. Having a longer planning cycles may sound like a possibility (e.g. you always plan a complete week, and mix within this week). However, the longer the planning cycle, the more likely that something will change. Hence, with larger change over times and hence larger lot sizes, this one piece flow leveling may not be possible. In this case you should focus on reducing change over times (see below). However, you still can do capacity leveling.

2.2 The Practical Implementation of One-Piece Flow

In sum, one-piece flow leveling is to have a lot size of one and to mix up the sequence as much as possible. This will smoothen your production and give you many of the positive effects of leveling. This is all very nice in theory, but hard work in practice.

2.2.1 How to Get There – Make Lot Sizes Smaller

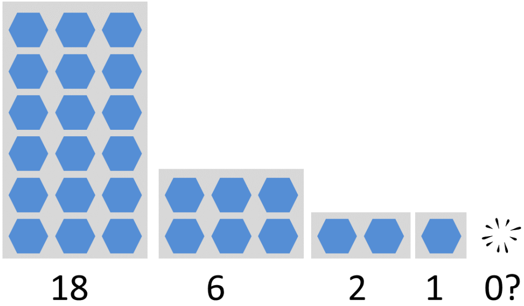

Figure 9: Lot size of zero is too small! (Image Roser)

Not every manufacturing system can jump to lot size one as soon as it wants to. Often, there are quite some technical difficulties to overcome. Sometimes more challenging are also the mental difficulties of the workers and managers to move away from the "*Large lot size is good*" thinking. In sum, you probably cannot change everything directly to lot size one.

Rather, do it in steps. Lean is all about doing many small steps. Try to reduce the lot size in **only one part of the plant** to **only as low as you dare**. Of course, you should pick the area with the highest chances of success, otherwise you risk that leveling is seen as a failure and waste of time. Or worse, your work and effort is seen as unhelpful on the shop floor.

2.2.2 The Tool for Lot Size Reduction – SMED

One key aspect of reaching one-piece flow is to reduce changeover times, ideally to zero. If you know even a little bit of lean, you have heard of single minute exchange of die (SMED), or quick changeover. That is the right approach here. Work on reducing your changeover times so you can have smaller lot sizes. I have written about SMED before, so I won't go into detail here.

2.2.3 When "Lot Size One" May Actually Be Too Small

In theory it is easy to talk about lot size one. In practice, however, there are examples where one may be too small. The lean approach was developed in the automotive industry, and for cars a lot size of one is definitely worth the effort.

Figure 10: Lot size one here, too? (Image Afrank99 under the CC-BY-SA 3.0 license)

But what if you produce screws? Or pens? Or bricks? Purists would say that in this case, too, lot size one is the ultimate goal. As a practitioner, I see it more as a relation between cost and benefit. Getting the screws down to lot size one is possible. However, I am not sure if the benefit is worth the effort. Even if you talk about a box of screws, it may be too little.

Calculating the cost of a lot-size-one screw production is already difficult. But estimating the benefit is even more difficult. Hence, doing a solid business case may not be possible here. My gut feeling tells me that a lot size one for screws may not be worth the effort. I would rather put the effort in getting smaller lots of raw materials (e.g., metal bars for screws) more often before going too deep into lot size one at the final production step.

What is the right lot size? For your plant, you must decide. But be wary that the effect of leveling is often underestimated. Often, an even smaller lot size than what you can imagine may still be worth the effort.

2.2.4 How Long It Will Take to Change Your Organization

Figure 11: May take some time … (Image Mutter Erde with attribution)

Hence, start small but do it right. If you now estimate how long it will take to make the entire plant lean, you will probably end up with multiple years. And this does not even include the suppliers. That is correct. It took Toyota thirty years to develop and implement their production system, and they are still working on it. They also started somewhere and did not do everything at once.

However, if your bosses want to turn the entire corporation into a lean system within six months … well … you may have a problem with unrealistic expectations. In this case, I can comfort you that this happens way too often, although this does not help you much. Sometimes an analysis of the prerequisites and conditions may convince management to give you more time, but unfortunately people do not become top management by falling over at every opposition.

2.3 Is There More in Leveling?

2.3.1 One-Piece Flow and WIP

In this post I've talked about one-piece flow as a tool for leveling. One-piece flow is also often used as an approach to reduce work in progress (WIP). The idea is that one-piece flow has not only lot size one but also no WIP between the stations. This is also a valid direction, although having absolutely no buffer between processes may not be a good cost-benefit for everyone. Just be aware that you need very stable processes, otherwise your overall output will go down drastically (see The FiFo Calculator).

Often, one-piece flow without WIP between stations is described explicitly for manual work, sometimes mixing up different concepts like *Chaku-Chaku* and U-lines. Manual work can be more stable than machine operations. Manual work can also catch up by increasing speed temporarily. Hence this no-WIP approach has benefits for manual work. Nevertheless, one-piece flow is also possible for machines. In any case, zero WIP it is not strictly necessary for leveling, and may even complicate things if you do it at the same time (small steps, remember?).

2.3.2 Combine One-Piece Flow Leveling with Capacity Leveling

One-piece flow leveling can be combined very well with Capacity Leveling , giving you the benefit of an even smoother system. In fact, these two approaches go together very well. However, please keep in mind that capacity leveling can be done almost always. One piece flow leveling on the other hand requires the ability to change over multiple times per day, which not all systems can do (yet).

2.3.3 A (questionable?) Theoretical Outlook

In literature, there is often a sequence of five different leveling steps described that you would have to go through. These often look like this [*with my comments in brackets*].

- Fixed sequence, fixed volume [*the classic* fixed repeating pattern EPEI, *often with a one month pattern*]
- Faster fixed sequence, fixed volume [*ditto, with a two-week or one-week pattern*]
- Fixed sequence, unfixed volume [*not quite sure what that is*]
- Unfixed sequence, fixed volume [*probably close to one-piece flow and capacity leveling*]
- Unfixed sequence, unfixed volume [*supposedly "true north" that not even Toyota has reached yet*]

However, whenever I see these, I always get the feeling that something is not right. It especially irks me that 3 is just the opposite of 4, 2 to 5 alternate fixed and unfixed volume, and that 5 is *whatever whenever*. I also have not yet seen 3 and 5 in reality. It looks like some theoretical abstraction lots of people copy without fully understanding. It is also usually explained only very briefly (except for 1, on which there is much detail). If you know more about this, let me know.

2.4 Summary

This concludes the seven-post series on leveling. Again, I recommend both capacity leveling and one-piece flow, but warn against EPEI repeating patterns, although I fear my opinion on EPEI may be controversial to some. In any case, I hope this was interesting for you. Now **go out and organize your industry!**

Also, Michel Baudin wrote a post on Theories of Lean and Leveling/Heijunka on his blog with a review of my series on Leveling. Some of his comments helped me to update and improve the above post. Check his post out for further details on Leveling.

3 Shop Floor Etiquette – Part 1

Christoph Roser, January 18, 2015, Original at https://www.allaboutlean.com/shop-floor-etiquette1/

Figure 12: A little courtesy often goes a long way! (Image Honoré Daumier in public domain)

There is often a distinct lack of appreciation and good manners toward shop floor employees. Yet, lean manufacturing happens on the shop floor. Not in Excel, not in PowerPoint, not in meeting rooms. As such, you need to become part of the shop floor in order to change the shop floor. For this, you need the support and goodwill of the people on the shop floor. The first step to getting their support is to have good shop floor manners. Due to the length of the post, I have divided it into two posts. These two posts will give you some guidelines on how to behave on the shop floor. (The second post is here)Nevertheless, the executive summary for both posts can be found at the end of each post.

3.1 A Short Problem Description

Figure 13: Luckily this does not happen too often (Image Honoré Daumier in public domain)

It is surprising how often managers, consultants, and other outsiders strut through the shop floor like they own the place, clearly signaling that they are better than the workers. Even if they indeed own the place, some small appreciation of shop floor etiquette will do wonders in forging a successful manufacturing system.

Also, all to often people are just ignorant about others. I once coached two trainees on a lean project. Two nice guys, friendly and very comfortable to hang out with. As part of this project, they went to observe a process with me watching them observe. After three minutes of intensive observation and note taking, I stopped them and asked if they had missed something in the preparation for the observation.

After some reflection, they brought up all kinds of ideas like getting more data, looking at the layout, making a better value stream analysis, etc. Neither of them thought about the worker at the process. None of them even noticed her beyond that she was part of the process. As I said before, these guys were nice and friendly. Yet they treated the worker like a mere piece of equipment.

Of course, this was not intentional. After I pointed this out, they apologized profusely to the worker and me, then introduced themselves and their work. But until I pointed it out, they didn’t even notice the human being as a human being. **Please don’t do that!**

3.2 Different Roles

Naturally, different visitors to the shop floor have different roles, and small differences in shop floor etiquette apply. For example, if you are an **external visitor**, it may be sensible to announce your visit a few days beforehand. On the other hand, such an announcement would make no sense at all if you are the **plant manager**.

Similarly, if you **focus on one or a few particular processes**, it may be sensible to spend more time introducing yourself to the people working at these processes. On the other hand, if you **walk through the entire plant**, this may be neither feasible nor sensible.

If your reason for the visit is only to **understand the current situation**, shop floor operators may be satisfied with a quick note. On the other hand, if you plan to **change the situation on the shop floor**, you would be well advised to spend more time informing the workers of your reason for the intended changes, and especially the impact on the workers.

Rules are also different depending on whether you are part of a **large group** that may hinder workers or you are a **single person** who is much less in the way of everybody else.

Figure 14: Many Languages (Image M. Adiputra under the CC-BY-SA 3.0 license)

Also, keep in mind the **local languages**. In northern Europe, Belgium, and the Netherlands, even normal shop floor workers speak a bedazzling amount of foreign languages, so you may be fine with English. For example, while working on a dutch shop floor, I asked the blue collar worker if he preferred English or German. “Either one is fine,” was his answer in flawless English.

Nevertheless, you may need an interpreter for some plants abroad (e.g., in China). I know of one group that worked with an interpreter in China, but nothing worked with the employees until after a week when they figured out that the interpreter spoke Mandarin and the locals spoke Kantonese, two totally different spoken languages. In my view, however, the embarrassing thing was that it took them a week to figure it out!

Overall, depending on the details of your visit, you may have to adjust the guidelines below.

3.3 Shop Floor Etiquette Rules

Below are a couple of things to keep in mind if you want to have a good interaction with the shop floor. Of course, you also can’t make everybody happy all the time. Change is not always welcome. But having a good standing on the shop floor will make it more likely that the change is accepted. Hence:

3.3.1 Announce Your Visit

Ideally, a few days before your visit, inform the shop floor management about your visit (who, where, why, when). The team leaders of the areas you visit should then briefly inform the operators. This way any questions can be sorted out before you arrive. Note: Make sure you inform the correct shift. It doesn't help if the morning shift knows about an visitor in the afternoon (Don't laugh, this has happened way too often ☹). Naturally, this is only sensible for visitors who do not commonly visit the shop floor, as, for example, top-level executives from other locations, external consultants, or other external visitors.

3.3.2 Introduce Yourself in Person

Figure 15 : Hello! (Image Tommyv580 under the CC-BY-SA 3.0 license)

Whenever you are observing a process on the shop floor, you should introduce yourself to the people working there. Say hello, state your name and affiliation. Then explain what you do and why (see next point). Be open, be friendly, and follow the rules of etiquette. For example, in Germany it is customary to shake hands. In Asia a polite bow is appropriate (with the angle depending on the rank of the people involved). And in the US, a friendly "H*ow are you?*" or similar is common. Using first names or family names also vary with regional customs. In the US it is often fine to use first names, while Europe reserves first names for close friends and Asia uses first names for dogs and children only). Skipping such details will reduce the positive effect of your introduction.

Of course, if you are not observing a specific process but rather walking through the entire line or plant, it may not be feasible or even sensible to introduce yourself to everybody. In this case, a general announcement may suffice.

3.3.3 Explain What You Do and Why You Do It

Now that you are here, the workers want to know why. If you plan to change things around, then you should spend quite a bit of time describing what you are doing and why. For the workers, the most interesting part is what will change for them. This is also the part where it may get tricky.

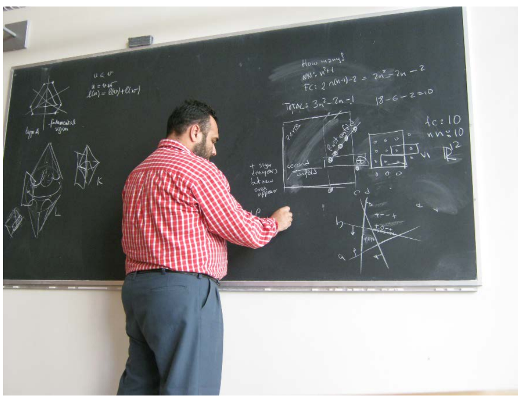

Figure 16: Keep it simple! (Image Magister Mathematicae under the CC-BY-SA 3.0 license)

Based on prior experience, workers probably believe that all negative aspects of the change will be much worse, whereas all positive aspects may or may not come. Hence, depending on your changes, this discussion may be a minefield. For example, if your goal is to reduce headcount by 10%, you better have an absolutely waterproof reason (e.g., the workers are needed on other lines/for new products). Otherwise it may be better to skip this step of "what" and "why" altogether.

Naturally, if you only visit to see the plant, you may also skip this step. In most plants I know, workers are accustomed to a "five-minute flyby" by top executives, where the plant manager does his best to hide the true situation anyway (See How to Misguide Your Visitor – or What Not to Pay Attention to During a Plant Visit!).

3.3.4 Do Not Make the Work More Difficult through Your Presence

This should be obvious. The workers on the shop floor usually have quotas and numbers to meet. Often, their pay depends on performance. If you mess things up for them, you may hurt the plant and – even worse – their income. In any case, they will like you less. Here are a couple of examples on how you can make or avoid trouble for the workers and hence in the long run for you.

Figure 17: Keep an eye out (Image StraSSenBahn under the CC-BY-SA 3.0 license)

Do not block the workers' access to wherever they need to go! If you and your group cluster around a process, workers and material supplies may not get through. Make sure to get out of the way. Make sure that the workers know that they can tell you to move if you are in their way. If necessary, break your group into smaller subgroups so that twelve people are not standing around one process, but maybe four people around three different processes. Similar applies to driveways. Try not to block forklifts or milk runs. Also, if you are in a larger group, inform all group members to pay attention to the workers' needs.

Also, **keep an eye out for safety light barriers!** These things will bring a machine to an emergency stop whenever someone or something goes through the barrier. It is important for safety, but it is also an annoyance for the workers if visitors walk through and their work stops. And, for the visitor, it is quite embarrassing to have brought everything to a standstill. Believe me, I know!

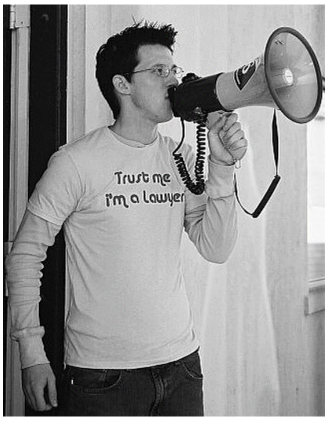

Figure 18: Not on the shop floor, please! (Image Joeydauben in public domain)

Keep your noise down! A shop floor is usually already loud enough, but a larger group walking through can make things worse. In a larger group, it may also be difficult for everybody to hear the speaker. However, this is NOT a good case for a megaphone. Instead, use smaller radio-controlled headphones and a microphone.

Also, **do not touch anything unless you really, really know what you are doing!** For example, when I was young and inexperienced, I had the opportunity to see a plant making some small metal parts. At one point in the process, I picked up one part from a conveyor, looked at it, and put it back. With a sigh, the operator took this part and the three before and after it and chucked them in a bin. It turned out that the parts were washed, and now had to be washed again thanks to me. Learn from my mistakes.

Still, I was much better off than another person having a guided tour through a foundry. He saw a piece of metal on the floor and picked it up to look at it. He quickly found out that it still was 1000°F (ca. 500°C) hot, resulting in third degree burns on his fingertips.

If you schedule a meeting with workers, **be on time!** Depending on the situation, you may even arrive early. For example, if you want to observe a changeover, don't ask the workers to wait until you are there. Instead, be there early and wait until the workers are ready to do the changeover.

Figure 19: No souveniers (Image unknown author in public domain)

And, of course, the most obvious rule: **Do not take souvenirs without asking for permission!** Any part on the shop floor is (usually) there for a reason, and a missing part may bring the entire plant to a complete standstill. Hence, do not take anything with you without permission (also known as stealing).

The [second half of this "miss manners" for the shop floor is in the next post](). However, if you can't wait, just read the summary below.

3.4 Executive Summary

Below is a summary of the guidelines of the two posts (Part 2 is here). Not all of them apply to every person or visit, hence use your common sense.

- Announce your visit
- Introduce yourself in person
- Explain what you do and why you do it
- Do not make the work more difficult through your presence
    - Do not block the workers' access to wherever they need to go
    - Keep an eye out for safety light barriers
    - Keep your noise down
    - Do not touch anything unless you really, really know what you are doing
    - Be on time
    - Do not take souvenirs without asking permission
- Appreciate their work
    - Take your hands out of your pockets
    - Do not bring anything to eat or drink
    - Do not overdress for the occasion
    - Listen to their input
- Get permission beforehand for taking times/photos/videos
    - Follow regulations
    - Do wear the required safety equipment
    - Wear clean room garments or similar
    - Follow other rules and guidelines
- Say thank you and good-bye
- Follow up
    - Inform the people you have worked with about the results
    - Show the appreciation through a small gift

4 Shop Floor Etiquette – Part 2

Christoph Roser, January 25, 2015, Original at https://www.allaboutlean.com/shop-floor-etiquette2/

Figure 20: A little courtesy often goes a long way! (Image Thos. McLean in public domain)

This is the second post of a two-post series on shop floor etiquette (first post here). I find this a very necessary post, as I have way too often observed visitors to the shop floor lacking manners (and occasionally, I may have lacked manners myself ☹). Hence, please do not treat this post as optional, but try to incorporate it into your daily shop floor work. Being accepted on the shop floor is crucial for any successful change on the shop floor. The executive summary for both posts can be found at the end of each post.

4.1 Shop Floor Etiquette Rules (Continued)

4.1.1 Appreciate Their Work

Another aspect important to a good standing is to appreciate their work. On the shop floor, people are working, usually physically and often hard. If you stroll along like you are on a holiday, it will make them feel their workload even more.

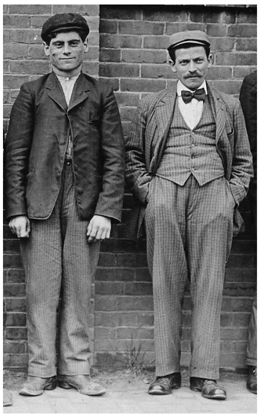

Figure 21: Hands in pockets or not? (Image Lewis Hine in public domain)

Hence, **take your hands out of your pockets.** Having your hands in your pocket is disrespectful to people working with their hands at the same time. Also, if you are staying on one spot for a longer time, do not lean on the wall or on machines or equipment. This also looks lazy and is disrespectful against others working in the area.

Similarly, **do not bring anything to eat or drink** unless you are sitting down with the workers in their rest area. It will not be appreciated if you have a cup of coffee or a doughnut while the people around you have to work.

Do not overdress for the occasion. Depending on your usual attire, you may choose to dress more casually than usual. Wearing a suit and tie, ideally combined with a long list of academic degrees, will distance you from the people on the shop floor. If you come along with all your fine clothes, it looks like you are not there to work. On the other hand, if you wear a boiler suit, you may have overdone it. Find some middle ground. (See also Dress for Success in Lean Manufacturing.)

Figure 22: Listen! (Image unknown author under the CC-BY-SA 3.0 Germany license)

Finally, and most importantly, **listen to their input!** Nobody knows the processes as well as the workers. No matter whether you want to merely understand or actually to change the process, value the input of the workers. They can alert you to ideas for improvement that you would have never though of. Similarly, they can warn you about problems that you would have never expected. Naturally, not every idea from a worker is genial – but neither are yours. Sort out the good from the bad. However, by listening to them, you have increased your *street credits* on the shop floor.

Getting these ideas out of the workers, on the other hand, may require a bit of an effort. Workers are often not used to talk to "higher-ups" or may have had a bad experience with previous attempts. A bit of coaxing or digging may be needed to access this treasure trove of knowledge.

4.1.2 Get Permission Beforehand if Taking Times/Photos/Videos

Depending on the reason why you are on the shop floor, you may want to take photos or videos, or measure times using a stopwatch. Stopwatches and cameras are red flags for operators. Depending on the rules and regulations in your plant, you may even be forbidden to use them without prior permission.

Figure 23: Under Surveillance (Image various authors in public domain)

For example, in many plants in Germany, the agreement of the work council is needed before you can take videos or use stopwatches. Every now and then one of my students – with best intentions – brings a stopwatch to the shop floor of his/her internship, only to face a rather angry work council member three minutes later. Similar applies to many plants in the US, often depending on the state they are in.

Plants in China or other low-cost countries often have more relaxed regulations, but this does not mean that the workers like it. I had many plant managers in China tell me that "*the workers are fine with it.*" Actually they are not, but they don't dare to voice their opinion.

In any case, no matter if required by law, local rules, or not at all, make sure that the operators are informed and, if possible, have agreed to the use of videos, stopwatches, or cameras.

4.1.3 Follow Regulations

Figure 24: Oh yes! (Image Mpelletier1 under the CC-BY-SA 3.0 license)

Of course, as a visitor you should **follow the rules and guidelines of the plant**. If the plant requires you to wear safety equipment, **do wear the required safety equipment**. ESD safety boots, safety goggles, hard hats, reflective safety vests, ear protection, and other items are there for YOUR safety. If you do not wear them, not only do you risk your own life and limb, but you also set a bad example for others.

Figure 25: Yours truly, but without titles (Image Roser)

In fact, I always have my own ESD safety boots, goggles, and vest in the trunk of my car. The latter is even printed with the logo of my university and my name, albeit I opted to skip the "*Prof. Dr.*" part and list myself only as "*Roser.*"

Similar applies to other gear that protects the machines and products from you. For example, if you visit clean rooms, wear the required overcoats, shoe slippers, hair nets, and whatever else is necessary. Hence, **wear clean room garments or similar**.

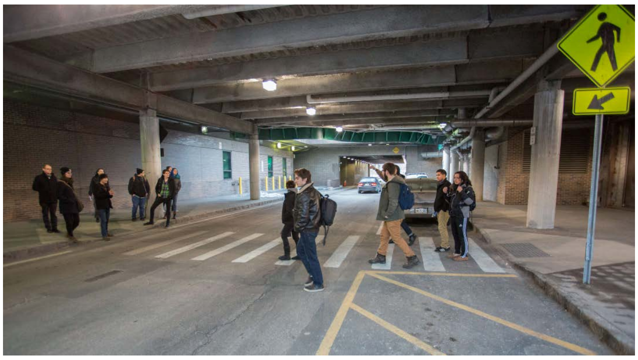

Figure 26: Use the Crosswalk (Image JimCricket under the CC-BY-SA 3.0 license)

Also, **follow other rules and guidelines**. For example, in one plant making floor paneling, you were not allowed to walk across the products (except that the plant manager did it all the time – not a good example). If there are separate doors for people and doors for forklifts, use the correct door. Stay on the marked walkways, unless your guide indicates otherwise. Use pedestrian crossings if available.

Figure 27: Stupidity is not a handicap! (Image Chris Potter under the CC-BY 2.0 license)

Do not park in a reserved parking spot (unless it is YOUR reserved spot). Again, I know one plant manager who decided that the handicapped parking space in front of his office was his own personal parking space despite the complete lack of any handicaps on his side. He could have just changed the label on the parking spot to make it his own spot, rather than announce to everybody that the rules do not apply to him (and therefore probably not to anyone else either?).

4.1.4 Say Thank You and Good-bye

Figure 28: Good-bye! (Image Tommyv580 under the CC-BY-SA 3.0 license)

Finally, at the end of the visit, **thank the people for their patience and assistance, and wish them a nice day**. Similar to the introduction, this may be only feasible and sensible if you have worked closer with or around a small group of people. Again, depending on the local customs, you may shake hands, bow, or use whatever is normal at departure.

4.1.5 Follow up

Possibly, after the visit you will analyze what you have observed or measured, create some Excel spreadsheets, PowerPoint slides, or even some real results ☺. It is common courtesy to **inform the people you have worked with about the results**. Of course, not the three-hour boardroom presentation, but the *executive summary*, or better phrased as the "*operative summary*" :). Use plain English (or whatever language is best) and a few graphs to show your key findings, then either forward it to the operators or even inform them in person. Naturally, keep confidential information out of this summary.

Figure 29: Thank You! (Image Roser)

If the operators not only tolerated you, but actively helped you and participated in the project, it may be a possibility to **show your appreciation through a small gift**. I personally always had good experience with a bag or a bucket of gummy bears. A bucket of gummy bears cost me five dollars, but the appreciation was priceless.

4.2 Don't Overdo It

Most of these guidelines above are common sense. You have to decide which ones apply to your situation or plant and which ones you can ignore. Following all guidelines no matter who you are may even be too much. If the plant manager announces every plant visit, it is weird. If you leave a bucket of candy just because you looked at the process, it is too much. Just use your own common sense. In case of doubt, err on the safe side and do a bit more. In any case, do not just forget it but treat the people on the shop floor as people, not as machines. Now **go out and organize your industry** by treating people like people.

4.3 Executive Summary

Below is the summary of the guidelines of the two posts (Part 1 is here). Not all of them apply to every person or visit, hence use your common sense.

- Announce your visit
- Introduce yourself in person
- Explain what you do and why you do it
- Do not make the work more difficult through your presence
    - Do not block the workers' access to wherever they need to go
    - Keep an eye out for safety light barriers
    - Keep your noise down
    - Do not touch anything unless you really, really know what you are doing
    - Be on time
    - Do not take souvenirs without asking permission
- Appreciate their work
    - Take your hands out of your pockets
    - Do not bring anything to eat or drink
    - Do not overdress for the occasion
    - Listen to their input
- Get permission beforehand for taking times/photos/videos

    - Follow regulations
    - Do wear the required safety equipment
    - Wear clean room garments or similar
    - Follow other rules and guidelines
- Say thank you and good-bye
- Follow up
    - Inform the people you have worked with about the results
    - Show the appreciation through a small gift

5 Basics of CONWIP Systems (Constant Work in Progress)

Christoph Roser, February 01, 2015, Original at https://www.allaboutlean.com/conwip-basics/

Figure 30 : CONWIP -go-round with different parts – like roller coaster seats with people (Image Jason Campbell (Brother Jay) under the CC-BY-SA 2.0 license)

There is broad agreement in industry that a **pull system** is in almost all cases better than a push system. The most famous way to establish a pull system is to use a kanban system. The idea of **kanban** is so much associated with pull production that the two terms are sometimes even used synonymously. However, there are other ways to implement pull. Another useful approach is **CONWIP**, standing for *Constant Work In Progress* and developed by Mark Spearman and Wallace Hopp in 1990. In this small series of posts, I would like to go into the details of CONWIP and its similarities to and differences from kanban. This first post will explain the basics, the next two posts will go into more details by answering some frequently asked questions, and the fourth post will discuss advantages and disadvantages of CONWIP.

5.1 The Kanban System

Kanban is both a type of card and a control system in manufacturing named after the cards. Both were developed by Toyota in Japan. **There are a limited number of cards, with each card representing a certain part type and a certain quantity (at least one).** In the picture below, we have cards for green squares, red diamonds, and blue hexagons. The kanban can be attached to a part or be separate. **Every part must have a kanban attached with it.**

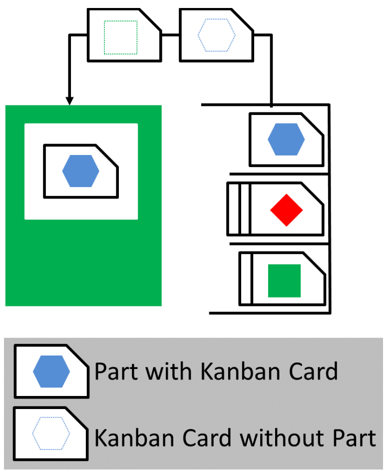

Figure 31: Kanban System with Cards (Image Roser)

Assume you have blue hexagons in stock, each with a card attached. If someone takes out a blue hexagon, the card is removed from the part and goes back for reproduction. A card without a part arriving back at the beginning of the loop is an order to reproduce this part. Hence the card eventually comes back to storage again with a newly produced part.

This is a kanban system in its simplest form. Of course, there are numerous additional details like how many cards to use, various prioritizing and grouping options of the cards for reproduction, and detailed usages of FiFo lines and supermarkets. For detail, see my numerous posts about kanban.

5.2 The CONWIP System

The CONWIP (*Constant Work In Progress*) system is very similar to a kanban system, except that the CONWIP card is not associated with a certain part type, but only with a certain quantity (also at least one). The illustration below is comparable to the illustration above except it represents a CONWIP system.

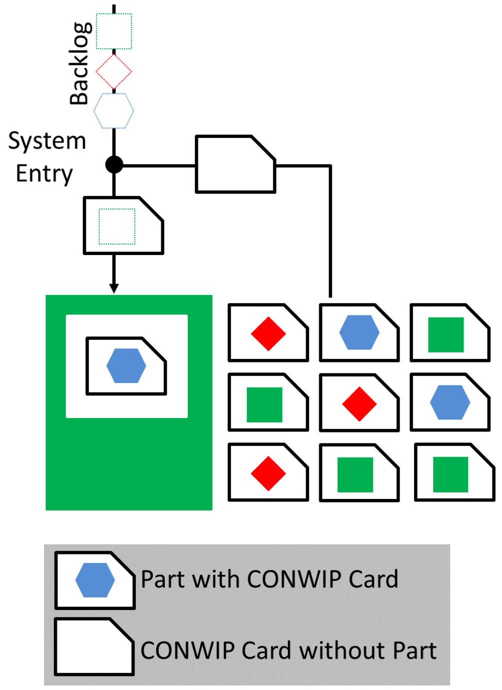

Figure 32: CONWIP system with Cards (Image Roser)

Completed parts all have a CONWIP card attached. If the part leaves the system (e.g., it is sold, used downstream, etc.), the card returns back to the beginning of the loop. Remember, the card is now not associated with a part type, only a constant quantity. On its way to the beginning of the loop, it meets the backlog. The backlog is a list of part types and quantities that need to be produced. The first part in the backlog is the most urgent one. If a CONWIP card comes back from the finished goods inventory, the next part type in line is assigned to the returning card. The card is hence a signal that capacity is available, and the backlog defines what to do with the capacity. The merging of the blank card with the part type is called the system entry. This part then gets reproduced and eventually makes its way back to the finished goods of the loop.

Hence a CONWIP card is like a kanban card, except the part type gets assigned only on its way back when it meets the most urgent demand in the backlog.

5.2.1 The Matchmaking – Merging the Backlog with the CONWIP Card (A.K.A. System Entry)

Figure 33: Matchmaking…sort of … (Image Lukas A in public domain)

A CONWIP card by default does not include a part number. The part type to be produced is defined when the CONWIP card returns back to the beginning of the loop. There the card meets the backlog queue, a list of different part numbers that are waiting for production. This backlog queue is sorted according to overall priority. The most urgent products are produced first, as soon as a CONWIP card becomes available – if there is material available.

Naturally, no matter how urgent the part, if you cannot get the material there in time, there is no point in starting production. Spearman et al. also suggest to write down the date and time of the matchmaking on the card, which can help determine the throughput time and also the sequence of production in the system. However, in this case you need to think about what happens to the CONWIP card after multiple rounds. Do you have enough space for many entries? When do you replace a card with a new one? It is doable, however.

5.2.2 The Backlog Sequence

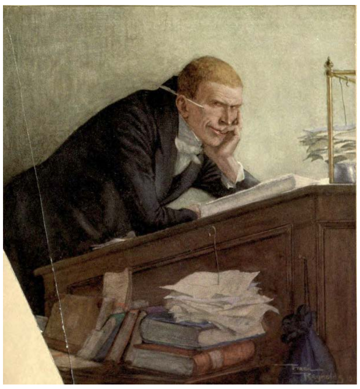

Figure 34: Production planning (Image Frank Reynolds in public domain)

Someone has to determine the backlog sequence (i.e., decide which part type is more urgent than the other one). Spearman et al. suggest the production and inventory control staff. I would phrase it more generally as the people who know the urgency best. It could be, for example, some type of clerk in the production planning or production control department, or a supervisor within manufacturing for internal supply lines. In modern manufacturing, the sequence will probably be primarily based on the available MRP data, combined with additional information through telephone or e-mail.

Please note that this sequence is by no means fixed once it is created. In a usually highly volatile environment such as a manufacturing system, new information comes up all the time. Customers may order more or cancel orders. Material availability may also change.

5.3 Summary

In short, a CONWIP system is like a kanban system without part numbers on the kanban. Instead, the product type gets assigned to the card on an as-needed basis. In the next post, I go into more detail about selected specifics of the CONWIP system and will answer some frequently asked questions about CONWIP. In any case, I find the CONWIP system useful, especially for made-to-order pull production. I also hope you enjoyed this post. Now go out and **Organize your Industry!**

5.4 Selected Sources

- Marek, R. P., Elkins, D. A., Smith, D. R., 2001. **Understanding the fundamentals of Kanban and CONWIP pull systems using simulation**, in: Winter Simulation Conference 2001; Proceedings of the Winter Simulation Conference 2001, pp. 921–929 vol.2.
- Spearman, M. L., Woodruff, D. L., Hopp, W. J., 1990. CONWIP: a pull alternative to kanban. *International Journal of Production Research* 28, 879–894.

6 Frequently Asked Questions on CONWIP Systems – Part 1

Christoph Roser, February 08, 2015, Original at https://www.allaboutlean.com/conwip-faq1/

Figure 35: CONWIP-go-round with different parts – like roller coaster seats with people (Image Jeremy Thompson under the CC-BY 2.0 license)

In the last post, I started with the basics of a CONWIP system, where CONWIP stands for *Constant Work In Progress*. However, there are some more frequently asked questions that are also important for CONWIP. These I will explain here.

Initially, I wanted to write one quick post explaining CONWIP. However, as it happens all too often, one post turns out to be not enough. It quickly expands into multiple posts of a series in order to give you a good, well-rounded overview of the topic. Hence, the frequently asked questions will be covered in two separate posts. After that, the fourth and truly final post of this series will discuss the advantages and disadvantages of CONWIP.

If you don't yet know much about CONWIP, check out the basics of a CONWIP system for an easier understanding of the following discussion.

6.1 Frequently Asked Questions on CONWIP – Part 1

6.1.1 What is the Sequence in the Production Line?

Figure 36: Parts in line at Ford (Image unknown author in public domain)

The manufacturing line should still be using a FiFo system, where the first part that goes in the manufacturing system is also the first part that goes out. Spearman et al. more generally speak of a "*First in System, First Served*" approach. The card with the oldest time of entry into the system (the matchmaking time) gets produced first.

For flow lines, this is no problem at all, as most flow lines usually include some sort of FiFo by default. However, this also works for job shops (see another question below).

Spearman et al. also suggest that this rule must be followed, except for rework. The assumption is that rework is long past overdue and therefore has to rush through the system. In my view, this is one possibility to break FiFo. However, there may be others (see my post [Theory and Practice on FiFo Lanes – How Does FiFo Work in Lean Manufacturing]() in the subsection on “Breaking the Rules”).

I can also imagine incorporating a priority system for normal parts. For example, it can make sense to always give exotic parts priority over high-runners to reduce the overall inventory for unchanged delivery performance. In any case, you should have a rule to ensure that no part is forgotten in the system. If it is entirely up to the operators, the more difficult/less pleasant/less productive parts may be forgotten for the next shift indefinitely.

6.1.2 What Happened to the Supermarket?

Figure 37: Is the supermarket still there? (Image Blink in public domain)

A kanban system has a supermarket at the end of the loop. A supermarket ideally has a line for each product type, similar to many parallel FiFo lanes, one for each type. Of course, a CONWIP system can also work without a supermarket, where there is just a general inventory at the end of the loop.

However, if you still have some high-runner products, it may make sense to have at least some aspects of a supermarket included at the end of the loop. At a minimum, if there is more than one of a certain part type in the finished goods inventory, the one with the oldest CONWIP card should be sent out first.

In any case, similar to the supermarket, the CONWIP cards return to the beginning if they leave the last inventory in the system. Unless, that is, you choose to return the card before the part enters the last inventory. For this, please see the next question below.

6.1.3 When Exactly Does the Card Go Back?

Good question. The literature does not quite agree on that. Two options seem to be used: Return the last card when the parts are removed for the next process or customer, or return the card as soon as the last process is completed.

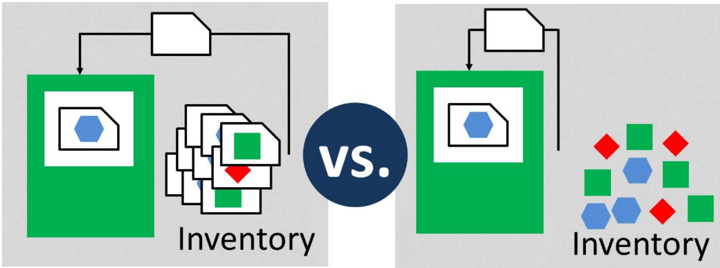

Figure 38: Two possible options for the CONWIP card to go back. (Image Roser)

Spearman says that "*When the container is used at the end of the line, the card is removed and sent back to the beginning.*" Others say to send the card back as soon as the last process is finished. Both are possible approaches.

Sending the card back when the parts are used downstream includes the inventory of completed products in the WIP control via the CONWIP system. This allows the use of a supermarket and prevents overproduction. On the other hand, this needs some more CONWIP cards, since many of them will be with the completed products. But then, just having less cards does not mean having less inventory. Merely part of your inventory has no cards. In any case, this approach will make the system compatible for a kanban-CONWIP hybrid.

Sending the card back as soon as the last process is completed will still prevent the line from choking itself. This will require less CONWIP cards. However, in this case it is possible to overproduce and make more parts than may be needed.

My preference would be to include the completed goods in the CONWIP loop (i.e., the cards are only returned when the parts are used downstream by the next system or the customer). This way we prevent overproduction, which is something I am very keen about preventing.

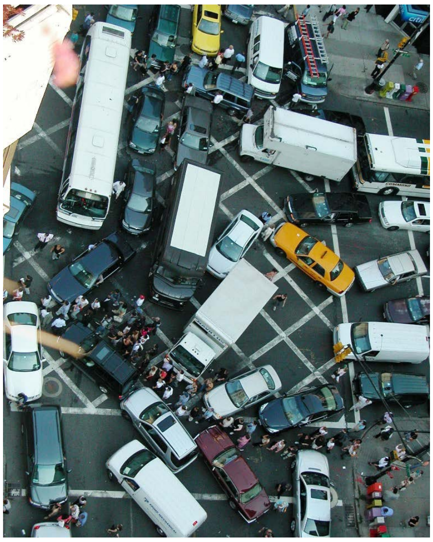

Figure 39: Gridlock! (Image Rgoogin under the CC-BY-SA 3.0 license)

However, this requires care with the backlog sequence. It is possible to block the system by using up all CONWIP cards for products that are not needed and then have no cards left for the products that are actually needed. Hence, a bad backlog sequence can jam the CONWIP system. Just imagine what would happen to your CONWIP system if a higher-up manager calls and tells you to produce only part X from now on, since that is for an important customer who complained about the lack of X. <sarcasm> *Of course, this never happens, right?*</sarcasm>

6.1.4 How Many CONWIP Cards Do I Need?

Figure 40: How many Cards? (Image Johnny Blood under the CC-BY-SA 2.0 license)

Similar to a kanban system, a CONWIP system needs cards. In a kanban system, the number of cards is often subject to lots of consideration (see, for example, How Many Kanbans? – The Kanban Formula). In a CONWIP system, the number of cards is of course also significant.

The number of kanban cards depends on the replenishment time and the different fluctuations. Similar would apply to a CONWIP system, albeit it is more tricky to determine. If the produced part would be used downstream right away (common for made-to-order products), the number of cards would represent the WIP level that lets the manufacturing system run smoothly and efficiently.

However, if you also have made-to-stock products, you somehow would have to include the buffer stocks required due to demand and production fluctuations. You cannot simply take the sum of all part types, because then you would end up with the right quantity but the wrong type. Similarly, you cannot look at all part types separately (as in the kanban formula), since your CONWIP card does not have part types!

Overall, I would recommend a method similar to another kanban approach (and actually my favorite way to determine the number of kanbans). Simply use enough CONWIP cards to make sure it runs smoothly. Then reduce them as needed. If you encounter repeated problems due to insufficient cards, either increase the number slightly or make your system even leaner than it is already (see How Many Kanbans? – Estimation Approach and Maintenance).

6.2 Summary

The more I research the CONWIP system, the more I like it for exotic parts. The more I like it, the more I research it. Hence, the next post will continue with more answers to frequently asked questions. After that I will discuss the advantages and disadvantages of CONWIP in my last post on this topic (for now🙂). In the meantime, go out and **Organize your Industry**.

6.3 Selected Sources

- Marek, R. P., Elkins, D. A., Smith, D. R., 2001. **Understanding the fundamentals of Kanban and CONWIP pull systems using simulation**, in: Winter Simulation Conference 2001; Proceedings of the Winter Simulation Conference 2001, pp. 921–929 vol.2.
- Spearman, M. L., Woodruff, D. L., Hopp, W. J., 1990. **CONWIP: a pull alternative to kanban**. *International Journal of Production Research* 28, 879–894.

7 Frequently Asked Questions on CONWIP Systems – Part 2

Christoph Roser, February 15, 2015, Original at https://www.allaboutlean.com/conwip-faq2/

Figure 41; CONWIP-go-round with different parts – like roller coaster seats with people (Image Breakdancer under the CC-BY-SA 3.0 license)

In the last two posts I described the basics of a CONWIP system and started with the frequently asked questions on CONWIP, where CONWIP stands for *Constant Work In Progress.* However, there are some more frequently asked questions that are also important for CONWIP. These I will explain here. The next and final post of this series will discuss the advantages and disadvantages of CONWIP.

If you don't yet know much about CONWIP, check out the basics of a CONWIP system for an easier understanding of the following discussion. Otherwise, let's continue with the frequently asked questions.

7.1 Frequently Asked Questions on CONWIP – Part 2

7.1.1 When Should the Line Run?

Figure 42: When to run (Image Allgemeiner Deutscher Nachrichtendienst under the CC-BY-SA 3.0 Germany license)

One question that is sometimes asked is when a CONWIP line should run. The answer is similar to other lines and does not depend on the control system (CONWIP, kanban, MRP, etc.). The production capacity of the line should match the customer demand as much as possible. If your customer demand is not so high, you may run the line less (less shifts, days, or hours). Of course, if your customer demand exceeds the line capacity, the line should run as much as possible (while still allowing for maintenance and changeovers, etc.).

In any case, if there is no demand (i.e., if there are no customer orders), the line should stop. Particular to CONWIP is also that if the backlog sequence points too far in the future, you also should stop the line. For example, if you have already produced all the parts for the next four weeks, do you really need to start with parts for five weeks ahead of time? Depending on your system, four weeks may already be excessive.

7.1.2 Does It Work for Job Shops?

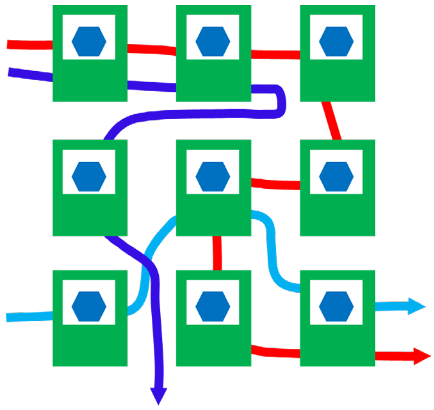

Figure 43: A typical job shop (Image Roser)

Kanban works well for flow shops, where the material flow is clearly defined. Kanban may be more difficult for job shops, where the material flow is often irregular. As for CONWIP, Spearman et al. state that CONWIP does not work for job shops.

However, I believe that, with some limitations, CONWIP may also work for job shops. Regardless if in a flow shop or job shop, you would need to make sure all parts leaving the system will return their CONWIP card. Similarly, all open jobs have to wait in the backlog for a new CONWIP card.

Since the CONWIP cards have a time of entry written on them, every process in the job shop knows which waiting part is the oldest. At every process, the next part to be produced should be the one with the oldest system entry time, not the part that arrived at this particular process first. This way older parts are likely to finish earlier. Hence all products are much more likely to have similar throughput times through the entire system. And a balanced throughput time makes for overall smoother processing.

Of course, there needs to be more CONWIP cards to ensure the job shop does not run out of work. Due to network effects, job shops may have neither their WIP nor their individual process workload distributed equally. Depending on the variable product mix, the busiest process (the bottleneck) will change. Additional cards will buffer these changes and increase throughput, of course at the cost of WIP. You will have to find a trade-off between throughput and WIP, but in a job shop more cards will probably be a better trade-off than a comparable flow shop.

7.1.3 Can I Just Use One Big Loop?

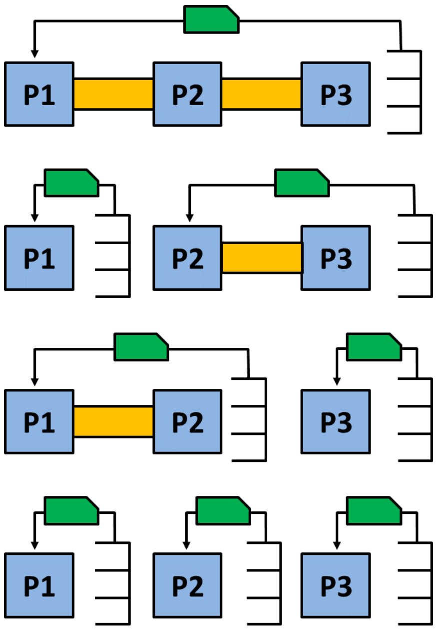

Figure 44: Kanban loop options for three processes (Image Roser)

A kanban system is often split into multiple different loops. CONWIP systems in literature, however, are usually depicted as one big loop from the very beginning to the very end. I don't quite agree with that.

In kanban systems too, it is a generally sound advice to create as small loops as possible by using FiFo instead of supermarkets. However, there are sometimes good reasons to use a supermarket instead of a FiFo and break one big loop into two. I have determined ten different reasons when to use a supermarket instead of a FiFo (for this original research, see Ten Rules When to Use a FiFo, When a Supermarket – Introduction and The Rules).

However, with CONWIP, there are some small differences. In particular, since the entry time is written on the card, CONWIP can do without explicit FiFo lanes and instead rely on the time on the card to determine the oldest item. Hence, any rules that help keep the sequence in order are not strictly required. Below is the original list with the ten reasons when to use a supermarket, but with annotated changes due to the particularities of the CONWIP system.

1) **Supermarket for process-specific lot size differences** (*Still valid for CONWIP systems.*)
2) **Supermarket in front of the customer** (*Still true, unless you manage for your customers to send you back the CONWIP cards – but quite frankly I would not risk it.*)
3) **Supermarket if material flow splits up into different directions** (*Instead of FiFo and supermarket, CONWIP can use any inventory and keep the sequence through the time on the card. However, you have to make sure that even though the cards split up, they eventually have to come back again to the same line. If you have parallel production lines for the same product, it does not help you, over time, to have all cards in one line and none in the other.*)
4) **Supermarket between very different cycle times** (*Again, here you can just use any type of inventory; the time on the CONWIP card will keep track of it.*)
5) **Supermarket between different shift patterns** (*Same as above; the time on the CONWIP card will keep track of it.*)
6) **Supermarket when creating different variants** (*Here, a split into different loops may make sense. This way you do not have to carry along the information of the final product from beginning to end. For example, when producing cars, you do not need to assign the*

color of the car when casting the engine block. Instead, the color of the car in which the engine block will go will be defined much later when it becomes relevant.)

7) **Supermarket for merging of material flows** (*Same reason as for splitting: any inventory will do, and the time on the CONWIP card will ensure the right sequence.*)

8) **Supermarket for large distance between processes** (*Still needed, albeit not as urgent as with kanban. If your CONWIP card extends in your manufacturing system all the way from China to the US, fluctuations in shipping will disrupt your system. Hence, splitting the loop may still make sense. On the other hand, if it is only from one hall to the next within the same plant, you may be able to use only one CONWIP loop.*)

9) **Supermarket in the case of high demands on flexibility and reaction time** (*Still true; a long loop has just as much lead time with CONWIP as with kanban. Shorter loops make you more* agile.)

10) **Supermarket for change of responsibility** (*Oh yes! The human tendency to quarrel exceeds any logic you can build in your system. Keeping loops within one area of responsibility cuts down on the blame game.*)

Figure 45: In case you are bored, here is more work … (Image unknown author in public domain)

Overall, with CONWIP, you potentially need less loops than with kanban. Hence it may be a bit easier to manage, having less administrative overhead. However, the overall workload will not be that much less, since now the workers on the shop floor always have to find out which part has the oldest CONWIP card. Hence, less work for administration but more for the shop floor (which is always popular with administration but less so with the shop floor). Unfortunately for the shop floor, administration is usually closer to the heart of the decision maker at the top ☹) However, I can easily imagine the shop floor avoiding this additional overhead pushed on them by simply not doing it (or doing it rather sloppily), in which case it would have been better to split the loops in the first place.

On a side note, preliminary research by my master students indicates that there is not much difference in WIP between one big kanban loop and multiple small kanban loops to achieve the same delivery performance. I am confident that this is also true for CONWIP loops. Hence having one big or multiple small loops will not make much difference in WIP.

7.2 Summary

Overall, CONWIP is a useful system similar to kanban. Like kanban, it is also a pull system, although it has more flexibility with made-to-order products. I will discuss the advantages and disadvantages of CONWIP in my next post. In the meantime, go out and **Organize your Industry**.

7.3 Selected Sources

- Marek, R. P., Elkins, D. A., Smith, D. R., 2001. **Understanding the fundamentals of Kanban and CONWIP pull systems using simulation**, in: Winter Simulation Conference 2001; Proceedings of the Winter Simulation Conference 2001, pp. 921–929 vol.2.
- Spearman, M. L., Woodruff, D. L., Hopp, W. J., 1990. **CONWIP: a pull alternative to kanban**. International Journal of Production Research 28, 879–894.

8 Benefits and Flaws of CONWIP in Comparison to Kanban

Christoph Roser, February 25, 2015, Original at https://www.allaboutlean.com/conwip-comparison/

Figure 46: CONWIP-go-round with different parts – like roller coaster seats with people (Image Stevage under the CC-BY-SA 2.5 license)

In my last posts I discussed the basics of CONWIP systems (*Constant Work In Progress*) and answered some frequently asked questions Part 1 and Part 2 on CONWIP. Overall, CONWIP is a pretty cool alternative to kanban, also establishing a pull system. It has some very valuable advantages, but it also comes with some disadvantages. In this final post of my series on CONWIP, I will shed light on some of these advantages and disadvantages, especially in comparison with kanban, but also with drum-buffer-rope.

If you don't yet know much about CONWIP, check out the basics of a CONWIP system for an easier understanding of the following discussion.

8.1 Advantages of CONWIP

8.1.1 The Big Difference: Number of Variants

Figure 47: Good for kanban (Image Haragayato under the CC-BY-SA 2.5 license)

Kanban works well with high-quantity low-variety parts. Since every card has a part number permanently associated with the card, the cards always replenish this part number. Of course, this works only if there is a continuous demand for this particular part number. A good example of this would be any made-to-stock parts that will be sold in larger quantities.

Figure 48: Not good for kanban, but no problem for CONWIP (Image Ssawka under the CC-BY-SA 3.0 license)

On the other hand, if you produce to order, a kanban will have difficulties. If every product you make is unique, then you would need a unique kanban for this product. But since kanban are always assigned a part number, this will be difficult.

CONWIP, on the other hand, has no part number assigned by default to the CONWIP card. Hence, any part number can be assigned (temporarily) to the CONWIP part, even if the part is produced only once. Therefore, CONWIP is well suited for made-to-order parts. However, for made-to-stock production, you need a good production sequence or you may end up in hot water with CONWIP (see further below).

8.1.2 Hybrid System with Kanban Is Quite Possible

Figure 49: Hybrids work, too! (Image TTTNIS in public domain)

Of course, since the cycle of the kanban cards and the cycle of the CONWIP cards is similar, it is easy to imagine a hybrid system (and it has been imagined already a few times). In fact, there are at least two different hybrid systems possible, where both kanban cards with numbers and CONWIP cards without numbers circle through the system.

The first hybrid system has **kanbans assigned to the high-runner part types and CONWIP to the low volume exotic parts**. Whenever a kanban card comes along, the part number of this kanban is produced. Whenever a CONWIP card comes along, the most urgent part from the backlog of low-volume exotic parts is produced. Both kanban and CONWIP cards wait in a joint queue. The only difference is that just before production, CONWIP parts get assigned a part number from the backlog. **This would create a good combination of the advantages of both kanban and CONWIP.**

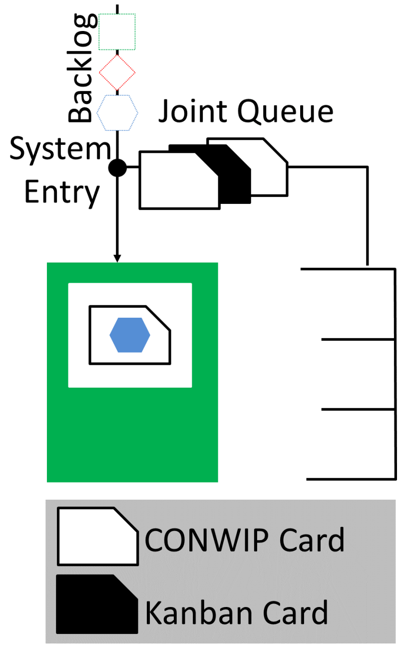

Figure 50: Kanban-CONWIP hybrid depending on part production volume (Image Roser)

Please be aware that there is also a second type of hybrid CONWIP-kanban system, where **both a CONWIP AND a kanban card are attached to the part.** In this system, CONWIP has one big loop and kanban has smaller loops within the CONWIP system. However, this would mean that you now have TWO cards attached to each part, a CONWIP and a kanban. This is twice the work, and two times the opportunity for mix-ups. Matching CONWIP cards with kanban cards will be quite a challenge. **Overall, my gut feeling tells me to stay away from this second type of hybrid system, since it includes excess work, more possibilities for failures, and not really any big advantage that I can see.**

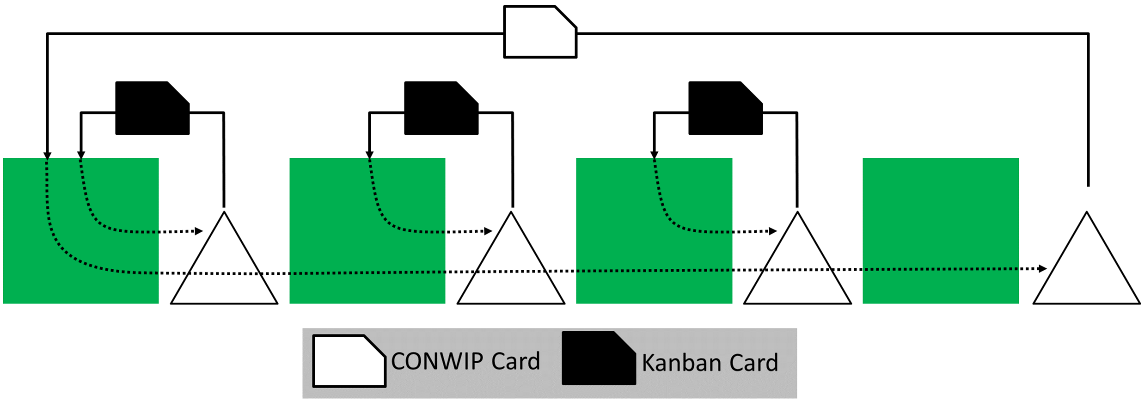

Figure 51: Kanban-CONWIP hybrid with two cards per part (Image Roser)

8.1.3 It Is (Also) a Pull System

CONWIP, like kanban and drum-buffer-rope, is also a pull system. As with any pull system, it prevents overloading of the system, prevents overproduction, and generally gives a much more efficient, smooth, and lean production system. As such, a pull system almost always beats a traditional MRP push system from a planning department.

8.2 Disadvantages of CONWIP

8.2.1 Does Not Manage Production Sequence Automatically

Figure 52: What was the sequence again? (Image Damastes in public domain)

Kanban has an additional advantage in that it automatically manages your production sequence. If you have enough kanbans of each part type, then the kanban system automatically reproduces what is needed.

CONWIP, on the other hand, needs human input to reproduce the correct products (or, in the case of exotic products, to produce the right products in the first place). This is a reasonable assumption if the people organizing the backlog know what they are doing. However, this is not always the case. Assume you have a system with 50 CONWIP cards. If someone messes up your backlog priority and puts 50 times the same product as a priority, then your entire system is full with this one product. You cannot even produce something else unless you sell one of the other products.

Overall, I think the risk is reasonable and can be managed. However, be aware that the risk of human decisions messing things up is there.

8.2.2 Sensitive to the Bullwhip Effect

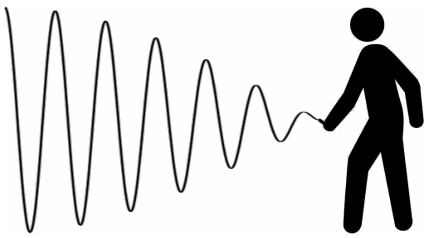

Figure 53: The bullwhip effect (Image Thwongterry under the CC-BY-SA 3.0 license)

One effect of these human decisions is a higher tendency for the bullwhip effect. This effect is a tendency of quantity swings to increase as you go back in the value chain due to human overreaction to demand signals. Since in CONWIP humans decide the priority, they can also overreact.

8.2.3 Uses Quantity, Not Time to Keep Workload Constant

CONWIP – and for that matter, kanban – both normally use the quantity of parts to prevent overloading of the production system. This works well if all parts produced have similar production times. However, if the parts have very different production times, then 500 quick-and-easy parts will have a totally different workload for the production system than 500 hard-as-nuts parts. Again, this problem is shared by both kanban and CONWIP in its usual form (although there are some workarounds).

Measuring the work content by time can prevent this. One method that measures the workload in time by default is drum-buffer-rope, but this has its own disadvantages (see A Critical Look at Goldrath's Drum-Buffer-Rope Method for details).

8.2.4 A (Bit) More Work

Figure 54: Overworked worker (Image Roser)

The CONWIP approach includes a separate sorting of the backlog and matching the backlog with the CONWIP cards. This, of course, is extra work that the kanban system does not have. Additionally, these may be more sources of errors. On the other hand, if you have lots of made-to-order or exotic parts, you cannot use kanban. In this case, a CONWIP despite its larger organizational overhead is quite usable.

In sum: If you have high runners, use kanban, since they are easier. If you have lots of exotic parts, use CONWIP. If you have both, use a hybrid system.

8.3 Claimed Advantages of CONWIP

8.3.1 Less WIP than Kanban

Figure 55: Is it more or less? (Image Axisadman under the CC-BY-SA 3.0 license)

Spearman claimed that a CONWIP system will have less WIP than a kanban system, since "in a kanban system, there will be generally WIP […] upstream from the bottleneck […]. In a CONWIP system, WIP will tend to collect at the bottleneck." I respect Hopp and Spearman very much (e.g., for their excellent book Factory Physics and its recent update, Factory Physics for Managers: How Leaders Improve Performance in a Post-Lean Six Sigma World), but here I cannot follow their logic (and bottlenecks are actually one of my key research topics).

If I understood it correctly, this WIP reduction is due to CONWIP having one big loop compared to kanban often having multiple loops in sequence. One of my master students analyzed this in detail and found that having one big loop or multiple smaller loops makes little difference in WIP for the same delivery performance. Therefore I do not believe this supposed advantage. Besides, CONWIP would also benefit from multiple smaller loops depending on the circumstances (see another original research of mine: Ten Rules When to Use a FiFo, When a Supermarket – Part 1 Introduction, and Part 2 The Rules).

Of course, you may assign a different number of kanban or CONWIP cards. However, this depends very much on the details of your system, and it is difficult to tell which one would need less cards and hence less WIP.

8.4 Summary

Overall, I like the CONWIP system. It seems to be quite useful, especially for made-to-order products. I can also imagine it to be quite suitable as a hybrid in combination with kanban. This concludes my four-post series on CONWIP. I hope this was insightful for you. It definitely was for me, as I am always learning new things by blogging about them (it kind of forces me to look up the details ☺). Now go out and **Organize your Industry!**

8.5 Selected Sources

- Marek, R. P., Elkins, D. A., Smith, D. R., 2001. **Understanding the fundamentals of Kanban and CONWIP pull systems using simulation**, in: Winter Simulation Conference 2001; Proceedings of the Winter Simulation Conference 2001, pp. 921–929 vol.2.
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9 How a Planned Economy Can Screw Up an Entire Country – Analogy between Cuba's Communist Economy and Push Systems

Christoph Roser, March 01, 2015, Original at https://www.allaboutlean.com/cuba-economy-1/

Figure 56: Cuban Flag (Image Roser)

Over Christmas I escaped the cold weather in Germany and relaxed on the warm beaches in Cuba. Of course, being a lean expert, I was also interested in the Cuban economy. As a communist economy (or more precisely, a socialist economy), it is based on centralized planning. In comparison, the capitalist system of the US (and most of the rest of the world) leaves most business decisions to individual entrepreneurs. This is somewhat similar to push and pull in manufacturing. Push systems also rely on centralized planning, while **pull systems have their signal from inside the system** to match the customer demand. As capitalism outperforms communism, pull usually outperforms push. Hence, in this post I would like to show you the shenanigans that happen in Cuba due to the effects of centralized planning. Warning: Lots of images ahead!

9.1 A Very Brief Bit of History

Cuba was claimed for Spain by Columbus in 1492 during his first voyage to America. After the Spanish-American War, Cuba became independent in 1902. In the decades afterward, Cuba prospered, heavily influenced by the US. By 1958 Cuba was one of the most prosperous nations in Latin America, doing well even compared to the rest of the world. However, this was based mostly on natural resources (especially sugar) and tourism. There was little manufacturing, which was also hindered by strong labor laws. Nevertheless, lots of infrastructure was built, and the middle class approached an American lifestyle.

Figure 57: Socialism or death! (Image Roser)

However, this all changed in 1959 with the Cuban Revolution. Among many other measures on their path to the communist ideal, the means of production were socialized. This included the often American-owned farm land, machines, and factories. As with all other communist revolutions, productivity dwindled and investments dried up. The American embargo that started during the Cuban Missile Crisis did not help the economy either.

While in 1958 the average Cuban earned 20% of the average American, nowadays it stands at only 10%. The official government salary is around USD $20–$30 per person per month, depending on your occupation. Even considering the lower cost of goods in Cuba, this is not enough to live, let alone to support a family. An active black market and *Sociolismo* (exchanging favors) outside the official system helps many Cubans to make ends meet.

9.2 Lack of Materials and Spare Parts

Figure 58: Improvise! (and don't forget to take some with you into the stall) (Image Roser)

The planned Cuban economy is plagued by a constant lack of materials. Centralized planning just cannot do the work as well as Adam Smith's invisible hand. Even to a tourist, who often gets priority treatment in the distribution of official goods, this deficit is obvious.

For example, there seems to be a shortage of paper towels (among other things). Hence, in the airport toilets, they added toilet paper to the paper towel holders. However, besides drying your hands, you also had to take some along beforehand for its intended purpose, since there was no toilet paper inside the stalls.

Figure 59: Not yet ready for the Olympics (Image Roser)

Another example was this sports field. It probably looked nice when it was built, but now it is falling apart. They lacked the spare parts (like a basketball basket, a volleyball net, or other things) to fix it, so it is now nearly unusable.

Figure 60: Lost its spin … (Image Roser)

Cuba also had one of the first rotating bridges in Central America, opened in 1904. This bridge still stands, but apparently is no longer able to rotate due to a lack of maintenance and spare parts. Luckily, when the mechanism gave way, it was in the closed position. It still is one of the important bridges in Matanzas, the City of Bridges. In fact, pretty much all major bridges date to before 1959.

9.3 The State of Commerce

9.3.1 Shampoo, Shoes, and Snacks …

Figure 61: Today you can have both shampoo and conditioner. You can even choose among two types of shampoo! (Image Roser)

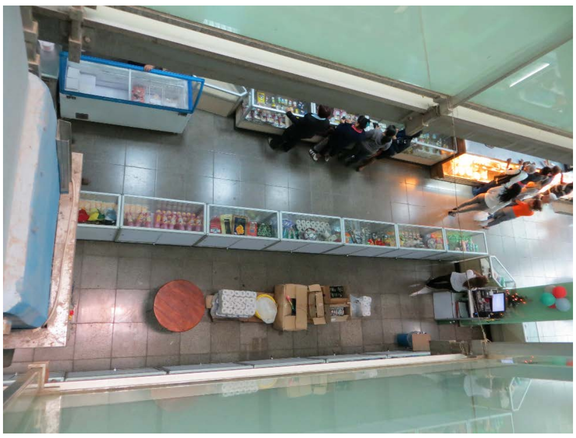


Figure 62: A typical Cuban "supermarket" (Image Roser)

A common experience with push systems is that there is often too much of one product and too little of another. This is very similar to the communist (socialist) system in Cuba. The official stores often lack some goods while they have too much of another. For example, the "supermarket" may have had conditioner but lacked shampoo.

Figure 63: Oversupply of rice cookers (Image Roser)

Another store got two pallets of beer delivered, much more than needed. Yet a third store had dozens of rice cookers for sale but lacked any other small electric items like blow dryers, mixers, or coffee makers.

Figure 64: Half of the shoe store (Image Roser)

Due to the mismatch between supply and demand, lots of small private stores and stalls are everywhere in Cuba. However, they also don't have the necessary supplies. For example, the average shoe store in Cuba had around 50 pairs of shoes available. Please note that these are **not** different 50 designs, available in many sizes, but 50 pairs in total. Lucky you if you can find both a matching size and a design you like.

Figure 65: Not much here in the official shop (Image Roser)

Figure 66: Highest sanitary standards in the private shop… (Image Roser)

Even with basic food items like home grown pork, the selection is meager. No matter whether you go to the official shop or the private shop, there is not much selection.

9.3.2 The Horror, the Horror …

Okay, if you are, like me, an engineering-minded male, you may not feel the pain if there is only a limited shoe supply. For me, if the shoe fits and it is not ugly, then everything is fine. Similarly, I survive well even if I cannot choose from 40 types of shampoo. Actually, it makes my decision of which one to buy much easier.

But now, let me show you a store whose lack of selection really, really hurts – up close and personal! Here’s your friendly neighborhood hardware store:

Figure 67: Large Hardware Store, Matanzas, Cuba (Image Roser)

That’s it! That is the selection in the largest hardware store in the province capital of Matanzas (pop. 150,000). **They have only one shovel!** The blue packages on the left are some leftover tiles (good luck in finding what you want). In the back they had a number of fittings and mountings in a glass vitrine, rather than the bulk containers with everything you are used to in the US and Europe. The entire store probably had less goods than half an aisle in the capitalist equivalent. Of course, if you like pink toilets, then you are in luck.

Figure 68: Peddling her plumbings… (Image Roser)

Figure 69: U-bends and kitchen ladles … (Image Roser)

Here, too, small entrepreneurs try to fill the gaps. Across the street, a woman in an entrance of an apartment was peddling her plumbings (and I mean this in a purely technical way). Three houses down, a small merchant offered some more u-bends, electrical junctions, and – to fill up the assortment – kitchen ladles. Even so, the selection was pitiful.

9.3.3 Some Things Are Plenty

Figure 70: Drown your sorrows… (Image Roser)

On the plus side, if you want to drown your sorrows over the lack of tools, the supermarkets are usually pretty well stocked with drinks, especially Cuban rum, but also other brands, including Heineken.

Another thing that is readily available is cigars (good ones or fake ones with cheap tobacco). Furthermore, bookstores are also well stocked. That is, if you are interested in one of the three available sections: children’s literature, the glory of Cuba, or the history of Cuba. No Hemingway books in Cuba. ☹

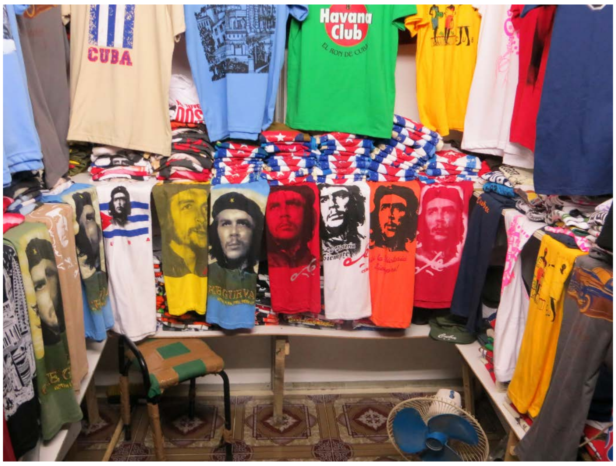


Figure 71: The capitalist side of communist face (Image Roser)

Finally, T-shirts are also common, especially with tourist motives like Che Guevara or Havana Club. However, there are no T-shirts with Fidel Castro. I have been told that he has to be dead first before they can print him on a shirt. Fridge magnets, however, are perfectly fine with Fidel and his beard. Don’t ask me why; I don’t get it either.

9.4 Summary

Overall, as push production can mess up both your inventory and your delivery performance, even larger planned economies like Cuba can make a mess out of an otherwise reasonable country. Cubans have relatively good education, no civil war, no major disasters lately, and a stable (albeit socialist) government. Usually, these are all good signs if you want to put an economy back on track. It is only lacking the invisible hand to guide them, and the very visible planned hand does not guide their economy very well. (They also have a bit of an embargo problem, which hurts them financially. But they could still get stuff through Venezuela and other countries.)

Personally, I hope they eventually get their things together and also manage to get along better with the United States. I also hope that you enjoyed this article, since it may have consequences for me. If the Cuban security apparatus reads this, they may notice a lack of praise for their Cuban economy, and also a lack of condemnation of the “*capitalist imperialist pigs*” (i.e., everybody north of them). In sum, I may not be able to go back there for a holiday. At least until the next Cuban revolution, that is. In the meantime, **go out and Organize your Industry** (and also enjoy the variety of goods the next time you are shopping).

10 The Seven Types of Waste (Muda) – Now with 24 More Types of Waste Absolutely Free!

Christoph Roser, March 08, 2015, Original at https://www.allaboutlean.com/muda/

Figure 72: Seven Trash Cans Labeled (Image Thomas Söllner with permission)

One popular and well-known concept of the Toyota Production System is the **elimination of waste**, in Japanese also called *muda* (無駄). It is one of the three evils of manufacturing systems, the others being unevenness (*mura*, 斑) and overburden (*muri*, 無理). In this post I would like to go through the details of waste with you. This includes the traditional seven types of waste – of which I am a big fan. For completeness sake I also included a lot more types of waste I have come across in industry. However, you have to decide yourself if these additional wastes are not themselves a waste.

10.1 A Quick History of Waste

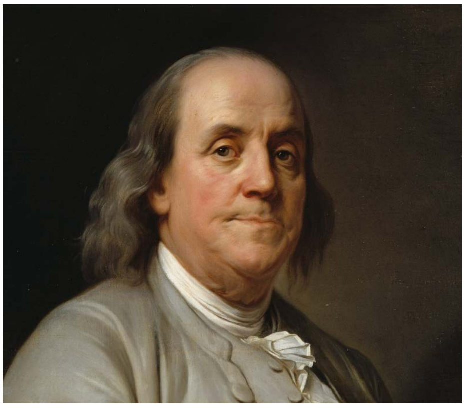


Figure 73: Thinking about waste … (Image Joseph-Siffrein Duplessis in public domain)

The idea to reduce waste, create order, and treat your workers humanely is not new. Reducing waste is probably the most obvious one, and has been around as long as there was manufacturing. For example, Benjamin Franklin clearly realized the waste of excessive inventory:

> *You call them goods; but, if you do not take care, they will prove evils to some of you. You expect they will be sold cheap, and, perhaps, they may [be bought] for less than they cost; but, if you have no occasion for them, they must be dear to you. Remember what Poor Richard says, 'Buy what thou hast no need of, and ere long thou shalt sell thy necessaries.' (Benjamin Franklin, The Way to Wealth, 1758)*

Taylor and Gilbreth also focused intensely on waste reduction through detailed analysis of motions. Also, Ford already had waste walks long before Toyota. Hence, eliminating waste is nothing new. It is through the popularity of the Toyota Production System, and by proxy, lean manufacturing, that it is mostly associated with Toyota. Nevertheless, it is one of the important concepts of the Toyota Production System, along with unevenness (*mura*) and overburden (*muri*).

In the Western world, waste is much better known than unevenness and overburden, and therefore it gets more prominence, often resulting in neglect of the other two evils. In any case, let’s go into more detail about waste:

10.2 What is Waste (Muda)?

Muda (無駄): futility; uselessness; pointlessness; waste;

Everything that is done in the company is divided into two groups: value-adding and waste. Generally speaking, value-adding is anything the customer pays for, and waste is anything the customer does not care about. Sounds easy, right? In practice, however, it is a bit more difficult, and there is a large gray zone.

Figure 74: Adding value … (Image Trix and friends under the CC-BY 2.0 license)

Assume that you are attaching a wheel to a car. Of course, the customer wants his car to have wheels. He would pay less for a car without wheels attached (well, I would!). Therefore, attaching the wheels and screwing on the bolts is value-adding.

Or is it? You could also say that the customer does not care about screwing on the bolts, as long as they are tightened. Hence, with equal validity you could say that only the last quarter turn tightening the bolts are value=adding, and all turns before are waste. Therefore, if you have a screw that needs less turns to hold the wheel securely, you would have reduced waste. Both views are equally valid.

As for transport, the wheels were probably not produced at the same spot where they are installed. Instead, a transport process brought them to the assembly site. The customer does not care if you carry around your wheels, hence it is waste. Yet, it is probably not possible to eliminate transport completely. Hence, in industry it is often differentiated between avoidable waste (that can be eliminated completely) and unavoidable waste (that can be reduced but not eliminated). Of course, like value-adding and waste, avoidable and unavoidable waste also have a big gray zone in between.

10.3 The Seven Types of Waste

Figure 75: Seven Trash Cans (Image Thomas Söllner with permission)

In particular for manufacturing, Toyota has defined seven types of waste in more detail.

10.3.1 Transportation

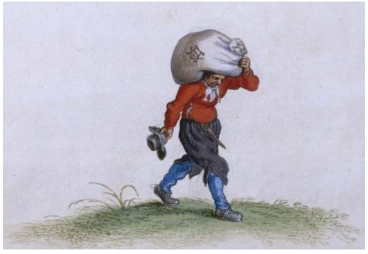


Figure 76: A man carrying a sack (Image Adriaen van de Venne in public domain)

Any type of transportation is waste. The less you transport, the better. Not only does it cost time and money, it can also cause damage or you can misplace the item completely.

10.3.2 Movement

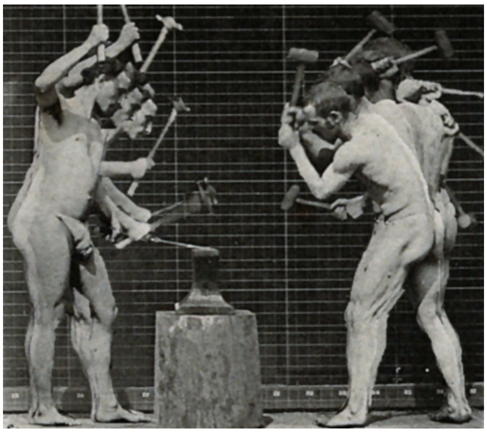


Figure 77: Some movement is necessary for (most) work. (Image Eadweard Muybridge in public domain)

Avoid unnecessary movements. Arrange everything so the worker has to move as little as necessary to assemble the product. MTM and REFA are strong methods in this aspect (see also Taylor and Gilbreth). This applies not only to workers, but also to machines, albeit the workers are more important. In a machine, do not move the tool 10 inches out of the way if 5 inches will suffice. The machine will be faster, and there will be less wear and tear.

10.3.3 Waiting

Figure 78: What a waste! (Image David Shapinsky in public domain)

This refers primarily to people waiting. Not quite as important but also included are machines waiting. Not included are parts waiting, since this would be included in the waste through inventory (even though Wikipedia says differently at the time of me writing this post). For people it is easy to see. You are paying them wages, yet if they have to wait for parts, machine processes, or other workers, this money is wasted. Crucially, Toyota also considers this disrespectful to the people.

This is also the main reason why waiting times for machines are considered less important. If you have the choice, you should rather let the machine wait for the operator than the operator for the machine. (OEE is a good measure here and can also help you to improve your utilization, as long as you don't fudge the numbers.) **Hence, machine utilization and OEE is NOT a type of waste!**

Of course, if you can increase both, it would be best – given that you actually need the products. Unfortunately, I have seen too many examples where management wanted to increase utilization of machines and merely ended up with lots of not (yet) needed inventory – leading to an even bigger waste of overproduction and inventory.

10.3.4 Over-Processing

Figure 79: Worlds largest Swiss Army knife! Exciting … but a bit too much! (Image Slartibartfass under the CC-BY-SA 3.0 license)

Over-processing refers to inclusion of additional features, parts, processes, or other things that the customer does not need and hence is not willing to pay for. This is the proverbial golden screw. It sounds obvious not to include features the customer does not want, but unfortunately it is not so.

Products are purchased by the customer but designed by the designers and engineers. Unfortunately, these have a completely different mindset, and may be aware of potential flaws and possible features that the customer has never ever heard of before. This is particularly common in industries where the designers and engineers are particularly attached to their product (e.g., the automotive industry or machine tool building), although pretty much any product is loved by at least some of their creators.

I have seen many products being over-designed and over-engineered to include features that 99% of the customers did not care about or did not even know about, yet the designers wanted *their baby* to be perfect. Yet, if it adds no value for the customer, it is a waste. See, for example, my Lean Obituary for Maybach, which was primarily built for the Daimler executives (although they did not pay for them themselves) and ended up losing half a million dollar per vehicle.

10.3.5 Defects and Rework

Figure 80: Defects! (Image unknown author in public domain)

Any product that does not satisfy the requirements and has to be reworked or thrown out. This is also an obvious and expensive type of waste. Similar to overproduction, you invested all the capacity, material, and time, but then you cannot even sell the product but have to throw it out.

Even if it can be reworked, it is an additional effort, will consume more capacity and time, and in general will mess up your production schedule. Hence, when you do it, do it right the first time.

10.3.6 Inventory

Figure 81: Just a little for bad times … (Image Benjamin Marshall in public domain)

Any kind of material you have but do not work on right now is a waste. You paid for it, but it merely sits around, has to be maintained, transported, and uses up space. Inventory can easily cost you 30%–65% of its value per year. For details, see my post [The Hidden and Not-So-Hidden Costs of Inventory](#).

Yet, in many firms, inventory is still seen as something good, especially on the shop floor. Inventory gives security. You always have something to work on, and you are more likely to have something to sell if the customer comes around. Yet, while you need inventory, it makes you sluggish and expensive.

10.3.7 Over-Production

Producing more than what is needed is a waste. Lean production is lean especially because it produces only what is needed. Overproduction ties up capacity, material, time, and other resources that are not yet needed. In effect you are paying today what you may have to pay only a week from now. Additionally, you now have even more inventory, and hence you are losing even more money.

In a traditional view, overproduction is the worst waste of all the seven types of waste. Overproduction will act as a multiplier to many other types of waste. It will (naturally) increase inventory, and also transportation and movement. Furthermore, defects may be noticed too late. Hence, try to avoid it if you can.

10.4 Many More Additional Wastes – What a Waste!

The idea of eliminating waste is a very easy-to-understand concept. Hence, it is no surprise that many people added additional types of waste to the classical seven types of waste above. Personally, I am a big fan of the above seven, and not so much of the others below. For me, all too often these additional wastes are difficult to measure, add little value, are too detailed, overlapping, and **may be even a waste themselves by being an excessive list of possible wastes**. Some are from Six Sigma, others from TPM (Total Productive Maintenance, which has 16! types of waste), and other sources in literature. :In any case, **see for yourself if any of the list below suits you, it mostly does not for me**:

- **Unused (Floor) Space**: Also a waste. At least one company I know generated this due to their hierarchy structure. Design and Manufacturing were separate entities, hence Manufacturing was not in charge of “over-processing” above. In order for them to still have seven types of waste, floor space was added. As far as waste goes, the idea is not bad, and less unused floor space is better.
- **Manufacturing goods or services that do not meet customer demand or specifications**: Added by Womack, also a possible candidate to consider
- **Unused Human Creativity/Potential; also known as Knowledge Disconnection**: This one seems to be popular with Six Sigma, and is also the most commonly found additional waste. Of course, wasting human creativity is not good. However, my problem with this type of waste is, how do you measure it? Everything above can be measured somehow, but how do you measure human creativity? In any case, while it is not part of the traditional seven types of waste, Toyota is pretty good at using this creativity.
- **Confusion**: Clearly wasteful, but also difficult to measure. In my view this is probably not a waste, but the result of other wastes. In any case, the less confusion, the better.
- **Unsafe Working Conditions**: Work environments that are not safe are of course a big potential source of trouble. For me, this could also be included in overburden (muri), but could also stand on its own.
- **Wasted Opportunity**: True, but how do you measure it?
- **Wasted Time in Meetings**: Also true, but way too detailed for my taste.
- **Time wasted chasing fads**: Way too detailed, even if you would know how to measure it. This waste may even be an ironic type of waste, as it could be its own fad …
- **Sub-Optimization**: Not optimizing everything as much as you can. Well … yes … but wouldn’t that result in one or more of the seven types of waste above?
- **Ignoring Lessons of History**: … right next to the waste of not being able to read and do math …
- **Equipment failure**: For me included in the seven traditional types of waste, depending on its effects as waiting, movement, or defects.
- **Change Overs**: also included in the seven traditional types of waste

- **Tool Change**: Same as above, way too detailed
- **Ramp Up Losses**: More of the same
- **Short time Stops and small breakdowns**: Small stops and breakdowns. This one comes probably from one of the three loss categories in the OEE
- **Speed Losses**: The system runs slower than it could – Probably another one from OEE
- **Planned Stops**: Probably another one from OEE
- **Management Losses**: This includes any failure of management. This could be huge, but TPM (where it came from) narrows it down quite a bit to lack of material or instructions and overproduction due to management failures.
- **Line Organization Losses**: This is to represent badly set up production lines. As far as wastes go, this is for me now only an example, and no longer a type of waste. At the same time the original definition from TPM did not even consider that not every production is a line, but there are also for example job shops and on site manufacturing.
- **Logistic Losses**: Manufacturing stops due to loading and unloading.
- **Measuring and Adjusting Losses**: Manufacturing stops due to measuring and adjusting. Also overkill in my view.
- **Usage Losses**: The materials used in production are not used efficiently. Examples are too sturdy products (which would be over-processing) or too much scrap.
- **Energy Losses**: Wasting of Energy of any type. May even make some sense, also feeds in the current *green* and *Eco* trend in industry.
- **Forms, Dies, and Tool Losses**: Losses due to design changes that require a tool change. Kind of true, but again way too much detailed.

10.5 Conclusion

Overall, knowing, identifying, and especially reducing the seven (or more) types of waste can give your production system a big advantage. Waste walks to identify sources of waste are also common in industry, although it is easy to find more waste than what the improvement system can handle. It is, for example, easy to see missing parts leading to the waste of waiting. Fixing them, however, is much more difficult. In any case, do not get lost with an excessive list of ill-structured types of waste. In case of doubt, stick to the original seven types of waste.

Additionally, do not neglect the other two evils, unevenness (*mura*) and overburden (*muri*). They also have a significant negative effect on your manufacturing system. Now go out, eliminate waste, and **Organize your Industry!**

11 Lies, Damned Lies, and KPI – Part 1: Examples of Fudging

Christoph Roser, March 15, 2015, Original at https://www.allaboutlean.com/kpi-lies-examples/

Figure 82: Don't get too excited about your numbers! (Image Roser)

Statistical measurements, usually called key performance indicators (KPIs) are found on pretty much every shop floor and in every company. Many management decisions are made based on KPI. Unfortunately, these numbers often are not reliable at all.

Mark Twain popularized the phrase "*Lies, damned lies, and statistics.*" Winston Churchill famously said, "*I only believe in statistics that I doctored myself.*" Hence, **both men were wary of trusting numbers. You should be too!**

Since many people's careers depend on good KPI, there is a large temptation to fudge the numbers, and hence they are frequently fudged. The higher up you go in hierarchy, the less you can rely on the numbers. Additionally, these KPIs often are not only incorrect, but much waste goes into manipulating these numbers. In this post I will give several different examples of manipulated KPI. In the next post I will discuss the negative effects of this KPI fudging. In a final post I will give some tricks on how to avoid or at least reduce the number fudging.

11.1 Common KPI Examples from Industry

11.1.1 OEE and Utilization

Industry is ripe with examples of numbers that have long since lost their meaning. I blogged before about my Top Three Methods on How to Fudge Your OEE. Personally I do not believe any **utilization** or **OEE** (Overall Equipment Efficiency) unless I have measured it myself. I regularly see OEEs above 90%, but when I measure them myself they turn out to be 60%. I even have seen some OEEs above 100%, meaning they produced more than the theoretical limit of 100%.

11.1.2 Delivery Performance

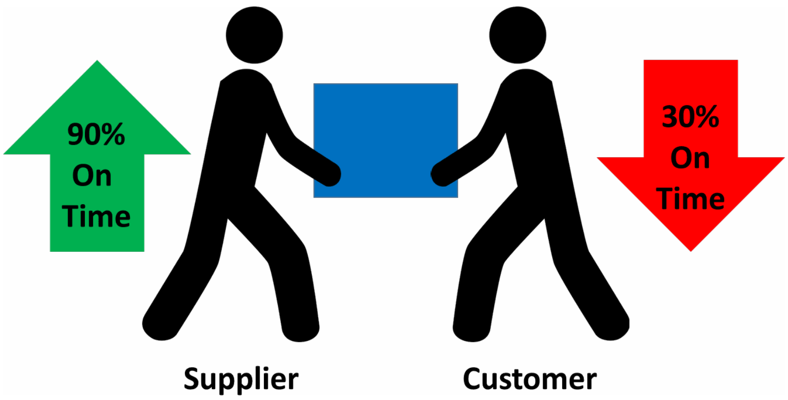


Figure 83: Measurement Discrepancies … (Image Roser)

Another popular KPI in industry and therefore a popular KPI to manipulate is **delivery performance**, measuring the percentage of customer deliveries provided in full on time. Most plants I have seen regularly have delivery performances above 90%, except nobody creating these numbers really believed them. One plant once made the mistake of asking their customer what the delivery performance was on the receiving side. While the plant measured 90%, the customer measured only 30%. Clearly, something was amiss.

11.1.3 Inventory and WIP

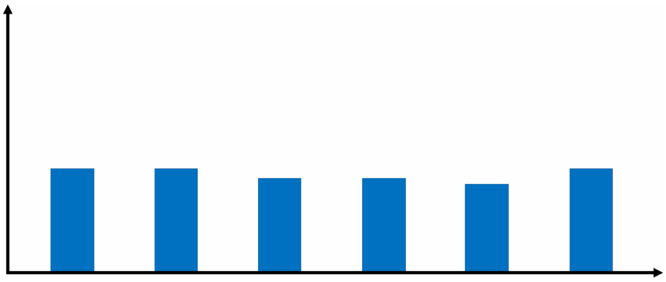


Figure 84: Monthly Inventory Data (Image Roser)

Yet another common KIP is **inventory**, especially if related to lean manufacturing. One company I know measured these inventory levels on a monthly basis, always at the end of the month. It looked like the graph on the left.

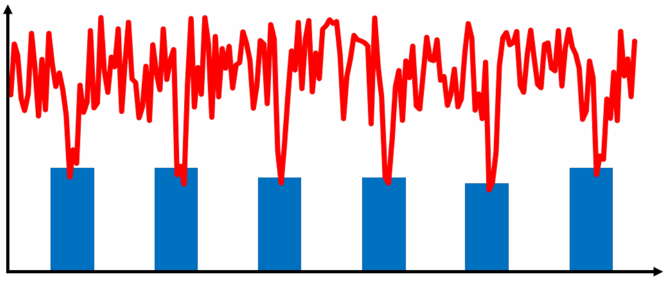


Figure 85: Daily Inventory Data (Image Roser)

At one point they decided to try to measure the inventory levels on a daily basis. Not all inventories but way too many showed a curve similar to the graph on the right. Miraculously, the inventory levels always dropped significantly at the end of the month. Again, was this coincidence, or was this an intentional effort to fudge the numbers? (Hint: It was not a coincidence!)

11.1.4 Quality

Figure 86: Quality Check: Good! (Image Roser)

To continue with popular KPIs, **quality** is also often measured. One manager producing dishwasher tabs made the mistake of starting to correctly measure the number of broken tabs in a factory where defective products were notoriously under-reported. Defect rates increased by factor of 10. More precisely, the defect rates always were there, but now the reporting matched the actual quality.

Of course, the new numbers destroyed the quality KPI of the entire plant. The problem, however, was solved quickly: The manager in charge was fired, people were sternly reminded about the quality targets, and hence reported quality rates returned to normal. Of course, quality did not improve at all in reality. (*Note: Normally I cannot go into that much detail due to confidentiality, but this example is published. See below for the source.*)

11.1.5 Cost

Figure 87: Pile of 100 Dollar Bills (Image Jericho under the CC-BY 3.0 license)

Probably the most important KPI in industry is **cost**. Unfortunately, the true cost of a product is very difficult to calculate. While work hours can be measured and calculated easily, how do you measure customer satisfaction if he gets his product on time – or not? Standard bookkeeping often has some assumptions that make a product cheaper or more expensive than it really is, especially when comparing in-house with external suppliers.

I have seen examples where in-house suppliers could calculate their offers with 100% efficiency, but received payments according to their true efficiency. Naturally, the offer of the external supplier could not compete, even if they would have been cheaper at the end. I have also seen the opposite, where the in-house manufacturer had to account all its old and rarely used equipment into the cost, which of course could not compete with the external supplier. Hence they ended up producing all the parts that no external supplier was interested in – the low-quantity, high-variety, and tricky products, which made them even more expensive.

11.1.6 Overarching Meta Performance Indicators

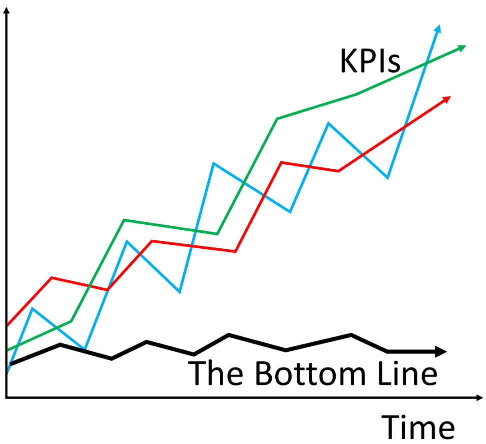


Figure 88: Meta KPI vs Bottom Line (Image Roser)

Yet some other companies have an overarching meta performance indicator to measure the performance of their plant. Throughout the years these meta-KPI continuously increased. It looked like the plants of these companies became better every year. Except the bottom line did not improve at all. There was no connection between the trends of the KPI and the money left at the end of the day. People just got better at fudging the numbers.

11.2 Some More Examples Outside of Industry

Figure 89: Different organization, same story … (Image Noclip in public domain)

I'm sure you can find many more examples in your own industry. Of course, the problem is not only in industry, but can also be found elsewhere. Governments are also well known for number fudging.

11.2.1 School Performance

For example, in the US, **students are scored using standardized testing**. Naturally, there are tons of reports on manipulations where, for example, teachers gave the answers to the students or corrected the tests before they were graded.

11.2.2 Financial and Economic Indicators

Economic growth and financial stability is also a measure of pride for many nations – and some are more proud than what reality would dictate. The growth rates of China are probably inflated. Greece joined the European currency based on highly questionable financial indicators – and now probably wishes they would not have done that. But somebody surely made a career with those numbers.

11.2.3 Industry Output

Production rates are also often manipulated. Socialist and communist nations especially excelled at this. In the Soviet Union, rather than reporting total quantities, the quantities of one shift or one worker was reported.

Figure 90: Hero of Socialist Labor Stakhanov (on the right) teaching his comrade how to fudge numbers (Image unknown author in public domain)

One particular individual, Aleksei Stakhanov, Hero of Socialist Labor, was reported to have mined 102 tons of coal in one shift, about 14 times his quota. Later he even exceeded that by mining 227 tons of coal in one shift. This was soon followed by similar over-achievements by other workers and named the Stakhanovite movement. During the great famine in China (1958–1961), farming yields were exaggerated up to the point of covering the field four feet deep with its harvest. Of course, neither Aleksei Stakhanov nor the fields in China were ever anywhere near these production rates.

11.2.4 Unemployment

Unemployment is also something that governments prefer not to have, or at least to have as little of as possible. Here, too, it is easier to fudge the numbers than to actually find jobs for people. In Australia, if you work one hour per week you are counted as employed. In Germany, lots of unemployed people are parked in otherwise almost useless “Job Training Programs,” in which (of course) they are no longer counted as unemployed.

11.3 Summary

These are only a few examples. Depending on which countries or which industry you are familiar with, you probably can easily add many, many more. The key statement is:

Be very, very wary of any kind of numbers if you have not measured and calculated them yourself!

Figure 91: Cartoon on KPI by LeanManufacturingPDF with permission. (Image Christian Mirra with permission)

In my next post I will discuss the negative effects of these fudged KPIs. More importantly, in a third post I will also show some ideas on how to reduce this negative effect of KPIs. In the meantime, **go out and organize your industry**, but do not believe only the numbers!

11.4 See also

Roser, Christoph. “Richtig Messen – KPIs Zum Nutzen Des Unternehmens Einsetzen.” Yokoten 5, no. 1 (2016): 26–29.

11.5 Selected Sources

The dishwasher tabs example is from Konsequent – Das Buch zum NTT by Thomas Hochgeschurtz; ikotes, 2009.

12 100th Anniversary of the Death of Frederick Winslow Taylor, the Father of Modern Scientific Management

Christoph Roser, March 21, 2015, Original at https://www.allaboutlean.com/100th-anniversary-death-taylor/

Figure 92: Frederick Winslow Taylor (Image unknown author in public domain)

It was exactly 100 years ago today that Frederick Winslow Taylor died. He is considered the father of modern scientific management, the first management consultant, president of the ASME, and the first management guru. He invented and patented the first modern tool steel, designed new golf clubs, and optimized the growing of grass. He could swear like few others, but he also won the US Open tennis championships.

His work was already controversial when he died, but nobody doubts the enormous legacy he has left for industry. Without his achievements, there would be no modern manufacturing.

12.1 Before Taylor

Until the end of the nineteenth century, coordinating work on the shop floor was based purely on experience. There was little understanding of the relations between work, time, and cost. While modern science started already around the sixteenth century, it was only with the steam engine in the eighteenth century that science entered product design. Nevertheless, by the beginning of the twentieth century, science has barely touched the art of manufacturing.

There were some discussions like Leonardo da Vinci measuring the speed of shoveling (500 shovels of soil per hour) and extrapolating the number of men and time needed to dig a canal. English mathematician and engineer Charles Babbage not only invented the first mechanical computer, but he also wrote probably the first book on manufacturing science, *On the Economy of Machinery and Manufactures*. However, it was up to Taylor to expand these ideas and put them in the limelight of manufacturing.

12.2 The Life of Taylor

12.2.1 Youth

Figure 93: Young Freddy at 17 (Image unknown author in public domain)

Frederick Winslow Taylor was born on March 20, 1856, in Germantown, Pennsylvania (hence you just missed the 159th anniversary of his birth yesterday 🙂). His parents were from a well-to-do and cosmopolitan family that traced its roots to the first settlers on the Mayflower. He went to school in Germany, France, and at a private school in the US, and was destined to become a successful upper-class lawyer like his father.

He also participated in stage plays, and had an enormous reputation for his ability to swear while still being classy. He also won the tennis doubles tournament of the US Open Championship in 1881.

12.2.2 Midvale Steel Works

However, eye problems forced him to change his paths, and he became a lathe operator at the Midvale Steel Works in 1878. There he quickly climbed the ranks and became chief engineer in 1884.

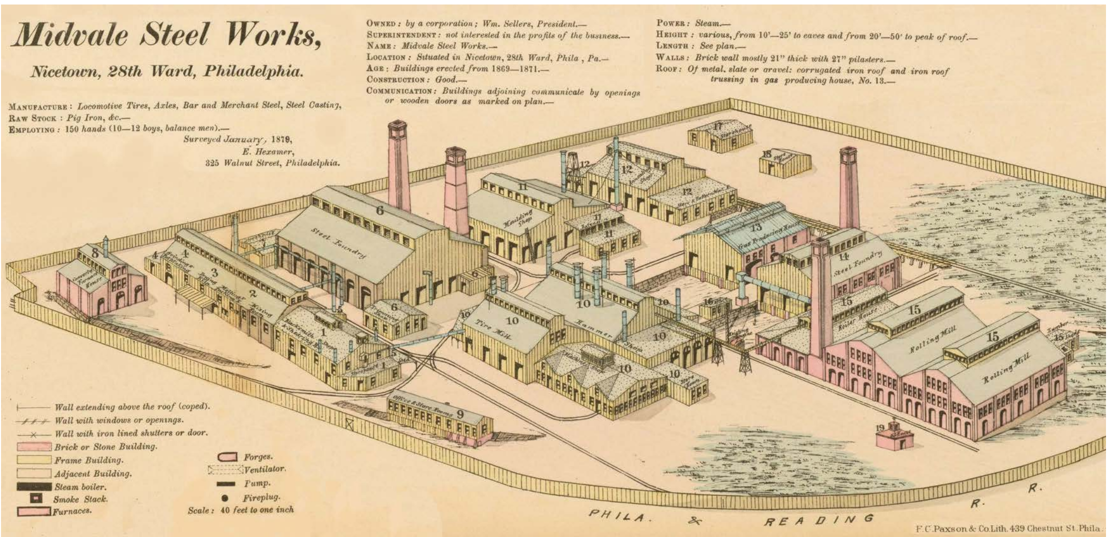


Figure 94: Midvale Steel Works (Image Hexamer in public domain)

It was at Midvale Steel Works where he developed his first ideas on scientific management, or what he called "task management" or "Taylor System." It all started with a detailed study of the work, breaking it down into small steps. Unnecessary tasks were disregarded, the technical aspect optimized, and the entire process adjusted for problems and deviations. The time and skills needed were also taken into consideration, and the salaries were adjusted accordingly. The result was clearly defined standards for the workers.

He tried it first in the lathe operations shop, where workers according to Taylor's estimate worked only one-third of what they could and intentionally slowed down. Taylor requested that each worker worked at the speed Taylor though appropriate or get paid less. Resistance was fierce. Taylor fired scores of people, lowered salaries significantly, and received death threats, but since he himself worked as a lathe operator for years he knew all the tricks. Besides, Taylor never avoided a fight or gave an inch if he thought himself right (and he usually felt he was. See also his battle with Frank Gilbreth in my post on The Tale of Taylor and Gilbreth).

Figure 95: Don't let the innocent looks fool you. He will fight you tooth and nail for his cause. (Image unknown author in public domain)

Eventually the workers gave in and increased speed, but they also intentionally increased scrap rates to prove that the speed was not possible. Hence Taylor fined them for broken tools and parts, with the money going into an welfare fund for the employees. He even fined himself when he accidentally broke a part. After three years of heated conflict between the workers and Taylor, the workers eventually gave way in the face of Taylor's determination.

Taylor also thought about the role of a foreman when he himself was a foreman. Back then the foreman did all the organization, from hiring and firing to production planning, setting targets, checking quality, and so on. He saw that these tasks were too much for one person and envisioned the split of these tasks to eight different people. Four of them he saw on the shop floor:

- the **gang boss** responsible for providing work to the men and teaching them how to set up the machines efficiently,
- the **speed boss** responsible for working speeds of man and machine once the machine has been set up,
- the **inspector** responsible for quality, and
- the **repair boss** responsible for fixing and maintaining machines.

The other four he saw within a planning department:

- an **order-of-work and route clerk** responsible for the production sequence on different machines,

- an **instruction card clerk** responsible for the standard procedures of the production process for both work and time,
- a **time and cost clerk** for tracking attendance and salaries, and
- a **shop disciplinarian** responsible for proper work behavior as, for example, timeliness, following standards, and respectful behavior, who could also adjust salaries accordingly and furthermore had the important role of a peace maker.

While Taylor never implemented this in all its rigor, it is pretty much the structure we have nowadays with foremen, quality department, maintenance, production planning, work instruction, human resources, and management.

Taylor left Midvale Steel Works in 1890. As it happens all too often, with the main driver gone the standards started to slip, and eventually the old system of slow work took over again.

12.2.3 Management Consulting

Taylor worked briefly for a financial company, but he disliked bankers ever afterward. To make ends meet he offered his services for focusing on shop management and cost reduction as a "*consulting engineer*" from 1893 onward, hence becoming the first management consultant.

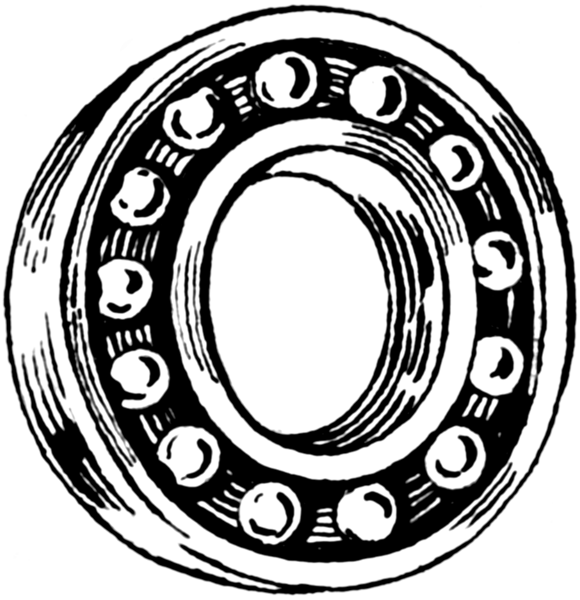


Figure 96: Ball Bearing (Image Pearson Scott Foresman in public domain)

One of the things he soon found out was that reducing working hours actually increased productivity. He wanted to reduce daily working hours from 10.5 to 10 for the same salary and production quantity for producing ball bearings. Initially the working girls refused, but again Taylor's stubbornness prevailed. Work times were reduced from 10.5 to 10, to 9.5, to 9, and eventually to 8.5 hours. Most surprisingly, daily production quantities increased, as did quality.

12.2.4 Bethlehem Steel Company

In 1898 Taylor started full-time consulting for the Bethlehem Steel Company. It was at Bethlehem were Taylor did his pig iron experiment, probably his best-known example of scientific management.

Figure 97: Taylor's Playground, Bethlehem Steel (Image William H. Rau in public domain)

Bethlehem Steel had tens of thousands of tons of pig iron in a yard that needed to be loaded onto railroad cards. The task was as simple as one could imagine. The worker picked up a 40-kilo piece of iron from the pile, walked to the railroad car and up a ramp, and dropped the iron before returning to the pile. This was, for Taylor, the perfect setting to demonstrate his scientific management approach. Over time he optimized the process, experimented with different intervals of rest and work, and looked into great detail in the process.

He calculated that a man should be able to load 48 tons per day, while currently they were loading only 12.5 tons per day. He focused his efforts on a single *mentally sluggish* worker, Mr. Schmidt (his real name was actually Henry Noll). Giving him detailed instructions combined with salary incentives, Mr. Schmidt was soon loading 47 tons per day. Later researchers, however, found many statistical and historical loopholes in the story, and it seems that Taylor may have polished his results. In any case, his efforts saved the company around $6.05 per day, much less than the cost of Mr. Taylor. (On a side note, Henry Ford would have just installed a conveyor belt.)

Also, Taylor was able to implement his ideas only with the lowest salary levels that offered the least resistance, and completely failed anywhere else. Hence after three years of work, there were little results. His protégé, Henry Gantt, however, did significantly improve productivity by using a much more cooperative approach than Taylor. Therefore, when Taylor returned from a holiday in 1901, he found the following letter on his desk:

> *Dear Sir:*
> *I beg to advise you that your services will not be required by this Company after May 1st, 1901.*
> *Yours truly,*
> *Robt. P. Linderman, President*

12.2.5 After Bethlehem Steel Company

Figure 98: Taylor's new focus: growing grass! (Image PublicDomainPictures in public domain)

Taylor took what you would call nowadays a time-out, built a house, and focused on gardening – although he did not switch from his scientific mind. He patented a method for moving and replanting large trees with their roots. He scientifically analyzed the growth patterns of grass depending on the soil conditions, conducting thousands of grass-growing experiments. He also designed a novel two-handed putter and other golf clubs.

In 1906, to his surprise, he was elected president of the ASME. It turned out that the ASME wanted to reorganize itself and thought Taylor was the best man for the job. He started with lots of motivation, but as it turns out, academics are much more stubborn and resistant to change than any lathe operator. His presidency lasted only one year and did not end on good terms. While before his presidency the ASME published many articles on Taylor's methods, there were almost none published afterward.

Nevertheless Taylor promoted his work, wrote papers, gave college lectures, and published his most influential book, *Scientific Management.* In the winter of 1912–13, he caught a cold which he could not get rid of, and he died of pneumonia 150 years ago today on March 21, 1915.

12.3 His Legacy

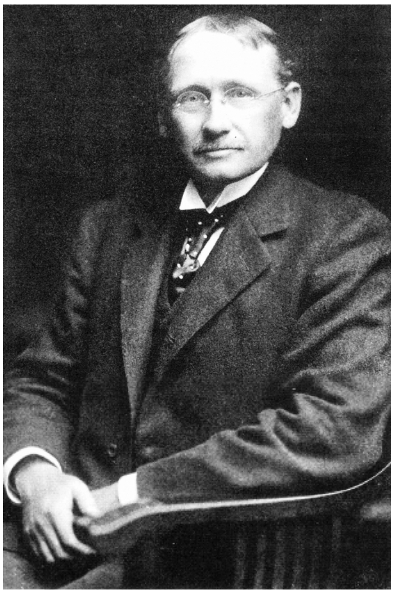


Figure 99: Frederick Winslow Taylor (1856 – 1915), controversial, but also genial (Image unknown author in public domain)

Taylor advanced many fields in industry and science, from metallurgy to gardening. But he is best remembered for his approach to scientific management, also known after him as Taylorism. He was the first who really used scientific methods to improve manufacturing efficiency (albeit with mixed results and some possible number fudging). He was the first to separate the task of managing work from actually working, dividing the management up in different specializations. He started the whole branch of management consulting, and was arguably the first management guru. His methods may also have been the first management fad.

Yet he was very controversial and often hated by workers and unions. While he was not loved, he did earn the respect of the workers that knew him. He was condemned by unions, who saw his methods only as a trick to lower wages, as a slave driver. However, this is not fair, as Taylor always tried to set proper wages and share the earnings with the worker. Yet, others that used his methods all to often indeed did use it as a tool to lower wages. However, Taylor did often have a low opinion of workers and rejected their ideas. For example, he said that, "*You are not supposed to think. There are other people paid for thinking around here,*" which would be just the opposite of lean manufacturing.

Hence the term Taylorism is often seen in a negative light. However, his achievements not only expanded the ideas of modern manufacturing management science, but he also pretty much singlehandedly created the field. Despite the controversies about him and his methods, he is one of the great contributors to modern management.

13 Lies, Damned Lies, and KPI – Part 2: Effects of Fudging

Christoph Roser, March 31, 2015, Original at https://www.allaboutlean.com/kpi-lies-effect/

Figure 100: About the ills of number fudging (Image Brian Jackson with permission)

Modern manufacturing works with a lot of performance measures, often called key performance indicators (KPIs). Unfortunately, they are rarely accurate, and often even intentionally misleading. In my previous post I described some examples of commonly manipulated KPIs. In this post I would like to explain the ugly consequences of incorrect or manipulated KPIs. In a final post I will also show some ways that you can reduce this negative effect. But first, how do bad KPIs (and hence most KPIs) hurt your company?

13.1 Emphasis on Treating Symptoms over Actual Cure

Performance indicators are merely a representation of actual performance. Yet, with a big focus on these measurements, the measurement becomes more important than the actual performance. One frequent KPI where I have encountered this is inventory. Common wisdom states that a lean company has little inventory. It is less well known that this reduced inventory is the result of hard work in improving the system.

The easy way to reduce inventory is to simply order less stuff. However, this does not make the company lean. On the contrary. If the manufacturing system is not yet ready to work with less inventory, simply reducing inventory will decrease efficiency and performance. All too often in my consulting life, the recommendation was to actually increase inventory to get out of the constant firefighting and to have time to fundamentally change the performance before being able to sensibly reduce inventory. However, frequently nothing was allowed to damage the inventory KPI, no matter how much sense it would have made.

13.2 Wasted Effort on Measuring and Analyzing KPIs

Figure 101: Lots of wasted effort for measuring (Image WavebreakmediaMicro with permission)

Usually, a lot of effort goes into measuring KPI. Some KPIs are measured by hand, where people count, take notes, and write down the data. Usually, this data is also input into a computer. Other measurements are taken almost automatically, for example through an ERP system. However, even then they need to be managed, analyzed, and reported.

One example I have seen measured a total of 45 logistics KPIs for one plant, half of which were measured daily. This took over two hours every day. My guess is that nobody looks at 45 KPIs, and this is just information overload. Hence, two hours wasted every day for something nobody looks at?

Additionally, a lot of these KPIs are not reliable, hence the entire effort above is a waste. On top of that, I have seen way too many performance measurements that were taken with great effort and then never used. They were established at one point due to a manager having a question related to this performance. Since then the manager has long forgotten his question, the question is no longer important, and the data is not looked at. Yet, the measurement still continues. As a manager myself, I was able to win quite some brownie points with my guys by stopping performance measurements that had long since lost their meaning. Of course, this included the risk that a year later somebody would ask for this KPI and I would not have it, but for me that was worth the risk.

13.3 Even More Waste in Manipulating KPIs

KPIs do not manipulate themselves. Lots of effort goes into actually manipulating them. In the easy case, all the loopholes of the regulation and calculation methods are utilized to get the maximum KPI out of the same system. See again my Top Three Methods on How to Fudge Your OEE for an example.

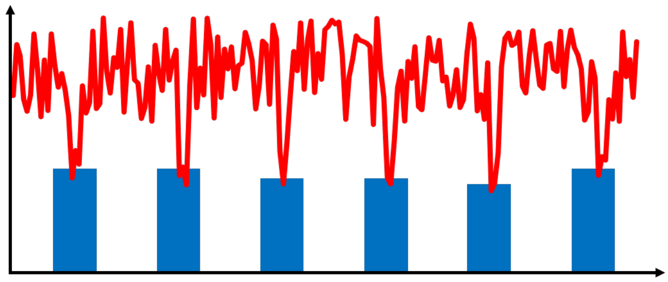


Figure 102: Monthly and Daily Inventory (Image Roser)

However, all to often this effort goes way beyond simple number fudging, and turns into actually harmful behavior toward the company. Maybe you remember the example of the **end-of-month inventory measurements** from my last post? Many plants regularly run out of material at the end of the month since material was only allowed to arrive after the 1st of the next month.

Figure 103: Here's your inventory! (Image Jochen Teufel under the CC-BY-SA 3.0 license)

Even worse, some plants regularly **loaded up their high-value goods on trucks, drove them to the highway rest stop, and parked it there until the end of the month**. Hence, the goods did not show up in the inventory at the end of the month, but they were still there. Except there was the substantial additional effort of loading, unloading, transporting, and renting trailers.

Another option is to use an external warehouse. You paid for the goods, they are already there, but they are not on your inventory books. Of course, this is also not free and the logistics provider takes his cut.

Figure 104: Just sell it! It will be good for your KPI! (Image Nyttend in public domain)

Or, lets take another example of costs. One popular approach to look good is to simply **sell all your buildings and property (sometimes even with the machines), and rent it back immediately**. In the short term you get a large cash inflow. In the long term … well … you better move to another position before the long-term comes around. However, since your cash flow KPI is good, it should not be a problem.

I'm sure you have seen many more examples of counterproductive activities in your career. Hence, all too often lots of company money is burned to make the numbers look good, rather than improving the system!

13.4 Bad Decisions Based on Bad KPI

Being a manager is a tough job. There is the constant need to make decisions without having all the information available. This uncertainty makes most people uncomfortable, even though they rarely admit it (although I am more scared of managers with a *consequences-be-damned* style of worry-free decision making). The higher up you go, the larger the uncertainty.

In this situation, KPIs are especially dangerous. There is a perceived accuracy of numbers on which a decision can be based. However, these decisions cannot be better than the numbers. Yet, as we have seen, these numbers are often not worth the paper they are written on. Hence, flawed KPIs give flawed decisions. As the uncertainty increases with hierarchy, unfortunately so does the quality of the KPI decrease. The CEO of Daimler Schrempp once famously (and correctly) called his headquarter a "*bullshit castle*."

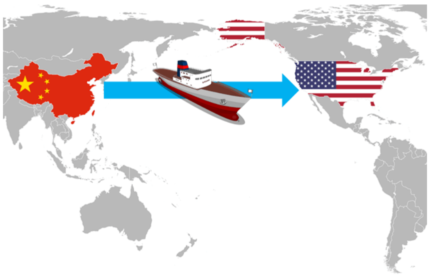


Figure 105: But it's 0.01% cheaper! (Image Roser)

To give you a smaller example, purchasing products for Europe and America are often sourced in Asia based on cost calculations that made them a fraction of a percent cheaper that way. Unfortunately, these cost calculations did not include a lot of quite relevant factors like delays, uncertainty, differences in quality standards, emergency air freight cost, and so on. Effectively it was much more expensive than local sourcing, even though the numbers still showed them to be cheaper. **Well, the numbers were wrong, and so was the decision!**

13.5 Worst of All: It Hurts the Honest People

Figure 106: Eliminate the honest ones … (Image peshkova with permission)

I reserved the worst effect for last: **KPI manipulation usually rewards the manipulators.** There are, basically speaking, two ways how you can make the performance indicators go up. First, you put in the work and improve the underlying system. Secondly, you fiddle with the numbers. Of course, it would be much better for the company to improve the underlying system. However, it is much easier to merely fudge the numbers.

All too often the superiors do not notice this number fudging (which is surprising, since all too often it is what got them in their position). Yet compensation is usually based on these performance indicators. Hence the dishonest ones get a better bonus. Even worse, the dishonest ones are much more likely to make a career, whereas the honest "underperformer" languishes in lower-level jobs or even may get fired (like the dishwasher tab manager in my last post).

Hence, KPI manipulation is a natural selection of the manipulators for higher positions. It is also self accelerating, as the more liars a company has, the more they will get.

13.6 Conclusion

Well, my last post stated that performance measures are often way too crooked. This post states that all the measuring may actually be more harmful than good. The question is, **do we still need KPIs?**

Well … yes. I admit I was toying with the idea of throwing all KPIs out of the window – but that would be too radical. A large corporation cannot be managed without at least some performance measures. Hence, we indeed do need measures! However, more care has to be taken when establishing, measuring, and especially verifying these KPIs. I will present some suggestions on how to improve this problem in my next post. Unfortunately, these suggestions are neither easy nor a cure for all your KPI-related woes. However, they will help! In the meantime, **go out and organize your industry!**

13.7 See also

Roser, Christoph. "Richtig Messen – KPIs Zum Nutzen Des Unternehmens Einsetzen." Yokoten 5, no. 1 (2016): 26–29.

14 Lies, Damned Lies, and KPI – Part 3: Countermeasures

Christoph Roser, April 07, 2015, Original at https://www.allaboutlean.com/kpi-lies-countermeasures/

Figure 107: How to measure good KPIs (Image Fotoalia with permission)

There is an inflation of key performance indicators (KPIs) in industry. In my last posts I have explained how KPIs are often wrong, and why bad and fudged KPIs are a huge waste. Yet, you cannot really run a larger corporation without KPI. In this post I will finally give some advice on (1) what you need to do to measure good KPI, and (2) how to avoid fudged KPI.

14.1 How to Create Useful KPI

Before we get on how to avoid KPI fudging, let's first discuss what you need for a good KPI.

14.1.1 Measure Only What You Absolutely Need

Figure 108:What do you need? (Image jarmoluk in public domain)

The first suggestion is to measure only the KPI that you really need. This sounds like a no-brainer, but unfortunately, in many organizations it is not. Just count for one moment how many KPIs there are in your organization, or how many you measure yourself or with your team. If you still think this is a good number, then ask yourself, *How many did I use to initiate improvement projects or warned you about upcoming trouble?*

Hence, make sure any KPI you measure is actually relevant for the success of the organization. In industry parlance, these are also often called critical success factors (CSF). A plant measuring 45 different logistics KPIs (actual example) cannot possibly have all of them relevant. In any case, nobody really looks at 45 different KPIs. While it sounds counter intuitive, **less is more** for KPI.

14.1.2 Use Temporary Measurements for Projects

Figure 109: Temporary only (Image dashadima with permission)

Sometimes you need more detailed KPI for projects. Depending on what you want to improve, you would need to measure the current state and also the situation after the project is completed. For this some additional KPI may be useful. There is, however, a tendency to keep these KPIs around even after the project is completed. Make sure that once the project is completed, the measurement of the KPI also stops, or at least their necessity is reviewed. Please note that, for me, completion follows the PDCA (Plan-Do-Check-Act) approach, and the completion of a project should include some time after the changes to see if your system actually improved.

14.1.3 Occasionally Clean Out No Longer Needed KPI

Figure 110: Good housekeeping (Image Alphos, Booyabazooka, Essjay under the CC-BY-SA 3.0 license)

Despite good efforts to prevent an accumulation of KPI, chances are that over time new KPIs are added. Please make sure that the existing KPIs are regularly checked and old KPIs are thrown out.

Usually, when you want to throw out a KPI, you will see some resistance. People dislike change, and there is probably at least one person who wants to keep this KPI (especially if that person is not the one doing the work of measuring it). Depending on the person resisting, it is worth eliminating the KPI anyway.

14.1.4 Cascading KPI Structure

Ideally, the KPI should be part of a cascading structure throughout the organization. It should be possible to aggregate KPI at the bottom-level groups into one KPI for the department. Department KPI should be aggregated into one for the plant, which then are aggregated into a business unit and eventually into a KPI for top-level executives.

Of course, this point clashes somewhat with the suggestions above. If you throw out a KPI that is part of a cascade, then the entire cascade may collapse, which will not please the higher-ups, and hence may be unpleasant for you. Here you have to find a trade-off between the cascade and cleaning out KPI.

14.1.5 SMART KPI

Term coined by management guru Peter Drucker. In his view good KPI have to be:

- Specific
- Measurable
- Attainable
- Relevant
- Time-Bound

Especially “4: Relevant” is in my view important to avoid waste, although the other four are also highly recommended.

14.2 Countermeasures against KPI Fudging

The above discussion helps you on establishing useful KPI. However, even with good KPI there is always the temptation to fudge the numbers rather than do the real work of improving the system. Some will fall into that temptation. However, a false KPI is even worse than no KPI. **The best situation of course is to know (having a good valid KPI). Worse is not knowing, but being aware of not knowing (having no KPI). Worst, however, is not knowing, but believing that you know (believing a KPI is true, while it is actually wrong)**. Hence, if you go through all the trouble of creating and measuring a KPI, make sure that it is correct.

14.2.1 Keep Measurements as Simple as Possible

Figure 111: Keep it simple stupid (Image Jantusla under the CC-BY-SA 3.0 license)

The simpler the measurement is, the harder it is to fudge. Although, in general it is not hard to fudge KPI. Even relatively simple KPI like OEE or delivery performance are regularly fudged (see one of my favorite posts on the Top Three Methods on How to Fudge Your OEE). However, if the measurement is simple, it is easier to debunk such fudging.

An example for a measurement that is complex is usually anything related to product cost, or money in general. If the product is too expensive, simply assume lower warranty-related expenses, or tweak some other assumptions, and the very same product is miraculously getting cheaper, at least on paper. The warranty cost has the additional benefit that the person in charge will likely be somewhere else when these costs pop up a few years later.

Another example: Do you know a big government project like building an airport (Berlin, Germany), buying a new aircraft carrier (USA), or anything similar? The final price tag is usually between twice and ten times the original price tag due to … *unforeseen* … cost overruns. Same things happen in industry if you do not take care. However, you probably need cost estimators. This leads us to the next point:

14.2.2 Verify, Verify, and Verify Again

Verify your KPI. Depending on the number of KPIs, you of course will be unable to verify them all every time. But you should make every effort to check them every now and then. There are different ways on doing that.

Figure 112: Something is off… (Image vkara with permission)

Do the KPIs match other KPIs? For example, if you are being told delivery performances, check occasionally with your larger customers if they also measure your delivery performance. If your guys claim that they are 98% on time in full, and your customer sees only 63%, then one side must be wrong. Even if your customer does not measure your delivery performance, you could tell them the percentages and ask for the customer's comment. (Note: Laughter means that you are probably not as good as someone wants you to believe.) Such cross-checks are often possible.

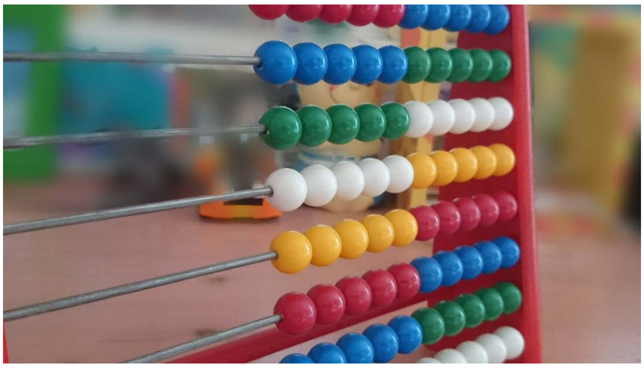


Figure 113: Check! (Image cleankidsmagazin in public domain)

Can you check in person? Visit plants or sites, and try to see if the claimed KPIs seem to be possible. If a machine is claimed to have an OEE of 93%, stop by to see if it is actually running. If they are proud of their low inventory, look at the inventory. It is easy to estimate the number of pallets and combine this with the observed material consumption to estimate the inventory reach? If they claim a wonderful Just-in-Time delivery, ask the operators. If they are telling you about their wonderful leveling, get the leveling pattern and compare afterward what really was produced (see for example The Folly of EPEI Leveling in Practice). In any case, do not announce your visit or check, but just pop in and check. Oh, and read my article on How to Misguide Your Visitor – or What Not to Pay Attention to During a Plant Visit!

Get help by a third party reporting directly to you! There are probably too many KPIs for you to check, especially if you are higher up in the hierarchy. In this case you can outsource these checks. Maybe an assistant can see if the reality matches the numbers. External consultants are also popular for especially this task, even though it is usually not the prime reason they are hired.

Figure 114: Trust your Instincts (Image Marek with permission)

Use common sense! Definitely use common sense! If the numbers sound fishy, they probably are. If the OEE exceeds 100%, this means that they produced more parts than the theoretical maximum. Same for delivery performances above 100%. Or one example from history: During the great famine in China (1958–1962), local leaders greatly exaggerated the amount of food produced on a field, eventually claiming quantities that would have covered the field 4 feet deep in grain. At that point even Mao stopped believing them, but as a son of a farmer he should have known much earlier.

By the way, people new in a position are less likely to fudge, since they do not yet know the fudging process, or at least do not control it. Additionally, it is a well-known strategy to remove all number fudging when starting a new position, in which case the previous occupant takes the blame for the fudging, whereas the current occupant comes across as honest. Over time, however, fudging may increase again, leading to a perceived improvement, until the next occupant of the position resets the fudging again. Over time this may result in a sawtooth pattern, although this is usually lost in the comings and goings of management in different positions.

Overall, these checks will tell you which KPIs are (probably) valid, and which KPIs are (probably) not. Therefore this will also tell you which of your people you can (probably) trust, and which you (probably) cannot, which brings us to the next point:

14.2.3 Punish Liars

Figure 115: Not here, not with me! (Image Markus Dallarosa under the CC-BY-SA 3.0 Germany license)

If you have found that you have been fooled, take actions or you will be the fool! If you're sure that one of your people feeds you bogus information, you need to issue a stern warning. If it is a repeated offender, you may have to exchange the person. This behavior has to stop one way or another. If you permit such skullduggery, you hurt the company, you hurt your reputation, and you foster even more skullduggery.

14.3 Summary

Overall, meaningful, correct, and not too many KPIs are part of an strong organization. If you can take action by removing unneeded KPIs or by checking the validity of KPI, please do so. It does not take much effort, but it can simplify life quite a bit. In any case, now go out and organize your industry!

14.4 See also

Roser, Christoph. "Richtig Messen – KPIs Zum Nutzen Des Unternehmens Einsetzen." Yokoten 5, no. 1 (2016): 26–29.

15 More On Cuba's Planned Economy: Cuban Industry

Christoph Roser, April 14, 2015, Original at https://www.allaboutlean.com/cuba-economy-2/

Figure 116: The state of the Cuban economy (Image Roser)

A few weeks ago I wrote an article on the Cuban economy, focusing on commerce (See How a Planned Economy Can Screw Up an Entire Country – Analogy between Cuba's Communist Economy and Push Systems). On the same visit I not only saw supermarkets, but I also had a look at industry. Unfortunately there are no visitors allowed in their government factories. Nevertheless, I was able to catch some glimpses of different industries.

15.1 The State of Industry

There never was much manufacturing in Cuba. Even before the revolution, the economy was based mostly on agriculture and tourism. Nowadays, it is mostly tourism and also some export of sugar, ores, oil, beverages, and some creams and lotions. Below I show some examples of different industries in Cuba, as well as the consequences for the average life of the Cuban people.

15.1.1 Sugar

Figure 117: The old glory, 1920 (Image unknown author in public domain)

Figure 118: Hershey, Cuba (Image Roser)

Before the Cuban Revolution, Cuba was a major producer of sugar, usually financed by US investors. One of the largest sugar mills was built by chocolate king Milton Hershey in 1918. He also added an electric train for transportation between Matanzas and Havana. Furthermore, he built a new model town *Hershey* with houses, healthcare, education, and recreational facilities for his workers.

Figure 119: Maybe a bit of paint would help…? (Image Roser)

After the Cuban Revolution, the government took this large factory over. Starting then, it ran almost continuously with little maintenance, until even Cuban ingenuity and duct tape could no longer hold it together (and falling sugar prices did not help). The factory was closed in 2011, after almost 100 years of operation, half of which with little to no maintenance.

Figure 120: … or maybe not. (Image Roser)

Since then, the former grand sugar mill is falling apart. Entering the rusting hulk is dangerous, as every now and then an old piece of machinery crashes through the rusting floors. At least the electric train still runs, although no longer with the original cars. Yet, even the new(er) trains are falling apart, and I had a good view of the tracks underneath through a gap in the floor.

15.1.2 Oil

Figure 121: Cuban government pumpjack (Image Roser)

Cuba has access to oil fields but does not manage them very well. As a result, Cuba is a net importer of oil. The oil pumps used by the government are old-style pumpjacks, used for wells with little oil.

Figure 122: The Chinese know how to do it! (Image Roser)

However, there is quite a bit of oil under Cuba, if you can get it. While Cuba does not have the technology or know-how, China does. The Chinese Great Wall Drilling company operates a number of different wells in Cuba, all of them technologically much more advanced than Cuba's old pumpjacks.

15.2 Maintenance of Vehicles

Popular legend has it that Cubans are the best mechanics in the world, since they can fix almost anything using almost nothing. This maybe true for private items that are valued. However, government items are still often neglected.

15.2.1 Boats

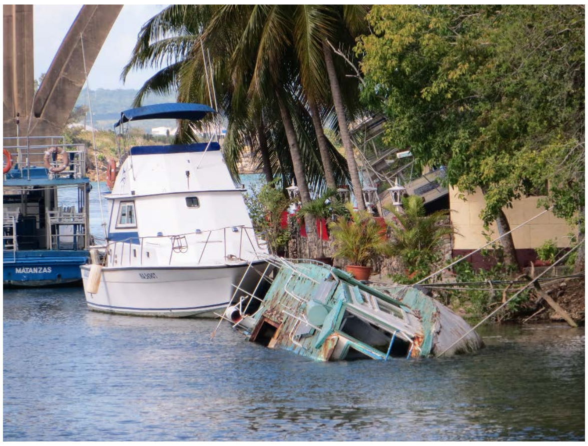


Figure 123: Four of their five boats (one behind the trees) (Image Roser)

During my stay I visited Matanzas, the province capital. Here I took a boat trip along a nice river. Interestingly, the company had five large boats, two of which sunk. One is still sunk since quite some time ago. Another one was recently raised, although estimating from the crust of barnacles on the hull it also spent quite some time under water.

The image on the left shows four of their five boats (the photo was taken from the fifth one – which luckily did not sink – yet). It looks like both boats sank due to neglect, and no one has bothered to lift them or fix them. Since they are government property, they belong to everybody, and hence no one cares.

15.2.2 Cars

Figure 124: Chevrolet 1952 Bel Air… (Image Roser)

Figure 125: …with 2000 Hyundai Engine (Image Roser)

Cars, on the other hand, are often private property, and keeping them running is not only a source of pride but also a source of income. In that aspect Cuba is famous for its many antique cars, mostly dating to before the Cuban Revolution in 1959.

It is one of the joys as a tourist to look at these cars and also ride them (never mind the lacking seat belts, the outdated crumple zone, missing airbags, and the long-since broken safety glass being replaced with normal window pane glass that gives sharp shards). Curiously, no matter if it is an old-timer or one of the newer government cars, I have never seen a working speedometer in any car.

Figure 126: Chevrolet 1955 Bel Air… (Image Roser)

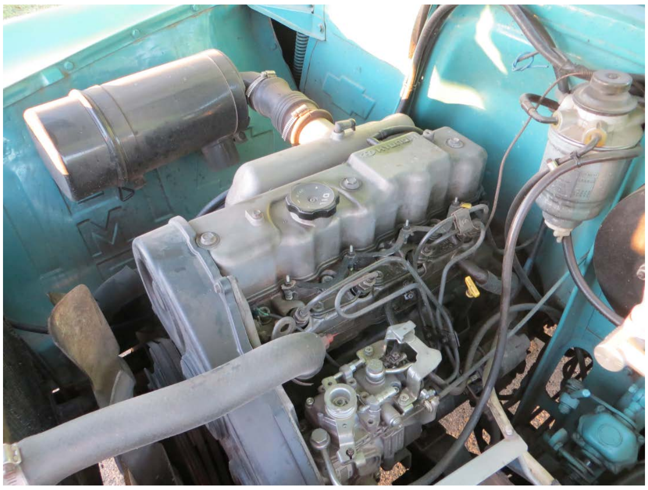


Figure 127: …with 1998 Hyundai Engine (Image Roser)

Yet, while the bodies of the cars may date (mostly) pre-1959, the engines do not last that long. Hence, whenever you look underneath of the hood, you will find a modern engine. It must have been quite a task to fit a modern engine into the ancient bodies. These modern engines are all hand-me-downs from the Cuban government, which sells its old engines to the general public. As with any socialist system, if you belong to the government, you still can get almost anything you want.

Figure 128: Chevrolet 1957 Bel Air… (Image Roser)

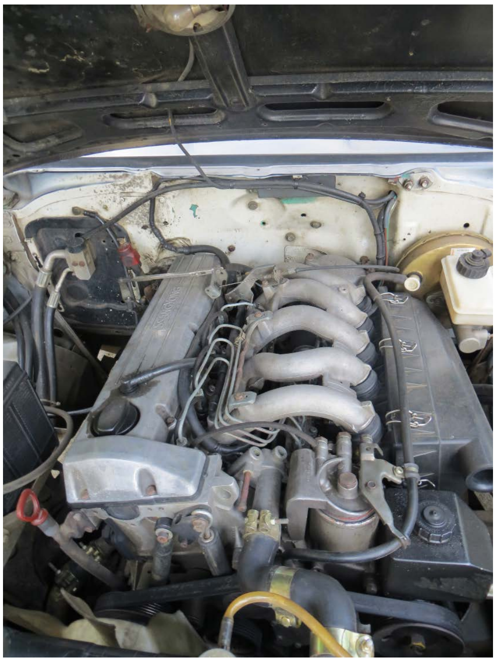


Figure 129: …with 2007 SSangYong Engine (Image Roser)

As for engines, there is also a certain ranking. Mercedes engines are considered to be the best, closely followed by Toyota. However, a Mercedes engine costs twice as much as a Toyota. Yet, these Mercedes engines are not actually Mercedes, they are from the Korean maker SSangYong, which produces them as part of a technology partnership with Daimler. In any case, my driver insisted that his 2007 SSangYong engine in his 1957 Chevrolet was a Mercedes engine.

In any case, his “Mercedes” engine promptly broke down due to a coolant leak. While I don’t know if Cubans are the best mechanics in the world, my driver was able to fix the problem using a knife, clamps, and some rubber.

In terms of prestige of engines, after Mercedes and Toyota, Mitsubishi and Hyundai are number three and four in popularity. But here, too, another driver of a 1955 Chevrolet insisted his 1998 engine is Mitsubishi, even though it clearly said Hyundai.

15.3 Effects on the Population

The lack of goods and spare parts forces additional efforts on the population to make ends meet. Things that we take for granted are anything but in Cuba.

Figure 130: Making money, oink by oink (Image Roser)

For example, I chatted with one waiter at a restaurant. She told me that she has raised a pig to buy a gas stove. (Raising pigs for money is a very popular Cuban pastime.) She did not want a big stove, since it was too expensive. Instead she wanted a small tabletop version. For three days she searched in three different cities and found none. Not even close.

Figure 131: Typical Cuban wiring in homes (Image Roser)

Eventually, she found a medium-sized stove. Although it was more expensive, she bought it anyway, since she did not want to waste time searching any longer. Now she is raising the next pig to buy the hoses, fittings, and a tank of gas. And the topper is that all of this was only necessary because the perfectly good electric stove she had does not run if the electricity is cut (often for hours), and she needed a backup stove for cooking. All this raising pigs and running around simply because of an unreliable electricity supply.

Another waitress told me that she had to walk 6 kilometers (4 miles) every day to work and back. I asked her why she did not buy a bicycle. Well, in fact she had a bike! A nice and expensive racing bike, in fact (worth about three months' salary of around USD $75 each). Unfortunately, after the original tires wore out, she was unable to find replacement tires. The store had only the tires for men's-sized bicycles, but none for the smaller women's bicycles. Hence, the bike is in the shed and she walks.

Figure 132: I can has no Internet (Image Nicolas Suzor under the CC-BY-SA 2.0 license)

By the way, if you are wondering why she didn't just Google it to find which store had her size bicycle tires or just order them online: they have no internet. The Cuban population (with the exception of some journalists, government officials, and tourists) is not online. No cute cat pictures for Cubans!

Since the official government salary is only around USD $20–$30 per month (depending on the job), everybody needs additional jobs or kickbacks (affectionately known as *Sociolismo*). A waiter earns around USD $1 per day, although tips – especially in tourist areas – often add USD $5 or more. With around USD $100 per month, life becomes much easier in Cuba. However, I have to point out that unlike many other poor countries, I rarely felt treated like a walking wallet. Despite being poor, Cubans are quite friendly to foreigners.

15.4 The Government Doesn't Get It

Another story I have heard was that German sport fashion maker Adidas wanted to sponsor some Cuban sport teams by providing free clothes. Nice of them, wasn't it? Well, the government officials decided that Adidas would have to provide clothes for ALL sports teams in Cuba or they wouldn't accept any of it. Hence, no Adidas for Cuba. My guess is that Adidas should have just offered some *samples* to the official, and the magic of *Sociolismo* would have smoothed the way.

15.5 Summary

It is easy to see all the waste needed to work around the constant lack of materials. If the material is missing, you have to work twice as hard to achieve half the result. In manufacturing, push systems are somewhat similar, albeit on a much smaller scale. However, in modern manufacturing, you usually have less options to make do using duct tape and rubber if you're missing the correct part.

These negative effects of socialist or communist systems onto the entire economy happen almost every time. I have also seen it while visiting (back then) socialist East Germany, and I have seen it in Cuba. I probably could also see it in North Korea, but heck no, I am not going there. That country is nuts! China and the Soviet Union also had it, but wisely they switched to a capitalist economy with a communist government structure. In any case, whenever possible try to avoid the waste and use pull systems. Now **go out and Organize your Industry!**

16 Muda, Mura, Muri: The Three Evils of Manufacturing

Christoph Roser, April 21, 2015, Original at https://www.allaboutlean.com/muda-mura-muri/

Figure 133: The three evils … (Image Giuseppe Canino and flydime under the CC-BY-SA 2.0 license)

In its never-ending quest to improve its production, Toyota has identified the three evils of any manufacturing system: waste (*muda*), unevenness (*mura*), and overburden (*muri*). In this post I will explain the concepts behind these three banes of manufacturing.

16.1 It All Started with a Good Fight(er)

Figure 134: Eliminating you opponent by eliminating waste, unevenness, and overburden (Image Gotcha2 under the CC-BY-SA 3.0 license)

The terms *muda*, *mura*, and *muri* (waste, unevenness, and overburden) are actually not an invention by Toyota. They were used in Japanese martial arts long before Toyota.

In martial arts, any excess movement in combat is a **waste**, since it tires the athlete and leaves him open for an attack. Similarly, any **uneven** or unnatural movement or thought, or an unnatural stance, will hinder your actions. Finally, trying to do too much at the same time or using techniques that you have not yet mastered is **overburden**.

Figure 135: The way of the warrior (Image Felice Beato in public domain)

The martial artist eliminates these three problems through the three pillars of martial arts: *Kihon* (基本): practicing basic moves; *Kata* (形 or 型): repetitive exercise of predefined moves; and *Kumite* (組手): free combat practice.

However, these are only techniques to practice. Additionally, marital artists also strengthen the body through exercises (*hojo undo,* 補助運動; and *taishou*, 体操). Finally, they also train the mind by building up a fighting spirit (*seishin tanren*, 精神 鍛錬, literally forging the spirit). Altogether they form the **way of war** (*budō,* 武道) in order to help you on the **way of the warrior** (*bushidō*, 武士道).

16.2 From Destruction to Creation

Figure 136: The way of the manufacturer (Image Minerva Studio with permission)

While *bushido* aims for the destruction of your opponent, *lean manufacturing* aims for the creation of value. Yet both should be relentless in the pursuit of these goals. As martial arts follows the **way of the warrior**, lean manufacturing should have a similar **way of the manufacturer** (which, loosely translated, would be *seisanshado*, 生産者道, although this is not an actual Japanese word). In any case, for my lean combat gear, see Seven Gadgets for the Basic Lean Toolkit ☺.

Nevertheless, the martial arts approach to perfection can help us here. So, let's go into the details of *muda, mura, muri*:

16.3 Waste (Muda)

Muda (無駄): futility; uselessness; pointlessness; waste;

Figure 137: Seven Trash Cans Labeled (Image Thomas Söllner with permission)

The most famous of the three evils of manufacturing is waste (*muda*). This is commonly divided into the famous seven types of waste:

- Transportation
- Movement
- Waiting
- Over-Processing
- Defects and Rework
- Inventory
- Overproduction (the worst one)

Of course, since Toyota developed the concept, many additional types of waste have been added. Most well known is probably wasted human creativity, but I have found at least twenty-four more types that are used somewhere. However, in my opinion, a lot of these types of waste are themselves a waste. Overall, the topic of *muda* is too long to be covered here. Please see my post [The Seven Types of Waste (Muda) – Bonus: Now with 24 More Types of Waste Absolutely Free!]() for more details on waste and its types.

In my view, the Western world puts way too much focus on eliminating waste, and neglects the elimination of unevenness and overburden. Don't do that! You will never reach the full potential if you only look at one of the three evils.

16.4 Unevenness (Mura)

Mura(斑): unevenness; inconsistency; erraticness; irregularity; lack of uniformity;

As the translation states, *mura* is any kind of unevenness or irregularity. While often used mainly for material flow, it is also a problem in many other cases outside of material flow. The following is a list of examples where unevenness could happen and cause problems:

- Uneven customer demand
- Inventory swings – from too much to too little
- Uneven production speed or changing production quantities
- Uneven quality of good parts (however, if the part fails or has to be scrapped it is waste)
- Irregular or erratic working rhythm
- Uneven training of the workers
- Uneven distribution of the workload

Figure 138: Erratic and inconsistent… (Image Jumbo2010 with permission)

Often, *leveling*, or *just in time*, is seen as countermeasures to *mura*. However, in my view, this is a too-narrow focus on material flow. Additionally, simply implementing leveling may actually make things worse (see my posts on leveling, especially the one on The Folly of EPEI Leveling).

You will have to watch for unevenness in many more places. Also, there is no standard cure (in fact, in lean manufacturing there is rarely a standard cure for problems). While work standards may often help, it depends on the type of unevenness and the details of the system to determine the best countermeasure.

Historically speaking, unevenness was probably the last of the three evils that have been identified in manufacturing. Of course, there were side effects of other methods that reduced unevenness, as for example Henry Ford and his assembly line. However, one early example was probably the use of a production rhythm in German Junkers aircraft manufacturing by 1930. This method made it to Mitsubishi in Japan, from there to Toyota, and then to lean manufacturing throughout the world, while all the time retaining its German word "*Takt*" (rhythm, timing, beat).

16.5 Overburden (Muri)

Muri (無理): unreasonableness; impossible; overdoing; beyond one's power; too difficult;

Again, as per translation, *muri* is overburden, unreasonableness, and things that are too difficult. Naturally, the main focus here is on people. However, it also can apply to materials, machines, and organizations. Here are a few examples:

People

- Working too long hours (and yes, I am frequently guilty of that myself)
- Heavy lifting
- Unsuitable posture or inadequate ergonomics
- Noise
- Too-difficult tasks
- Too-easy tasks (which may be boring or mentally tiring)
- Excessive stress
- Anything that leads to burn out, bore out, or repetitive strain injury
- Lack of training
- Humiliation, but possibly also excessive praise
- Dangerous, dirty, and difficult tasks (the 3K in Japanese)

Organizations

- Demanding that the supplier delivers what we want whenever we want it without providing a good and stable signal from our side
- Abusing your market power to fleece suppliers or customers (I feel this temptation may be difficult for many companies in the western world to avoid)

Machines and Materials

- Pushing machines and tools to the limits of its capabilities, leading to increased wear and tear
- Skipping maintenance (you can skip an oil change in your car, but your car won't like it)
- Mistreatment of materials; e. g., storing parts in unsuitable conditions
- Loading a vehicle or container beyond its weight limits

Figure 139: Muri in action (Image Wolfgang Zwanzger with permission)

Similar to unevenness, there is no catch-all countermeasure. Depending on the type of overburden and the system, a different solution may help. Sometimes 5S is the answer, sometimes improved ergonomics, or sometimes just plain old respect for your fellow human beings. Also, similar to unevenness, it is often neglected in the Western world, where the focus is on eliminating waste.

Historically, avoiding overburden also happened before Toyota. For most of history, employers tried to get the most out of their employees, usually by having them work harder and longer. Only during the end of the nineteenth century did employers realize that working less is actually more productive, gradually reducing working times from up to sixteen hours per day to eight hours or even less. To their surprise, productivity increased – not only by the hour but per day. Even nowadays it is a well known secret that your most productive workers are often part-time workers.

16.6 4M and 5M – but more is not better here…

By the way, besides these 3M there is also a 4M and even a 5M, although they do not originate from martial arts or Toyota. The two additional M's are Muchi (無知) for ignorance and Mushi (無視) for ignoring (yes, I now they are almost the same). I found very few references for these together with muda, muri, and mura (one in Japanese and one in Indonesian). I think you can safely ignore them, unless you want to impress people with more buzzwords. However, if someone tries to impress you with these buzzwords, now you know them!

16.7 Summary

Of course, now that you know the three evils in detail, you would be interested in how to banish them. Unfortunately, this would exceed this post. This would also exceed a whole series of posts. In fact, the entire Toyota Production System aims to reduce these three. Hence, you could say that this entire blog describes how to reduce these three evils, and even then it would be incomplete.

Figure 140: The three evils – after a lean make-over (Image Leoba on Fotolia with permission)

In fact, I believe it is impossible to eliminate all three completely. The more you have eliminated, the harder it is to fight the remaining traces of *muda*, *mura*, and *muri*. Yet, if you stop eliminating these evils, they will grow again. Also, if you look only at one of them and neglect the others, system performance will not increase. Hence, do not forget *mura* (unevenness) and *muri* (overburden). Therefore, **go out and organize your industry**, even though your work on this will never end.

17 How 5S Works

Christoph Roser, April 28, 2015, Original at https://www.allaboutlean.com/5s-method/

Figure 141: The joy of cleaning! (Image Nick Youngson / Alpha Stock Images under the CC-BY-SA 3.0 license)

5S is one of the basic methods in lean manufacturing, used to create and maintain a clean and organized work environment. As far as lean methods go, it looks pretty easy. After all, everybody has cleaned something at least once. Unfortunately, cleaning it once is not enough. **The challenge is to keep it clean!** And this is where most 5S activities fail. In this post I want to describe the basics of 5S and how it works (plus also 4S, 6S, and even more S's). In my next post I want to point out the hidden dangers of failure, and give some advice on how to make 5S stick.

17.1 Why 5S?

The advantage of 5S is that a cleaner workplace is easier to work in and hence more productive. Having the right tools in good order reduces scrap and rework as well as accidents. Easy access to the tools in a standard location makes their use faster, and hence overall productivity will increase. There may be also less space needed, and the number of required tools can go down. The time for a new worker to familiarize himself with the workplace may be reduced. Furthermore, while cleaning the machines or workplaces, the workers may notice and fix some minor issues that they may otherwise have missed. Overall, it can have quite some benefits.

However, the above advantages do not always materialize, either because the 5S is done incorrectly, or it is used in an area ill-suited for 5S (more in my next post), or the effort exceeds the benefits. In any case, it is often useful, but not always and everywhere.

17.2 The Method

Below I will show you the basics of the method, giving the Japanese 5S and common English translations of the 5S with some explanations. The method sounds easy enough, but especially the last two S's are where projects fail. Please also note that the method is, in the West, often seen as a step-by-step approach. In Japan, however, these steps are a) different and b) do overlap. But more on that farther below.

17.2.1 1: Seiri – Sort

Seiri (整理): sorting; arrangement; organization; putting in order; adjustment; regulation; tidiness,

In the first step, all unnecessary items are sorted out and removed. This includes tools, parts, instructions, and any other items that are not needed. You would have to go through the area and decide for every item if it is necessary for the work. If it is not necessary, then it is a disturbance that is in the way and that has to be removed.

Sometimes a red tag is used to label all items that are not necessary. In a second step, all items tagged are removed and collected for other use, refurbishing, recycling, or throwing out. Another option would be to tag all items, and the workers remove a tag whenever they use an item. All items that have still tags after a certain period of time are removed or discarded.

17.2.2 2: Seiton – Systematic Arrangement, Set in Order

Seiton (整頓): orderliness; put in order; tidying up; arranging neatly

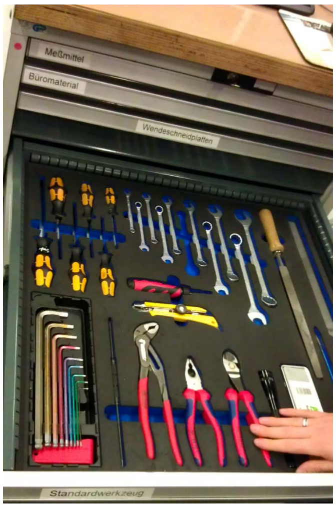


Figure 142: Systematic Arrangement (Image Tasma3197 under the CC-BY-SA 3.0 license)

Create a systematic arrangement for the items that you want to keep at the workplace. Each tool and all parts should have a defined place. If space is tight, the more frequently used tools should be closer to the point of use, with less frequently used tools should further away. Ideally, whenever a person needs a tool, it should be in exactly the same spot every time.

This arrangement is often also supported by markings or storage design. The image on the left shows a drawer where each tool has its assigned place. You see immediately which tool goes where and which tool is missing.

Figure 143: Knives drawer in Alcatraz – you don’t want knives to go missing in a prison! (Image Adam Kliczek under the CC-BY-SA 3.0 license)

A similar approach is also a shadow board, where each tool has a shadow or outline. Hence the location for each tool is easily marked, and missing tools are also quickly identified. The image shows a knives drawer in the Alcatraz prison. A missing knife can quickly be identified, as the wardens are very keen to know if the prisoners have knives or not.

Figure 144: Fire extinguisher found here (Image JonathanLamb in public domain)

Another option is to mark the floors for places where items or material goes. Some of this is even regulated by laws. For example, the locations of fire extinguishers and first aid equipment are required to have certain markings and labels in standardized colors. Similar to other tools, this helps to find them quickly when you need them – and in case of fire, I would like to find the extinguisher quickly! Similar labels and markings can also be done for other parts and tools to make sure they all have their assigned place.

Figure 145: 5S Cleaning Station (Image Tasma3197 under the CC-BY-SA 3.0 license)

Additionally, all of the above can also be labeled with text to not only mark the place, but to also describe what goes in there or even how. Overall, in many modern factories there is a multitude of floor markings and other systematic positioning. However, a word of advice, this is also the part where over-enthusiastic 5S managers also often go overboard and plaster the place with labels – which then are quickly ignored by the workers.

This process usually also involves fixing broken items or painting, although this is also sometimes included in the next #3 – Seiso.

17.2.3 3: Seiso – Shine, Sweep, Sanitize, Scrub

Seiso (清掃, also sometimes written Seisou): cleaning

Figure 146: Shine it! (Image jarmoluk in public domain)

Now that you have removed all unneeded items (1: Seiri – Sort) and arranged the necessary stuff properly (2: Seiton – Systematic Arrangement), the next step is to clean the workplace and all items on it. Depending on which 5S version you read, this may be interpreted as shine, sweep, sanitize, or scrub.

As the name says, you clean the place. If you haven't done it yet in step 1 or 2, you should also replace or fix everything that is broken or damaged. Additionally, cleaning also can include maintenance on machines.

Doing cleaning once is not a problem. Even my apartment has been clean, once, too. The challenge is to keep it clean! This is where the next step comes in:

17.2.4 4: Seiketsu – Standardize

Seiketsu (清潔): clean; hygenic; sanitary; pure; virtuous; immaculate

While Seiketsu is in English often phrased as "standardize," this is a gross mistranslation. Hence, the use of this S is slightly different in Japan, where it stands for keeping it clean.

Sometimes in the English version it is said that here you should create a standard to keep it clean. In my view this is flawed. The first three S's **are the standard**. With #4 you now have to **keep the standard**. If you need a standard to keep a standard then something is wrong. In any case, with #4 you should make sure that your sorted (1: Seiri – Sort), arranged (2: Seiton – Systematic Arrangement), and cleaned (3: Seiso – Shine) workplace should stay that way.

17.2.5 5: Shitsuke – Sustain, Self Discipline

Shitsuke (躾, usually written しつけ): discipline; training; teaching manners

Figure 147: Fight your inner Temptation! (Image sognolucido with permission)

Finally, there is Shitsuke, where you need the discipline to keep everything clean and orderly. Unfortunately, workplaces – of any place for that matter – have the tendency to become messy if they are not taken care of. Hence, to keep it clean a constant effort is needed.

However, in my view, this #5 overlaps with #4 – standardize. In any case, in combination #4 and #5, this is probably the hardest part of the 5S.

17.3 Is That All?

17.3.1 Too Much. Can I Have Only 4S?

Sure. When Toyota started using this method, they had only 4S as shown below, with the English interpretation by Toyota:

- Seiri – Sort
- Seiton – Oder
- Seiketsu – Neatness
- Seiso – Cleanliness

You quickly notice that Shitsuke (self-discipline) is missing, and that the order of Seiketsu (standardize) and Seiso (shine) are switched. Also, the translation given by Toyota is different from the English 5S used above. Finally, in case you missed it in the definitions above, in Japanese the words 1: Seiri and 2: Seiton have identical meanings.

An acronym for this was also RICK, for Remove, Identify, Clean, and Keep clean. At Toyota, the self-discipline is part of their culture, and they have no need for a 5th S. As for the switch of Seiketsu and Seiso, either way works, especially if you use the original Japanese meaning. Overall, in Japan this is usually not used as a step-by-step approach, but more as a nifty mnemonic. In my view, even the first 3S are enough as long as you do them regularly.

17.3.2 Too Little. Can I Have One More?

Sure, here you go:

Shukan (習慣): custom; habit; manners

This is a possible sixth S that is sometimes found in a version for 6S. You could also call **Shukan** "**Style**", which is the closest word I found in English starting with a "S". The idea is to get into the habit of doing the other 5S. I am not quite sure where that S came from. To me it looks redundant with #4 Seiketsu (standardize) and #5 Shitsuke (self-discipline). Hence, if a project cant sustain its 5S using #4 and #5, an identical #6 won't really help. In any case, it is rarely used.

17.3.3 Can I Have Even More, Please?

Figure 148: Stay safe! (Image Mpelletier1 under the CC-BY-SA 3.0 license)

No Problem. Sometimes there is also an S standing for "**Safety**." The idea is to check also for potential safety problems. This is a Western addition, as I am not aware of a Japanese word used in this context, especially not one that starts with S. However, if you insist you could use the Japanese version of the English word *safety*: セーフティー. Also, please note that this is not a 7S, but usually used as a different sixth S of the 6S version.

17.3.4 More! More! Give Me More!

All right, all right. Sometimes "**Security**" is also used as an additional S. The idea here is to see and understand risks to machines and other property. This even includes intellectual property and confidential information.

Again, I am unaware of this used in Japan, although here, too, you could use the Japanese version of the English word: セキュリティ.

17.4 4S, 5S, 6S, 7S, 8S – I Am Confused. Which One Should I Use?

Quite frankly, it does not matter! It makes no difference if you have 4, 5, 6, 7, or even 8S. These S's are only a mnemonic to help you get your stuff in order and keep it that way. These are not a step-by-step approach, but more of a reminder. For example, when as a kid your mom asked you to make your room *neat and tidy*, she did not want you to first do step 1 and make the room *neat*, and then do step 2 and make the room also *tidy*. Same goes for *clean and sparkling* or *polished and refined.*

However, it of course does make sense first to throw out stuff (#1) before you clean and organize the rest rather than throwing out items after cleaning. As for the other S's, the order is much less important. In any case, if you can't get 4S working, more S's won't help either. When explaining the method, I usually go for 5S, since it is the most commonly known version in the Western world and most easily accepted. However, the impact will be the same from the first 3S upward.

On the other hand, if the client is mightily impressed by a consultant that has more S's (*after all, more is better, right?*), I seriously doubt the abilities of both the client and the consultant – although the latter will be more profitable. I am no friend of buzzwords and other **bling*bling**. Additionally, I usually observe an inverse relation between the use of buzzwords and the performance on the shop floor. **The more buzzwords, the worse the factory!** *Unless, of course, you find a consultant that knows 9S. They must be really, really good and you should hire them… Or maybe not.* In any case, this brings me to my next post on why 5S fails and how to make it stick. In the meantime, **go out and organize your industry!**

18 How to Make 5S Stick

Christoph Roser, May 05, 2015, Original at https://www.allaboutlean.com/how-to-make-5s-stick/

Figure 149: How to keep it clean … (Image Nick Youngson / Alpha Stock under the CC-BY-SA 3.0 license)

In my last post I detailed the 5S method (and its variants 4S, 6S, and so on). However, knowing the theory is the easy part. Successfully implementing 5S is much more difficult, and industry is ripe with anecdotes on failed 5S implementations. Here I will give you a few tips on how to increase your chances of success. However, there is no magic bullet. Cleaning and organizing a shop floor is hard work, and keeping it that way is even harder.

18.1 Mini Recap: What is 5S?

Figure 150: The 5 S'es (Image T-REX with permission)

As described in my previous post How 5S Works, 5S is a mnemonic that can help you get a shop floor (or any other area) organized. The most common 5S are:

- Seiri – Sort
- Seiton – Systematic Arrangement
- Seiso – Shine
- Seiketsu – Standardize
- Shitsuke – Sustain

Toyota uses only 4S, and others even use 6S, with the last S being either Shukan (custom, habit, manners), safety, or security. Overall, the words, their order, and the numbers of S's vary, but when done correctly will lead to the same results. For familiarity's sake, I will use 5S as reference below, rather than a 4S or 6S. If done correctly, this method can help you organize your shop floor and reduce waste stemming from misplaced/old/dirty/ill-maintained tools, machines, and parts. Again, more details on the basics in my last post on How 5S Works.

18.2 Why Does 5S Fail So Often?

Examples of 5S failures are plentiful. So plentiful, in fact, that on the shop floor, 5S often has a different meaning: "*Some Stupid Supervisor Said So.*" Here are some reasons why 5S fails so often:

18.2.1 Let’s Do 1S and the Rest Should Come Automatically!

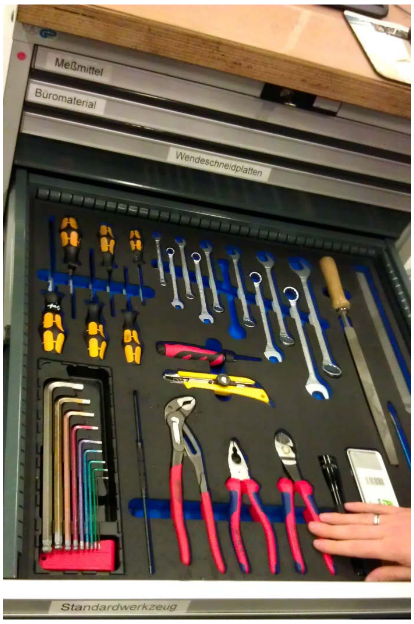


Figure 151: Ohhh … that’s nice! (Image Tasma3197 under the CC-BY-SA 3.0 license)

Probably the funkiest and most interesting of the S’s is #2: Seiton – Systematic Arrangement. Unskilled lean project managers just love to label everything, mark all spots, and create cut-outs or shadows for tools. It appeals to a sense of order and arrangement.

Unfortunately, in their enthusiasm they sometimes forget to first sort out the necessary and unnecessary items (#1: Seiri – Sort). They also often forget #3: Seiso – Shine, since it is so much more fun to create some new gizmos than to clean old dirt or repair damaged stuff. They may even end up arranging tools that then will not be used ever.

Hence, overall there is little improvement by doing only 1S, and it is usually not worth the effort.

18.2.2 Umm… Isn’t 3S Good Enough?

Okay, lets do it better. Besides #2: Seiton – Systematic Arrangement, we also do #1: Seiri – Sort and #3: Seiso – Shine, and we will even do it in order. Isn’t that good? Well, a little, but not for long. The shop floor will improve – until it falls back into its old mess shortly thereafter. Often, the improvement is usually not worth the effort.

Hard core lean purists still would condemn you to the circle of hell reserved for bad lean implementations. However, I believe that 3S can be an improvement. After all, doing all 5S is not that much different from doing 3S very frequently. Yet, if you do 3S only once, you fall far short of the potential improvement. If you include the time and money for improving the shop floor once, only to have everything revert within one month, it may not be worth the effort.

18.2.3 Hey, We Can Do 5S without Those Annoying Shop Floor Workers!

No, you can’t! Since it looks easy, there is a temptation to do it without involving the employees on the shop floor. However, anything you do on the shop floor should involve the people there. How would you know which tools are necessary and which ones are not (#1: Seiri – Sort)? In what way would you determine a good placement for the items (#2: Seiton – Systematic Arrangement)? Finally, the #3: Seiso – Shine is something the workers have to do regularly, so you best involve them early on.

18.2.4 But Consultants Always Start with 5S!

Figure 152: Hey, I have an idea… (Image bramgino with permission)

No! Definitely no! Bad consultants do love to start with 5S. So do inexperienced lean project manager. And especially bad, inexperienced lean consultants!

5S is a very quick and easy way to create some nice colorful changes that impress the person on top who pays the bill (and who often also has little shop floor connection). Cleaning and marking a shop floor also usually lasts long enough for the consultant to charge the client. The inability to sustain it afterward is then no longer a problem of the consultant, but the client (i.e., you!).

Figure 153: For $3,000 per day he will teach you how to clean (Image Elnur with permission)

In short, doing 1S–3S is easy and can look very good, but it is so much more difficult to sustain. It also often lasts only until the consultant is gone. Additionally, not all lean consultants really know lean, and may be trying to do good but lack the knowledge.

In any case, if you have enough money to pay someone $3000 per day to teach you how to clean your shop floor, then, well, okay… call me. Although I would prefer to use my paid time to **your** advantage. In any case, during my consulting time, we never did 5S on its own, and I do not plant to start it now.

18.3 Where Not to Do 5S

Figure 154: No 5S here! (Image Bukk in public domain)

5S can be incredibly useful if done correctly. However, even if done correctly, it is not something to do everywhere. Let me give you one example: **During one of my employments, one of my colleagues had the great idea to do "5S with our office briefcases."**

He wanted to get identical briefcases, add foam inserts so every marker and pen would have its 5S place, and standardize it across the group. Let me tell you clearly why this is a bad idea:

- 5S is to help people find tools quickly. I know my briefcase. I know the stuff in my briefcase. Hence, 5S won't help me getting better organized.
- If anybody else sticks their hand in my briefcase, they are in trouble!
- Since I carry my briefcase around the world frequently, I try to save on weight and volume. Foam inserts and a new box-style briefcase are not things I want to lug around.
- I don't use text markers in my brief case.
- I would have no space for my flashlight, which I use frequently.
- The effort of sticking stuff into foam inserts and pulling them out again by far exceeds its benefit for me.

Figure 155: Seriously ?!?!?!? (Image Roser)

Similarly, you can also find examples of 5S on office desks. **Over-eager consultants have marked and labeled the spots on the desk for stapler, hole puncher, pens, etc. This is nonsense!** Besides, other research shows that, especially for creative workers, the paperwork on their desks is a sort-of brain extension. Hence some degree of messiness helps them think better. **Overall 5S is good for shared workspace but has limited use for private workspace like someone's desk – and especially my briefcase!** Luckily for me and most of my colleagues, the idea of a 5S briefcase never materialized.

18.4 How to Make 5S Stick

After going through many different ways to fail, here are some tips on how to make 5S actually stick!

18.4.1 Do Not Do Standalone 5S Projects

It is much better to do 5S as part of another, bigger project. For example, if you optimize worker efficiency by rearranging the workplace, improving the material flow, or establishing a new manufacturing line, 5S will come much smoother as part of the natural flow. The workers will see 5S not as a nagging mom telling them to clean up the room (and yes, we all know how that feels), but as part of a bigger piece of improvement.

18.4.2 Pick Your 5S Playground Carefully – Where is It Useful?

Do not do 5S for people's private workspace. No matter if it is a desk, a machine where very few people work, or especially my briefcase. 5S can help in work areas where many people, often in different shifts, need to access the same tools. It can also help with shared tools, as for example cleaning equipment.

5S can also help if your tools are sensitive or your products fragile. For example, if you own a nice expensive camera, you most likely own a padded camera bag to protect your gear. Putting the camera back in its bag may be part of your 5S routine.

18.4.3 Involve the People

Figure 156: Ask us! We can help! (Image Cherie A. Thurlby in public domain)

When doing 5S, involve the people of the area you are optimizing. With their knowledge you will achieve a better result. Even more important, the chances of sustaining it are higher. Unless you want to clean the shop floor yourself all the time, you need the cooperation of your people.

5S can work if people take responsibility of their own environment, but management also has to give them the responsibility. All too often 5S is a management project forced on the operators, resulting in lots of activity with little improvement.

18.4.4 5S is Hard Work, Especially for Management

A shop floor is in this aspect very similar to an apartment. Cleaning it once is pretty straightforward. Keeping it clean is not. It is a constant effort to keep it clean. This also means it is a constant effort for management to pay attention to it. Hence, unfortunately, 5S is not a "*fire and forget*" method that you set up once and then forget about it. Instead, management has to check if the shop floor stays clean, and has to start countermeasures if not. The last two S's, self discipline and standardize, are not only on the shop floor, but especially at the management level.

18.4.5 Update Occasionally

Over time, your shop floor will change. New tools are needed, old tools will go out. Every now and then, the first two S's (sort and set in order) need to be repeated to bring your shop floor up to date. #3 Shine should be done regularly anyway. As for how often to repeat, it depends.

Again, lean purists may say monthly, but I think this may be too much, depending on the level of change on your shop floor. Use your common sense here (and hopefully everywhere else too).

In any case, if you do the first three S's regularly, you get the last two for free ☺. **Now go out and organize your industry!**

By the way, Mark Graban did a nice *Lean Office and 5S Gone Wrong* parody video, so if you have time, watch it:

The Video by Mark Graban is available on YouTube as "Parody: Lean Office and 5S Gone Wrong" at https://youtu.be/t8IfQp4A4ZI

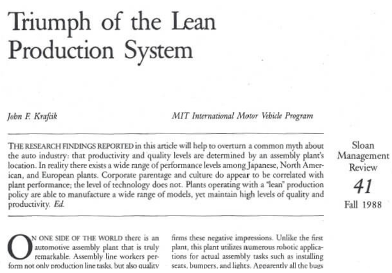
19 Definition of Lean Production

Christoph Roser, May 12, 2015, Original at https://www.allaboutlean.com/definition-of-lean/

Figure 157: What exactly is it? (Image Web Buttons Inc with permission)

As the name says, this site is all about lean manufacturing. But, what is lean? How do we define lean manufacturing? After all, since most of industry talks about lean, we should have a definition to make sure that we're all talking about the same thing. Unfortunately, **a) we do not have a good definition of lean, and b) not everybody means the same thing when they talk about lean.** So, what could lean manufacturing mean? Let's have a look at the different definitions out there:

19.1 The Origin of the Term "Lean"



Triumph of the Lean Production System

John F. Krafcik — *MIT International Motor Vehicle Program*

Sloan Management Review 41 Fall 1988

THE RESEARCH FINDINGS REPORTED in this article will help to overturn a common myth about the auto industry: that productivity and quality levels are determined by an assembly plant's location. In reality there exists a wide range of performance levels among Japanese, North American, and European plants. Corporate parentage and culture do appear to be correlated with plant performance; the level of technology does not. Plants operating with a "lean" production policy are able to manufacture a wide range of models, yet maintain high levels of quality and productivity. *Ed.*

ON ONE SIDE OF THE WORLD there is an automotive assembly plant that is truly remarkable. Assembly line workers perform not only production line tasks, but also quality

firms these negative impressions. Unlike the first plant, this plant utilizes numerous robotic applications for actual assembly tasks such as installing seats, bumpers, and lights. Apparently all the bugs

Figure 158: That's how the term started (Image John F. Krafcik at Sloan Management Review used as an excerpt/Citation.)

English language publications started to note the Toyota Production System around 1975. Soon thereafter, the term "*Lean Production*" was coined by John Krafcik in his 1988 article, "Triumph of the Lean Production System," and it has been used in industry ever since. After a slight delay, the term "*Lean Manufacturing*" also appeared.

From 1998 onward, Six Sigma also took on the term "*Lean Six Sigma*," although in my opinion [they did not really add anything valuable to it](). Nowadays, "*Operational Excellence*" is pushed as a replacement for the aging term "*Lean Production*," although I still prefer lean. The chart below gives you an overview on how often the words are used in literature (Data from [Google Ngram viewer]())

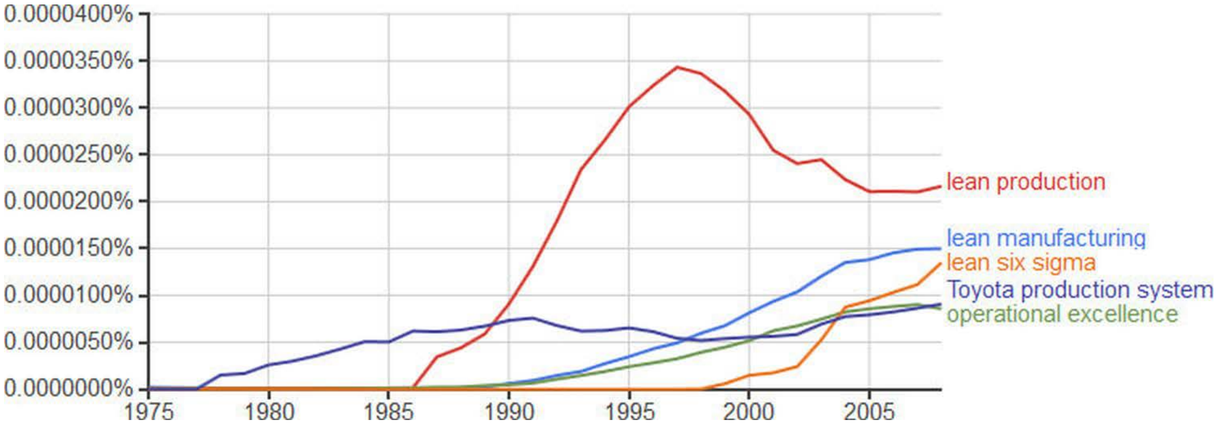


Figure 159: Usage of different lean terms throughout time. (Note: Start 1986 due to incorrect dated books.) (Image Roser)

19.2 Selection of Lean Definition

Below are some definitions of lean found in literature and the web. In pretty much all instances there would be many more similar definitions out there. However, for the sake of brevity, I usually cite only one or two of them.

19.2.1 Lean is Whatever Toyota Does!

Figure 160: Copy me! (Image Toyota for editorial use)

> *Lean manufacturing is the term most commonly used to describe the Toyota Production System (TPS). (emsstrategies.com)*
>
> *"Lean" is the set of management practices based on the Toyota Production System (TPS). (Mark Graban Lean Blog)*

Well, these definitions are mostly correct. Pretty much everything we do in lean is a (rarely better, often worse) copy of the Toyota Production System. The Western world added a few new aspects to lean, but very few of them are actually useful (see, for example, how the original seven types of waste from Toyota bloomed into up to 31 types of waste).

However, while the definition is correct, it is of little use. For one thing, what is good for Toyota is not necessarily good for everybody. Toyota is a mass-producing auto company. If a small custom-made machine tool maker would use methods identical to Toyota, it would be anything but lean, and the methods would probably kill the company.

Secondly, while it is okay to say that lean is whatever Toyota does, it does not help at all in figuring out what exactly Toyota does! But luckily, here are a few more lean definitions for you:

19.2.2 Lean is 5S, SMED, Kanban, JIT, … !

Figure 161: Hey, I have an idea! (Image bramgino with permission)

This is (luckily) not a definition I have found written down. Unfortunately, when talking with people in industry and academia, all too often it feels like that is some people's definition. "*I'll just do kanban and JIT, and then I will be lean. Or better, I'll have somebody else do it for me.*"

Lean is not just a set of different tools. Just as a car is not just a pile of parts. Michelangelo was not just someone with a chisel. It is the art of using these tools that makes production lean.

While the reduction of lean production on its tools is luckily not an official definition, the reduction on one tool is unfortunately all too common: waste elimination!

19.2.3 Lean is Elimination of Waste!

> *Lean manufacturing or lean production, often simply "lean," is a systemic method for the elimination of waste ("Muda") within a manufacturing process. (English Wikipedia, but also similar on French, Portuguese, and Dutch Wikipedia)*
>
> *Lean manufacturing involves never-ending efforts to eliminate or reduce [waste] in design, manufacturing, distribution, and customer service processes. (BusinessDictionary.com)*

Figure 162: Seven Trash Cans Labeled (Image Thomas Söllner with permission)

Defining "lean" as reducing waste is actually surprisingly common. Of the definitions I have come across, most are using waste elimination to define lean. Maybe it's because of the word "lean" itself, which, among other things, means "*containing little or no fat.*"

However, reducing lean production solely to elimination of waste is in my view also far too short-sighted. Lean production is so much more than simple elimination of waste.

19.2.4 Lean is Fast, Efficient, and High Quality!

Figure 163: I didn't know my Tin Lizzy was lean… (Image Ford Motor Company in public domain)

> *Lean Production refers to the both economical and time-efficient use of factors of production resources, personnel, materials, planning, and organization in the context of all company activities. (Gabler Wirtschaftslexikon, translated by me)*

Defining lean as being fast, efficient, and high quality is just the other side of elimination of waste. Besides, how do you, using this definition, distinguish lean from other types of production systems? Pretty much every manufacturing entity since the dawn of time aimed to be efficient.

For example, Henry Ford's assembly line also was geared toward efficient use of resources and time through relentless elimination of waste. Therefore, defining lean through efficiency and waste elimination would mean that Henry Ford invented lean production. While Ford certainly contributed to the ideas at Toyota, he did not have a lean production system!

19.2.5 Lean is Flow!

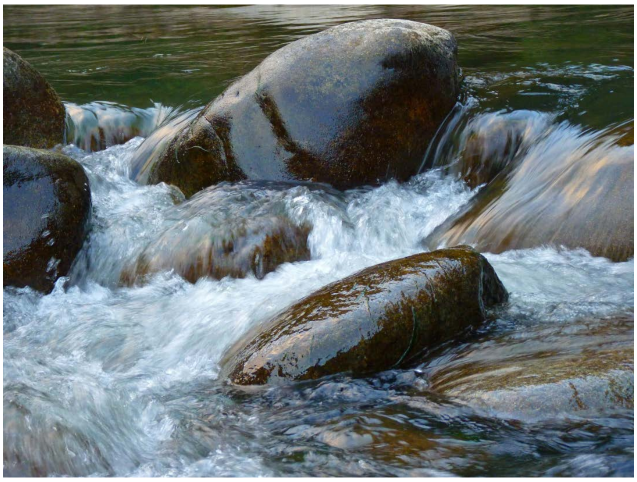


Figure 164: Let it flow! (Image LoggaWiggler in public domain)

> *Lean manufacturing is a management model focused on creating flow to deliver maximum value for customers, using the minimum resources necessary. (Spanish Wikipedia, translated by me)*

Another concept often associated with lean is the idea of optimizing the flow of material. This is also found at least partially in many definitions of lean. While it is an important aspect of lean, it is in my view also far short of the true ambitions and values of lean production. Similar to waste elimination or efficiency, one aspect of lean is not enough to define lean.

19.2.6 Lean Is a Culture!

Figure 165: What is a culture? (Image Chris 73 under the CC-BY-SA 3.0 license)

In discussion with other practitioners, yet another set of definitions tries to define lean as a culture. It certainly is a culture, but it becomes rapidly fuzzy when one tries to define what kind of culture it is. Defining the culture of lean inevitably falls back to any of the above definitions of eliminating waste, increasing value, or adding flow.

19.2.7 Lean is Adding Customer Value

> *The core idea is to maximize customer value while minimizing waste. (LEI Institute)*
>
> *Lean is the permanent struggle to flow value to one customer. (Mike Rother)*

Yet another set of definitions goes toward adding customer value. While I like the customer as part of the definition, he is certainly not the only stakeholder. The latter definition by Mike Rother also includes flow, and importantly, the element of continuous improvement. However, again we find the focus on eliminating waste in order to create value.

Even including continuous improvement, flow, and elimination of waste (or in Japanese *kaizen*, *mura*, and *muda*), we still fall far short of what lean really is. For example, in none of the definitions above have I found the **elimination of unreasonableness**, which is the third of the three evils of manufacturing. Also the entire concept of **respect for people** is missing completely.

19.3 How Toyota Defines TPS

Well, after all these sometimes-better, sometimes-worse attempts by Westerners to define lean, we can only agree that it came originally from Toyota, although this does not help us. Well, let’s have a look at how Toyota defines its own Toyota Production System. I found the following three definitions by Toyota themselves.

> *A production system which is steeped in the philosophy of "the complete elimination of all waste" imbuing all aspects of production in pursuit of the most efficient methods. (Toyota Global)*

The first definition is the basic “eliminate waste” definition that we have seen many times above, nothing new here.

The practical expression of Toyota's people and customer-oriented philosophy is known as the Toyota Production System (TPS). ([Toyota Australia]())

The second definition not only has customers included, but also its own Toyota people. I like that. However, as for the definition of the Toyota Production System, even Toyota says that it is whatever Toyota does.

The Toyota Production System is built on two main principles: "Just-In-Time" production and "Jidoka." Underlying this management philosophy and the entire Toyota production process is the concept that "Good Thinking Means Good Product." ([Toyota Georgetown]())

The third definition uses the two main pillars of the Toyota Production System: JIT and Jidoka (Autonomation). However, in my view, these are only two aspects of the whole Toyota Production System. It seems even Toyota does not agree on its definition of the Toyota Production System.

Besides, from my point of view, they are not even the most important ones. I believe they are the pillars of Toyota because these two originate from the Toyoda clan, and not one of its employees like Taiichi Ohno. My gut feeling is that Toyota likes to praise its own bloodline and is working on legend building.

19.4 So Which Definition is Right?

Good question. Just as an iterative brain teaser, here is the definition of definition:

Definition (noun ˌde-fə-ˈni-shən\): a statement that describes what something is.

To define something, you would need to make the definition clear enough to distinguish it from other similar things. However, most of the definitions above clearly fail at distinguishing it from almost all other production systems. Most of them would be, for example, perfectly valid for Henry Ford and his assembly line, or pretty much any production system developed after the Industrial Revolution.

Additionally, none of the above definitions really include the **respect for people**, which I consider one of the important elements of lean. Other important concepts like reducing unevenness (mura) and overburden (muri) are also missing. Therefore, in my view, none of the above definitions really capture the essence of the Toyota production system and lean production.

19.5 The Blind Men and the Elephant

Overall, it reminds me of the fable of the blind men and the elephant. A group of blind men touch an elephant to learn what it is like. Each one feels a different part, and in the end they disagree completely on what an elephant really is.

Figure 166: Blind monks examining an elephant (Image Hanabusa Itchō in public domain)

19.6 Conclusion: The Definition of Lean Production

Okay, now that I have criticized all the other definitions above, it is time for my own definition … except …

I don't have one!

Gosh, that's embarrassing! Despite my 20+ years of experience in lean, I cannot come up with a definition that I feel comfortable with. Whenever I try I just come up with something similar to the many definitions above. And whenever I add respect for others, it sounds cliché.

After all this lengthy discussion, we only find out that we have no good definition! Most definitions are too detailed about some methods that – except for their modern Japanese names – have been known a long time. The rest is too fuzzy and vague and reads like a typical company mission statement (which in general says "do good" using fancy words while trying not to offend anyone). However, my overall conclusion on this mess of definitions is pretty clear:

We haven't understood yet what lean production really is!

Probably all the difficulties we have in implementing lean production and all the failed projects with only a few successes in between probably stem from this lack of understanding. Even people who instinctively do things right have a hard time explaining it to other people. It is somewhat comforting that while Toyota does it right, even they cannot define it well.

In any case, I hope I have not confused you too much with this mess of definitions. Now go out and organize your industry, even though you may not be able to define what you are doing ☺.

P.S.: The idea for this post was initiated by an e-mailed question by Troels Andersen (Differience Consulting, Copenhagen, Name mentioned with permission). By the way, if you have a question related to lean, feel free to ask me!

20 How to Find a Good Lean Consultant

Christoph Roser, May 19, 2015, Original at https://www.allaboutlean.com/find-lean-consultant/

Figure 167: Whom shall it be? (Image kantver with permission)

Lean manufacturing is difficult. External expertise can help you in improving your business. However, the wrong consultant can at best have no effect, or worse damage your company, or at worst kill the company. Hence the consultant you hire will have a significant impact on the outcome of the project. This post will give you some advice on how to select a good consultant.

20.1 Some (Public) War Stories

The advice of consultants can make or break a company. Here are some examples of high-quality consulting work (all examples from The Gateway, but there are plenty more out there):

- Boston Consulting successfully helped GM, Chrysler, and Ford with their turnaround after the 2008 US government bailout
- PA Consulting saved the UK Defence Ministry £17 million
- McKinsey warned beforehand about the high risk of failure of the ObamaCare website

Of course, failures are also plentiful. However, both consultants and clients like to talk about successes and try to downplay the failures. Besides, creating a direct correlation between the consultant's advice and the failure of the project is sometimes difficult. Nevertheless, there are also stories of failures in consulting. Here are a few. As with all failures, depending on who you ask, there may be always someone else to blame:

- Oliver Wyman advised UBS to invest in sub-prime debt instruments
- Swissair went into bankruptcy after implementing a McKinsey strategy
- Oliver Wyman named an Irish Bank the best bank in the world in 2007. The next year, the Irish government was forced to nationalize the bank.

Often you will hear stories of failures associated with big names. This is simply a) because they are big and have many projects, and b) it makes a better story if everybody knows the consultancy. As an former McKinsey consultant, almost every time I introduce myself and my background to a group of people, there is one person with a jaundiced comment about McKinsey. McKinsey is not bad. It is actually quite good – although like all others it also has its share of failures.

20.2 Before You Look for a Lean Consultant

Before you look for a consultant, there are a couple of things that you should be clear about:

20.2.1 Know What You Want

As in most things in life, the more precisely you know what you want, the more likely you will get what you need. The fuzzier your goals are, the more likely you will be disappointed. If you pay a consulting team $250,000 to do something, they surely will do "*something*".

Figure 168: All your problems on one slate (Image cacaroot with permission)

Especially in lean manufacturing, **it does not help if you narrow it down to money, time, and quality**. Money, time, and quality include pretty much all problems you can possibly have on the shop floor (unless you are in legal trouble and the cops are looking for you – but let's hope this is not the case).

One point is quite important here: **You need to describe your problem clearly. However, do not fall for the temptation to describe the solution!** If you tell the consultant that you want kanban, sure, you will get kanban. Unfortunately, it is far from certain that this will actually help you to improve. On the other hand, if you say that your delivery performance is bad, increasing your delivery performance will be much more likely improve your bottom line. If during the project, the team decides that kanban can help you with that, no problem. But keep the focus on the problem, not the solutions.

It is also possible that you have exhausted your list of detailed problems. You know that your performance is not yet where you want it to be, but you don't know where to start. In this case, an analysis and comparison of the potential levers is a very valid lean consulting project.

20.2.2 Be Prepared for the Possibility of a Failure

Projects sometimes do fail. A good consultancy can increase the chances of success, but even then failures do happen. It is estimated that between 70% and 90% of all lean projects fail, both consulting and otherwise. Of course, the real outcome and the outcome on PowerPoint can look quite different. I estimate about 70%–90% of all consulting projects are reported as successes, even though only 10%–30% really are (see also my series on KPI fudging). In any case, be prepared for the possibility of a failure.

Of course, if you will only hire a consultancy that promises you a successful project no matter what, then you are pretty much paying someone to lie to you.

20.2.3 Know about Lean Manufacturing

This is a tricky one. If you know lean manufacturing, it helps you to weed out the frauds. On the other hand, if you really know lean manufacturing, you may be better off doing it yourself. From the consultant side, I can also attest that clients with a half-baked knowledge of lean are quite difficult to handle. If they think they know it all but don't, then it makes it more difficult to have a successful project.

Ideally, you should know enough lean to sort out some of the bad consultancies, but please do not try to micromanage them. For money, most consultants will do what you want them to, but not what may have been necessary. By the way, to learn more about lean, reading AllAboutLean.com helps 🙂.

20.2.4 The Beauty Contest

Figure 169: Which one do you like best? (Image Joseph M. Maurer in public domain)

In consulting language, the *"beauty contest"* is the time where a client receives proposals from different consultancies and selects a candidate. Since it is difficult to objectively measure which one is the best, subjective impressions are relevant, quite similar to a beauty contest. Below I will give some hints on how to spot the fake noses and how to see through the makeup to find true inner beauty.

Also, do not underestimate the value of the beauty contest. After all, you do need to get along with the consultant. You could have the best consultant in the world, but the project would probably be a failure if you can't stand each other. Hence, impressions during a beauty contest are quite relevant.

20.2.5 Ask your Shop Floor Management

Figure 170: Ask me, too! (Image WavebreakmediaMicro with permission)

You as the main client will spend quite a bit of time with the consultants. However, your shop floor management and their people will in all likelihood spend much more time with the consultant. Hence, it is not only the chemistry between the consultant and you that matters, but equally important the chemistry between your lower&middle management and the consultants.

Hence, do include your operative side in the decision making. If possible make a small team with a selection of foremen, team leaders, and group leaders, and possibly also department leaders and plant managers. Have this team also choose which consultant is most likely to help them in their daily business. **If the consultants is impressive in boardroom power point meetings but not with the people that know the shop floor, then the results are also likely to look good on paper but will not materialize in reality.**

20.2.6 Attitude towards “Lowly” Employees

Figure 171: Be nice to her! (Image PublicDomainPictures in public domain)

Brief your secretary/receptionist beforehand, and ask him or her afterward how the consultants treated them. Did they greet them, smile, or even make small talk? Good!

On the other hand, disrespectful or rude behavior toward others below their perceived status is a no-go. Besides, if they don’t know yet that the assistants are some of the most powerful and important people in a company, then they know nothing!

20.2.7 Shop Floor Behavior

During the beauty contest, bring the consultants to the shop floor. Does it feel like their natural element? Or do they feel more comfortable in meeting rooms with PowerPoint? (See also my posts on Shop Floor Etiquette). Suit and tie can be optional on the shop floor. Do they have safety shoes with them? If I want a consultancy to change my shop floor, then I want them to be familiar with a working environment.

20.2.8 Buzzword Bling Bling

When the consultants are present, what part of the presentation do you actually understand? How many Japanese terms or abbreviations do they use (also see my Glossary)? Often, consultants (and others) hide their lack of understanding through the use of buzzwords or consultant-speak. While few consultants avoid such jargon altogether, an excessive use indicates low-quality understanding of lean and therefore low-quality lean consulting.

20.2.9 Size and Cost

Should you get a big or a small consultancy? Either one works. Often, in smaller consultancies the people in the beauty contest will also be the one doing the work. Larger ones, on the other hand, can draw on a large back office and support, and an internal network. It is a matter of choice really.

Does the price matter? Yes! I think it is like wine. If you pay $2 per bottle, expect a headache. Similarly, if you splash out $500 for a bottle, you probably won’t taste the difference from a $20 bottle, although you may feel better for having something fancy.

20.3 During the Project

There are also some things to consider while the project is ongoing.

20.3.1 Good Lean Consulting Will Take Your Time

Figure 172: Learning and Coaching (Image Photographee.eu with permission)

Lean manufacturing in my opinion stands and falls with leadership. Hence, for a successful project, a good consultancy also wants to work with higher or top management and coach them in the way of lean manufacturing.

If, on the other hand, you expect consultants to do their job and only show up every now and then with a fancy status presentation, of course they will do that. However, the results will probably be less than with coaching of top management.

Also, a really good consultancy may sometimes also tell you things about yourself you don’t like (always a risky thing, especially with CEOs ☹). Don’t shoot the messenger, but take their feedback seriously. If, however, you are in the habit of shooting the messenger, I as a consultant would rather find out sooner than later before we waste each other’s time (and your money).

20.3.2 Good Lean Consulting Will Take Your People’s Time

Similarly, a good consultancy needs a strong counterpart on the shop floor. The consultancy may be an expert in lean, but chances are your people are the experts in whatever gizmos you produce. The knowledge of both has to come together to make things work. A good consultancy works together with the shop floor, from the operator upward. And yes, the consultants will also learn a good deal from you.

20.3.3 Good Lean Consultants Teach Rather than Do

> *Give a man a fish and you feed him for a day; teach a man to fish and you feed him for a lifetime.*

While a good lean consultancy should not be afraid to get their hands dirty, they should teach your people. For one thing, this will increase you ability to do projects yourself. More important, however, is that it will increase shop floor acceptance, and hence the likelihood of success.

20.4 Summary

Overall, it is difficult to estimate the quality of a consultancy beforehand, and even more difficult to predict the outcome of a lean project. The above points will give you some clues, but you will know for sure only afterward. You could also have a smaller test project to see how they work before giving them access to your crown jewels. Similarly, getting a trustworthy recommendation may help in finding a good consultancy, even though in both cases previous performance does not guarantee future success.

Finally, **if you are daring, you can request a “no PowerPoint slide” project**. Consultants often spend an insane amount of time on slides, which of course reduces the time for actual problem solving. However, taking PowerPoint away from consultants may put some consultants out of whack!

Also, as not every consultant may be right for you, not every client is right for a consultancy. Both sides have to work together to increase the chances of success, and the chemistry between consultant and client is important. Now **go out and with or without help organize your industry!**

PS: If you are looking for a (good?) lean consultant in or near Germany, and feel my writing makes sense, don't hesitate to contact me ☺.

21 Twenty-five Years after Ohno – A Look Back

Christoph Roser, May 28, 2015, Original at
https://www.allaboutlean.com/ohno-25-years/

Figure 173: Taiichi Ohno, Father of the Toyota Production System (Image unknown author in public domain)

Twenty-five years ago today, on May 28, 1990, Taiichi Ohno passed away. While he was not the only person behind the Toyota Production System, he was its key driver and is considered the **father of the Toyota Production System**. To commemorate the anniversary, let's have a look back at his life, and also at how lean changed after he passed away.

> *To produce only what is needed, when it is needed and in the amount needed.*
> *(Taiichi Ohno)*

21.1 The Life of Taiichi Ohno

21.1.1 Youth

Figure 174: Ohno's birth-town (Image 塩崎伊知朗 in public domain)

Taiichi Ohno (大野耐一) was born on February 29, 1912, in Dalian, China during the Japanese control and later occupation of Manchuria. His unusual first name *Taiichi* comes from the work of his father making fireproof bricks. After returning to Japan, he graduated from Nagoya

Technical High School. He received no further formal education beyond his high school diploma.

Figure 175: Toyoda Spinning and Weaving looked like this (Image Bariston under the CC-BY-SA 4.0 license)

After graduating in 1932, he started at the Toyoda Spinning & Weaving company, a few years before Toyota Motor was officially founded in 1937. It was during his time at Toyoda Spinning & Weaving that its main competitor, Nichibo, outperformed Toyoda both in quality and in cost. One of the key differences at Nichibo was small lot sizes and integrated manufacturing lines, and it is quite possible that this inspired Ohno later with the Toyota Production System.

21.1.2 The Toyota Production System

Figure 176: Toyota Motor Plant in the 1950s (Image unknown author in public domain)

In 1943, Ohno moved from Toyoda Spinning & Weaving to the Toyota Motor Company, and three years later he was in charge of a machining workshop. Now Ohno had his first playground to improve. Soon the machines were arranged in sequence of operation, established multi-machine handling, and used small lot sizes.

Figure 177: Piggly Wiggly, the first Supermarket (Image Clarence Saunders in public domain)

It was at that workshop that he also started pull production using supermarkets by 1948. Supermarkets were modeled after US retail supermarkets, which Ohno had only heard of when he started the system. Only later in 1956 did he actually visit the US and its supermarkets. To get the information back from the supermarket, they initially just wrote the information on a scrap of paper. This was later formalized, and even later given a proper name: kanban.

Soon Ohno also extended this pull system to his suppliers. Hence Ohno at Toyota pretty much single-handedly established the now-familiar pull system using supermarket and kanban.

From today's standpoint, this pull system looks so easy and natural. However, in 1950 it wasn't all that easy. In fact, the "change management" as we would nowadays call it was anything but easy. Ohno faced a lot of resistance. Neither the workers nor the managers liked the new system, which until the early 1960s was known as the Ohno system, or less flattering, the "abominable Ohno system."

Figure 178: W. Edwards Deming (Image FDA in public domain)

He also incorporated useful methods from other parts of the world, as for example the quality-control approach, developed in the US and brought to Japan by W. Edwards Deming. Toyota also got much inspiration from Ford, as well as the Training within Industry program in the US during World War II, and even from German aircraft manufacturing and their "*Takt*" time.

21.1.3 Ohno's Personality

Japanese have a reputation of being polite and quiet. But not Ohno! In order to put his ideas through, he used his entire personality and not always in a positive way. It is said that he was nice to workers, but much less so to managers. He yelled at people, kicked them, and sent them impossible tasks (although this abuse was usually reserved for managers, and he treated ordinary workers rather well).

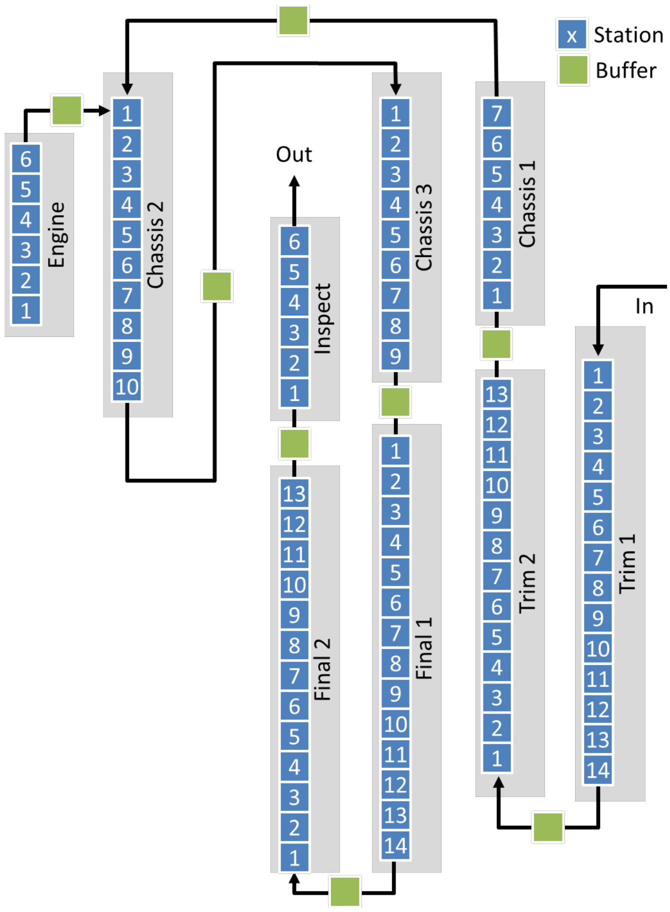


Figure 179: Current Layout of Toyota Motomachi Plant (Image Roser)

Among other things, he fiercely resisted the adding of any buffer stock in their main assembly lines, which was implemented only after his death (See Evolution of Toyota Assembly Line Layout – A Visit to the Motomachi Plant).

Many of his coworkers were scared of him, and some even had trouble sleeping due to his abuse. Yet to the frustration of some of his colleagues, Ohno's system outperformed the rest of Toyota. Over time he was given more and more responsibility, and was able to establish his system in more and more areas at Toyota.

21.1.4 Lean in the Western World

Book Cover "The Machine that changed the World" by James P. Womack, Daniel T. Jones, Daniel Roos removed due to copyright concerns

Around 1970, the oil crisis hit industry hard worldwide. Sales evaporated, as did profits. Japanese car makers, especially Toyota, fared quite well. A wave of low-priced high-quality Japanese cars hit the US, leading to detailed studies of the Toyota Production System, the most famous one being probably The Machine That Changed the World by Womack and Jones. There was much interest in the *"Secrets of Toyota,"* and Japanese people with Toyota experience like Shigeo Shingo soon reached cult status in the US.

Book Cover "Toyota Production System: Beyond Large-scale Production" by TaiichiOhno removed due to copyright concerns

Ohno also wrote some books about the Toyota Production system (see here for examples). However, if you read these books carefully, you will find little about the details of the Toyota Production System, but rather high-level inspirational content. Even most of the examples are not from Toyota, but from other companies like 7-Eleven.

There even exists a supposed interview where Ohno admits deception (described in the book Profitability with No Boundaries by Pirasteh and Fox). However, I would find it strange that Ohno would admit such a thing, and even stranger that the interview was "*in the early 1990s*" in Chicago, even though Ohno died on May 28 1990 in Japan at the age of 78. Some things don't quite add up here…

In any case, even nowadays the true values of the Toyota Production System are hard to grasp and seem to be entirely absent in many wanna-be lean implementations.

21.1.5 His Later Years

Figure 180: Founder Sakichi Toyoda (Image unknown author in public domain)

Figure 181: and his son Kiichiro (Image unknown author in public domain)

By all accounts, Ohno is one of the key contributors to the continuing success and profitability of Toyota. Yet, in official publications of Toyota, he is barely mentioned and usually listed as one of the many second-row people behind the founding Toyoda family, especially Sakichi and Kiichiro Toyoda.

Also, career-wise, he should have become a president and a chairman at Toyota. However, he never made it beyond vice president when he left Toyota in 1978. He afterward became chairman of one of the other companies in the Toyota group, Toyoda Gosei. In view of his achievements, this is definitely an affront against Ohno.

As for the reason for this slight, there are two theories. First, it is said that while Ohno muddled the information about the Toyota Production System, he did speak about it, and hence released confidential information. However, another theory, which sounds more plausible to me, is that through his forceful personality, he made too many enemies who eventually blocked his career advance.

Taiichi Ohno died twenty-five years ago today on May 28, 1990, in Toyota City at the age of seventy-eight from heart failure.

21.2 His Legacy

Due to his forceful personality and his high standing within Toyota, he had a major influence on Toyota. Without him, I doubt that Toyota would have been anywhere near as successful, and may not have become the largest car manufacturer in the world. His ideas and visions still hold true for modern manufacturing. Creating a pull system and establishing flow is still one of the keys for an efficient production. He is rightfully considered by many to be the father of the Toyota Production System.

22 The (True) Difference Between Push and Pull

Christoph Roser, June 02, 2015, Original at https://www.allaboutlean.com/push-pull/

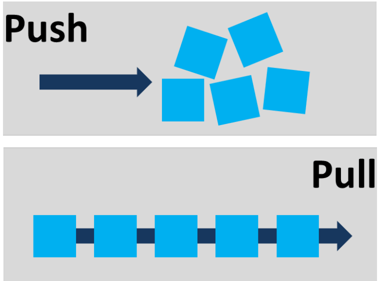


Figure 182: Common, but misleading illustration of push and pull (Image Roser)

One of the key differences in lean production is to use pull production rather than push production. While pretty much everyone knows (at least in theory) how to implement it using kanban, the underlying fundamental differences are a bit more fuzzy. But what exactly is the difference between push and pull? Also, what makes pull systems so superior to push systems?

It turns out that most definitions are going in the wrong direction. Even the names "push" and "pull" are actually not well suited to describe the concept. Neither are common illustrations, including the one here in the upper left.

22.1 What It Is Not! – Common Misconceptions

Let me start you with a selection of different definitions of push and pull that I've found online. For each of them I selected one actual quote, although many more similar definitions could be found.

22.1.1 Misconception 1 – Make-to-Stock and Make-to-Order

> *"Push type" means "make-to-stock," in which the production is not based on actual demand. "Pull type" means "make-to-order," in which the production is based on actual demand. ([Lean Manufacturing Japan](#))*

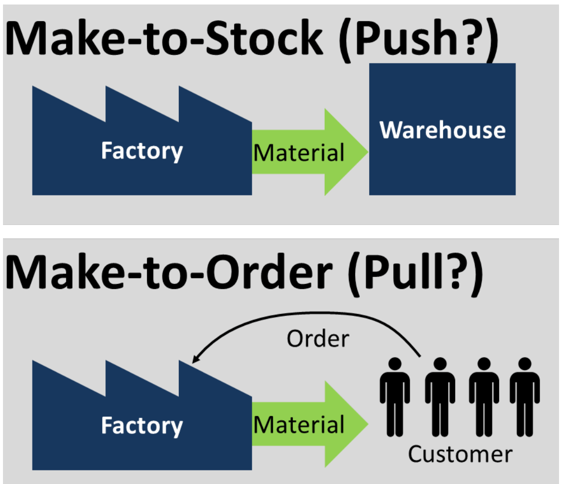


Figure 183: Is it really? (Image Roser)

Often, push and pull are (incorrectly) explained through "make-to-stock" and "make-to order." Supposedly, a push production creates products without having a specific customer request (make-to-stock). A pull production supposedly produces only if there is a request for a product by the end customer (make-to-order).

That is a simple but very flawed view of the difference between push and pull. Even Toyota produces some of their cars without a specific customer order, instead building up stock of popular models for walk-in customers. Hence, it is perfectly possible to produce make-to-stock using pull production.

On the other hand, using this definition, pull production would be centuries old, since make-to-order production is a very old concept. Every cobbler before the Industrial Revolution made shoes only if a customer requested them. However, these cobblers were anything but lean, and were usually surrounded by piles of material.

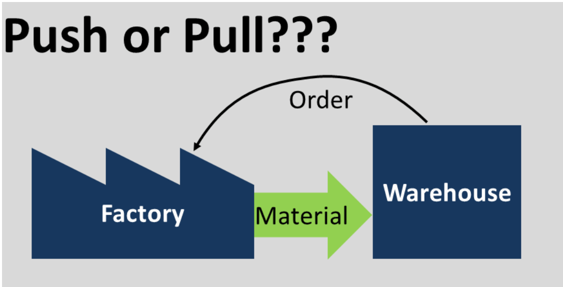


Figure 184: What is it now? (Image Roser)

Sometimes it is attempted to correct the above definition by stating that the "order" in "make-to-order" does not have to be an end customer, but could be a stage in between. However, even for make-to-stock, somebody somewhere has to give the order to start producing. In this case, this "somebody" would be the customer, and any make-to-stock would be identical with make-to-order.

22.1.2 Misconception 2 – Market Forecast vs Actual Demand

> *Push Manufacturing: manufacturing activities are planned based on a market forecast[...]. Pull Manufacturing: manufacturing plan is based on actual customer demand. (Lean Enterprises Blog)*
>
> *[Pull] means that no one upstream should produce a good or service until the customer downstream asks for it. (Womack and Jones in in Lean Thinking)*

This (incorrect!) definition uses slightly different words but is otherwise similar to the make-to-stock and make-to-order definitions above. As shown by the second quote, even the best lean thinkers are muddled on this topic.

22.1.3 Misconception 3 – Direction of Information Flow

> *The difference between push and pull is the direction in which information and orders are forwarded. Push has a central logistic plan. Pull has an information flow opposite of the material flow. (Item24.de, translated by me)*

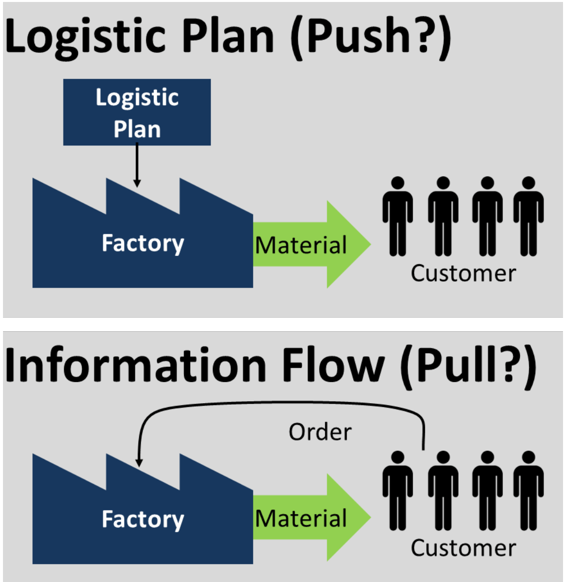


Figure 185: Are you sure? (Image Roser)

Often, the main difference between push and pull is seen as the difference between having a central logistic plan or information directly from the customers. If there is a central logistic plan, it is supposedly push. If the orders come directly from the customer, it is supposedly pull.

Yet here we have again the same problems as before. The logistic plan is not created out of thin air, but based on the demands of the customer. Depending on the customer demands and the lead time, the logistics department starts make-to-stock or make-to-order production.

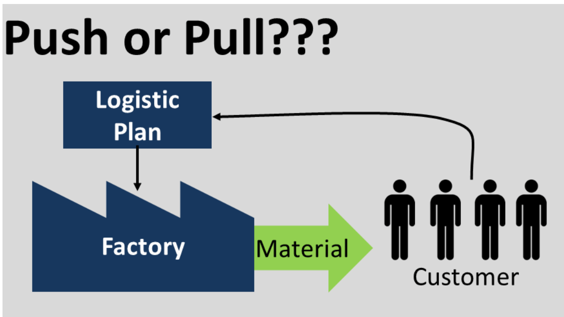


Figure 186: What is it? (Image Roser)

Also, while a functioning kanban system is a pull system, it does not necessarily have to be based on paper kanban cards. A kanban system can also be digital using an ERP system, in which case the logistic plan would create its orders based on kanban. Hence you would have a pull system with a central logistic plan. Therefore this definition of push and pull does not work either.

22.1.4 Misconception 4 – MRP and Kanban

> *Push is MRP, pull is kanban (not really a quote, but often heard in industry).*

Of all the views of push and pull, this one is at least partially correct. A well-implemented kanban system (i.e., not just a plant where every paper is miraculously called “kanban”) is indeed a pull system. However, it is not the only possible way to create a pull system. You could also use, for example, CONWIP.

Similarly, MRP can also be set up as a pull system using electronic kanban or similar methods. Hence, it is entirely feasible to implement pull using MRP.

22.2 What Is Really the Difference between Push and Pull?

All of the definitions above fail to capture the true essence of a pull system. The confusion probably stems from the rather unfortunate names “push” and “pull,” which are actually misleading. Regarding the true difference between push and pull, Hopp and Spearman are right on the money:

> *A pull production system is one that explicitly limits the amount of work in process that can be in the system. [...] a push production system is one that has no explicit limit on the amount of work in process that can be in the system. (Hopp and Spearman "To Pull or Not to Pull")*

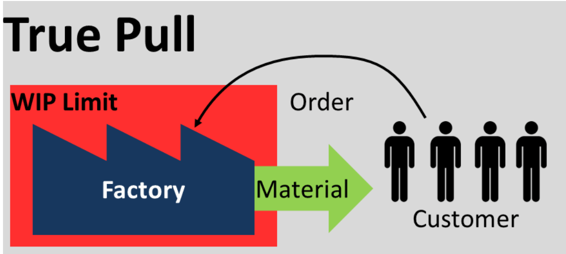


Figure 187: True pull has an upper limit on WIP (Image Roser)

Yes, if you explicitly limit your work in progress (WIP), it is a pull system. If not, it is a push system. It has nothing to do with physical pulling or pushing of material or information.

For example, a kanban system has a fixed upper limit on the work in progress. You cannot have more material than what is allowed by the number of your kanban cards. This limit is explicitly defined (the number of kanban cards).

Of course, any shop floor has an upper limit. If all available space is crammed full with WIP, at one point the shop will stop production. However, this limit is not well defined as it depends on the creativity of the logistics people to find more spaces to put stuff. Additionally, this limit is usually much more than any sensible kanban system would allow.

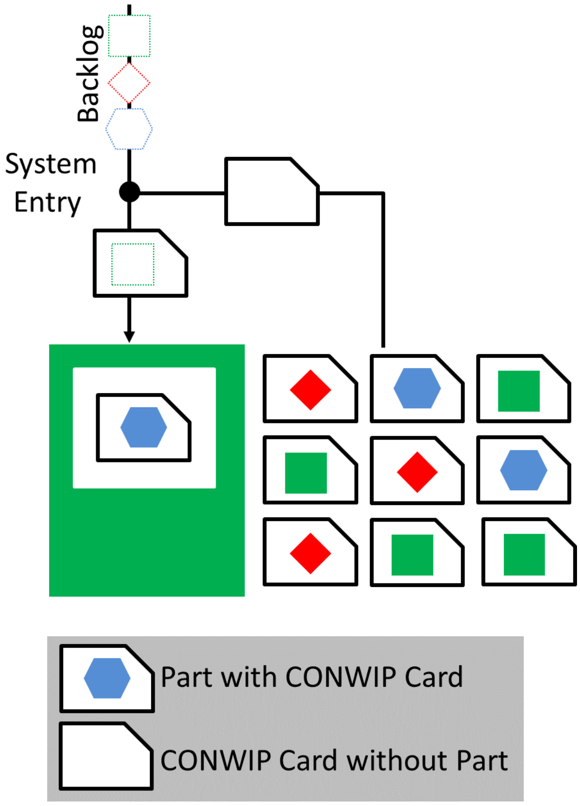


Figure 188: CONWIP system (Image Roser)

A true pull system starts production only if the WIP limit has not yet been reached. For example, in a kanban system, if there is material in the supermarket at the end the customer can take a part, and a new order is released. If there is no material, then all the WIP allowed is already in the queue. The customer gets no part, and no new order is released.

Similarly for CONWIP systems, a backlog of open orders is only started if there is a free CONWIP card available (see Basics of CONWIP Systems for details). While an order is not rejected in a CONWIP system, it still has to wait until a WIP slot in the form of a free CONWIP card is available.

22.3 Summary

Overall, most sources and most practitioners define push and pull incorrectly, probably because the names “push” and “pull” are actually quite misleading. This confusion is quite unfortunate, since pull is one of the key elements of a successful production system. The main difference is the WIP limit. **If you have an explicit WIP limit in your production, you have a pull system and hence have access to all the benefits of a lean pull production. If there is no explicit limit on WIP, it is a push system.** See also my posts Different Ways to Establish a Pull System – Part 1 and Part 2. I hope this was insightful for you. Now go out, limit your WIP, and **organize your industry!**

22.4 Selected Source:

Hopp, Wallace J., and Mark L. Spearman. “To Pull or Not to Pull: What Is the Question?” *Manufacturing & Service Operations Management* 6, No. 2 (April 1, 2004): 133–48. doi:10.1287/msom.1030.0028.

23 Why Pull Is So Great!

Christoph Roser, June 09, 2015, Original at https://www.allaboutlean.com/why-pull-is-great/

Figure 189: Pull your production! (even though the term "Pull" is quite misleading) (Image Luis Louro with permission)

One of the most significant insights of the Toyota Production System is its concept of pull production. While often misunderstood, the essence of pull production is a clearly defined limit on the work in progress. Push or pull actually has nothing to do with the direction of the information or material flow. But why does this limit on work in progress make so much difference? Why do pull systems vastly outperform push production systems?

23.1 Effect of Inventory on Performance

The optimal state of many performance indicators often is either the maximum (e.g., productivity, delivery speed) or the minimum (e.g., defects, cost…). Inventory, however, is different. Too much can be as bad as too little, and you would have to find a sweet spot with just the right amount of inventory.

23.1.1 Too Much Inventory

Figure 190: The expense of having stuff (Image unknown author in public domain)

Inventory is one of the seven types of waste (muda) in lean production. Having too much inventory has many negative side effects and hidden and not-so-hidden costs. **Besides the obvious tied-up capital, there is storage, handling, taxes and insurance, administration, obsolescence, and theft**.

Figure 191: The speed of your plant with too much inventory! (Image Jürgen Schoner under the CC-BY-SA 3.0 license)

On top of that, and probably as bad as all the previous, a **large inventory makes you sluggish**. If the customer demand stays constant and you increase your WIP, all parts have to wait longer until they reach the customer. Hence new products or new orders will take longer to reach the market. Yet especially in today's fast paced business, companies can ill afford to delay their deliveries.

Overall, both the **expenses and the delays will cost you anywhere between 30% and 65% of the value of the goods per year**. While I am not sure if all companies have understood this expense associated with inventory, many are reducing their inventory, even if all too often the reason is simply because Toyota does it too. However, simply reducing the inventory brings up another problem, as we will see next.

23.1.2 Too Little Inventory

Figure 192: Your material flow (Image mattbuck under the CC-BY-SA 4.0 license)

In any production system there are fluctuations. Different products are produced, parts may arrive early or late, processes will take longer than expected or will be faster, or workers may be available or not. In essence, material does not flow at an even speed, but often comes in waves, sometimes faster and sometimes slower.

This is especially true if you do not look at the total inventory, but at each individual part number. When you produce one product, you have a large demand of parts for this product. If you produce another product afterward, you may no longer need the first parts but a different type of part. Hence, your material flow on a part number basis is uneven. The effect is similar with other disturbances.

To cancel out these uneven demands, **inventory** is your friend. The buffer inventory going up and down like waves allows the machines and workers to work at a constant speed, and will provide the customer with material despite a fluctuating demand.

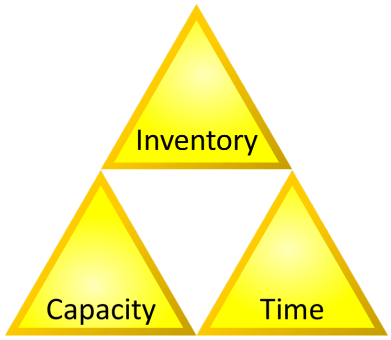


Figure 193: The Triforce of Inventory, Capacity, and Time decouples your fluctuation (Image Ian Moody in public domain)

However, if you cut your inventory, you will have a problem, since you can no longer decouple these fluctuations using inventory.

Besides inventory, there are two more ways you can handle fluctuations. After inventory, the second option is **capacity** adjustments. You ramp up your capacity when needed and reduce it when not. However, this is often unfeasible on short notice in a highly volatile modern production system.

If you cannot use inventory or capacity to handle these fluctuations, by default the third option will apply: **time**! Your manufacturing system will have plenty of waiting times. Workers, machines, and customers will all be waiting for material. The more you cut inventory, the lower your utilization and production rates will be. Altogether, your fixed cost will go up since you have lots of machines that you do not use.

If you reduce your inventory too much, your efficiency goes down and your fixed cost goes up. This can soon be more expensive than the buffer inventory in the first place. To add insult to injury, your inventory won't really go down that much either! If the system lacks the internal capacity due to lack of material, but you still order parts like you have full capacity, you will end up with piles of material anyway. Except that it is mostly the wrong kind. If you need 100 parts to make a product, you will have 99 on hand but 1 is missing. Hence 99 parts are lying around and cannot be produced.

23.1.3 Just the Right Amount of Inventory

Overall, too little inventory can be as bad or even worse than too much inventory. Hence, somewhere in between there is a sweet spot where your total cost is minimal. For simplicity's sake, the graph below shows the total cost as a sum of the inventory cost and the fixed costs, although in reality it is a bit more tricky with some more costs involved.

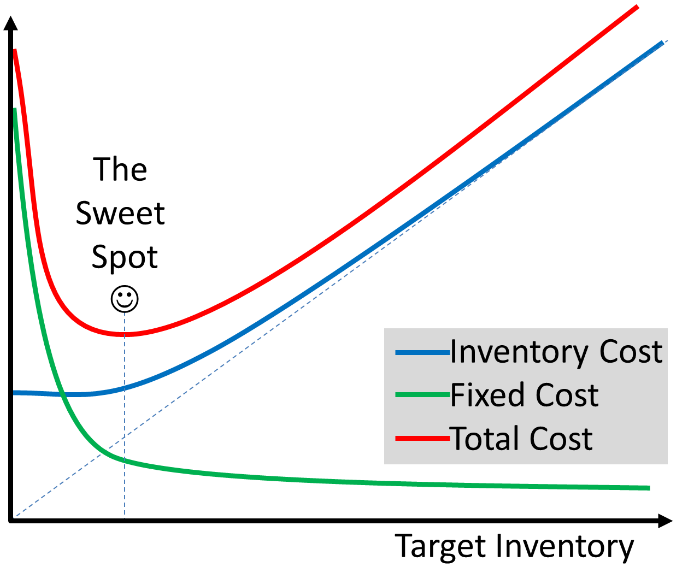


Figure 194: The sweet spot between too much and too little inventory. (Image Roser)

Your system works more efficiently if there is not too much but also not too little inventory! Of course, finding this exact spot is difficult, and it is pretty much impossible to calculate with any practical accuracy, but luckily this spot is usually a wider valley. Therefore, having a small bit more or less does not have such a drastic impact. Also, please remember that such a sweet spot is not static. It can change by itself, or – much better – you can change your system to move the sweet spot to an even sweeter spot 🙂.

By the way, while most companies understand than lean production involves a reduction of inventory, they often miss the point that the system has to be improved too. Wannabe-lean companies that simply reduce inventory even past the sweet spot have too little inventory and should actually increase inventory. Also, do not forget that it is possible to change the curves by improving (or worsening) the system itself.

23.2 Effect of Pull Production

23.2.1 It puts a cap on WIP!

Figure 195: A hard limit … (Image unknown author in public domain)

The great thing about pull production is that it limits the work in progress. As explained in my last post, the (True) Difference Between Push and Pull is not the information flow or where the information comes from. The difference is that **a pull system has a clear upper limit on the work in progress, whereas a push system does not**. Hence the superior performance of pull systems comes directly from the cap on WIP, since it allows manufacturing systems to maintain an inventory close to the sweet spot.

23.2.2 It does it automatically

Having a pull system in place is like having an automatic system that keeps your inventory below a certain limit, no matter if you implement pull using kanban (high volume, low variety), CONWIP (low volume, high variety), any combination thereof, or even a more exotic drum buffer rope system. If the system is working, it needs only a little maintenance to check for lost cards or to update the number of cards if the system is changing.

23.2.3 Suited for almost any production system

Pull systems are suitable for almost any production system, no matter if you are mass producing a few part types (**high volume, low variety**) or customizing every individual product (**low volume, high variety**). It works with **flow shops** and **job shops**, and even with **construction sites** (limit the number of construction sites to your capacity). It works for big and small parts. Pull can be implemented for **discrete parts** (things you can count like screws or cars), for **continuous production** (chemicals, oils, gases, …), and even **digital calculation** and **information processing**. Pull can be used in **administrative processes**, **product design**, and even in **hospitals** (but you have to get the prioritization process right for the last one!).

Figure 196: Try turning that off … (Image Alfred T. Palmer in public domain)

Pull would work for pretty much any production system. There are very, very few production systems where push is better than pull. One example would be the manufacturing of integrated circuits, where each part passes through the process repeatedly and the process has very little variation. In this case, a good push system is marginally better than pull.

Another example would be processes where it is quite expensive to shut the process down, as for example the crucible of a steel furnace or some chemical process industries. In this case you prefer to run the process even if the demand goes down, because the inventory increase is still cheaper than the shut down of the process. Of course, if you can sort-of hibernate the process without production, it may also be an alternative.

23.2.4 Inventory can still fluctuate, but that's fine

Please note that while in pull production the inventory levels have a cap, inventories still can fluctuate. For example, with kanban systems, theoretically all of the kanban could be sitting in the supermarket with its associated material, and we would have max WIP. However, it is also possible that all cards are waiting for production and our WIP would be zero. Of course, in reality it is usually something in between.

This fluctuation is fine. The kanban formula and the alternative kanban estimation approach determine the number of cards needed to operate smoothly, but average WIP will usually be much less than the sum of the kanban cards.

23.2.5 It is Robust!

Figure 197: Conventional push systems are rather tricky to handle (Image Peacefulmovements under the CC-BY-SA 3.0 license)

There are different ways how to control your production system. You could plan using available capacity and required deadlines, which would be the conventional push approach. Unfortunately, both capacity and deadlines are usually rather volatile and can change quickly. Hence, planning ahead is difficult, and frequent changes to the production plan are needed to match changing requirements. Overall, it is very tricky to plan using conventional push production.

Figure 198: Pull systems are much more stable and robust (Image Leon Petrosyan under the CC-BY-SA 3.0 license)

With pull production, however, you merely plan the limit on WIP (and maybe prioritize which part to produce next). There is no need to plan the capacity in detail, nor the deadlines as long as your system is fast enough.Additionally, the system is very robust against the limit on WIP. It doesn't matter if your limit is a bit too high or a bit too low, in all likelihood your system is still going to work fine, even if you haven't hit the perfect WIP levels. Small changes in the WIP limit do not lead to larger changes in the performance. Hence, pull production is overall very robust and insensitive to fluctuations in the system.

23.3 Summary

Hence, overall pull systems are so great because they have a cap on inventory and can – if set up correctly – keep the inventory close to the sweet spot between too much and too little inventory. Pull systems can do this regardless if they are set up using kanban, CONWIP, or any other method for inventory caps. They can be applied to almost any production system. Hence, **if you have the chance to change your system from a push system to a pull system, it will help you to get your industry organized!**

24 Theory and Practice of Supermarkets – Part 1

Christoph Roser, June 16, 2015, Original at https://www.allaboutlean.com/supermarket-basic/

Figure 199: All about supermarkets… (Image Linsensuppe under the CC-BY-SA 4.0 license)

Kanban, FiFo lanes, and supermarkets are the backbone of many pull system. Some people even define lean production through its use of kanban and supermarkets. Yet why are supermarkets so useful? First we will look at what exactly makes an inventory into an supermarket. My next post will then give tips and hints on the practical use of supermarkets on the shop floor.

Simply said, supermarkets are inventories at the end of a pull system. However, not every inventory at the end of a pull system is a supermarket. There are some additional requirements on supermarkets that are not strictly necessary for pull systems and may sometimes even be not useful. But before we go deeper, let's look at a bit of history.

24.1 A Bit of History on Supermarkets

Figure 200: The original Piggly Wiggly supermarket (Image Clarence Saunders in public domain)

Supermarkets in manufacturing are actually named after retail supermarkets, or more precisely self-service grocery stores. Before, whenever you went shopping, you told the attendant what you wanted, and he or she got you the items from the back of the store, quite like many modern pharmacies.

The breakthrough in supermarkets was that the customer picked up the items themselves and paid at the check out. The company that pioneered this was Piggly Wiggly, opening its first store in Memphis in 1916, but the idea soon spread due to the savings being significantly greater than the occasional theft.

One small aspect of these supermarkets was the reordering principle. While not a completely novel concept, they simply reordered whatever quantity they sold to the customer. It is this aspect that defines modern supermarkets in manufacturing.

The first implementation of these supermarkets was by Taiichi Ohno at Toyota in 1948. Back then there were no supermarkets in Japan, but Ohno had heard about them and seen pictures taken by a classmate. Hence he named his inventories *supermarkets*. Only ten years later, in 1956, did Ohno visit the US, where he made sure to stop by some real retail supermarkets.

24.2 What Are Supermarkets?

Let's look at what defines a supermarket in manufacturing. But before that, we would briefly need to look at pull systems.

24.2.1 What kind of finished goods inventory can I have in a pull system?

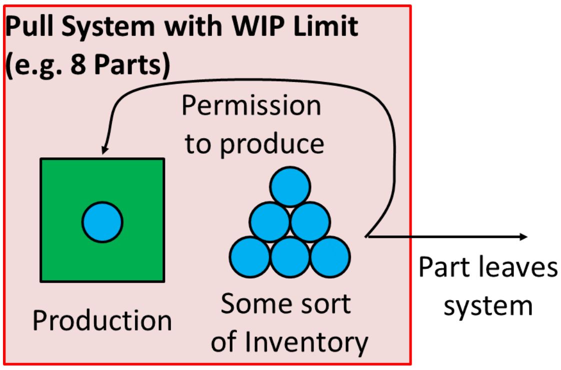


Figure 201: In a pull system, you can only produce if a part leaves the system! (Image Roser)

The difference between push and pull is that a pull system limits the amount of inventory in the system (see my post on the (True) Difference between Push and Pull). In a pull system, completed parts are also counted toward the inventory limit. Hence, regardless of how we store the inventory, there cannot be more parts than what the cap on WIP allows.

Only if a part leaves the system is a signal given to start production of another part. In a kanban system, this signal is the kanban and tells the first process to re-produce exactly this part and quantity. In a CONWIP system, the signal is a CONWIP card and tells the first process to produce whatever order is most urgent.

Regardless of the type of inventory, if the limit on WIP is maintained, it is a pull system. It is not necessary to have a supermarket in order to have a pull system. Even if it is an absolutely unorganized and chaotic inventory, it is a pull system if the cap on WIP is maintained. Only when a part leaves the system (hopefully sold to a customer, but could also be scrapped or broken) is permission to produce another part given.

24.2.2 What are the requirements of a supermarket?

Figure 202: Spices in a supermarket shelf (Image Blink in public domain)

A supermarket is not just any inventory. Instead, a supermarket is an inventory organized according to some rules. The three primary conditions that define a supermarket are:

1) The products are split by part type: In a supermarket, parts are stored in groups according to their part type. Ideally they are stored in physical groups, which allows easy observation of the current state (visual management). Alternatively, they could also be merely digitally arranged within an ERP system, although in this case you would need to dig through the data to see if you are running out of stock.

2) FiFo (First-in-first-out) is maintained: The first part of one type that went in the supermarket is also the first part that is taken out if that part type is required. The FiFo principle ensures that the oldest part is always used first.

3) A part leaving the supermarket gives a signal for re-production or delivery of more goods: The requirement for pull production is that any part leaving the last inventory (the supermarket) gives a signal (e.g., a kanban card) to replenish the part(s). If the supermarket is at the end of a production line, the signal is to produce more. If the supermarket is at the end of a logistic chain, the signal is to order more. Hence, it is a requirement for a functioning supermarket to give exactly such a signal. Only having a part type specific FiFo (the first two conditions) is not a supermarket, but merely a nice inventory.

24.2.3 Are there additional requirements?

Some practitioners also add a minimum limit to the supermarket. This is possible. An inventory of completed goods in the supermarket below this level indicates something is going wrong. The supermarket is in danger of running out of parts. If your supermarket falls below this minimum, you should check if more parts of this type are in the pipeline. If there are no parts in the pipeline that will become available shortly, you may have to act and re-prioritize production to avoid stock-outs.

Please do not confuse a minimum level with an inventory that cannot be touched. Of course, if you need the parts, use them! Just do some troubleshooting to find out why there are not more parts in the supermarket.

As for the minimum quantity, the minimum level should be large enough that you still have time to act if you reach it. On the other hand, it should not be so large that you have lots of false warnings.

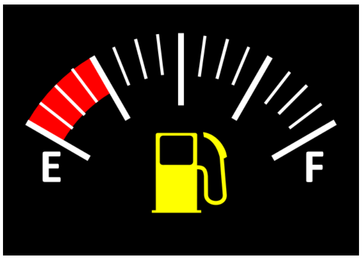


Figure 203: A familiar image (Image Roser)

Take, for example, the fuel gauge in your car. If the warning light goes off when you have only three miles left, then this probably is way too late. Hence, your minimum is too low. On the other hand, if the warning goes off if there is still half a tank of fuel, then it will be more annoying than helpful. In this case, your minimum is too high. Finally, if your fuel gauge is set at 20% but starts to blink five times a day, then **your fuel tank is too small!** Same goes for supermarkets.

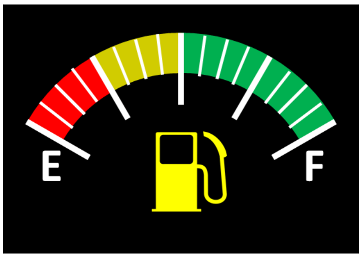


Figure 204: Too much information? (Image Roser)

Some people get really excited with adding a minimum, and want to do more. Sometimes they add also a yellow area to indicate a pre-warning and a green area to indicate everything is fine. Frankly, I would advise against that. It may be a case of too much labeling or too much 5S. Again, take your fuel gauge as an example. Do you really need a yellow and a green area? If you have too many yellow and red colors, it confuses the image and makes people ignore warnings. In any case, don't expect shop floor people to pay attention.

24.3 Summary

Hence a supermarket is an inventory at the end of a pull system that stores items sorted by their part types in a first-in-first-out sequence. Whenever a part leaves the supermarket, a signal for reproduction is sent back to the production system. Hence, in theory supermarkets are rather easy. In practice, however, they are a bit trickier. My next post will give you some additional tips on how to use supermarkets in reality. In the meantime, **go out and organize your industry!**

25 Theory and Practice of Supermarkets – Part 2

Christoph Roser, June 23, 2015, Original at https://www.allaboutlean.com/supermarkets-usage/

Figure 205: How to use supermarkets correctly … (Image ed_davad in public domain)

In my last post, I described how supermarkets work in theory. But while knowing the theory helps, actually creating a working supermarket is much more difficult. Are there situations where supermarkets are not so useful? (Hint: Yes!). And what is needed to have a working supermarket? Let's find out!

25.1 What Are the Advantages of a Supermarket?

Supermarkets have a number of advantages compared to "normal" inventory. Regarding pull systems, they are **designed to give a signal to production if material leaves the system**. However, this can also be implemented in other ways.

If your supermarket is implemented physically and not only through digital sorting in an ERP system, you can get an overview of your system through a quick glance at the supermarket. It is usually easy to see which inventories are high, low, or dangerously low. Hence, a supermarket is often **very helpful for visual management**.

Probably the biggest advantage of a supermarket is its **FiFo principle**. By maintaining FiFo, the oldest parts are sold first. Thus you are less likely to run into problems due to old parts being left over somewhere in the inventory. Additionally, if you have a quality problem, it is often easier to track if the parts come down the system in a FiFo fashion.

25.2 Supermarkets in Practice FAQ

25.2.1 How big should the supermarket be?

The question of the size of the supermarket is a tricky one. Ideally it should be able to fit the material on all kanban cards (i.e., they should be able to hold all of the WIP that is permissible in the system). Hence your supermarket is big enough to fit all your kanban cards. As for the number of kanbans, this is actually a bit more tricky. See my posts on the kanban formula, or the easier approach with kanban estimation.

However, in a normal system, many of the kanban cards would be waiting for processing or currently processed. It is possible but unlikely that your supermarket is completely full. Hence, reserving all the space for inventory that you rarely need may be wasteful. I also have seen supermarkets that were too small for all the inventory but could hold the current inventory most of the time. In the rare cases of a full supermarket, the material was stored in a general area as a sort of overflow storage.

Overall, both are possible. You can size the supermarket to the maximum WIP, or lower. The first one takes up more space. The latter takes up more effort to handle material and maintain

FiFo in case of overflow. It depends on your circumstances what is best. My preference, however, would be to improve the system so you can work with less WIP altogether. ☺.

25.2.2 Where should the supermarket be located?

Figure 206: Let's put it right next to where I make the parts … (Image michaeljung with permission)

The supermarket is managed by the processes that supply the supermarket. To reduce the distance for both the material and the information flow, supermarkets are best located at the end of the supplying process. If you locate the supermarket at the location of the customer, it will be more cumbersome. Hence, supermarkets should be, whenever possible, close to the last process on the supply side.

25.2.3 How about multiple lanes for the same parts?

To maintain FiFo by hand, some handling is needed. Many supermarkets make this easier by using rolling lanes or slides. Parts added at one side roll or slide down the inclined lane toward the other end. Such rolling systems can be used for many different-sized parts, from small plastic boxes to full-sized pallets.

For pallets and items in rolling containers, I have also seen a sort of railings, where the carts or pallets are pushed in on one side. With pallets, the forklift drivers usually push them in using forklifts. Due to the railings, they cannot leave the track but maintain FiFo.

Figure 207: Here, there, elsewhere … (Image S_E with permission)

A small problem is if there is not enough space in one of these lanes for all the parts of this type. Of course you could reduce the inventory through SMED or other improvement methods. Nevertheless, such multiple parallel lanes with the same part type are found frequently in industry. The problem with these is maintaining FiFo. I have seen a number of solutions, including simple upside down plastic flower pots in different colors on the lanes that are to be used, mechanical barriers that allow removal or adding only in one lane, or even fancy digital systems.

Figure 208: Keep your flower pots away from me! (Image Katarzyna Kobiljak in public domain)

I am usually not convinced. Even with such a system, the FiFo can be mixed up if there is very little or very much material. Most of these systems are also an additional burden to shop floor logistics. Especially the upside-down flower pots are a hassle. For example, forklift drivers would have to get out of their vehicle to move these pots.

Believe me, you will not be popular with the forklift drivers. I would be willing to push for it if there is a clear advantage by maintaining FiFo. This could be, for example, with quickly aging products (milk?), frequently updated products, or if FiFo really helps you track problems in your particular case.

However, I have in the past also opted to break FiFo and allowed both adding and removing randomly in whatever lane the operator chooses. The random adding and removing is not quite FiFo, but in these cases there was no system in place to track problems anyway (which was another problem). Additionally, the products did not really age quickly, nor was their design changed frequently. Although if there was a design change, special care had to be taken so as not to mix up the old and the new products. I agree, it is not a perfect solution, but at that time it was in my view the best option.

25.2.4 When to use a supermarket, when a FiFo?

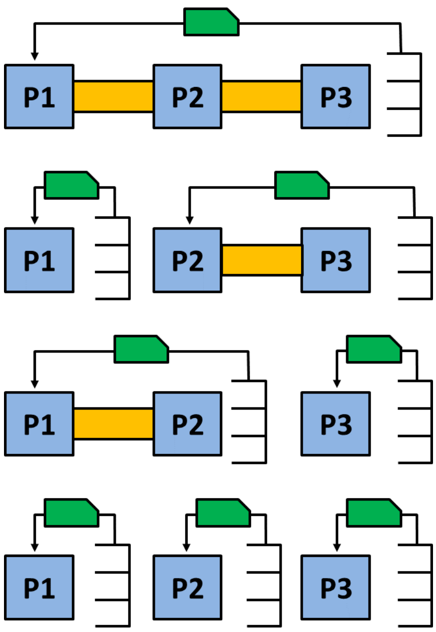


Figure 209: Kanban loop options for three processes (Image Roser)

When transforming a value stream into a pull system, there is always the option between two processes to split a loop in two by adding a supermarket or to keep one loop by adding a FiFo lane. I did some original research on this. For details, read my posts on Ten Rules When to Use a FiFo, When a Supermarket – Introduction and the ten rules.

The rules in brief are: Use a FiFo whenever there is no reason to use a supermarket. The ten possible reasons to use a supermarket are:

1. Supermarket for process-specific lot size differences
2. Supermarket in front of the customer
3. Supermarket if material flow splits up into different directions
4. Supermarket between very different cycle times
5. Supermarket between different shift patterns
6. Supermarket when creating different variants
7. Supermarket for merging of material flows
8. Supermarket for large distance between processes
9. Supermarket in the case of high demands on flexibility and reaction time
10. Supermarket for change of responsibility

25.2.5 When is a supermarket NOT useful?

Figure 210: High quantity, low variety (Image Haragayato under the CC-BY-SA 2.5 license)

Figure 211: Low quantity, high variety (Image Ssawka under the CC-BY-SA 3.0 license)

Supermarkets can help you in managing your inventory at the end of the pull system. However, they also have limitations. Supermarkets are well suited to high-quantity, low-variety products. Since they are used in combination with kanban, there should be a continuous demand for more of the same product. A lane in the supermarket should have only one part type, and that part type is always reproduced after consumption.

However, not all products are high quantity, low variety. Many industries have quite the opposite, a low-quantity, high-variety production. In the extreme, every part may be unique for one individual customer, as, for example, many machine tool makers. In this case it makes no sense to assign an entire lane in the supermarket to this single product, which is produced only once in a lifetime. In fact, the entire kanban system is the wrong approach to these type of products.

Figure 212: CONWIP -go-round with different parts – like roller coaster seats with people (Image Jason Campbell (Brother Jay) under the CC-BY-SA 2.0 license)

Luckily, in this case, CONWIP systems can be used. CONWIP works very similarly to kanban, but CONWIP cards are not assigned to individual products. Rather, they generically permit the production of the next most urgent job in the queue.

Luckily, it is pretty easy to combine hybrid kanban-CONWIP systems by having both types of cards. The kanban cards would go in a supermarket, and the CONWIP cards would go in an ordinary type of inventory.

But do not use supermarkets for high-variety, low-volume products!

25.3 Summary

Initially I wanted to write a brief post on supermarkets, hoping that I get enough material to cover around 1000 words. As it turns out, there is a lot more to supermarkets! These two posts together have more than 2500 words, even with only linking to some more detailed topics like the number of kanban or the decision where to place supermarkets. If you liked this article, you can also check my related posts on Theory and Practice on FiFo Lanes and the Top Five Cases When NOT to Use a FiFo. In any case, I hope this helps you to **go out and organize your industry!**

26 A Eulogy for Little's Law

Christoph Roser, June 30, 2015, Original at https://www.allaboutlean.com/littles-law/

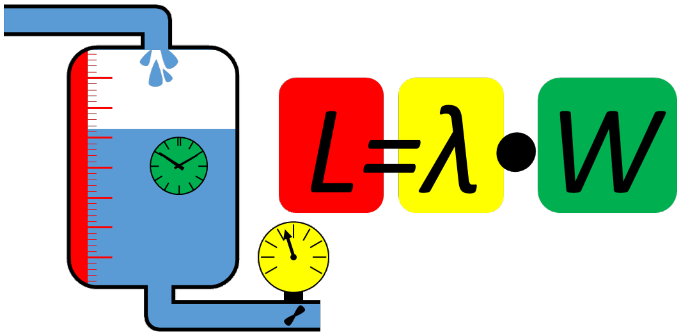


Figure 213: Water Tank Littles Law (Image Roser)

One of the most significant fundamental relations in lean manufacturing is the relation between the inventory, the throughput, and the lead time. The inventory and the throughput are usually easy to measure. The lead time, however, is more difficult. You would need to take the time when a part enters the system and then take the time again when a part leaves the system. Luckily, **the lead time can easily and accurately be calculated using Little's Law**, one of the most fundamental laws in lean manufacturing (and also many other places).

Little's Law was first published around 1954. It is named after John Little (an MIT professor and not one of Robin Hood's merry men ☺). He did not invent the law, but he was the first to mathematically prove the universal validity of it in 1961.

26.1 The Variables

First, let's first explain the variables. Throughout this post, I will use a supermarket checkout as an example, assuming that all of you have at one time or another waited in line at the checkout. Hence, our example system is the checkout system, defined as the system including all customers waiting in line or being processed (but not still shopping for goods).

26.1.1 Inventory

Figure 214: Little's Law applies here! (Image Robert Kneschke with permission)

Inventory is simply the number of parts in the observed system. You could also call it WIP (Work in Progress). For our supermarket checkout, the inventory would be the number of people waiting in line, including the customer currently being served (but not the cashier – that would be the process).

The inventory is usually quite easy to measure. You simply count the number of parts in the system, either by hand or by looking up your ERP data. You could use the current inventory if you are interested in a current state of the system. You could also use the average inventory over a longer period if you want to analyze the average behavior of the system.

26.1.2 Throughput

The throughput is the average number of parts completed in a given time. Taking again the example of a supermarket, it could be measured in customers per hour.

The throughput is also rather easy to measure. You check how many parts you have produced during a period of time. Dividing the number of parts by the total time gives you the throughput.

As for the throughput, again there are different ways you could measure it. You could look at a longer period, including weekends and off-shift times (i.e., how many parts did you produce during the month?). Alternatively you could only observe during actual working hours (i.e., how many parts did you produce during an 8-hour shift?). Both are possible. Depending on which one you use, you will get the throughput time in working hours or total hours including off-time.

26.1.3 Lead Time

Figure 215: Time on Hand (Image geralt in public domain)

The lead time is the time a part takes to pass completely through the system (i.e., it is the time between entering and leaving the process). In the example of supermarket checkouts, it is the time from when you start to wait in line until you pick up your goods and leave.

The lead time is difficult to measure directly. In a supermarket, you could have everyone measure their own waiting time. For physical parts, however, someone would have to measure it. In reality, this is quite impractical.

The lead time, however, is an important value in manufacturing. A longer lead time means that you will need more time to implement changes.

26.2 Little's Law

26.2.1 The Law

Little's Law is actually quite simple. 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 very simple relation as shown below.

$$L = \lambda \cdot W$$

However, for sake of clarity I prefer to write it out in full. Hence:

$$Inventory = Throughput \cdot Lead\ Time$$

Hence, to determine the lead time you calculate:

$$Lead\ Time = \frac{Inventory}{Throughput}$$

And finally, to determine the throughput you calculate:

$$Throughput = \frac{Inventory}{Lead\ Time}$$

26.2.2 The Underlying Assumptions

Often in academia, you can find very boastful research results – except if you read the assumptions closely, you find out that it applies only to a very special and highly unrealistic situation. Quite frequently, these limitations make the research results unusable in practice.

Little's Law, however, has only two major assumptions. First, **you need to have a stable system without major changes**. In other words, the three variables involved (inventory, throughput, and lead time) do not change significantly while being observed. Assume again you have a supermarket with one cashier. Using Little's Law, you calculate the estimated waiting time based on the speed of the cashier and the number of people in the queue. However, if a second checkout line is opened, the speed of the system doubles. Hence, your calculation is no longer valid, since the system speed has doubled. Similarly, if the queue gets longer because more people arrive than leave, then Little's Law no longer gives the average waiting time. Therefore the arrival and the departure rates have to be similar.

Second, **the units used for the inventory, throughput, and lead time have to be consistent.** Measuring the throughput in batches per hour, the inventory in individual items, and the lead time in days will mess your calculations up, unless you convert the values into consistent units.

In practice, however, both assumptions are very reasonable assumptions. First of all, most manufacturing systems do not change drastically within a short time, even if you merely update the values for the formula and get the new numbers. Regarding the units, basic knowledge of math and common sense can easily avoid this problem. Therefore, **Little's Law has an almost universal validity and is highly applicable in practice!**

26.2.3 What Is Not Relevant

The beauty of Little's Law are all the factors that do not matter. This universality makes Little's Law extremely practical in everyday shop floor operations.

- **Random distribution of the arrival and the departure speeds (the throughput)**: Regardless if you have normally distributed variables, exponentially distributed variables, or any other random distribution, Little's Law holds true.
- **Sequence of the material processing**: No matter if you have FiFo (First in First out), LiFo (Last in First out), or any other or even a random sequence in your material flow, Little's Law is valid to calculate the mean values! Of course, depending on your sequence, the fluctuation in throughput time may be much more in LiFo than in FiFo, but the mean is correct.
- **Size of the observed loop**: Again, it does not matter if you look at one machine, the complete manufacturing line, the entire plant, or even your entire logistics network. Little's Law is valid!
- **Everything else you can think of**: As long as the two conditions above hold true, Little's Law is valid!

26.2.4 Some Example Calculations

Figure 216: Calculate the waiting time (Image ed_davad in public domain)

Let's do some sample calculations. Assume a supermarket checkout line. How long does a customer have to **wait at the supermarket checkout** for the following example:

- L: 5 customers waiting in line
- λ: 2 customers leave the checkout per minute

$$W = \frac{5 customers}{2 \frac{customers}{minute}} = 2{,}5\ minutes$$

Hence a customer waits an average 2.5 minutes in line. Let's expand this for the entire supermarket. **How long does the average customer spend in the supermarket?** Let's assume:

- L: 30 customers in the supermarket
- λ: 2 customers leave the checkout per minute

$$W = \frac{30 customers}{2 \frac{customers}{minute}} = 15\ minutes$$

Hence the average customer spends 15 minutes in the supermarket, of which he spends 12.5 minutes shopping and 2.5 minutes at the checkout. If we observe the people more closely, we would also see that 25 of them are shopping and 5 are waiting at the checkout.

Figure 217: Reach of a warehouse (Image Axisadman under the CC-BY-SA 3.0 license)

Let's do a manufacturing example. What is the average duration a part spends in the finished goods warehouse (i.e., what is our reach on finished goods)?

- L: 10,000 pieces are in the warehouse
- λ: 15,000 pieces are sold per month

$$W = \frac{10\,000\,pieces}{15\,000\,\frac{pieces}{month}} = 0.667\,months$$

Hence the average piece spends two-thirds of a month in the warehouse. Let's look at the **lead time of the entire material flow**:

- L: 15,000 units are in the system (of which 10,000 are in the warehouse, and 5,000 in various stages of completion)
- λ: 15,000 pieces are sold per month

$$W = \frac{15\,000\,pieces}{15\,000\,\frac{pieces}{month}} = 1\,months$$

Hence a part takes roughly 1 month to pass through the entire system. Now let's assume we have a kanban system. **How long takes a kanban to complete the loop?** Assume one kanban represents 100 pieces, and there are in average 50 kanbans waiting for production.

- L: 20,000 finished and semi-completed units and planned units in the form of kanban are in the system (of which 10,000 units or 100 kanban with 100 parts each are in the warehouse, 5,000 units or 50 kanban are in various stages of completion, and 5,000 are represented by 50 kanbans waiting for production)
- λ: 15,000 pieces are sold per month, or the equivalent of 150 kanban with 100 pieces each

$$W = \frac{20\,000\,pieces}{15\,000\,\frac{pieces}{month}} = \frac{200\,Kanban}{150\,\frac{Kanban}{month}} = 1.33\,months$$

Hence it takes 1.33 months before a kanban completes an entire loop.

Figure 218: 160 years in average … (Image Charles Dawley, Daniel Case under the CC-BY 2.0 license)

You can also use Little's Law for continuous processing as, for example, chemicals. Let's calculate **how long water stays in America's largest lake, Lake Superior, before it leaves the lake**.

L: 12,087.73 cubic kilometer (km^3)

λ: Water outflow is adjusted and varies throughout the season, but let's assume it is 2,400 cubic meters per second (m^3/s), which is 75.68 km^3 per year.

$$W = \frac{12\,087.73\,km^3}{75.68\,\frac{km^3}{year}} = 159.7 \text{ years}$$

Hence water stays in Lake Superior for almost 160 years before it flows out. More than half of the water in the lake was already there when Abraham Lincoln was President 🙂.

26.3 Why It Is Relevant

Little's Law is almost always valid and very easy to calculate. It also shows the relation of the two factors influencing the lead time: inventory and throughput. The graph below shows this relation in relative terms.

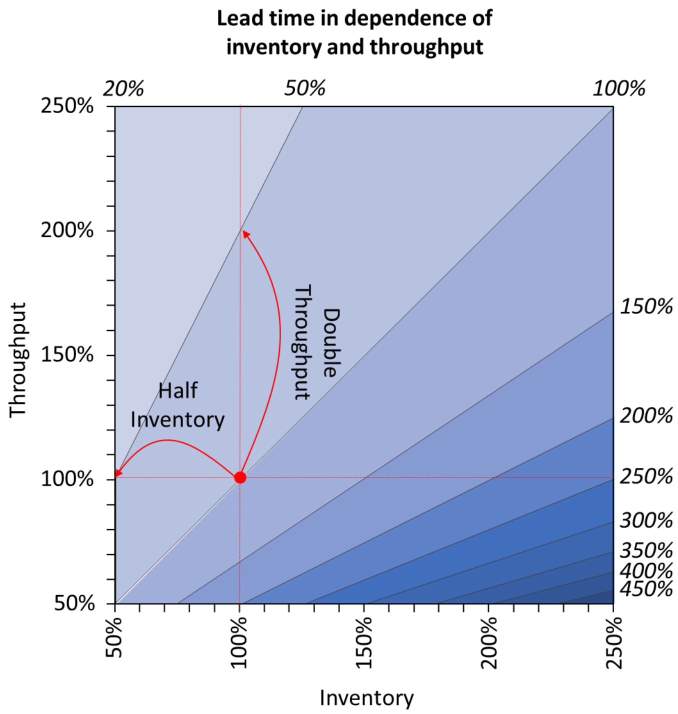


Figure 219: Littles Law Relations (Image Roser)

Hence, if you want to reduce your lead time by half, you would have to either double your throughput or halve your inventory. Both would achieve the same results. However, doubling the number of parts produced in a given time is probably rather difficult and expensive in practice. Halving the inventory is usually much easier. Besides, if you halve your inventory, you may even get money back by temporarily selling more than you purchase or produce.

Therefore, Little's Law is another mathematical justification for the push in lean production to reduce inventory, and the advantage of pull production and its fixed limit on WIP. But please, keep enough inventory for your system to work smoothly, or it will be more expensive than before.

I hope this article was interesting for you and helps you with your daily work of improving your system. Now, go out, calculate your lead time, and **organize your industry!**

PS: This is my 100th post on AllAboutLean.com. Thanks for reading, following, and commenting 🙂.

27 230 Years of Interchangeable Parts – A Brief History

Christoph Roser, July 08, 2015, Original at https://www.allaboutlean.com/230-years-interchangeability/

Figure 220: It fits! (Image optmedia with permission)

Today 230 years ago on July 8, 1785, Honoré Blanc demonstrated the first large scale interchangeability of complex mechanical parts in the courtyard of the Château de Vincennes by disassembling musket locks, mixing the parts, and assembling them again. While it took another 150 years for the idea to take hold firmly in industry, it all started here with 50 muskets. Time for a look back in history.

27.1 The Benefit of Interchangeable Parts

The interchangeability of parts is nowadays taken for granted. If, for example, you buy a M10 bolt in America, fly to China, and buy a M10 nut, they will fit.

This is amazing!

Imagine for a second if they would not fit. Imagine not having worldwide standards for screws. Or even a standard within your own company. While for Screws different standards exist, most of the world nowadays uses the metric screw standard.

Figure 221: Don't mix 'em up! Threads Metric M12, M12x1.25, M12x1.5, 1/2' UNC, 1/2' UNF, 1/2' BSW (Image Roser)

In your assembly line, you expect that each part delivered to the line fits into any of the products. For most of history, however, this was not true. Even around 1900, the most important tool in assembly of metal parts was a file. Almost every part that was delivered to the assembly line needed to be filed down in some place to make it fit.

Figure 222: If it doesn't fit … (Image Dake under the CC-BY-SA 3.0 license)

Now consider modern automotive manufacturing. Imagine the unlikely case that a piston would not fit in the cylinder. 😮 Imagine that person having a file available on the assembly line. 😮 Now imagine someone filing the piston down to make them fit. 😮😮😮

I am pretty sure most of the employees of that company – including the CEO – would know that piston maker's name … or more likely remember his name, since he would probably never again set foot in that company. Yet that was the standard up to 100 years ago.

27.2 Interchangeability Before Le Blanc

The idea and the benefit of interchangeability was realized long before Honoré Blanc. However, often these were either very loose tolerances, very simple parts, or expensive samples. For example, already in the Arsenal of Venice, wooden parts for ships as, for example, benches, were pre-cut, so they could be assembled with only minor adjustments.

Swedish inventor Christopher Polhem reportedly achieved interchangeability in his workshop for clocks in 1720, but it definitely did not spread beyond his workshops.

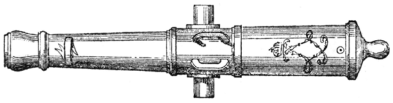


Figure 223: Gribeauval standard 16-pound cannon (Image unknown author in public domain)

For metal parts with tighter tolerances, interchangeability was created only for very simple parts. A pioneer here was Lieutenant General Jean-Baptiste Gribeauval (1715–1789). French artillery and artillery carriages were already standardized to five classes of cannons: 4, 8, 12, 16, and 24 pounders. More for aesthetics than technical reason, Gribeauval continued this standardization. By 1780 this quest for aesthetic uniformity had a surprise side effect – wooden parts for the carriages no longer had to be fitted, but were interchangeable.

Figure 224: Old cannon ball gauge (Image Roser)

Gribeauval also pushed for standards in the manufacture of the cannons themselves. Go gauges to ensure that a cannon ball fits in the barrel have been used since medieval times.

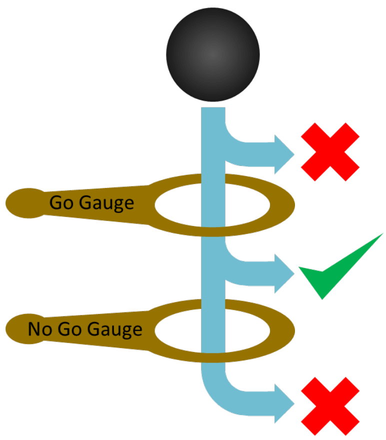


Figure 225: Go/no go Gauge (Image Roser)

Griebeauval also added another no-go gauge to check if the ball was too small. If a cannon ball passed through the go gauge, it was at least not too big. However, if it also passed through the no-go gauge, it was too small. Only balls that passed through the go but not the no-go gauge were within acceptable tolerance limits. They also added additional requirements to prevent egg-shaped balls from passing through a series of gauges.

Using a similar system for the cannons, Gribeauval was able to have both standard caliber balls and cannons, resulting in probably the most advanced artillery of its time. Nevertheless, round holes and round balls are very simple geometries, and hence easy to check.

Musket locks, however, have a much more tricky geometry. Especially a small piece inside the lock called the tumbler (necessary to fire the gun) had a complex shape and tight tolerances. The first one to demonstrate interchangeability for musket locks was Guillaume Deschamps in 1723. However, his locks were ridiculously expensive, and for one of his interchangeable locks you could buy seven normal ones. Hence he only produced a few hundred guns in total.

27.3 Honoré Blanc

Figure 226: French Musket 1800 (Image Antique Military Rifles under the CC-BY-SA 2.0 license)

Honoré Blanc (1736–1801) was a French gunsmith, and from 1763, he was in charge of quality control for the French Army. The French Army tried to lower costs and to increase quality by putting pressure on French gunsmiths. The gunsmiths, in turn, preferred not to work for such a troublesome customer and rather supplied weapons to the American Revolution soldiers for a higher profit and less fuzz.

An attempt by the army to force gunsmiths to sell their product to them was unsuccessful, and the army was in serious danger of running out of weapons. Out of this problem, the idea was born to take control of the value chain by introducing interchangeable parts.

Yup, it had nothing to do with ease of assembly, or the possibility of in-field repairs while under combat, but only with replacing annoying headstrong craftsmen with more docile unskilled labor.

Figure 227: Château de Vincennes: First proof of interchangeability in 1785 (Image Roser)

Honoré Blanc developed a multitude of tools and gauges to ensure accuracy, hardened the parts slowly in horse manure to avoid warping, and eventually succeeded. **Today 230 years ago on July 8, 1785 in Château de Vincennes, he disassembled 50 locks, picked pieces for 25 locks**

at random, and – to the amazement of the assembled officials and representatives – assembled them again.

Duly impressed, the French government had him set up a workshop. Since Le Blanc was now rather unpopular with his fellow gunsmiths, this workshop was located (for protection) in the dungeons of the Château de Vincennes where he also held his demonstration. This dungeon was previously a prison with such famous prisoners as Diderot, de Mirabeau, Jean Henri Latude, and the infamous Marquis de Sade.

Nevertheless, even the strong walls of Château de Vincennes did not protect his workshop from the French Revolution, and his workshop was destroyed. Even worse, his supporter Gribeauval died in 1789. Determined to continue, Le Blanc set up his own workshop and produced large quantities of interchangeable gun locks at only 10% additional cost before he died in 1801.

However, after his death a political posse formed between proponents and opponents with documents and demonstrations against counter-documents and counter-demonstrations about the interchangeability of parts. Eventually the opponents won, the production of interchangeable parts stopped, and France lost the knowledge of interchangeable parts – and even forgot that they ever knew they had it.

27.4 Springfield and Harpers Ferry Armory

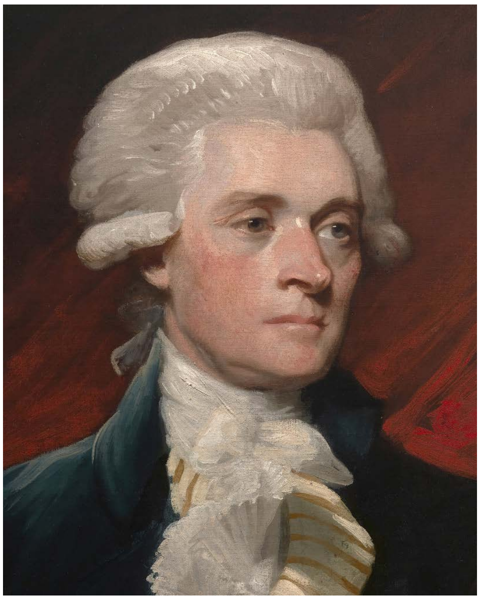


Figure 228: Thomas Jefferson while in France (Image Mather Brown in public domain)

By coincidence, however, a new US ambassador to France Thomas Jefferson (better known nowadays as the third president of the USA) was able to witness the demonstration by Le Blanc in 1785. Jefferson brought the idea and samples back to the USA, and promoted interchangeability there.

Eventually, the young nation established two armories, one in Springfield, Massachusetts, and one in Harpers Ferry, West Virginia. One of their goals, besides having a reliable supply of weapons, was to establish interchangeability of parts.

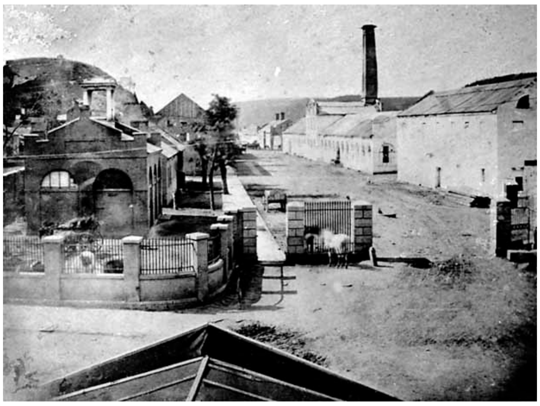


Figure 229: Harper's Ferry Armory 1862 (Image unknown author in public domain)

The two armories differed enormously. While Springfield pushed for organization and structure, Harpers Ferry was a hotbed of corruption and waste. Yet, it was in Harpers Ferry that the US produced their first interchangeable locks. Gunmaker, inventor, and proponent of interchangeability John Hancock Hall (1781–1841) was sent to Harpers Ferry to set up a workshop, independent from the rest of the armory. Hence, Hall not only had to solve the myriad of technical details of interchangeability, but also fight against the Harpers Ferry superintendent, who tried to hinder and hamper this outsider whenever he could. Hall had constant problems getting men, material, machines, or even a workshop large enough to set them all up.

Hall realized that interchangeability was all about precision. While conventional gun lock parts had a precision of ±0.2 mm, he needed ±0.02 mm for interchangeability. He achieved this interchangeability with the help of gauges, using a total of 63 gauges to verify the tolerances of the components of a lock. He also invented new measurement techniques, and created new and sturdier machines to reduce vibration. He also improved the new technology of milling. By 1824 the parts for his locks were completely interchangeable.

Figure 230: M1819 Hall rifle (Image Antique Military Rifles under the CC-BY-SA 2.0 license)

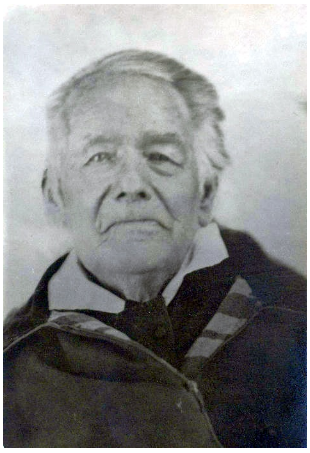


Figure 231: Simeon North (Image unknown author in public domain)

The next step was interchangeability across different workshops. This he achieved together with fellow gunsmith Simeon North (whose 250th anniversary of his birth, July 13, 1765, is coming up in five days). It took some time, but by 1834 North's and Hall's lock parts were completely interchangeable. Eventually, Springfield Armory also achieved interchangeability, but only in 1849.

By the way, you may have heard about interchangeability being invented by Eli Whitney (1765–1825). However, he was much better with words than with metal. Constantly promising to deliver 10,000 guns, he eventually "*demonstrated*" interchangeability to President John Adams and Vice President Thomas Jefferson in 1801.

Figure 232: Eli Whitney, ~~gun smith~~ word smith (Image Samuel Morse in public domain)

However, in this presentation of "*interchangeability,*" he was very careful not to disassemble the complex locks. Instead, he only took the locks out of the wooden gun stock and placed them in another wooden gun stock. With no moving parts, this had a much looser tolerance. Additionally, Whitney used only ten carefully selected gun stocks that had been specially adjusted to fit all ten locks. Detailed analysis of existing Whitney muskets definitely prove that there was no interchangeability of the locks themselves.Hence, the entire demonstration was staged and Whitney "duped government authorities" (Smith, M.R 1980) about his lack of interchangeability.

He also was 10 years late in delivering his 10,000 guns. And, while I am at it, he did not invent the milling machine either. He did invent a small improvement to the cotton gin, although even this is contested (see below for a selection of my sources).

27.5 Spreading the Idea

Figure 233: Singer sewing machine (Image Vincent de Groot under the CC-BY-SA 4.0 license)

In any case, the idea of interchangeability was now firmly set in American gun manufacturing. Additionally, hundreds of machinists and technicians working for the armories eventually moved to other industries and brought their knowledge with them. Many of the new complex products benefited from the experience of the armories, including typewriters, sewing machines, bicycles, and eventually the automobile.

However, even then it took time. For example, famous sewing machine maker Singer did not achieve interchangeability until around 1900. Similarly, as late as 1900 most automobile parts were still not interchangeable.

Figure 234: Cadillac Model K 1907 (Image Thomas Quine under the CC-BY 2.0 license)

A famous demonstration was with three Cadillac Model K's in 1907. These new vehicles were tested on a racetrack and then completely disassembled. The many high-precision parts were then mixed, and three vehicles were assembled again. They not only successfully completed another 500-mile test, but one of the vehicles even won a subsequent 2000-mile reliability test. What nowadays would be standard in interchangeability was in 1907 an outstanding achievement.

Hence, the idea of interchangeability that we take for granted nowadays was a long and winding road. Many inventors and supporters were needed to establish the idea and to bring it into the market. Most of them were idealists, and Le Blanc, Hall, and North all died poor or without significant wealth. Nevertheless, without their contributions, our modern world would look quite different. Hence, remember them when you **go out and organize your industry!**

28 Visualize Your System – Overview of Diagrams in Manufacturing

Christoph Roser, July 14, 2015, Original at https://www.allaboutlean.com/manufacturing-system-diagrams/

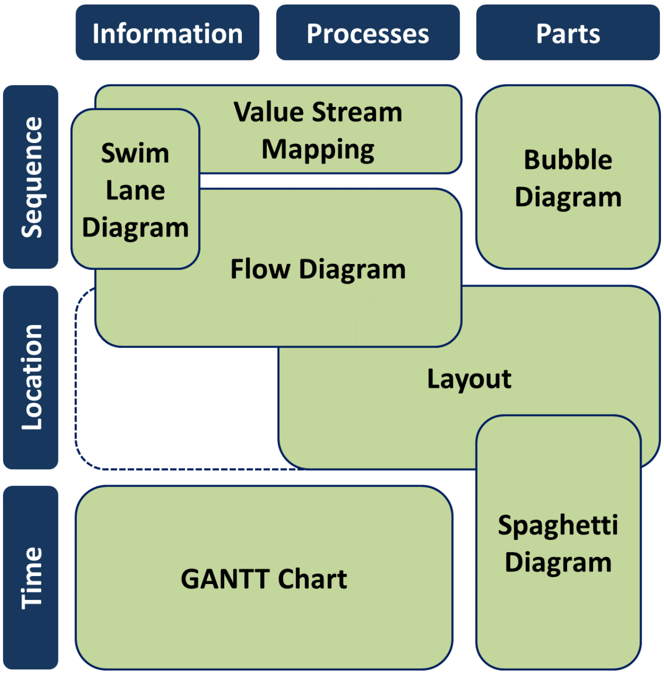


Figure 235: Manufacturing Structure Visualization Methods (Image Roser)

Organizing your manufacturing system is one of the keys to success in manufacturing. There are different tools available, although I have the feeling they are often mashed together or confused. **Time for a structured overview of the different manufacturing diagrams available**, with recommendations. The following post does not give a full explanation on how these visualizations work. Instead, I want to give you a summary of what is out there, so you can pick the right tool to improve your system.

28.1 Different Visualizations

There is a multitude of different ways to visualize your value stream. The well-known value stream mapping is only one of many ways to structure it. Here I will give an overview of some of the options you have. Most of them have a structure according to either

- Time
- Physical location
- Sequence

or any combination thereof. Depending on what you want to achieve, some may be better than others. There is no single answer; it all depends on what problem you want to solve. All of these should be done only if they help you solve your problem. I have seen too many examples where it is done simply for the sake of doing it (in this case, don't expect any improvement or benefit from your effort – except maybe for your career if your boss wants you to do it just because ☺).

28.1.1 Layout

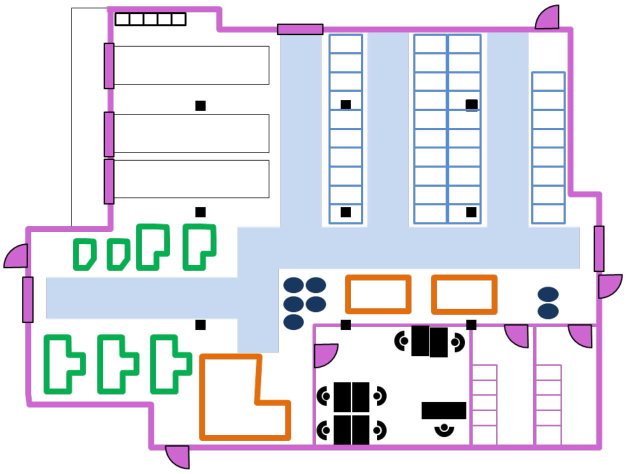


Figure 236: Plant Layout (Image Roser)

Probably the oldest and easiest way to display the structure of your value stream is a physical layout. It clearly shows which process is located where.

However, it (usually) does not show how the processes are related to each other. Nor does it show any time-wise organization. Pretty much all plants have a layout. However, if you design a value stream, the layout should be the last thing done. You need to get other structures completed before you can think about how to fit everything on your existing or future shop floor.

28.1.2 Bubble Diagram

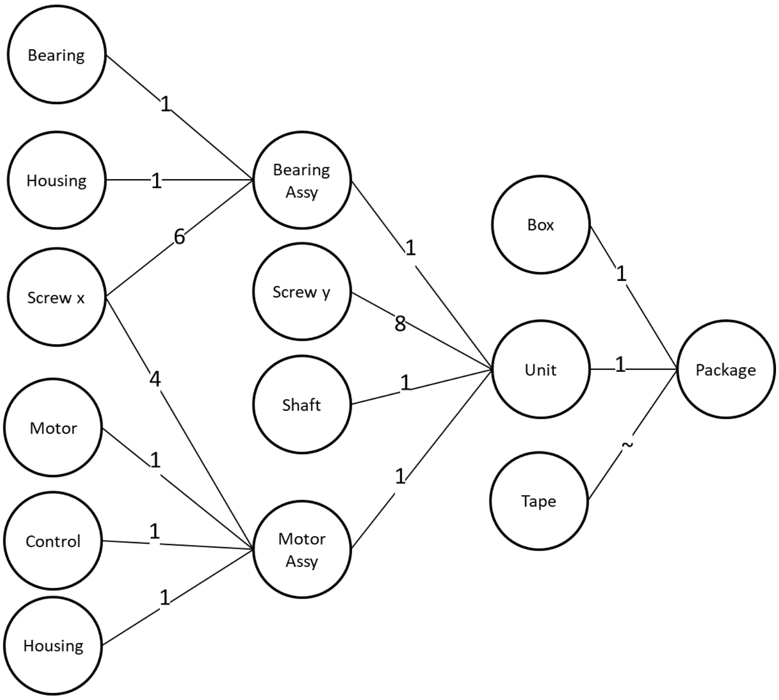


Figure 237: Bubble Diagram (Image Roser)

Another way you can structure your material flow is a bubble diagram. It shows you the sequence of parts needed to create your product. You simply make a bubble for each part and connect them in the order they are assembled or processed.

To make a bubble diagram, you usually start with all your parts for one product. For example, you could take all your part numbers in the different bill of materials related to one product. Then you arrange these parts and connect them with lines. Usually, you start at the left with the purchased components and work your way to the right. In most cases the parts merge, but depending on your product they may also split. Each part should exist only as a single bubble. If you need the part for more than one other component, you add more than one outgoing line to the bubble.

Importantly, a bubble diagram **does not show processes**, but only parts. If you are interested in the processes, a flow diagram or a value stream map may be more helpful. For more details see my post [Bubble Diagrams to Visualize Material Flow]

28.1.3 Flow Diagram

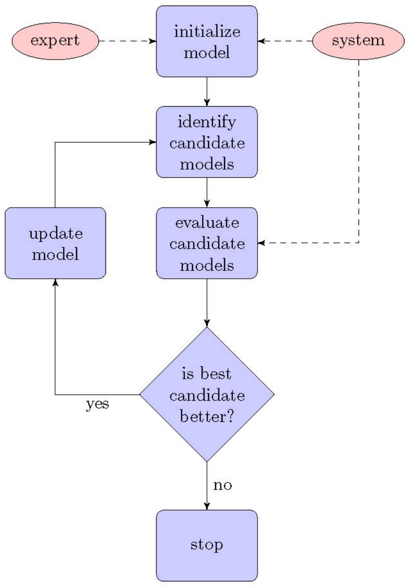


Figure 238: Flow Diagram (Image Kjell under the CC-BY 2.5 license)

Flow diagrams have also been around for quite some time. They show the sequence of a flow of information and items. A flow chart can show only a **sequence of events or processes**. In this case, the flow usually starts at the top and flows toward the bottom. However, it is also possible to group related processes in the flow diagram.

Alternatively, the flow can also be **represented on a layout** by connecting different locations on the layout. In this case, the flow starts and ends wherever it physically starts or ends in the system.

Often, a nomenclature is used where, for example, round shapes indicate start and end points, square boxes indicate actions, diamond shaped boxes indicate decisions, etc. Six Sigma uses flow diagrams more frequently and calls them process maps.

When I am doing lean, I generally do not use flow diagrams very often. For most problems, I find a value stream map more useful. However, a value stream map is basically nothing more than a flow diagram with different symbols.

28.1.4 Value Stream Mapping

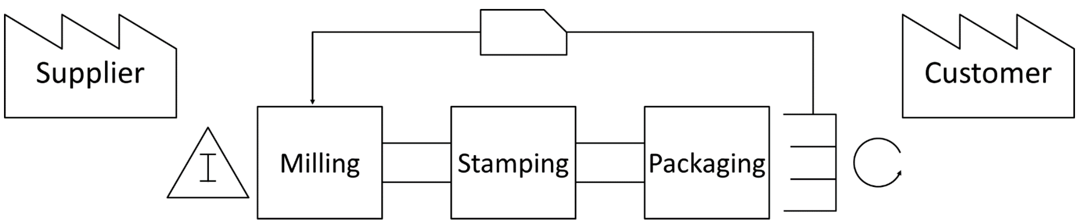


Figure 239: Value Stream Map (Image Roser)

A value stream map (VSM) is a structured display of the material and information flow. Usually the material flows from left to right, and the information flows in the opposite direction. The symbols most frequently used originate from the bestselling book Learning to See by Rother and Shook. They can help you understand the current state of the manufacturing system and how to design the future state.

VSMs feature very prominently in Western-style lean manufacturing. While I use this tool quite frequently, I often see it overblown and used without purpose. Many companies spend much time and effort in perfecting their current and future state value stream maps, to the point that they have no time left for actual improvement. I describe value stream mapping in more detail in my posts When to Do Value Stream Maps (and When Not!), Overview of Value Stream Mapping Symbols, Basics of Value Stream Maps, and Practical Tips for Value Stream Mapping.

28.1.5 Spaghetti Diagrams

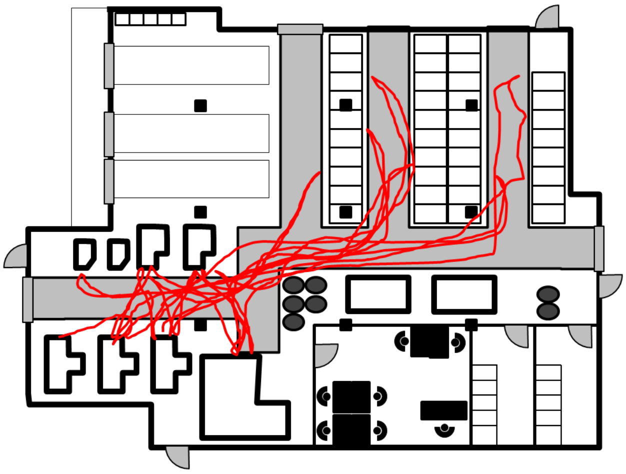


Figure 240: Spaghetti Diagram (Image Roser)

Spaghetti diagrams are a representation of the distance a person or part travels on the shop floor. You simply put a pen on a layout, and as you follow a part or person around, you let the pen wander on the layout to mark where the part or person went. The result usually looks like a bowl of spaghetti, hence the name.

For a later analysis, you estimate the total distance traveled and then see how you can reduce this distance. For more read my post on All About Spaghetti Diagrams.

28.1.6 Swim Lane Diagram

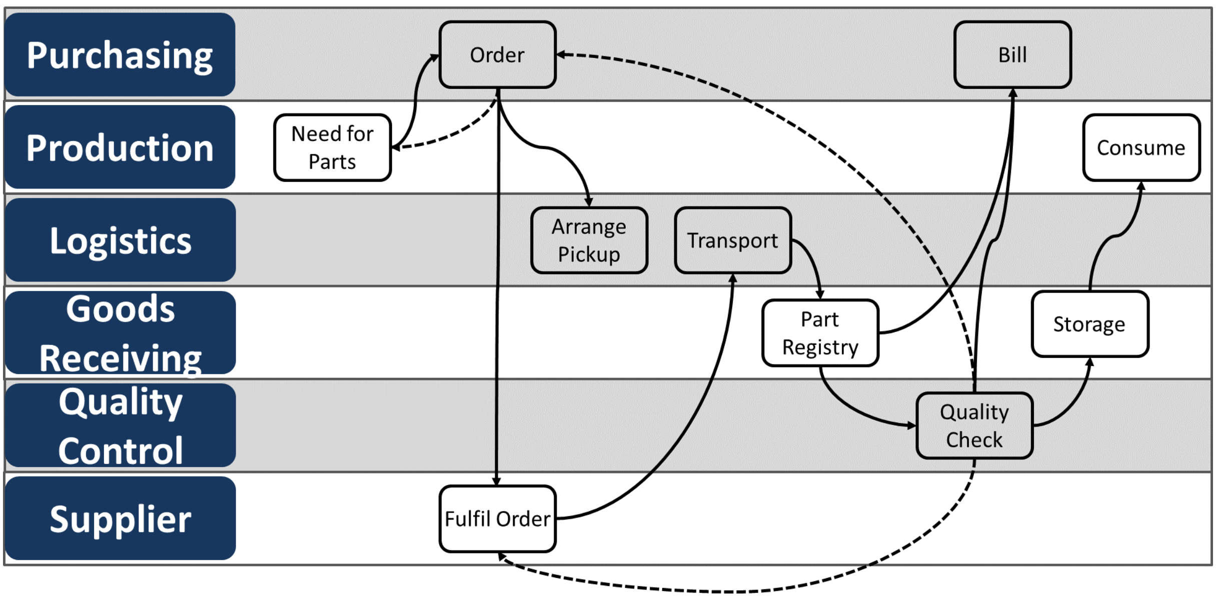


Figure 241: Swim Lane Diagram (Image Roser)

For indirect or administrative processes, a value stream map is ill suited to show the information (and sometimes material) flow. Usually, this flow is way too unstructured, iterative, parallel, and confusing.

To represent these flows, a swim lane diagram can be used. The name stems from the use of lanes similar to the lanes in a swimming pool. The name is by no means universally accepted, and this is also called “process mapping.” Naturally, it also has a Japanese name. If you want to impress others, you can call it *makigami*, although this simply means “a roll of paper” in Japanese.

Each lane represents one department or person or office. From left to right (less common also top to bottom) the process unfolds. Each action is written in the lane of the corresponding department. Hence, different from value stream mapping, you can quickly see how the information or parts flow between different departments. Also different from value stream mapping is that the swim lane diagram allows loops, splits, and recursions. These happen, for example, if two departments work in parallel, or if due to problems or uncertainties the job is given back to a previous step. Most real-world swim lanes have a lot of iterations in them. For more read my post on [All About Swim Lane Diagrams]().

28.1.7 Gantt Charts

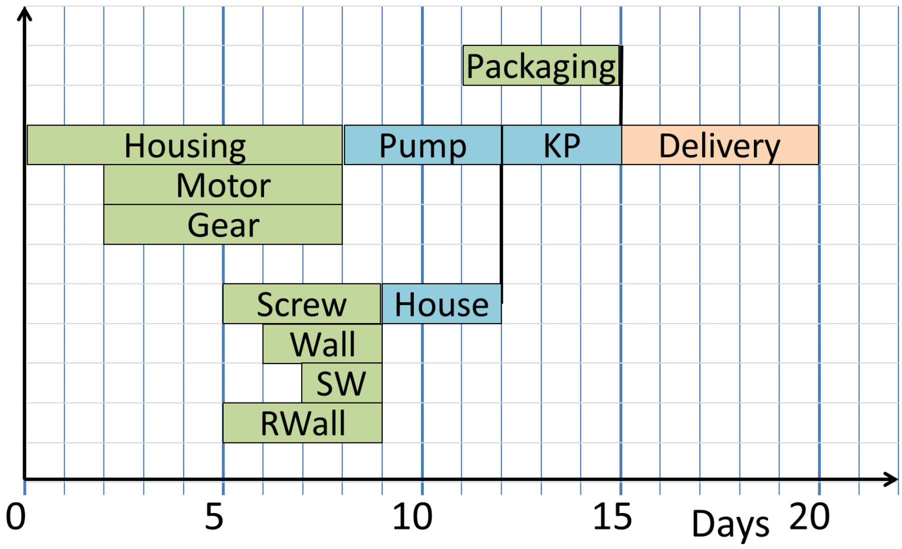


Figure 242: GANTT chart (Image Roser)

Gantt charts are named after Henry Gantt, a protégé of [Taylor](). However, they were also developed before by Karol Adamiecki. They were THE hop topic and a popular buzzword in 1910, although nowadays they no longer impress others ☺. Nevertheless, they can still be enormously useful.

Gantt charts show the relations of a schedule. Each action is added as a bar on a timeline. The arrangement of the bars show which processes depend on what other preceding processes, parts, or information. It is easy to find the critical path that you have to improve in order for the entire system to improve.

An expansion of the Gantt chart is PERT, which stands for either *Program Evaluation and Review* Technique or *Project Evaluation and Review Technique*, although it is more for visualization of project management than shop floor manufacturing.

28.2 Is That All?

Oh no! There is more out there. However, most of the additional approaches are variations of the above. They may have a different name, different symbols or layouts, or come as an (expensive) software package that promises to solve all your problems (but make sure you read the fine print!).

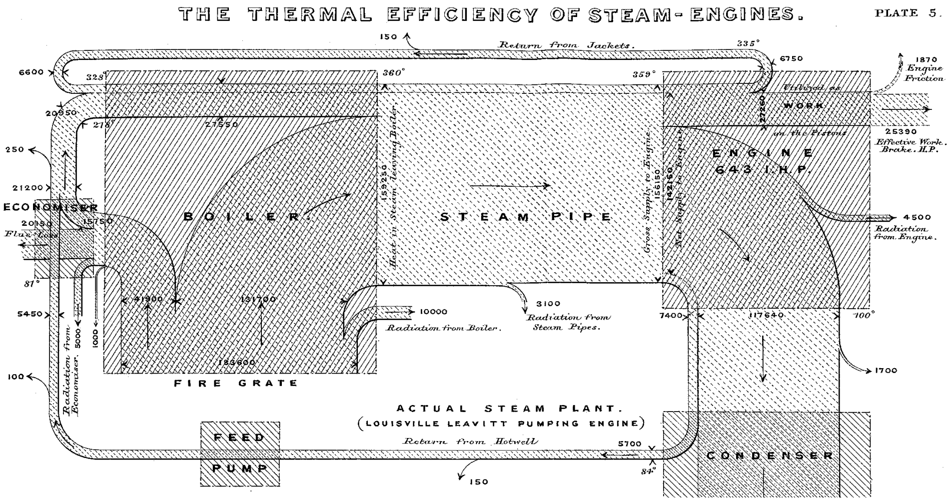


Figure 243: The work of Matthew Henry Phineas Riall Sankey (Image M. H. Sankey in public domain)

Another one may be Sankey diagrams, a type of flow diagram where the width of the connecting arrows represent the quantity flowing through (material, cost, energy). These arrows can merge into larger ones or split into smaller ones. Due to the high demand on graphic accuracy it is difficult to make by hand and usually requires software support. Named after an Irish engineer with the impressive name of Matthew Henry Phineas Riall Sankey (1853-1926), who used it to show the energy flow in a steam engine. However, it was used already earlier, e.g. by French engineer Charles Minard in 1812 showing the flow of troops of Napoleon in Russia.

There are probably even more diagrams that I don’t know (yet). For me, the above is a useful set for most manufacturing related visualizations. If I missed an important visualization, let me know.

28.3 When to Use What?

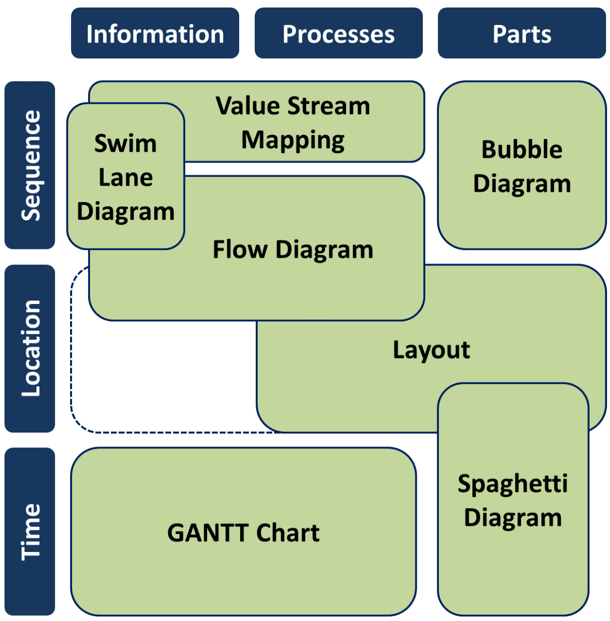


Figure 244: Different Visualizations for different purposes (Image Roser)

Most of these visualizations are very useful to show a certain aspect of the system. It depends if you are interested in the time, location or sequence of the information, processes, or parts to determine which approach will be most suitable.

Most of these visualizations can be done for either the current state or the future state, or even an intermediate state if necessary. They can be done for a detail of some processes (micro perspective), for a big overview (macro perspective), or anything in between, depending on your needs. **Please don't try to do a detailed visualization for the big picture, as you will get nowhere!**. They can be done by hand (usually my preferred method) or by computer (probably most useful for Gantt charts and finalizing layouts).

To get an overview of a new line, I usually start with a bubble diagram. As a next step, I detail the combined information and material flow using a value stream map. Finally, a layout tells me what to put where. Spaghetti diagrams are then for optimizing existing value streams.

However, these are only a way to visualize the current or future state. These are NOT methods to determine how the future state should look. They help you to see and understand, but not to decide on what to do. For this, you need more tools out of the lean toolbox, and most importantly you need common sense.

For each of these, you can probably find people on the web telling you exactly the one single correct way to do it. Don't believe them. Having used all of the above methods, I prefer to adapt the methods to match my problem. For example, in value stream mapping I sometimes hear that you must add the data before you can do anything with it. However, most of my value stream maps have little data in them initially. Only if I need the data do I actually invest the effort. It all depends on the problem you want to solve. In the next few posts, I will go into more detail on some of these methods. Until then, go out and **organize your industry!**

P.S. A Russian translation by Valery can be found here: Визуализируйте вашу систему — Обзор используемых в производстве диаграмм

29 Bubble Diagrams to Visualize Material Flow

Christoph Roser, July 23, 2015, Original at
https://www.allaboutlean.com/bubble-diagrams/

Figure 245: Bubble diagrams are easy (Image travnikovstudio with permission)

One of the many different ways to visualize a value stream on paper is a bubble diagram. While not quite as prominent as value stream mapping, it does help you in the design of a new line. Bubble diagrams are used in many different contexts, but here I will explain their use for lean manufacturing.

29.1 What Are Material Flow Bubble Diagrams?

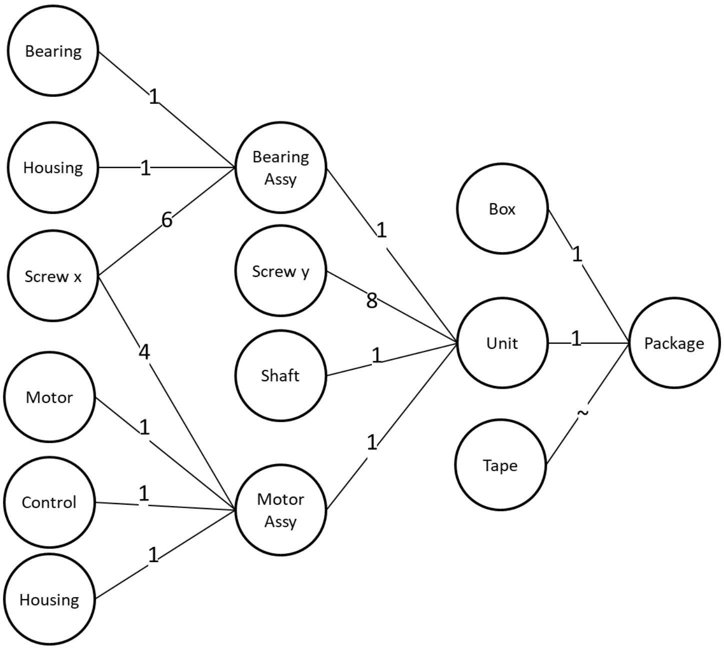


Figure 246: Bubble Diagram Overview (Image Roser)

Bubble diagrams show you the material flow in detail, but do not go into details of the information flow. As such, they are faster to make and can show a larger number of material flows simultaneously.

29.2 How to Make a Material Flow Bubble Diagram

There are two different versions of a material flow bubble diagram.

29.2.1 Material Bubbles Only

In this version of the bubble diagram, there is one bubble for each part. If you're using a MRP system, you could simply get all part numbers associated with the product by looking up the bill of materials (BOM). Each part has its own bubble – or any other shape, since it is not really a standardized approach. Hence, if you prefer a box or an oval, go for it. You could even distinguish purchased components and manufactured components by color or the shape of the bubble.

29.2.1.1 Step 1

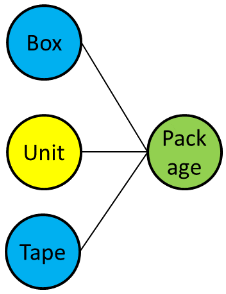


Figure 247: Bubble Diagram Step 1 (Image Roser)

In this example, I used green for the completed product, yellow for pre-assemblies, and blue for purchased parts, which works if you do it in digital form. If you do it using pen and paper (preferred), it may be easier to use different shapes for boxes. I usually start with the final part on the right side of the paper and add all items on the bill of material as bubbles immediately to the left.

29.2.1.2 Step 2

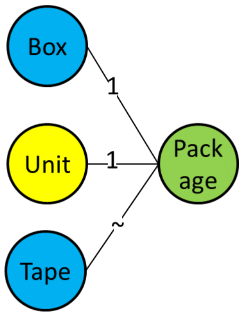


Figure 248: Bubble Diagram Step 2 (Image Roser)

In the next step, I add the number of parts required on the connecting lines. In this example, we need one box, one unit, and an unspecified amount of packing tape to assemble one package.

29.2.1.3 Step 3

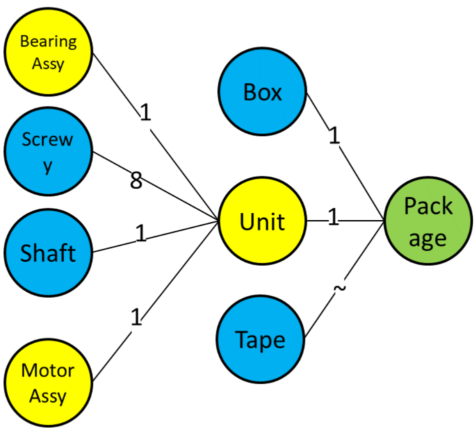


Figure 249: Bubble Diagram Step 3 (Image Roser)

The box and the tape are purchased components. The unit, however, is a product manufactured within the system we are looking at. Hence, it also has a bill of material. I repeat the step using the bill of material for the unit, which itself consists of four different parts that it will need between one and eight times.

29.2.1.4 Step 4

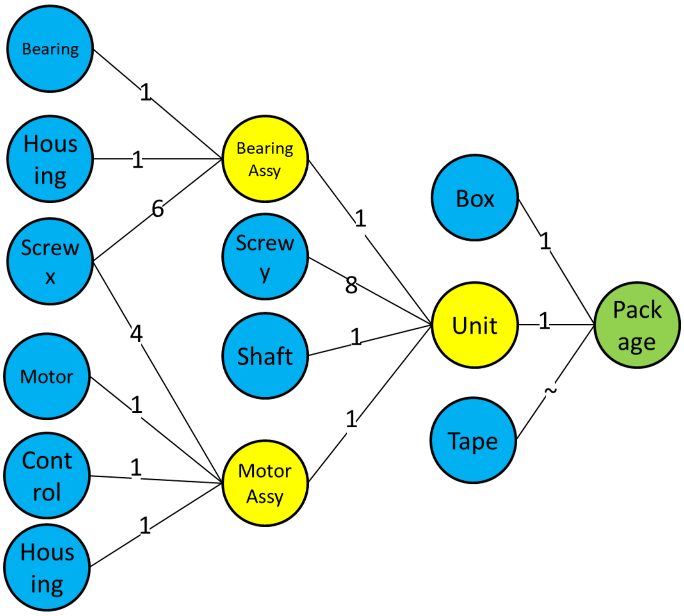


Figure 250: Bubble Diagram Step 4 (Image Roser)

The bearing assembly and the motor assembly are also produced within the scope of the line under investigation. Hence, again I add the bill of materials until only purchased components or components from outside of the investigated manufacturing system are left.

This version of the bubble diagram includes only parts. It has no information on the processes needed to manufacture them. Hence it is a very easy-to-make diagram.

29.2.2 Material and Processes

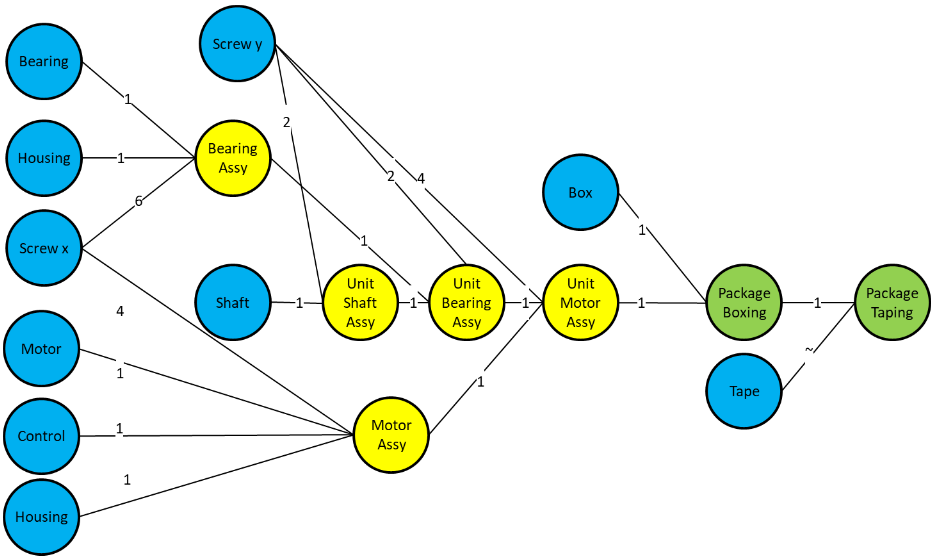


Figure 251: Bubble diagram with processes (Image Roser)

A second option is to include processes in the bubble diagram. In many cases the result would look the same, as often a part gets a new part number after each process. However, if there is a sequence of processes having the same part number, it may be helpful to include the processes.

The process is very similar, except now a produced part can have multiple bubbles if the production is spread across different processes. Overall, this gives you a good picture of which parts are needed at which processes.

29.2.3 Additional Variants

There are many additional variations possible. First and foremost, a bubble diagram should help you in solving a problem. You add whatever is necessary to help you, and leave out whatever is not.

For example, you could add the part numbers into the diagram. This may reference the part more clearly than a simple verbal description. You can also leave out the number of parts needed for each manufactured part if you don't need them.

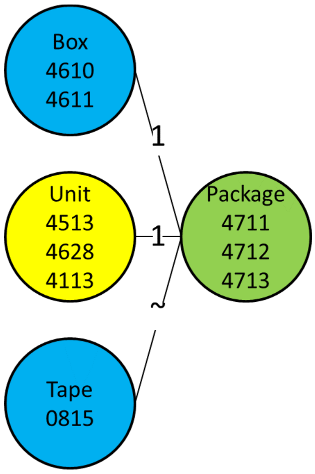


Figure 252: Bubble diagram with additional variants (Image Roser)

If you produce more than one variant of a final product, chances are that you have at least some parts that differ between variants. A variant may need more parts, different parts, or less parts than another variant. This can also be added to the bubble diagram. You could add extra bubbles for variants, or add additional part numbers within a bubble if there are different types needed for different products.

For example, the image on the left has three different finished goods. They all use the same tape, but have two different boxes and three different units. This way you can keep track of the needs of the different products manufactured in your production.

You could also use different shapes (circles, squares, diamonds …) and colors, different lines, etc. You can use post-its on a whiteboard, write it on paper, and so on. The possibilities are almost endless. This of course also includes the risk of overdoing it, and getting lost in a mess of formats and styles. As always, fit the tool to your needs!

29.3 When to Make a Material Flow Bubble Diagram

A bubble diagram can give you an overview of the material flow for a line or site. You could also use a value stream map, but if you have many parts this will quickly overwhelm you with the details for the information flow. Sooner or later you may have to do a value stream map for all parts, but not necessarily on the same sheet of paper. Hence, a bubble diagram is easier than a value stream map.

Going in the other direction, you could also simply look at the different bills of material. However, this would be a pretty big data set, which I find easier to understand if it is represented in graphic form. This bubble diagram is pretty much a bill of material in the form of a diagram.

Hence a bubble diagram may help you keep track of all the parts needed for your assembly. I find that a value stream usually looks only at some important key parts. However, you need all parts to make a product, not only the “important” ones. This tool helps you not forget any parts in your design and layout of your manufacturing area.

Figure 253: They can blow bubbles too … (Image The Factory with permission)

Granted, the above tool is not a groundbreaking new innovation that will change your life. Even if a consultant invents a fancy Japanese name for it, he would be hard pressed to sell it to his clients as a novelty – but then I have been sometimes surprised by what kind of ordinary common sense things are sold as exciting and expensive novelties in lean manufacturing ☹.

However, even though it is a small tool, I find it helpful when designing a value stream. As such, I hope it helps you too when you **go out and organize your industry!**

30 When to Do Value Stream Maps (and When Not!)

Christoph Roser, July 28, 2015, Original at https://www.allaboutlean.com/when-vsm/

Figure 254: Why to do value stream maps (Image lazyllama with permission)

Value stream mapping is a method to create a structured image of the material and information flow on the shop floor. You often hear that a value stream map should be the first and last thing to do during a lean project. It sometimes sounds like all you need is VSM and Kaizen and you are on the road to success. **This is bollocks!** While value stream mapping is sometimes quite useful, it is not a universal tool.

30.1 A Bit of History

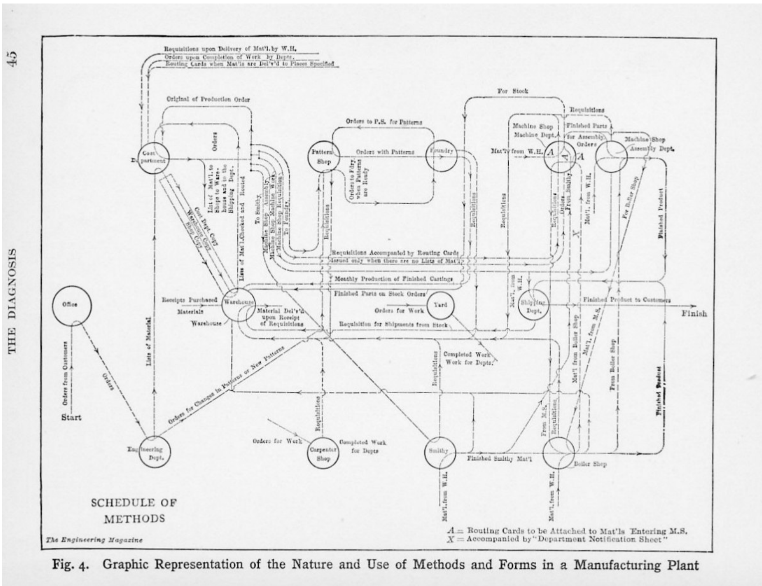


Figure 255: 1918 material and information flow (Image Charles E. Knoeppel in public domain)

The idea of a structured diagram of the material flow in manufacturing was there long before Toyota and lean. A 1918 book *Installing Efficiency Methods* included diagrams very similar to modern value streams (Thanks, Bryan Lund and [Michel Baudin](#) for digging that and other details up).

At Toyota, it was called Material and Information Flow Analysis, or MIFA for short. Another name was MIFD for Material and Information Flow Diagrams. There it was used mainly at the internal lean consultancy group OCMS. From there it made its way into lean manufacturing.

Cover of book "Learning to See: Value-Stream Mapping to Create Value and Eliminate Muda" by Mike Rother and John Shook removed due to copyright reasons.

The bible for value stream mapping in the Western world is the best-selling book Learning to See by Mike Rother and John Shook, published in 1999. They also coined the terms value stream mapping (VSM) and value stream design (VSD), and defined the most commonly used set of symbols in value stream mapping.

The modern Western view of value stream mapping stems from this book. However, it almost took on a life on its own, and in the Western world, VSM nowadays features much more prominently than the authors ever imagined, and sometimes even more than they wanted (more on that later).

30.2 Why Are Value Stream Maps so Popular?

30.2.1 About the Importance of Value Streams

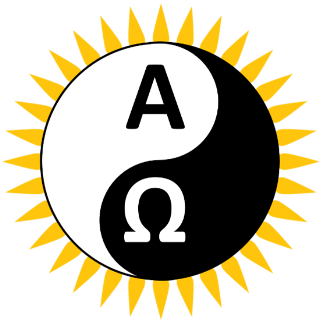


Figure 256: A value stream is everything … NOT! (Image Roser)

Often, you hear that value stream maps are the beginning and the end of lean improvements, they are your alpha and your omega, they are your morning and your night, your ying and yang, your A and Z, your … **This is bollocks!**

The benefit of value streams are by far exaggerated in the Western world. At Toyota, in fact, they do very few value streams. They prefer to work directly on the shop floor.

While I like value streams and use them frequently, I personally find that **the Western world puts too much emphasis on value stream mapping.** Many invest too much time in making a value stream and then have no time or energy left to actually improve the situation on the shop floor.

I have seen companies where the bonus of the plant manager depended (among other things) on how often per year the plant updates its value stream. Once per year was lame, twice was acceptable, but only with four plant-wide value stream updates per year did the bonus start to look good. Hence, two to four times per year, all shop-floor-related management spent a day drawing value streams. They were rarely used for anything useful, except to improve the chances of a promotion for all involved. In my opinion, these value stream maps were a colossal waste of resources.

Again, value stream maps can be very useful if applied to the right problem. Doing them “just because” is a colossal waste of time!

30.2.2 Then Why Are Value Streams so Popular in the West?

Figure 257: So … what are you producing again? (Image BillionPhotos.com with permission)

At Toyota, improvements on the shop floor are done by people from the shop floor, and they know it very well. In the West, lean projects are often driven by external consultants. These consultants (hopefully) have a lot of experience in improvement projects, but chances are they have little knowledge of your products and know even less about how you make them.

Hence, they need to understand the shop floor first. However, imagine the consultant telling the client that during the first week of the project they're not doing anything. They'll only try to understand what the client knows already – how to make his products. Of course, the consultants still want to bill the client for the time they are doing nothing but learning to understand the client's system. In all likelihood, the client would be less than impressed.

Figure 258: You need that … please! (Image bramgino with permission)

However, if the consultants tell the client that they start right away with a value stream, it already sounds much better (and much more billable). If the consultants tell the client that the value stream map is the most important thing for lean and cannot be skipped under any circumstances, it is so much easier to bill for the time and to get the support of the client to educate the consultants. Plus, in the end, the consultants even have a nice, fancy chart (the value stream map) to show the client.

Value stream maps are often pushed by consultants that need to familiarize themselves with the shop floor of their client.

Additionally, in **Western companies, management often likes fancy slides and frilly charts**. Value stream maps fulfill that desire. Yet, having a value stream map and improving the shop floor are not one and the same. Make sure the solution fits the problem. Besides, in my opinion, management rarely goes into the details of value stream mapping of somebody else, but rather treats it as a nice wallpaper.

30.2.3 So Does This Mean that Consultants Shouldn't Do Value Streams?

Whoa, whoa, hold your horses. Do you really want a consultant fiddling with your shop floor without understanding what is really going on? Giving the consultants time to understand the shop floor is a necessity for a successful lean project! If they make a value stream map on the side, it does not hurt. Just remember that a value stream has a specific use but is not a tool to solve all problems.

Figure 259: An alternative to educate your consultants… (Image Brilliant Eye with permission)

However, if you merely want to bring outsiders up to date with your system, another possibility would be to give the consultants a boiler suit and have them work in the line for a day or two along with the normal operators. This also gives them a good understanding of the shop floor, possibly even more than a value stream map would. Although I imagine this may not be too popular with some consultants.

30.3 When to Use Value Stream Maps

The value stream map can give you a graphic representation of the information and material flow. This in turn can help you with both understanding and improving your shop floor organization.

30.3.1 When You SHOULD Draw a Value Stream Map

As with all lean improvement projects, you should **first have a problem that you want to fix!** Then, depending on the problem, you collect data, make different analyses, and use appropriate lean tools to improve your problem. A tool by itself is not a solution. Like many other lean tools, doing value stream mapping for the sake of doing the map won't help you much.

Figure 260: Keep on top of the material and information flow (Image unknown author in public domain)

A value stream map is a flow layout of the material and information flow. As such, it can help you visualize and understand the material and information flow. This can be done for the current state (also called value stream analysis or VSA) and also for the future desired state (also called value stream design or VSD).

As such, value stream maps can help you with understanding the flow of information and material. It can help you to see problems and inconsistencies. Common issues where value stream mapping is often useful are, for example:

- Designing a new manufacturing line (where it is part of the process)
- Improving the flow of material and information of an existing line in a flow shop (in comparison to a job shop)
- Determining lead times and replenishment times in flow shops (e.g., to calculate the number of kanban)
- Reducing unevenness (mura) in the material and information flow of flow shops

Please keep in mind that depending on the exact problem you try to solve, the maps can look differently. For example, if I want to determine the lead times, I count material. However, if I don't need the inventories, it would be a waste to count them.

30.3.2 When You MAY Draw a Value Stream Map

Figure 261: Value stream mapping can help you only with some (Image Thomas Söllner with permission)

For other problems, a value stream map may or may not help, depending on the details of your problem. Below are some examples of when a value stream map can be done somewhere during the improvement, but this is not necessarily clear at the beginning of the project.

- Capacity constraints
- Efficiency issues

- Finding and eliminating waste (helps you to find some, but also misses a lot. Not a perfect tool for waste elimination.)
- Cost issues
- Delivery performance problems
- Flow related problems in **job shops**, because the material flow is not standardized and may differ for every part. This makes a value stream map difficult to draw, and hence usually quite incomplete. You could focus on a more frequent high-value part, but this will still give you an incomplete picture. The more common parts you have, the more it makes sense to do a value stream map.

30.3.3 When You SHOULD PROBABLY NOT Draw a Value Stream Map

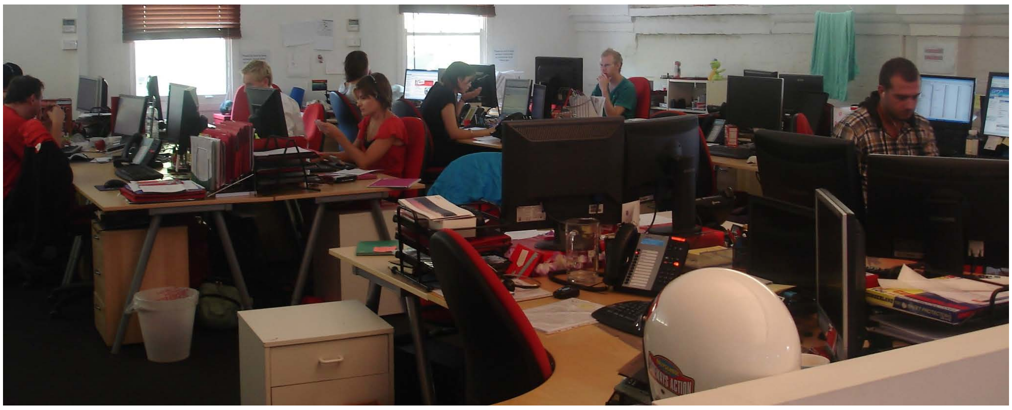


Figure 262: No VSM here (Image VeronicaTherese under the CC-BY-SA 3.0 license)

Value stream mapping is a useful tool. However, it is not a catch-all multi-purpose tool that solves all of your problem. Any issue not connected to the material or information flow is unlikely to benefit from a value stream map. Similarly, systems without a highly linear information and material flow usually do not benefit from drawing a value stream map either (for this, swim lane diagrams are more useful). Common examples of when a value stream map usually makes no sense are, for example:

- Ingoing or outgoing quality problems
- Down times and breakdowns of machines
- A manager higher up wants a value stream (Okay, depending on the manager, this one may help your career, so you may move it up to the "*definitely before anything else*" category)
- Employee morale issues
- Supplier development
- Indirect areas, administrative areas, and support services, because they often have no structured flow. Swim lanes are much better here.

30.4 Summary

Again, **get the right tools for the problem, not the other way around!** Value stream maps have a lot of good uses, but they are not for every problem. Do a value stream map if you think it can help your particular problem, but not just because someone tells you to do it. In my next post Overview of Value Stream Mapping Symbols I will go through the value stream mapping symbols, including frequently found alternative versions. More posts discuss Basics of Value Stream Maps, and Practical Tips for Value Stream Mapping. In any case, I hope this was interesting and helpful to you. As always, I am looking forward for comments here or through social media. Now go out and **organize your Industry!**

31 Overview of Value Stream Mapping Symbols

Christoph Roser, August 04, 2015, Original at https://www.allaboutlean.com/vsm-symbols/

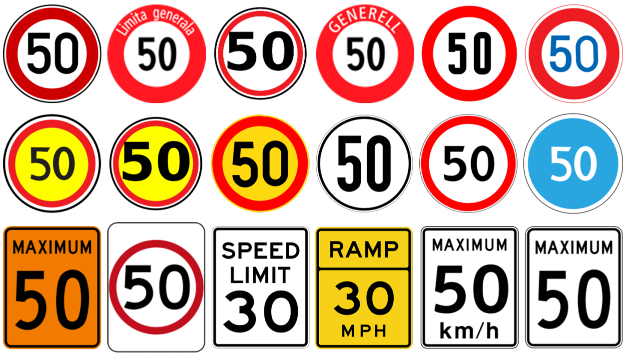


Figure 263: Different symbols for the same thing … (Image various authors in public domain)

Value stream maps are usually drawn using standardized symbols…or that is what most people believe. While there are some symbols that are used pretty much universally, other elements have different symbols in different organizations or by different sources. Other identical symbols are used in a different way by different organizations. And, every day people seem to invent new symbols. In this post I will (try to) give an overview of what is out there, along with my opinion on what I use frequently and what I usually avoid.

31.1 The Symbols

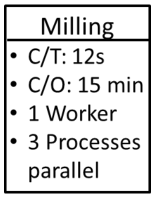
Since the material and information flow is represented in symbols, we need different symbols to show the flow. A few of them are used almost universally across industry. However, many symbols have lots of variants and small differences that are either interpreted differently or not used at all in other organizations. I will try to give you an overview of the different symbols, with some (personal) preferences.

This list is also by no means complete. If you do VSM, you will sooner or later come to a point when it will be difficult to represent the VSM using the existing symbols. In this case, many organizations invent "new" symbols. For the sake of clarity, I prefer to stick to common symbols and write a small note next to it. **Symbols I use frequently have a white background. Less frequently used variants have a gray background.** You can also download a PowerPoint file with an overview of VSM symbols for you to use, although I recommend doing it by hand on paper

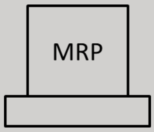
All value stream symbol images below by Roser. The powerpoint can be downloaded at https://www.allaboutlean.com/wp-content/uploads/2015/07/VSM-Symbols.pptx.

31.1.1 Processes

This is the most basic process box. Merely a box and a name within it. While it is sometimes frowned upon by other lean experts, I use it quite frequently when I do not need more detailed information for my processes. Sometimes these boxes are also shaded if they are shared with other value streams. In another version shading could also stand for rework processes, and shared processes have a double cross hatching. Some practitioners also use a triangle for batch processes, an U for one piece flow, or a second box around it for parallel processes. The possibilities are endless, there is no standard.



Optionally, you can add data into the box. The data depends on your needs but may include cycle times, changeover times, number of workers at the machine, number of machines (if this box represents multiple boxes in parallel), number of shifts, defect rates, and whatever you think you need. I have even seen the CO_2 footprint of a machine in a value stream.



For data management processes as, for example, the central MRP or logistics system, a slightly different box is sometimes used (although you may as well use the normal process box from above).

Slightly different boxes are used for customers. The image represents a typical saw-tooth roof of many industry buildings. This customer can be both external or internal, but is the end point of the value stream you look at. Usually there is only one customer shown, but you may have more than one.

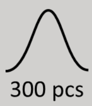
Suppliers are similar to customers, except that they are the input into your value stream. Again, you should have at least one, but you can have more.

This image represents a worker or a person. In a value stream map it is rarely used, as the info is usually contained in the info box, if needed at all. However, this image is frequently used for layout purposes.

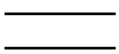
31.1.2 Inventories

This triangle with an “I” for inventory is the image of a basic uncontrolled inventory (i.e., an inventory that has no fixed upper limit). You can write the inventory observed below, but this depends on why you do a value stream. If you need the number, write it down. If not, just draw the triangle. Some companies draw these in red to indicate that this is not a good way to handle stock.

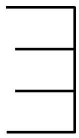
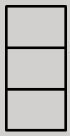
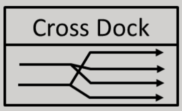
This is a small variation of the inventory above. This is the type originally shown in *Learning to See*, but I am usually fine with not adding the two bars on top and below.



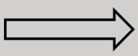
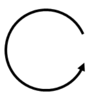
The meaning of this symbol is the same as above. This one is used by Toyota for their material and information flow analysis (MIFA). Depending on your interpretation, it represents a pile of material or a normal distribution. Except for the different design, the meaning is identical as above.

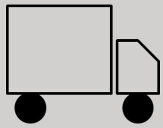
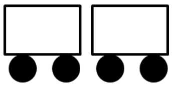
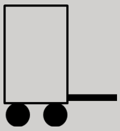


A FiFo lane. Some companies make them in green to indicate that a FiFo is generally a good way to store material. You can write either the maximum capacity, the current capacity, or both below the FiFo lane.

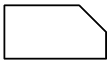
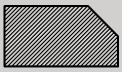
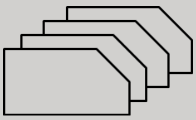
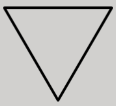
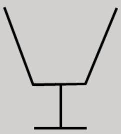
	An alternative version of the FiFo lane as originally envisioned by *Learning to See*, although for me it is usually too much effort to draw and write the additional information. However, the arrow in the FiFo is a good reminder that the material flow through the FiFo also contains an information flow too!
	Symbol for a supermarket (i.e., the end point of a kanban loop). For a supermarket to be complete, an information flow has to come out of it and bring a kanban back to one of the preceding processes or transports.
	This symbol is sometimes used for safety stock, although it is not too common in my experience.
	Another version of the safety stock, using a similar triangle as above. Similar icons with an X instead of an S are also sometimes used as a blocked stock that cannot be used.
	A cross dock where material is rearranged from inbound or for outbound shipments.

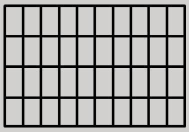
31.1.3 Material Flow

	A push arrow, representing a material flow that is not controlled by a pull system (i.e., a cap on WIP). It is often found in combination with the inventory triangles above. I personally hate this symbol. It is a pain to draw it by hand (but maybe this is intentional so you create a pull system in order to avoid the drawing by hand ☺). In any case, I usually use a simple arrow similar to the manual data flow below instead.
	Similar to the push arrow but representing a transport to the customer or from the supplier. Also generally called a shipment icon.
	This is a sequenced pull ball. It is part of the original set of symbols in “Learning to See”. It is used as a sort of kanban for a supplying system that can produce the parts needed in a short period of time. This fast “just in time” production does not need a supermarket. The symbol originates in colored golf balls used as kanban signals. Can be useful, but is little known and I have not yet seen it in a real value stream.
	A parts withdrawal symbol. This represents a pull system and is usually found after a supermarket.

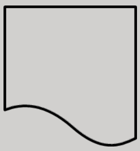
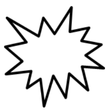
	An icon for transport by truck. It is usually combined with the white push arrow from above, although I rarely use it.
	A milk run representing a cyclical transport of material.
	A fork lift (sort of). More similar icons for airplanes and other things can easily be invented.

31.1.4 Information Flow

	A symbol for a Kanban card. This is usually drawn on top of the information flow going back from a supermarket to a preceding process or transport. Technically speaking, a white card indicates only a production kanban, although I do not make this distinction.
PI	Alternative MIFA symbol for a production kanban.
	Symbol for a withdrawal kanban that does not start reproduction but merely takes the material out of a preceding inventory. I find this redundant, as the end point of a normal white kanban tells me where the material came from. Hence I skip the shading. Some companies also use different colors for production and withdrawal kanbans.
PW	Alternative MIFA symbol for a withdrawal kanban.
	Symbol for kanban arriving in batches. I usually do not use this symbol and prefer to use a single kanban and make a small note in or on top of it.
	A triangle kanban, which is a special type of kanban system with only one kanban. Loosely similar to reordering points of Economic Ordering Quantity. I have rarely seen this used, and I don't use it myself on VSM, although I find triangle kanbans in general quite useful.
	Box for collecting kanban (*Learning to See* calls this a kanban post). It is usually near a supermarket and indicates that kanbans are collected and picked up only periodically. I have used it sometimes, but only when the information flow needed this detail.
	Load leveling, or more generally, leveling. It is part of the information flow in a kanban loop.

	Heijunka board, or leveling board. This is not part of the set in *Learning to See*, but rather in MIFA. Yet it fulfills a very similar function, although I rarely see it.
	This arrow indicates a manual information flow. Can be combined with text on the type of information.
	This arrow indicates a digital information flow. However, I usually simply use the manual information flow for everything, unless it is critical that the flow is digital.

31.1.5 Other Symbols

	These”go and see” goggles indicate an observation as part of the information flow. For example, if a supervisor checks the inventory and then decides what to produce next. Usually too many goggles are not a good sign, as they indicate an unstructured firefighting type of manufacturing.
	Rarely used symbol for a document.
	Symbol used to indicate problems and trouble spots identified on the value stream.
	Symbol used to indicate a solution, idea, or improvement suggestion.
	Timeline below the value stream, used to calculate the percentage of the time in value add. Usually the “troughs” are waiting times, and the “hills” are processing times. In most value stream, I find this not necessary, but sometimes it is useful. The length of the symbol depends on the number of processes above, with one “dent” in the line per process.

31.2 On the Symbols…

As you have seen, there are tons of different symbols. Often, there are different symbols for the same thing, depending on which organization you are in. Many of them are also a pain to draw (e.g., the push arrows or all of these truck symbols). At other times, you will find that these symbols are insufficient to express the details of your value stream and you are lacking some symbols that you need to describe your system.

While the above symbols look like a worldwide standard, they are not. I often find lots of gaps, redundancies (push arrow and unstructured inventory), and uncertainties on how to draw them exactly. Often my colleagues and I have different opinions, eventually coming to the conclusion that "*both are possible.*" In any case, pretty much any value stream drawn needs to be understood only by the team that is working with the improvement. For everybody else, especially higher up, they are just eye candy.

Hence, feel free to adjust, skip, or modify the above symbols to fit your need. It's not like primary school where Miss Krabappel grades you on your spelling. I usually stick to a basic set of symbols (the ones above that are not grayed out). I mostly skip or ignore the others, because I often don't need them, don't like them, and find that they can confuse others on the team.

I also often find the existing symbols lacking. Every now and then I come across a situation that I cannot represent to my satisfaction using the existing symbols. I urge you to resist inventing new symbols; we already have more than enough. If anything, write a small text on the document explaining what you want to do. Nevertheless, **the set of symbols sometimes feels incomplete or inadequate. Am I the only one, or did you sometimes have this feeling too? Let me know.**

31.3 Summary

These above are also only the tip of the iceberg. There are many other sets of symbols out there – for example, for flow diagrams and layouts, many of which are surely used somewhere in value stream maps.

This post is part of a small series on value stream mapping, with more posts on When to Do Value Stream Maps (and When Not!), Basics of Value Stream Maps, and Practical Tips for Value Stream Mapping.

In any case, the value stream map can be a great help with some problems but a burden if they are done without proper purpose. Do what is necessary, but don't over-complicate the things to **organize your industry!**

32 Basics of Value Stream Maps

Christoph Roser, August 11, 2015, Original at https://www.allaboutlean.com/how-to-vsm/

Figure 264: Guy with Map (Image berc with permission)

Knowing the symbols for value stream mapping is only a first step. This is like the difference between knowing the alphabet and writing good stories. There are much more things to consider for generating a good value stream. In this post I will go through the basics of drawing value stream maps. I found it surprising how much detail there is to what in literature is often simply abbreviated to “go out and draw it.”

32.1 Why Do I Need a Value Stream Map?

The first step in drawing a value stream map is to think why you need it. Depending on the reason, you may have a completely different map at the end. Also, consider alternatives to value stream mapping that may be more beneficial to your particular problem (see my post on Overview of Diagrams). Depending on your problem you may also find out that you do not need a value stream map at all. The tool has to fit the problem you want to solve. If you have no problem, you don’t need a value stream map. (See also my post When to Do Value Stream Maps.)

32.2 Preparations

If you know why you need a value stream map, there are a couple of things you should think of before you put the pen on the paper. Two of the most significant aspects are to **define the area where you want to do the value stream** and **which level of detail you need**. This may sound cliche, but it should be neither too wide nor too detailed. I have seen too many value stream maps with so much detail that they were never used because they were too complex.

Cover of book “Learning to See: Value-Stream Mapping to Create Value and Eliminate Muda” by Mike Rother and John Shook removed due to copyright reasons.

The value stream mapping bible Learning to See describes four levels where a value stream is possible: within a single process or line, within a plant, across multiple plants within a company, or across multiple companies. But, please, don’t make them all! Focus on your problem, not on your value stream maps.

You may also **narrow it down to a certain product or product group**. This again depends on the problem you are trying to tackle. If you want to generally improve the flow within a line, it may be helpful to look at some of the major products. If you want to improve the flow for a certain product, naturally look at this product.

Depending on the problem you are trying to solve, you may **have a team of people involved**. Hopefully some people from the shop floor, maybe some management or some technicians. In any case, the team that does the improvement project is also the one that should be doing the value stream together. For me, **the “value” of a value stream is doing the value stream map,**

not having one. You and your team learn most from drawing the value stream. If, on the other hand, one person of the team does the value stream alone and then presents it to the others, nothing is learned by the others.

Hence, involve the group unless you are a team of one. This is also fine. I have drawn many value streams simply for myself to understand the situation. Yet, if you want other people to use a value stream, they should be involved in making it!

32.3 The Basic Concepts

32.3.1 Material Flow

Figure 265: Material flow is usually easy to see … (Image Katarzyna Kobiljak in public domain)

The material flow is the flow of parts through your manufacturing system. On a value stream map, by convention the material flows primarily from the left to the right. Hence your supplier(s) is at the left and your customer(s) at the right of the map.

Material flows can split and merge. For example, in an assembly process, many material flows merge. These may be more than what you can draw reasonably on any sheet of paper. Focus on the flow of parts that is critical for your task at hand.

32.3.2 Information Flow

Figure 266: Information flow is difficult to observe! (Image ndoeljindoel with permission)

The information flow represents how the information travels on the shop floor. Basically, there are two types of information that can travel on the shop floor.

Information flow to the processes: The production processes need to know what to produce. Hence, an information flow has to go at least to the first process in the system. This information could be a production order or a kanban. Of course, all the other processes also need to know what to produce. If you use FiFo for your material flow, this also doubles as an information flow. Any process that is at the end of a FiFo does not need any other information.

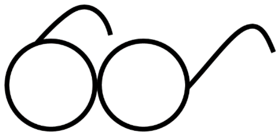


Figure 267: Go and see! (Image Roser)

Information flow from the processes: The control system (may) need information about the production system. Depending on how you control the system, you may need to gather data about the items produced or the items in the inventory. Hence, information flow also can go backward from the production to the production control. Some of this may be standardized, but in a not-yet-good production system this usually also involves lots of people going to the shop floor and looking at parts or asking people. The better your value stream is organized, the less go-and-see actions are needed.

32.4 Different Options for Drawing the Current State Value Stream Map

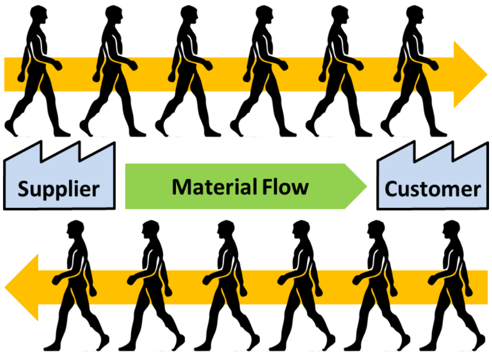


Figure 268: Which Way? (Image Roser)

Following the lean principle of going to where the action is, you should draw value stream maps on the shop floor. Ideally you walk from the customer to the supplier, although in my view this doesn't make a huge difference. The five main reasons for starting at the customer are, in my opinion, in order of priority. (See also my post on Value Stream Mapping – Why to Start at the Customer Side.)

- Mental weight to the customer
- New thinking through different view
- See the information flow in pull systems
- Understand branches in material flow
- Sound smart to impress people (which is a lame reason on its own)

As for actually drawing the value stream, I find myself using different approaches at different times.

32.4.1 1) Drawing the Complete Value Stream While Walking the Line End to End

Figure 269: Walk it once? (Image Siyuwj under the CC-BY-SA 3.0 license)

You could go to the line and **draw the value stream from scratch while walking along the line end to end**. This is often the standard approach mentioned in literature (go to the line from customer to supplier and draw the value stream).

However, I often find myself overwhelmed with the mass of information that I have to take in at once. Keeping track of the material flow, the information flow, the data details, and all the juicy morsels of information about inconsistencies and waste is a huge task.

32.4.2 2) Draw Material Flow before You Go to the Line

Figure 270: Prepare beforehand? (Image bls.gov in public domain)

Therefore, I have also done it slightly differently. If I know the line already, I start to **draw the material flow beforehand and then go to the line**. The material flow is (usually) more standardized and hence a bit easier to draw. I usually start with drawing the supplier, the customer, and the main process boxes. This helps me to keep the overview of my value stream.

The information flow, however, is usually much less structured. Hence I always draw this while walking along the line on the shop floor. Of course, I also check if my "idea" of the material flow is correct. If I find differences, I of course update my map accordingly.

While I prepare parts of the value stream at a desk, my gut feeling tells me that drawing a value stream while walking along the shop floor is the better approach. This is in line with Toyota's philosophy of "*goto gemba*" and "*genchi genbutsu.*" Nevertheless, I sometimes do the processes and maybe part of the material flow beforehand. It helps me to sort out my thoughts better.

32.4.3 3) Walk Line to Draw Material Flow, Then Walk Again for Information Flow (and Again?)

Figure 271: Walk it more than once? (Image Siyuwj under the CC-BY-SA 3.0 license)

What I probably feel most comfortable with is a **combination of the above**. I again **first draw the material flow, and then the information flow**, but I do **both while walking along the line**. This way I get the benefits of both approaches. I can focus more on the material flow, which I do first because it is usually easier. This gives me a framework for the second round where I look in more detail at the information flow.

Yet, in both rounds I get the benefit of observing directly at the shop floor. Hence, I draw not the idealized state it should be (a common pitfall), but the real state I observe. An additional benefit of this approach is that I see the line twice and can hence observe if there are different standards at different times (or, more precisely, the absence of a standard).

If necessary, I walk the line even more. For example, if you need data of the processes, I often collect this during a third walk along the line, and even a fourth iteration is possible. Again, this depends on the problem you want to solve. By the way, if you read *Learning to See* closely, they also suggest to do more than one walk (quick walk first, then detailed to gather more data).

How do you do it? Which method do you prefer? Looking forward for any comments!

32.5 A Note on Data…

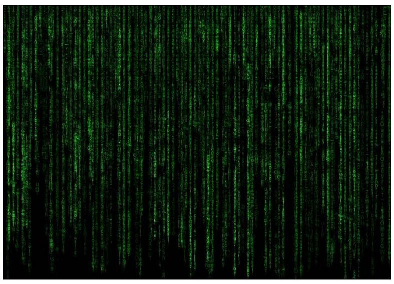


Figure 272: Data Graphic (Image Comfreak in public domain)

Sometimes I read that a value stream map is not complete without the data. I disagree. It depends on the problem you want to solve. Most of the maps I drew had little to no additional data on it, because I simply wanted to get a grasp of the flow and its organization. I added data only if I needed it, for example to calculate the number of kanban or the lead time.

To get the data, you have two options: look it up or measure it yourself (counting, taking times, etc.). Usually, doing it yourself takes longer but gives you higher quality data. You would be surprised by the vast amount of outdated, manipulated, or even simply wrong data in manufacturing (see also my series on Lies, Damned Lies, and KPI).

Similarly, you can draw a zigzag time line underneath the value stream that shows how long each process takes and how long the parts wait between each process. This can then be summarized to show the percentage of time a part is worked on and the percentage it is waiting. In Six Sigma, this is called a process cycle efficiency (PCE).

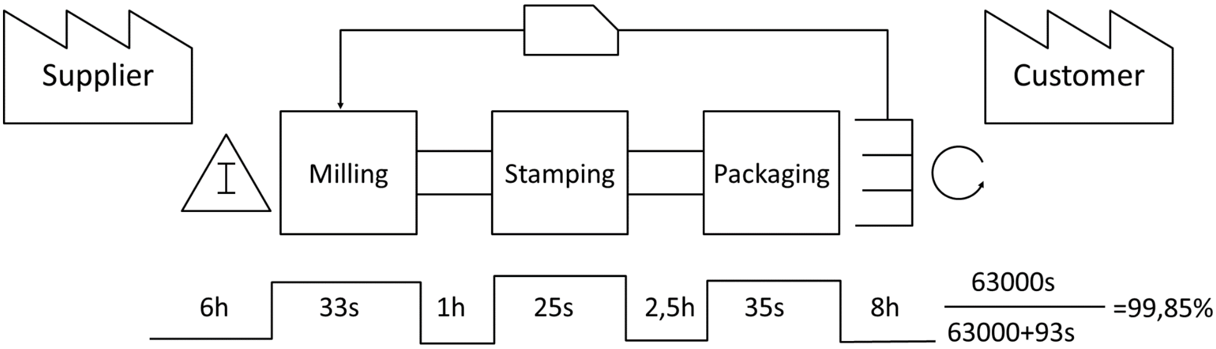


Figure 273: Notice the time line underneath of the value stream map! (Image Roser)

Unless you have a batch process like annealing or baking involved, the result will be something around 99.95% waiting and 0.05% working. If you need the number, do the calculations. However, I rarely needed this number, and if i need it then only to generate a sense of urgency and to demonstrate the effect of excess inventory. Most of the time I did not bother to add this line, since I had more important things to do. It is up to you if you want to do it.

32.6 The Future State

Figure 274: The future state… (Image lazyllama with permission)

With value stream maps, it is also possible to draw a future state map. This is helpful if you want to change the organization or structure of the material and/or information flow. The basis for the future state is your current state map.

Unlike the current state, however, you and your team can draw the future state in a meeting room. Some people simply replace all push arrows and unstructured inventories with FiFos, supermarkets, and kanban loops. However, the hard part is to implement it. The value stream map is only a visualization. The actual improvement comes through the use of different tools. Again, focus on the problem at hand!

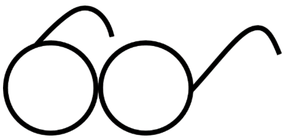


Figure 275: Your current state probably has lots of these (Image Roser)

By its nature, the current state ends up messy. You will probably find lots of unstructured "go and see" actions or multiple conflicting signals. This can be also used as an effect to show others how messy the system really is. Even if you include only the more frequent information flows on a typical shop floor, management is usually surprised about the mess and the lack of structure.

In contrast, **the future state is usually much cleaner and more organized. Of course it is! After all, it is a theoretical and idealized thought structure.** This does not mean that its implementation will actually be as perfect as the plan makes it look. This depends on the quality of the implementation. For more on value stream mapping see also When to Do Value Stream Maps (and When Not!), Overview of Value Stream Mapping Symbols, and Practical Tips for Value Stream Mapping. So go out and make the reality as perfect as your plan showed it in your never-ending quest to **organize your industry!**

33 Practical Tips for Value Stream Mapping

Christoph Roser, August 18, 2015, Original at
https://www.allaboutlean.com/vsm-pitfalls/

Figure 276: Value Stream Mapping Tips (Image niroworld with permission)

After discussing when to do value stream maps, the symbols, and the basics of value stream mapping, I want to give some more practical tips for value stream mapping. What tools should you use? Do you use a computer (yuck) or a pen and paper (yup)? I'll also summarize some generally helpful hints in drawing a value stream.

33.1 Options for Drawing a Value Stream

There are different methods for drawing a value stream. I don't mean the gathering of information (see Basics of Drawing Value Stream Maps), but how to put it on paper.

33.1.1 Use Pencil and Paper

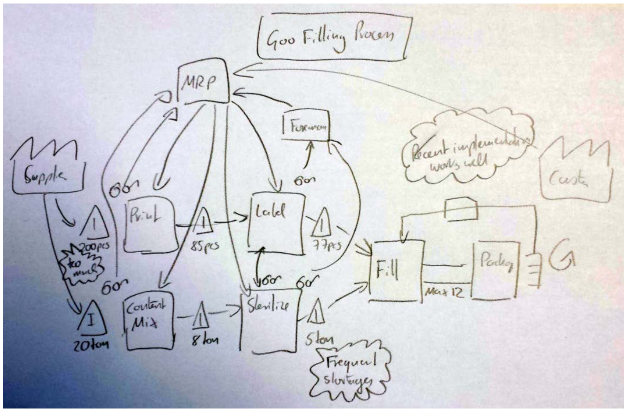


Figure 277: The Beauty of Simplicity! (Image Roser)

This is by far my most preferred method. It is quick, easy, and can be changed using a simple eraser. As for paper, I usually go for an A3-sized paper. In the United States this would be called tabloid or ledger and measure around 11 x 17 inches. It is big enough to fit the relevant data of a value stream, yet still small enough to be carried around on the shop floor.

33.1.2 Pre-Printed Cards on Pin board

Another option I have seen and used are pre-printed cards. You have cards with all relevant value stream mapping symbols, and pin these to a pin board.

While pre-printed cards may appeal to a sense of order, I personally don't like them much. Generally, with such cards, we were usually running out of some symbols (usually the unstructured stock triangle – yes, I know, lots of potential there) while having way more than necessary other symbols (customers, suppliers, trucks …).

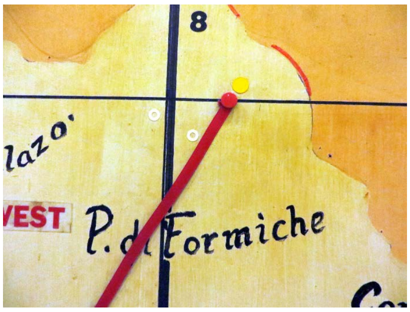


Figure 278: Pins and yarn are hard work… (Image Roser)

You can draw on the pin board if you put a large sheet of paper over it beforehand, so that would work. This way you can easily add information flows. However, I once observed others who added the information flows using wool yarn and pins. While it looked nice, it was a lot of work to add, and even more to change. Definitely not recommended.

Finally, it is more difficult to bring a pin board along in the factory, hence it gives a tendency to a conference room value stream with all its disadvantages.

33.1.3 Pre-Printed Post-its or Magnetic Cards

Figure 279: VSM symbol Post-its (Image Roser)

Another alternative that I liked more (but still less than pen and paper) were cards that could be stuck on a whiteboard. I worked with magnetic cards and have seen Post-it style cards.

Both are doable. They still have the disadvantage that you will run out of “popular” cards and have to lug around a mobile whiteboard (if you have one) or be stuck in a conference room altogether (if you don’t have a mobile board).

The advantage here is that you can draw information flows and other details easily on a whiteboard. Even more importantly, it is easy to change. The lines can be erased, and the magnetic or Post-it stickers can be moved quickly. Still, pen and paper is best.

33.1.4 PowerPoint or Excel or Visio

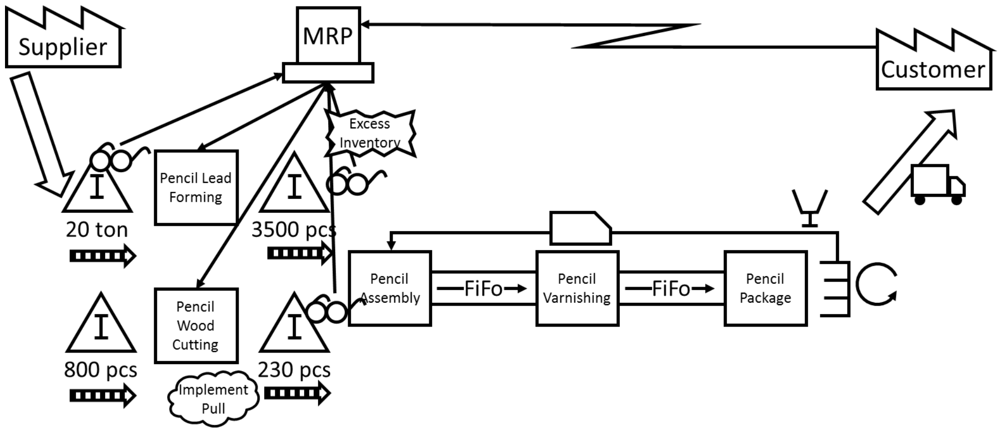


Figure 280: An "A" for effort, I guess … (Image Roser)

Probably the most common but unfortunately (in my view) the worst way to do a value stream is in PowerPoint (really bad) or Excel (even worse than PowerPoint! Shudder!). Visio is actually designed for such tasks, and hence is slightly better, but still in my view inferior to pen and paper. It makes everything more difficult. You can't really do teamwork, hence you are limited to one guy with the computer and ignore the others. Taking a laptop on the shop floor is possible, but not really for drawing diagrams. To use a computer (even a laptop) to draw value stream maps, you need a desk and a mouse. Otherwise, it will be an exercise in balancing eggs on your head.

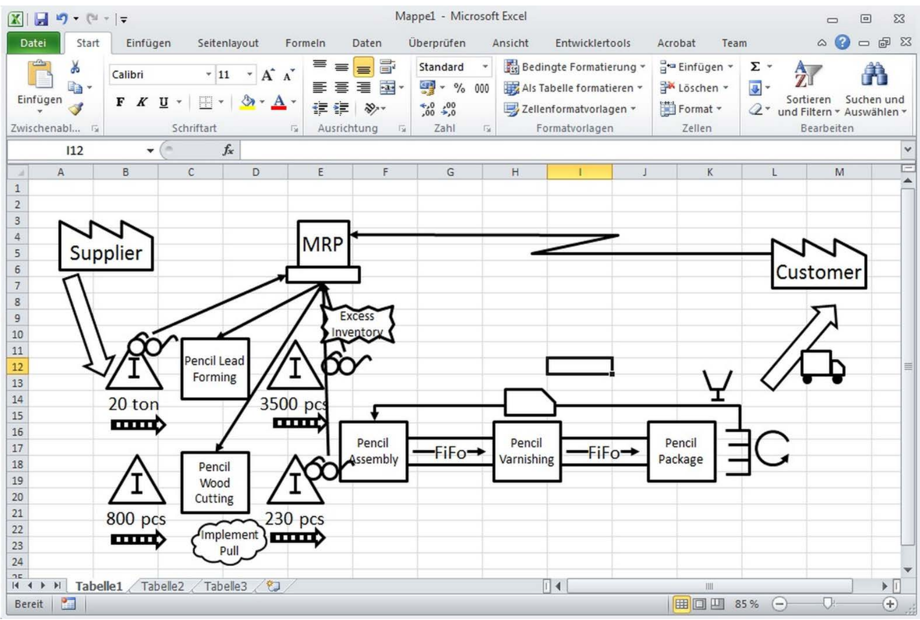


Figure 281: Excel is unsuitable for drawings. (Image Roser)

You spend a lot of time fiddling with the program rather than problem solving. Do not underestimate the effort needed to make a simple VSM on a computer. If you doubt it, just make a competition. Give two people the same simple value stream to map, one by hand on paper and the other using a computer. Even if the computer user is skilled and has done these before, he will take longer than a beginner with pen and paper.

Pretty much the only advantages of a computer version are a cleaner and more organized look, and the ability to share it easier with others online. However, while this means that lots of people can look at it, it will be mostly people who either don't care or don't understand and in any case cannot give any useful feedback. It is in effect a wallpaper that looks pretty and impresses people (although those things still can make or break a career). In case you still want to use PowerPoint or Excel, I have you a [PowerPoint file with an overview of VSM symbols]().

33.2 Common Pitfalls

33.2.1 Too Much Detail

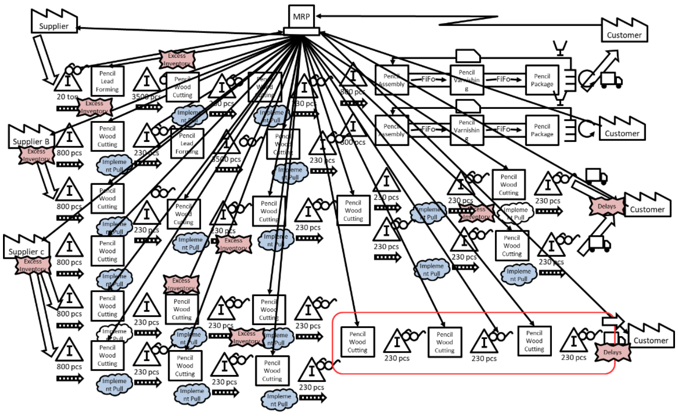


Figure 282: Everything clear? (Image Roser)

A common mistake is trying to add too much detail into the value stream. While you may believe that more information is better, the bottleneck is your ability to keep on top of it all. Too many details may confuse things more than they clarify them. Personally, I think **the sweet spot is between 4 and 15 process boxes**. Hence, I try to keep my number of process boxes on a value stream map below15. Anything above 30 is a waste of time. Another option is to limit yourself to one sheet of A3 paper. If you cannot fit it on one sheet, then it is too much. I once made the mistake of doing a value stream map with over 60 process boxes, but nothing useful came ever out of this.

Hence, try to focus on the processes and parts that are relevant, and do not try to make a complete encyclopedia of everything that goes on on the shop floor. You will only waste a lot of time on something that you cannot possibly fit on one piece of paper.

33.2.2 Designing Processes Where More than One Information Flow Ends

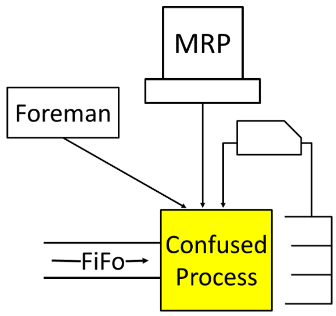


Figure 283: Four signals – What do you want me to do? (Image Roser)

Having more than one information flow going into a process makes the work for the process confusing. Which information is valid? Both? Which is most important? Sooner or later the process will be selecting the wrong choice, hence try to have only one information flow per process. Please remember that a FiFo lane also doubles as an information flow (i.e., the process simply makes the next part in line).

Do not use more than one information flow going to a process! This will increase confusion and is again a sign of a badly designed value stream. If a process has a choice between different production signals, they will sooner or later produce the wrong thing. The signal for each process must be clear and unique!

33.2.3 Information Flow Ending Not in a Process But in Inventory

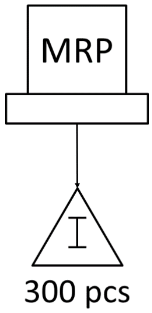


Figure 284: What do you want to tell me? (Image Roser)

A common beginner's mistake is to end an information flow at an inventory. However, an inventory is a passive element. It cannot do anything with information. Information has to go to a manufacturing process, data processing, the supplier, customer, or to a logistics or transport element. Hence, **make sure that an information flow always ends at an element that can process the information!**

33.2.4 Confusing Layout and Value Stream Mapping

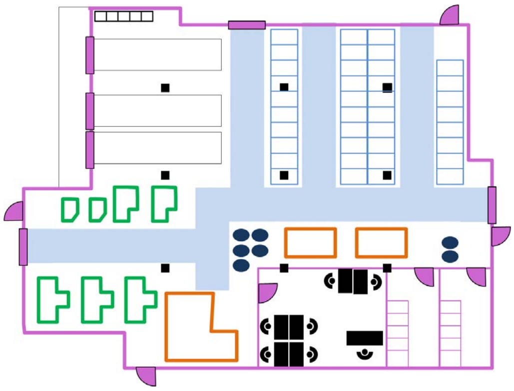


Figure 285: Not suitable for a value stream! (Image Roser)

A layout tells you where things are. A value stream map tells you the sequence of material and information flow. Hence, a value stream map usually has no relation to the physical layout, but only shows the sequence. By convention, the material usually flows from left to right, whereas (most of) the information flows from right to left, although there may be exceptions for special circumstances.

33.2.5 Draw the Current State without Going to the Shop Floor

Figure 286: I know everything … (Image Paperbaghead in public domain)

The current state should represent the current state **on the shop floor!** Hence, to draw it you need to go to the shop floor. Do not make the mistake of drawing it in an office or meeting room. Of course, you will end up with a value stream map, but this map is how it should be and not how it is.

If you want to believe that everything is going according to plan, then that would be fine. My experience is, however, that it is rarely going according to plan. Yet exactly these deviations from the idealized standard are the things you want to know!

A similar result can happen if you merely ask different employees about the value stream but do not verify it on the shop floor yourself. Again, you will get the ideal state the value stream should be, not the real situation on the shop floor.

This is the last post on my series on value stream mapping, with the others being When to Do Value Stream Maps (and When Not!), Overview of Value Stream Mapping Symbols, and Basics of Value Stream Maps. I hope the above hints and suggestions were helpful for you in your daily work. If you have more, let me know in the comments. Otherwise, go out and **organize your industry!**

34 All About Spaghetti Diagrams

Christoph Roser, August 25, 2015, Original at https://www.allaboutlean.com/spaghetti-diagrams/

Figure 287: Working hard on that diagram … (Image StefanieB with permission)

A spaghetti diagram is a quick and easy way to track distances of parts and people on the shop floor. The name comes from the result looking like a plate of spaghetti. In this post I will explain the details and give some tips and tricks on how to make a good spaghetti diagram.

34.1 Why Do I Need a Spaghetti Diagram?

A spaghetti diagram, also known as spaghetti chart, spaghetti model, or spaghetti plot, is a particular tool for determining the distance traveled by (usually) man or (in some cases) material. Hence, a spaghetti diagram can help you if you want to reduce the distance traveled by either parts or people. Obviously, this works best for an repetitive environment where the work repeats in the same or similar style multiple times.

This allows you to then analyze and optimize the distances. The benefit can be either faster delivery or the same delivery with less effort.

34.2 How to Make a Spaghetti Diagram

34.2.1 Spaghetti Diagram for a Person

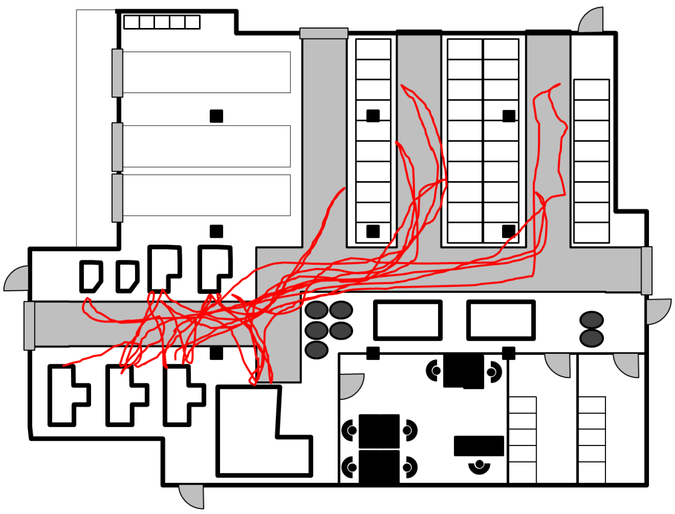


Figure 288: Example of a Spaghetti Diagram (Image Roser)

Spaghetti diagrams are most useful for determining the route a person has traveled by either walking or driving (e.g., with a forklift). It even works for automated guided vehicles (AGVs), even though, in lean wisdom, waiting times of people are much worse than waiting times of machines. All you need is a layout, a pen, someone observing, and someone observed. Other lean sources also suggest a stopwatch and a measuring wheel, although I am usually fine with my normal watch and a distance estimate.

Naturally, you should inform and, if necessary, get consensus of the people observed and possibly the works council or union representatives.

Whom to observe depends on the question and scope of the problem you want to solve. If you are worried about the efficiency of a machine operator and noticed that his task includes some walking, you may observe a typical machine operator for these machines. On the other hand, if you are more interested in optimizing the material transport, then you should look at one of the people transporting goods. In sum, observe the work of people that you want to optimize.

During a typical work day, meet with that person and follow him around on his normal work. **When you start, note the start time on the diagram. While he walks through the factory, mark his route with a pen on a layout of the factory.** I usually use a colored pen on an ideally not colored layout (just use a gray-scale printer). You can also add arrows to indicate directions. Whenever I observe him doing something worth remembering, as, for example, searching, making mistakes, or doing other types of waste, I also make a quick note on the layout. This can also include times and will come in handy later on for the improvement. Do not skip any parts, even if it becomes messy (unless the worker needs a toilet break).

Figure 289: All done … (Image rukxstockphoto with permission)

Theoretically, you could follow the worker all day long. Practically, this is usually a waste of time. Besides, the worker usually doesn't want you to record his toilet break. There is no fixed rule for the duration of a spaghetti diagram. I usually observe long enough that I feel I have understood the situation and then add a little more time to see if something unexpected happens. However, even for highly cyclical work, following only one round is definitely not enough!

After you complete the observation, write down the end time so you have the interval observed. If you take breaks, note the start and end of the breaks. Congratulations, you have completed a spaghetti diagram.

34.2.2 Spaghetti Diagram for a Part

Similar to following a person, you can also follow a part. This makes most sense if you have a job shop. If you have a flow shop, you will end up with something like a straight line. Just follow the part from the inbound warehouse to the outbound warehouse (or whichever area you are interested in).

Figure 290: Waiting to be used … (Image WoGi with permission)

When following people, you have the advantage that they usually don't like to wait. Hence, with people you will see a lot of action. Parts, on the other hand, don't mind waiting. In fact, parts usually wait quite a long time in manufacturing. It would be a waste of time to wait along the part until it is needed often days later.

There are two ways out of this. You could either follow the next similar part that leaves the inventory. It won't be exactly the same part, but it is the same part type. The resulting diagram will likely be the same, but with much less effort.

Another option is to simply look up where the part would go next based on the production plan. Hence you would create a spaghetti diagram based on available data. **In theory, you could make the diagram while never leaving your desk. That is risky. Being on the shop floor gives you much more information than what is in the official data set.** In the computer data, you will rarely see all the problems, confusions, mix-ups, and other issues that you could improve. Hence, following the data train instead of the physical part is only a last resort – for example, if you track shipments across a world map.

In any case, **following the people doing the work is usually much more interesting than following the parts that are worked on**. After all, since you want to improve the work, it is much better to observe it directly than to guess the work based on the path of a part! Overall, a spaghetti diagram is, even more than other lean projects, a pen-on-paper exercise!

34.2.3 Spaghetti Diagram for Multiple People or Parts

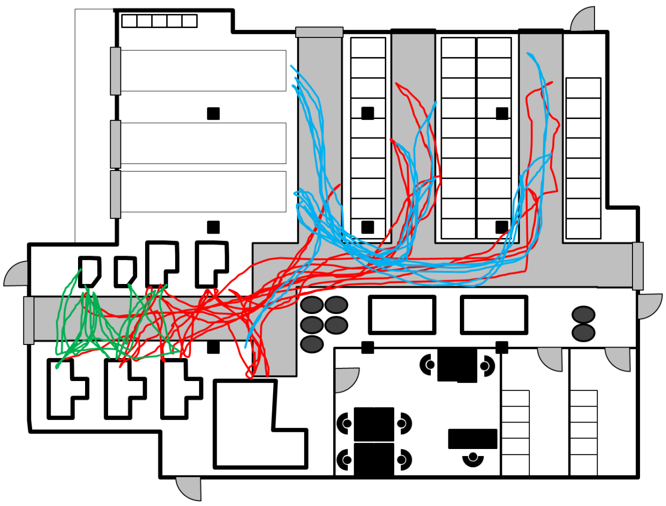


Figure 291: Multicolored spaghetti diagram (Image Roser)

You can also take a diagram for multiple people or parts. Besides taking separate diagrams, you could also use the same diagram and add different colors. In this case make sure you use a thin pen, or you may not see much anymore afterward.

Except for following multiple people (or parts), the result will pretty much be the same.

34.3 What to Do After You Have the Diagram

34.3.1 Analyze Status

Please note that the spaghetti diagram is, by itself, not an optimization method. It only gives you the current state data of the distances. What you do with the data afterward will make the difference. To analyze the situation, it is often helpful to estimate the total distance walked.

You can simply do a rough estimate of the distance walked by taking the distances on the layout and multiplying it by the number of times they were walked (counting back and forth separately, of course).

Another option is to use a step counter, also known as pedometer. Simply give the worker a step counter, reset it at the beginning and note down the steps at the end. An average step is around 2.5 feet or 70 cm long. The average walking speed is 3.1 miles or 5.0 kilometer per hour if you also want to calculate the time needed for walking.

You can also get the current state for a larger number of workers simultaneously by distributing multiple step counters. While you do not get the exact routes, you will get the distances walked. This is very useful for a before-and-after comparison. For larger projects, I simply get a box of 10 or 20 simple step counters for little money, which the workers can have afterward as a gift.

34.3.2 Improve Situation

Figure 292: The first webcam (Image Quentin Stafford-Fraser under the CC-BY-SA 3.0 license)

The real money in the whole exercise is of course in improving the situation. Everything up till now only helped you understand the current state. While there is, to my knowledge, no strict formal method, there are lots of common sense ideas. Most of the time common sense is all you need anyway. You should also definitely ask the people doing the work; they often have quite a lot of common sense and can give you lots of ideas. You could do any of the following:

- Move parts closer to where they are needed.
- Arrange machines and processes to be more in sequence or at least closer to each other (make sure that while you are improving one workload or part, you are not making it worse for all others).
- Simplify processes. For example, rather than searching for a part on a shelf, have the part location printed on the request paper (sounds obvious, but saved a lot of time in a project of one of my employees).
- Determine if you can do it electronically. Walking across the plant just to look something up is a waste of time. For example, the first webcam was installed at the University of Cambridge simply to inform others if there is still coffee in the coffee pot. I also had great success with changing an manual valve two floors below the control room with an electrically operated valve.
- Determine if you arrange it in a better sequence. Don’t be like the roofer that goes down to pick up every tool he forgot.
- Determine if you have to do it at all. Can it be automated? Can it be eliminated?

- Distribute the workload differently to reduce walking times.
- Reduce errors, searches, waiting, and other interruptions of the normal work flow.
- Determine if you can use any type of visual management to make the process faster or more reliable.

All of the above can help you reduce the overall distance traveled and the total time needed to do the work. Please note that reducing the distance is one thing, but with this observation you also have the possibility of reducing waiting times and working times, which will also benefit the overall bottom line.

34.3.3 Verify if New Status Is an Improvement

After you have implemented improvements, definitely do another spaghetti diagram or step counter measurement to see if you made a difference. This would be the "check" of the Plan-Do-Check-Act (PDCA) cycle. Nothing pleases management more than if you can tell them how many dollars you've saved them.

Figure 293: Different part, same pasta… (Image Michael Apel under the CC-BY-SA 2.5 license)

Spaghetti diagrams originated in manufacturing, but are now used in many other areas, too, from studying butterflies to following weather buoys.

Well, all this writing about spaghetti has made me hungry. I need to check if we have spaghetti in the kitchen. So, while I eat some spaghetti, you can think about how spaghetti diagrams can help you **organize your industry!**

35 Happy 2nd Birthday AllAboutLean.com

Christoph Roser, September 01, 2015, Original at https://www.allaboutlean.com/2nd-birthday/

Figure 294: Happy 2nd Birthday! (Image Zerbor with permission)

Today, AllAboutLean.com turns two years old! Exactly two years ago, on my first day as a professor, I started blogging about my favorite topic: lean manufacturing and its history. It's been a great time so far! I have learned tons of new things about lean, have had many good interactions with my readers, and have enjoyed writing this blog immensely. Thank you all for the interest in my writing. I hope it helped you organize whatever processes create value for your company and hence also for you! Time for another look back:

35.1 Selected Praise

Many of you were kind enough to leave comments on my posts with questions, additions, and sometimes even praise. Below is a small selection of some of the positive feedback I've received. To everybody who commented, regardless if mentioned below or not, regardless if here or on LinkedIn, Twitter, Facebook, or elsewhere, thank you!

> *Bravo! No cookie-cutter solutions to problems that do not exist. Good thinking, good writing. This blog is quickly becoming a VA part of my routines, for which I make time. Thanks (by Brian Peshek)*
>
> *This is really a good post I am looking for a long time,pls keep doing this good thing for ever I really love all your posts (by Felix)*
>
> *Great job, keep on going (by Robert)*
>
> *Articles of great inspiration, thank you. (by ingfl)*
>
> *Thank you for your blog posts which really make me think. (by Pedro)*
>
> *We look forward to your final post [on bottleneck detection] with your favorite method. (by LeanLab from the multilingual lean blog LeanLab)*
>
> *Thanks for this once again great article. (by Johann Anders from the German language lean blog Sehen Lernen)*

35.2 Chronological List of Updates and Changes

Since last year – besides blogging at least 1000 words every week – I had some changes and updates. Let me give you an overview:

- In October 2014 I translated, transcribed, and subtitled a great video by Prof. Peter Kruse with the Eight Rules for Total Gridlock in Organizations.

- In December 2014 I added a page with legal blah-blah. That page serves no purpose for you – unless you like reading legal fine print in German and English – but is necessary to protect myself from liability issues. So far nothing has happened. Let’s hope it stays that way.
- In February 2015 I subscribed to a stock photo site, Fotolia. Since then I feel my articles have much more spiffy images.
- In March 2015 I added a glossary with almost 200 lean-related terms. Different from other glossaries, I often add my opinion to help you separate the useful from the buzzwords. This list is continuously expanding, as I always find more terms and abbreviations related to lean floating around. If I missed one, let me know!
- In May 2015 I followed a helpful suggestion from LeanLab and started publishing my blog posts on LinkedIn groups and other social media sites. The number of clicks on my blog doubled within a month ☺, and I have much more interaction with my readers on these sites.
- In July 2015 I added a page listing all posts and pages in chronological order. This page is updated automatically.
- In July 2015 I also signed a book contract with CRC Press on my favorite topic, manufacturing history. If everything works out, the book will be available by the end of 2016. More updates sure to come on this site!
- In July 2015 I took a major step and moved my site from web servers in the USA (at FatCow) to web servers in Germany (WebGo24). The move went relatively smooth, my site was unavailable for only ~1 day while the name servers updated around the world. Since I forgot to set a flag within WordPress, Google did not index my pages, and for a week AllAboutLean.com did not exist in Google search. But all is fixed now (I hope ☺). The American legal system can potentially be quite expensive, especially if you are not American. German law is less risky for me, hence the decision to move to Germany to make this from a legal point of view a fully German-owned and operated site.
- The European Union decided to protect your privacy by creating a EU cookie directive – and it feels like it was designed for a 1995-era Internet Explorer. Additionally, nobody is sure how to interpret the law, hence it is a mess. In any case, since July 2015 there is a small banner at the bottom of the page asking you to click OK for this site to use cookies. However, my recommendation is if you are worried about that, just set up your browser to block cookies or delete them automatically after the session. As for ads, you can use AdBlockPlus.

35.3 Most Popular Posts

Figure 295: Top 10 (Image Roser)

Below are the top ten posts and pages of AllAboutLean.com within the last twelve months, based on the number of page views.

- Theory and Practice of Supermarkets – Part 1 and Part 2
- Why Pull Is So Great!
- Bubble Diagrams to Visualize Material Flow
- Professor Dr. Christoph Roser: Surprisingly, the page about me made it into the top 10 😎.
- Poka Yoke Training – Simple Mistake Proofing Game
- Theory of Every Part Every Interval (EPEI) Leveling & Heijunka
- The (True) Difference Between Push and Pull
- SMED – Creative Quick Changeover Exercises and Training
- Ten Rules When to Use a FIFO, When a Supermarket – Introduction and The Rules: My original research 🙂
- How Many Kanbans? – The Kanban Formula, Part 1 and Part 2

35.4 Strong Exponential Growth

The number of visitors and number of views per day is also increasing nicely. Last year I had a solid exponential trend in the number of clicks per day. Back then I was wondering if my blog would be able to maintain this strong growth. As it turns out, it did!

While you should never really predict an exponential trend far in to the future, I applied an exponential model to the data of last year. This model predicted around 700 clicks per day for August 2015. As it turns out, we had around 700 clicks per day in August, and still have exponential growth 🙂. The number of clicks, in average, doubles every 5 months!

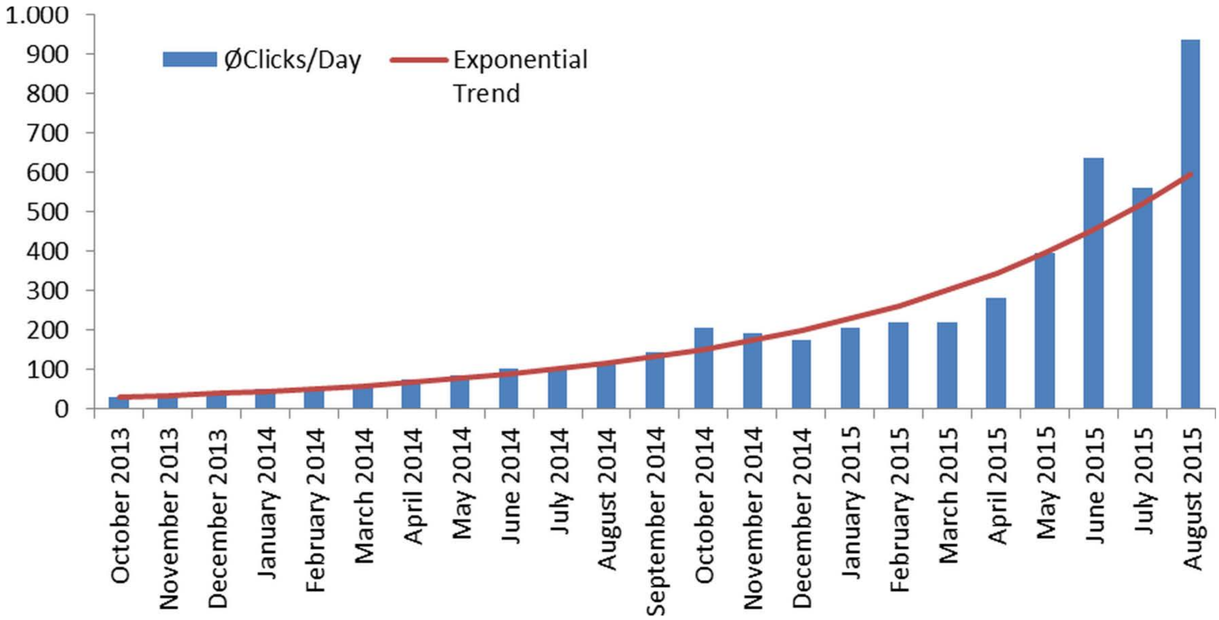


Figure 296: Still going strong … Thank you for Reading! (Image Roser)

Figure 297: World Domination by 2030 … Muhahaha (Image J.J under the CC-BY-SA 3.0 license)

Continuing this exponential trend further into the future, I am still on track to overtake Wikipedia by 20 19, and Facebook and Google by 2024. By 2026, each and every click on the Internet will be on AllAboutLean.com. At the latest, by 2030 world domination by AllAboutLean.com is certain. The numbers in the model are very precise. Now we just need to keep this exponential trend going for the next 15 years 😛.

So, my dear readers, please keep on reading, commenting, and – above all – using lean manufacturing to **organize your industry!**

36 All About Swim Lane Diagrams

Christoph Roser, September 08, 2015, Original at *https://www.allaboutlean.com/swim-lane-diagrams/*

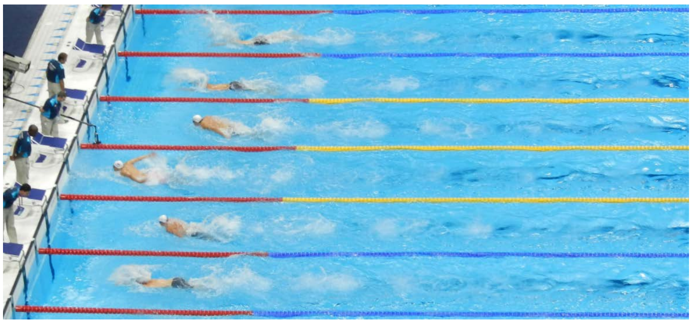


Figure 298: All About swim lane diagrams (Image Madchester under the CC-BY-SA 3.0 license)

In my previous posts I described the details of value stream mapping. However, value stream mapping works only for highly linear material and information flows. Unfortunately, many industry processes, especially in administrative or indirect areas, are all but highly linear. To visualize these processes, a new diagram was developed – the **swim lane diagram**. In this post I will show you how swim lane diagrams work.

36.1 A Quick Overview of Swim Lane Diagrams

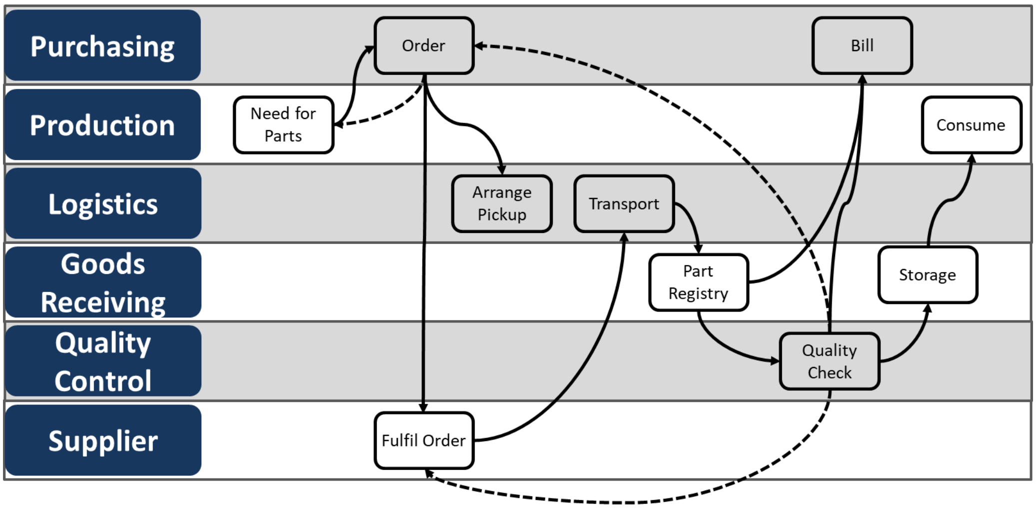


Figure 299: Looks familiar? (Image Roser)

At their core, swim lane diagrams are flow charts. The feature that distinguishes a swim lane diagram from a normal flow chart is the lanes in the diagram that represent different departments/functions/offices, etc. Since these lanes make the flow chart look like the lanes of a swimming pool, this type of diagram is often called a swim lane diagram.

Besides the most commonly used name, **swim lane diagram**, it is also called **functional bands** (in Microsoft Visio) or **process mapping**. The earliest reference I am aware of is a east German standard from 1968 (TGL 22452 *Kybernetische Blockschaltbilder zur Modellierung von Organisationssystemen, Koordinatendarstellung*, thanks to Ben Bolland for pointing that out). [Actually, Braz commented below and found an even earlier example from the US Bureau of the Budget bulletin on Process Charting from November 1945.] They are also sometimes known as **Rummler-Brache Diagrams** based on the 1990 book Improving Performance: How to Manage the White Space on the Organization Chart by Geary A. Rummler and Alan P. Brache. Yet, in lean there are few things that cannot also be said much more fancily in Japanese, hence they are also known as **makigami** (巻紙). However, translated this means nothing more than a roll of paper, since makigamis … sorry … swim lane diagrams are often created on a big roll of brown paper.

36.2 Where Are Swim Lane Diagrams Useful?

Swim lane diagrams are used for **information flows** (and to a lesser degree also material flows) that involve different **separate entities** that are **not necessarily working in a linear sequence**. It is often used for administrative processes as, for example, order processing, part development, marketing, etc.

36.2.1 What Kind of Entities Could There Be?

The defining feature of swim lane diagrams is … well … their swim lanes. Each lane represents a different entity. An entity is usually associated with a certain function. Hence, it could be a department, a subgroup of a department, an office, individual people, or it could even be larger than a department as, for example, a plant, a site, the customer, or the suppliers.

What entities you will need depend on the problem you are trying to address. The diagram should include all entities that are involved in the process you are trying to visualize. In my experience, I usually end up between 4 and 12 groups. If there are less, then the diagram may not be detailed enough. If there are more, you may get lost in the details.

36.2.2 What Flow Is Shown?

In swim lane diagrams, you follow the processes of a certain job or document. For example, if the customer calls and places an order, how does this order flow through the different entities until the customer eventually gets its part?

This primarily includes information flows. Which group gives which information to what other group? If the customer representative forwards a request to Development, this would be an information flow. Swim lane diagrams can also include a material flow. While this is common, in my experience the material flow is usually only a minor part of the flows.

36.2.3 What about the Nonlinear Sequence?

In value stream mapping, the material flow is usually highly linear. Administrative areas on the other hand are much less linear. This is where the swim lane diagram comes in handy. In this diagram, it is no problem for flows to **split and merge** again later. For example, the billing office may work on the same project at the same time as Development.

Similarly, information can also go in circles (which is unusual for value stream maps). For example, Purchasing could find out that they did not get enough information from Development, and hence calls Development for more information or sends the document back to development altogether. Potentially a document or a job could go around in circles for multiple times.

36.3 How to Do a Swim Lane Diagram

36.3.1 Who Should Do It?

You can do a swim lane diagram on your own or as a team. If you work in a team, you may get more information out of it. Try to include people from the areas that you are looking at. A good team size would be 3 to 4 people.

36.3.2 Do it on Paper?

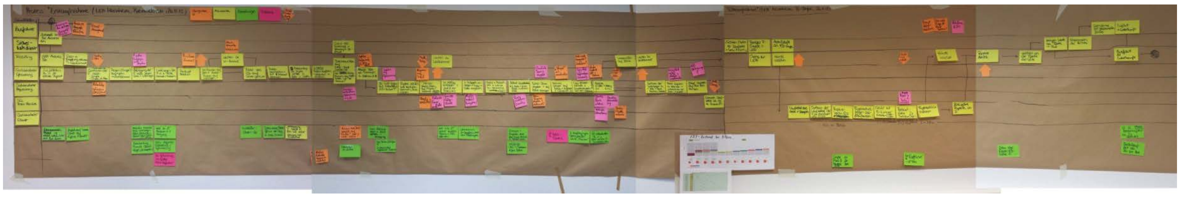


Figure 300: The swim lane for [Lean for Refugees](), although I usually use less detail for more clarity. (Image Roser)

For almost any kind of diagram, I prefer working on paper. It is easier, faster, and can be an interactive experience if you work in a team. Ideally, you have a large pin board on wheels and brown packing paper. If the pin board has wheels, then you can actually move it around while you observe the system. I use brown packing paper since it is cheaper, but if you prefer/have good white paper, that works too. The color doesn't really make much difference.

To make the lanes, I recommend not using a pen or marker. This will be confusing later if you add all the information flows. Rather, I recommend folding the brown paper every 10 or 15 cm (4 to 6 inches). These folds show up well enough to indicate lanes, but cannot be confused with flow arrows later on.

For the different steps in the lanes, you can use simple pin board cards. The connection flow arrows are drawn directly on the brown paper using any kind of flip-chart marker. Another possibility is to do it on a whiteboard using post-it notes an marker, which also makes it easier to rearrange.

36.3.3 Do It Digital?

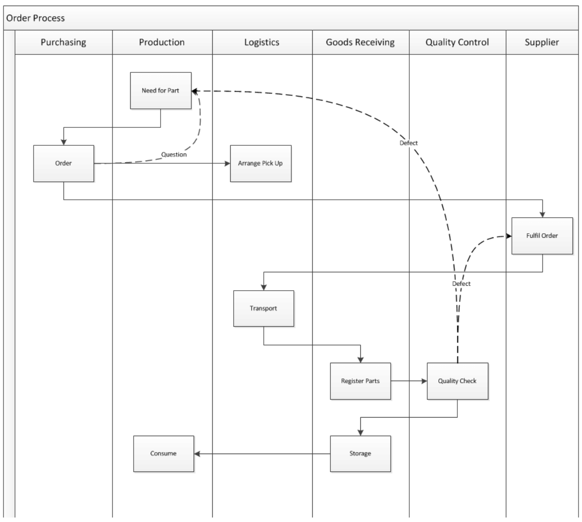


Figure 301: Vertical swim lane diagram in MS Visio (Image Roser)

Swim lanes can also easily be produced digitally, and are included in many flow chart products. For example, in Microsoft Visio, look for the term "functional bands." However, I prefer paper over computer. For one thing, it costs time. All the effort needed to handle the software takes brain power away from actually understanding the problem. Your brain will look for good ways to draw it, rather than looking for problems and ways to improve it. Do not underestimate this type of brain drain!

Additionally, if you work in a group, it is much more difficult to interact while creating a computer document.

The advantage of digital is, of course, that it looks nicer and is easier to print, e-mail, or otherwise share. Hence, you can impress a lot more people that neither need nor understand these diagrams.

36.3.4 Horizontal or Vertical?

You can do these diagrams either with horizontal lanes or vertical lanes. When I am working with paper, I usually go for horizontal lanes, as it is easier to make a larger diagram by putting multiple pin boards next to each other. If I have to use a computer, I go for vertical lanes, as it is easier to scroll up and down. Both work; use whatever fits your problem best.

36.3.5 Do It Where It Happens!

Probably most important is to generate the diagram in close interaction with the people doing the tasks on the diagram. Ideally, you can walk through the different offices and interview people or observe them doing their work.

When interviewing, keep in mind that people usually tell you the way it **should** be (because that's all they usually are ever asked). However, we want to know how it **really** is! Hence, with every person you talk to, do some digging for things that do not go as planned, where the information was incomplete, or where the information is simply wrong. Try to incorporate this in your value stream map as much as possible! That's where the value of a swim lane diagram is!

36.3.6 Where Should I Start?

In value stream mapping, the mantra goes to start at the customer side (see my full post on Value Stream Mapping – Why to Start at the Customer Side). However, for swim lane diagrams, in my view either direction is fine. Actually, since the information often goes in loops, you would need both directions, or at least ask at every stop to understand both directions.

36.4 What Goes on the Diagram?

First, I would label the lanes with the offices that I know will be part of the diagram. Keep some lanes free for additional functions you come across later. Then I would add the starting process by drawing a box and writing the action inside of the box. This could be, for example, the customer calling and placing an order. From there on, I just follow the flow of information and material and add more boxes. These boxes are connected with simple arrows.

Please keep in mind that flows may split, merge, and loop. For normal information flows as they should be, I simply use a normal straight line arrow. For recursions and non-standard information flows, I use dashed lines or a red pen to indicate that this flow is not how it should be. This will help you to understand where waste occurs.

Figure 302: Problems and Solutions (Image Roser)

I also use star shapes to note problems that I observe and cloud bubbles for improvement ideas. If your diagram has only a few of those, then you are doing something wrong. Mine are usually quite full with these items. In fact, **these problem and improvement ideas will be the biggest benefit you get from a makigami!** For added effect, you can also use colored Post-its for problems (red) or ideas (green).

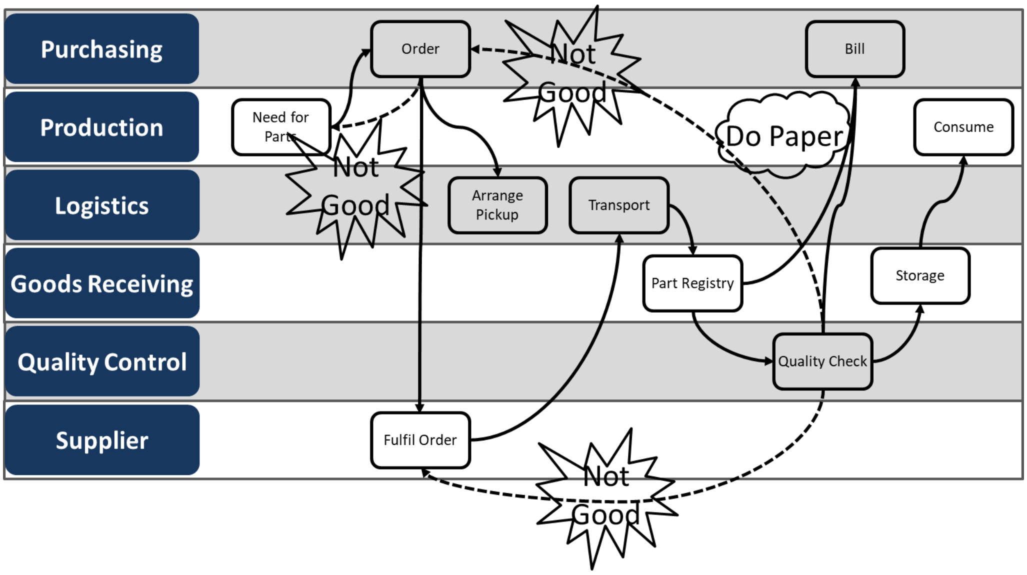


Figure 303: Example result of a swim lane diagram (Image Roser)

Feel free to adapt and adjust the style to fit your needs. For example, if you want to use a diamond shape for decisions, by all means go for it. The symbols for swim lane diagrams are even less standardized than those for value streams.

36.5 Gizmos and Gadgets to Avoid!

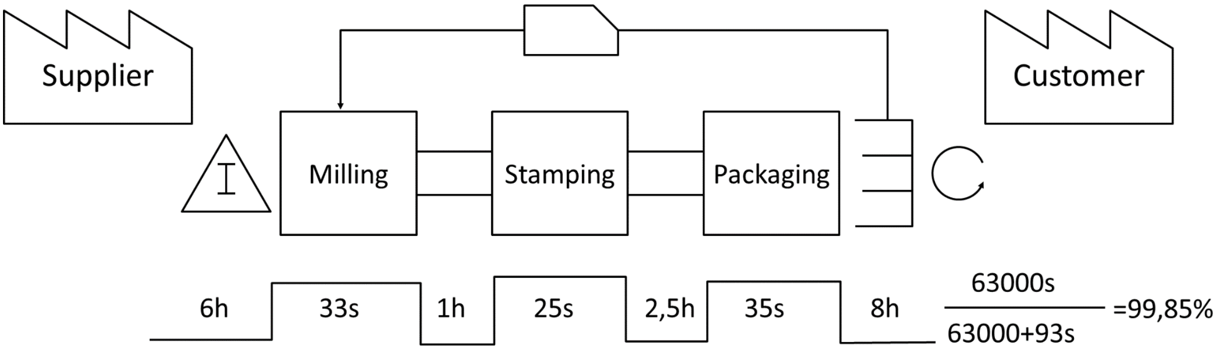


Figure 304: Not even useful in a value stream map! (Image Roser)

There are more things you can do with a swim lane diagram. However, just because you *can* does not mean you *should*! For example, in value stream mapping, some people draw an up-and-down line underneath the entire map to show the value-added time and the non-value-added time. I don't even like this for value stream maps (see my post), and it is even less useful for swim lane diagrams. Due to the loops and very different work content between different jobs, you probably will be hard pressed to get meaningful data. For example, if you handle incoming orders, you will have some customers that are a breeze and others that you wish never ordered.

Similarly, some people will tell you to add all the data and cycle times to the diagram. Don't do it unless you really need it! Especially with usually little-standardized processes often found in swim lane diagrams, these times have a high variation and are probably next to useless.

36.6 Current and Future State

As with value stream maps, you should start with a current state. This alone may give you enough improvement potentials to keep you busy for weeks.

You can also do a future state for a swim lane diagram, but again: Do it only if it helps you. If you do not plan to revamp the flow but only improve on the current problems, you probably don't need a future state.

36.7 Summary

A swim lane diagram hence is useful for nonlinear information flows across multiple departments or groups. It can help you to see problems, but it is only a tool to see them, not to fix them. The real work comes afterward in improving all the little details and problems you found. Yet, applied in the right situation and to the right problem, it will help you organize your processes. Hence, **go out and organize your industry!**

37 On the Different Ways to Measure Production Speed

Christoph Roser, September 15, 2015, Original at https://www.allaboutlean.com/production-speed-measurements/

Figure 305: Trouble with Times… (Image Hal Roach Studios in public domain)

The speed of your production system is a key aspect of your manufacturing system, and controlling it is important for the success of your organization. Unfortunately, there are many different and confusing ways to measure the manufacturing speed. Even a simple question on how to call a speed is often confused, with many practitioners using the same term for different measurements, or different terms for the same measurements. This post aims to give an overview of what is out there, and what it is good for.

37.1 Lots of confused Terms

There are tons of different terms used by practitioners about the speed of the line: *cycle time, takt time, process time, target cycle time, effective cycle time, line takt, …* and many more. Unfortunately, often different lean practitioners mean different things using the same term, or mean the same thing but use different terms. This is not good. The line speed is one of the important aspects in improving your system. **Yet, exactly at this key point of lean manufacturing, the terminology about line speed is absolutely not standardized. This has potential for major confusion!**

What I describe below is what I think makes most sense, but I also often point out how it also may be called by others. So please, if you have a different idea on how to call things, please let me know!

37.2 Many Questions to ask

Figure 306: Question Mark (Image Horia Varlan under the CC-BY 2.0 license)

To sort out these different speed measurements there are a few key questions to help you figure out the differences:

- **Does the measure include losses or not?** I.e. does the time include delays like breakdowns, defects, speed losses, and so on or not? The ratio between these two times would be the OEE.
- **Do you measure a time per part, or its inverse of parts per time, or only a time?** Depending on the answer you have a unit of time per piece, pieces per time, or only time without any pieces, e.g. the time it takes to go through the process(es). I.e. the difference between the time between parts leaving the system or the time they stay in the system.
- **Is it the actual time or the target time?** I.e. do you measure how fast your system/process should be or how fast it actually is?
- Do you look at a single process, or do you look at an entire system?
- **Do you need the average, a maximum, a minimum, a median, or a percentile value?** In most cases you probably use the average, or more precisely the arithmetic mean, although the median can also be useful sometimes. However, sometimes there are situations where you are looking for a maximum value, i.e. if you promise your customer a delivery date, you better use the maximum lead time, or a lead time that you are 95% sure you can reach (95 percentile).
- **Do you measure the average of all parts, or separately for every part type?** The number of parts per hour will be different if you include all part types, or if you focus only on part 08/15.
- **Do you mean an absolute or relative time?** I.e. is it a time stamp (like June 15th 7:33 AM) or a duration? For the remainder of the article whenever I discuss times I usually mean a duration.
- **For batch processes: Do you measure the average time for a single part or for a batch?** If you bake a batch of 100 pieces in an oven, the time per batch is 100 times the average time per piece.
- **Do you include some additional times on top of the speed?** This is common for setting targets for manual work. The operators sometimes have to go to the bathroom, or need small mini-breaks. In any case they cannot work continuously at 100% as a machine could. Hence, the target speed is increased by an additional percentage to cover these times (often between 5 and 20% depending on local regulations and union negotiations).

As you can easily see, there is a plethora of possible speed measurements out there. Luckily, not all of the 768+ combinations of the questions above are useful in practice. A brief overview is given below for the first four questions:

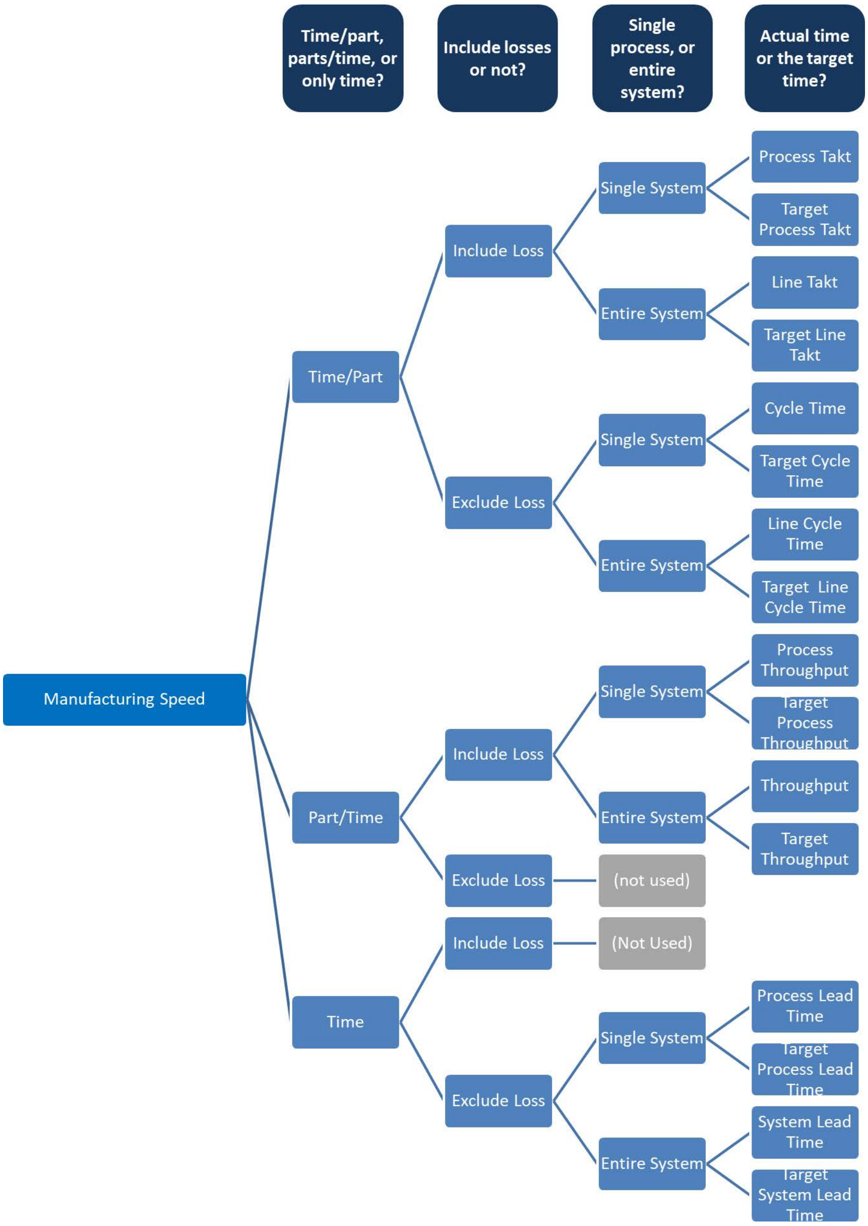


Figure 307: Different Manufacturing Speed Measurement Options (Image Roser)

Some are more common than others, but it definitely has a lot of potential for confusion. Let's have a look at the most frequently used measurements. For the sake of simplicity I use discrete parts for my examples below, but you can easily adapt it for continuous production in process industry, e.g. if you produce liters of beer per hour 🙂.

37.3 Different Speed Measurements

37.3.1 The Takt Time

Figure 308: Giving the Takt… (Image Vladimir Voronin with permission)

The takt time is probably most well known for the **customer takt**. The customer takt is the available work time divided by the customer demand during this time.

$$Customer\ Takt = \frac{Available\ Work\ Time}{Customer\ Demand\ during\ Available\ Work\ Time}$$

Please keep in mind that this is of course an average time between customer orders. In reality, the customer will order much more erratically. You can also calculate the takt for a single process or an entire manufacturing system. It is important that this always includes the losses! This is useful if you want to find out if your system is able to satisfy demand.

You should also distinguish between the target value and the actual value. For example, if you determine that your system has produced 6000 parts during the last week with 40 working hours, your **system or line takt** is 24 seconds/part. If, however, you would have needed 7200 parts, then your **target system/line takt** is 20 seconds/part, and your system is too slow. If you have two machines in parallel producing parts, then your **machine takt** or **process takt** is 48 seconds/part, but your **target machine takt** or **target process takt** is 40 seconds/part.

Also, please be aware that quite a few practitioners call takt time for processes cycle times! This has lots of potential for confusion! I strongly prefer to use cycle time only for times without unplanned losses or delays – see more on cycle time below. In any case, if discussion takt times and cycle times with someone else, please verify what they are talking about! For more details see my posts How to determine Takt Times and Pitfalls of Takt Times.

37.3.2 The Throughput

Figure 309: How many per hour? (Image Haragayato under the CC-BY-SA 2.5 license)

The throughput is simply the inverse of the takt time, although usually only used for actual or target production, and only rarely for the customer demand.

$$Throughput = \frac{Parts\ produced\ during\ Available\ Work\ Time}{Available\ Work\ Time}$$

It also must include losses. Hence, you can also have a **system or line throughput**, a **target system/line throughput**, a **machine or process throughput**, or a **target machine/process throughput**. This naturally must be measured in parts per time.

37.3.3 The Cycle Time

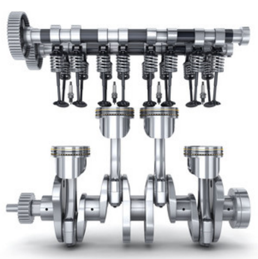


Figure 310: Also a cycle, although the measurement RPM is closer to a throughput (Image Vladislav Kochelaevs with permission)

The cycle time is like the takt measured in time per part. The important and often confused difference, however, is that **the cycle time does not include losses! The cycle time is the fastest repeatable time in which you can produce one part.** I.e. it is an idealized time that you need per part if everything goes perfect, having no breakdowns, quality defects, or other problems (for more on losses see my articles on OEE).

Hence, you cannot simply divide the production time by the number of parts, but you do have to measure every part individually, and figure out what your system can do under ideal circumstances. Here you may choose not to use a mean, but instead use a median, or even a lower percentile, e.g. speed of the 10th percentile. Please note that you can add means to get the mean of the lead time, but this does not work with medians or percentiles.

Cycle times are usually measured for individual processes, where you have both a **cycle time** for the current state and a **target cycle time** for the speed you actually want. By the way, the difference between the cycle time and the takt time of a process is the OEE.

It is also possible to calculate a **system or line cycle time** for an entire system. You would have to figure out how fast the system would be if there are no losses. If you have only sequential processes with each process cycle needed only once for the final product, then the system cycle time would be the slowest/largest process cycle time. Similarly, you can set a **target system/line cycle time**. However, due to the interactions of the losses in the processes that slow down the system in reality in my view it is difficult to use a system cycle time number in a meaningful sense.

If you have batch processes, you also would have to distinguish if you are measuring the time per batch or the time per part. Depending on what you use the measurement for either one may make sense. If you want to figure out how fast your batch process should be, then of course you set the cycle time for the entire batch. If you want to find out if your batch is fast enough for the customer, and your customer takt is in individual pieces, then you would need the cycle time of an individual part, and see if it is fast enough for the customer takt if you also include OEE losses.

Please be aware that this definition above is far from universally accepted. Some practitioners define cycle time to include losses. However, based on a discussion on the LinkedIn Group TPS Principles and Practice, cycle time is more often defined excluding losses (Many thanks to all who contributed in this discussion).

For more on cycle times check my posts How to Measure Cycle Times – Part 1 and How to Measure Cycle Times – Part 2, as well as Cycle Times for Manual Processes.

37.3.4 The Lead Time

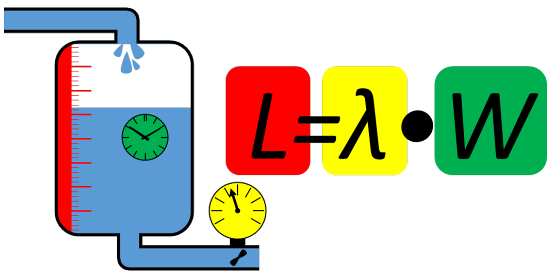


Figure 311: Use Little's Law for the Lead Time (Image Roser)

The lead time is the time it takes for a single part to go through the entire process or system. Therefore, this way of measuring production speed is quite different from the takt time, cycle time, and throughput above. **The takt/cycle times is important if you want to know if you can produce enough. The lead time is important if you want to know if you can deliver on time.**

If your cycle time is good but your lead time is not, then you will have enough but too late. On the other hand, if your lead time is good but your cycle time is not, you will build up unprocessed orders which increase your lead time and hence you will have neither enough nor on time.

Similar as with the cycle times, we have a **process or machine lead time**, a **system or line lead time**, and of course all of them also as target values: **target process/machine lead time** and **target system/line lead time**.

To measure the lead time of parts directly is in practice quite difficult. However, there is a very cool fundamental law in production systems that allows you to determine the lead time based on the throughput and the work in progress (WIP): Little's Law, with

- L – Inventory, measured, for example, in units or quantity
- λ – Throughput, measured in units or quantity per time
- W – Lead Time, measured in time

$$L = \lambda \cdot W$$

This is actually one of my favorite equations in lean manufacturing, since it is valid everywhere as long as you have a stable system (i.e. no ramp up or other system changes). Read my Eulogy for Little's Law for more details.

37.3.5 What about Process Time?

Another term often used is process time. However, here it gets a bit confusing. Some see process time as the sum of the cycle times in a series of processes, i.e. excluding losses. Others use it as a synonym to lead time. Yet other describe it as a synonym to cycle time or sometimes also takt time. Again other definitions I have read in my view confused more than clarified, calling e.g. the process time a part of the cycle time. Overall, I tend to stay away from using the term process time since it is too often confused.

37.4 Summary

These above are the most commonly used measures to express the speed of your system. The way of measuring depends of course on what you want to do with the measurement. However, there are more pitfalls when actually determining these numbers, which can make or break your improvement project. Hence, I will go into more details about measurements in the following posts. Please also **be wary about the confusion on the nomenclature, and lots of people have different names for the times above!** While these are a lot of different numbers, I hope this helps you to avoid confusion on what is what, even though the terminology in the field is highly inconsistent! So, do not get confused, but go out and **organize your Industry!**

PS: While writing this post I had input from different members of the LinkedIn group TPS Principles and Practice. Thanks to everybody who shared their views!

PS2: Michel Baudin added a commentary on my "*useful and well researched*" post on his blog. I agree with his comments and have updated the post above to include most of them. Thanks, Michel ☺!

38 How to determine Takt Times

Christoph Roser, September 22, 2015, Original at https://www.allaboutlean.com/takt-times/

Figure 312: The rhythm of your system (Image Vladimir Voronin with permission)

The customer takt (or takt time) is one of the fundamentals for determining the speed of a production system. It represents the average demand of the customer during a time period. Whenever you design a new production system or change an existing system, one of the early data inputs you need is the customer takt. While the customer takt can be simply calculated by dividing the demand by the time available for production, there are many more details needed to understand it fully.

38.1 Why do we need Takt Time?

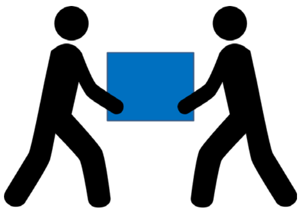


Figure 313: Match Supply and Demand (Image Roser)

The takt time gives us a measure of the customer demand over time, of which for practical reasons the inverse is used (i.e. the time over demand). There are two main reasons why you need the customer takt:

Production Speed: If you know how fast your customer requires parts, you know how fast your processes have to run in average, or – dividing the customer takt by the OEE – how fast your processes have to be before the usual break downs and other problems slow you down. Hence, the customer takt helps you to determine how fast your processes must be.

Number of Kanban: If you use a kanban based pull system, you need to determine the number of kanban. One way is to calculate them. For this, the customer takt is an important input in the calculation.

Attention: For the same line and the same period, the customer takts may be different. For the production speed you need to calculate the customer takt across all part types. For the kanban calculation, you must calculate it separately for every part type that you need kanbans for. Do not mix these two up!

Additionally, you can not only calculate the customer takt that you need, but also the **process, system or line takt** that the system can deliver. Of course, the **target system/line/process takt** should be slightly faster than the customer takt.

Please be aware that **a significant number of practitioners prefer to call the process or line takt a "cycle time"! This has significant potential for confusion!** I strongly prefer to use cycle time only for times without unplanned losses or delays. In any case, if discussion takt times and cycle times with someone else, please verify what they are talking about!

38.2 How to calculate the Customer Takt

Figure 314: Drummer Girl (Image Ollie Harding under the CC-BY 2.0 license)

Simply said, the customer takt is the average time between the demand for a part. To calculate it, you divide the available working time by the customer demand during that time.

$$Customer\ Takt = \frac{Available\ Work\ Time}{Customer\ Demand\ during\ Available\ Work\ Time}$$

By the way, the throughput is simply the inverse of the takt time, although usually used only for the actual or target production, not the customer demand:

$$Throughput = \frac{Parts\ produced\ during\ Available\ Work\ Time}{Available\ Work\ Time}$$

However, while the formula looks (and is) simple, there are still many possibilities to put in the wrong data. Hence, we'll look at the two variables in more detail:

38.2.1 The Available Work Time

Figure 315: What is your available work time? (Image geralt in public domain)

The numerator in the equation above is the available work time. Hence, we should definitely exclude times that the production system in question is not running. For example, if your system works only two shifts for five days per week, **do not include off shifts**. We should include only these two shifts for five days per week. Additionally, we should also **exclude regular breaks like lunch or breakfast**.

We could additionally exclude other irregular but scheduled breaks like company meetings, although in my opinion this is blurring the line. In my opinion this effort is usually not worth the benefits. You may get a customer takt that is slightly more precise, but the difference in all likelihood will not be that large. Later, when we use the customer takt to design the line speeds, we should keep some flexibility anyway.

You should **include non-scheduled breaks** that are part of the regular operations of the system like breakdowns, change overs, or repairs. Overall, try to include as much of the lost time in the work time. The distinction to an efficient time is done later with the cycle time.

Later, we will use the customer takt in combination with the OEE to determine the target cycle time of the system. For the OEE, we also use a working time as part of the OEE calculation. **The definition of available time you use for the customer takt must be the same as the time basis you use to calculate the OEE!** For example if you exclude maintenance for the customer takt, you must also exclude it when calculating the OEE. If you include it for one but not the other, the numbers no longer match. See my posts on OEE for more details there.

38.2.2 The Quantity

Figure 316: To demand or not to demand … (Image Ivonne Wierink with permission)

As for the denominator of the demand, this represents the total demand by the customer during the available work time. This is usually the predicted demand for the future, which by its nature may include uncertainties. Additionally, the customer may order anytime day or night, but your manufacturing will produce it only during work times. Hence, if the customer orders 10.000 products in one month, the available work time of this month is divided by the number of products.

As for the quantity, you could either use the sum of all parts produced on the line, or you could split it by product type. Both is quite feasible. **If you want to determine the speed of the machines, you must take all parts into account.** On the other hand, **if you want to** calculate the number of kanban**, you must calculate the customer takt and the subsequent number of kanban for every part type separately.**

Naturally you need to keep an eye out for the difference between the demand of the end customer and the demand by the next station down the line. For example, if the customer will order 2000 cars per month, your demand on wheels would of course be 8000 wheels per month, since one car (usually) equals to four wheels.

38.2.3 The analyzed Period

Figure 317: Four Seasons (Image Cherubino in public domain)

Another relevant question is to decide which period you want to analyze. Are you interested in last week or next week? Do you want to know the next month, quarter, or the entire year?

In my experience, past customer takts are rarely calculated (unless you assume that the future will behave similarly to the past). Most practitioners are interested in future customer takts to prepare their systems for future demands. One problem is to determine the behavior of the future. Since the available work time is usually set by the plant, you have some certainty about the behavior of the work time.

On the other hand, customers are known to behave quite unpredictably. How do you know what the customer will order next week, let alone next year? I can’t help you with that problem here (this would be another post), but I can tell you a bit about what period to use. It all depends on what you want to do with the customer takt. If you merely want to update the number of kanban, then a shorter view of a few weeks or months may be sufficient.

If you have a highly flexible line where you can adjust e.g. the number of workers, you may be interested in the customer takt for next week to determine how many workers you should plan for that line.

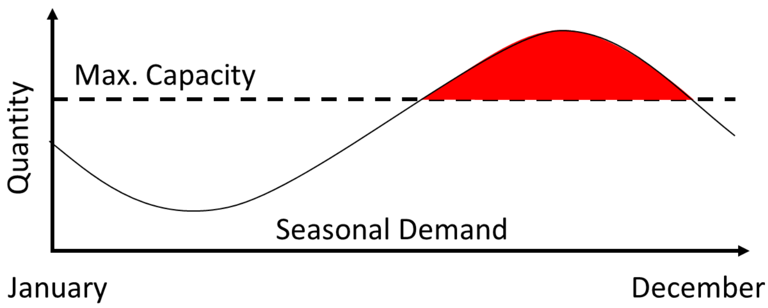


Figure 318: What demand quantity should you use? (Image Roser)

If you are building a new line or expanding an existing line, you may be interested in multiple months or even years of demand. For such long term plans the customer behavior becomes not only less certain, but it may also have seasonal behavior.

Do you want to set up the system for the average demand, or the peak demand? How much can you ramp up your capacity, how much do you want to stock beforehand, and how much are you willing to risk in missed sales? In any case, it does help to understand the peak demand of the year, e.g. the month with the highest sales, even though you may still choose a line speed below the peak demand.

38.3 Customer, Line, and Process Takt

Figure 319: Also sort of a line takt … (Image Mr Bound under the CC-BY-SA 3.0 license)

As you can calculate the time per part for the customer demand, you can also calculate the time per part your line or process can produce. These I call line takt or process takt – although **there are a lot of different and non-standardized terms out there in the field for this speed measurement**.

Ideally, your line takt should be a teeny bit faster than the customer takt. If you are slower, you won't be able to satisfy the customer demand. If you are much faster, your people or machines have not enough work. The easiest way to adjust this is through the working hours.

38.4 Summary

Overall, takt time is the available work time divided by the average number of parts needed (or produced) during that time. The above calculations are an easy case. In my next post Pitfalls of Takt Times I talk more about the pitfalls of takt times, especially for parallel processes. I will also briefly talk about history and why this Japanese technique has a German name, and will calculate an example. In the meantime understand the rhythm of your system so you can **go out and Organize your Industry!**

39 Pitfalls of Takt Times

Christoph Roser, September 29, 2015, Original at https://www.allaboutlean.com/takt-time-pitfalls/

Figure 320: UCLA Marching Band (Image Eric Chan under the CC-BY 2.0 license)

The customer takt (or takt time) is one of the fundamentals for determining the speed of a production system. After my post on How to determine Takt Times, this second post on takt times gives a bit of history, and then goes into more details about possible pitfalls and problems when calculating the customer takt. I also added an example for easier understanding.

39.1 A Brief Bit of History

Takt (German): pulse, stroke, gating, timing, beat, cycle, meter, work cycle

Figure 321: Moving with the beat (Image Seuffert under the CC-BY-SA 3.0 Germany license)

The word "*Takt*" comes from the German language, since the method was developed in Germany in 1926 in the Junkers aircraft plants. Production of different steps was timed so that the airplanes moved to the next stations at fixed intervals, a method they called *Taktverfahren* (*Takt* method). This was not a moving assembly line as with Henry Ford, but a pulse line that moved at fixed intervals (the *takt*).

This system was also used during World War II in Germany. During that time, about 250 German aircraft engineers and technicians moved to Japan to support the wartime production of their Japanese ally. Through this contact, Mitsubishi learned about the *Takt*. From Mitsubishi the method spread to Toyota, and hence lean production uses the German word *Takt*, albeit in a marginally different context.

Please note that when most people talk about customer takt nowadays, they mean the average time between parts. In reality, of course, the time between parts may be quite different. For example in a batch job you may get 100's of parts at the same time, and then nothing for a long time. The historical takt time above was something set by the people that organized production, and the goal was to keep it constant. Hence, historically the meaning was a bit different from the modern usage of takt in manufacturing.

(Thanks to Joachim Knuf and Michel Baudin for this important piece of history – for more see the highly interesting post 1, post 2, post 3, and post 4 on Michel Baudin's blog.)

39.2 Takt Times for Parallel Processes

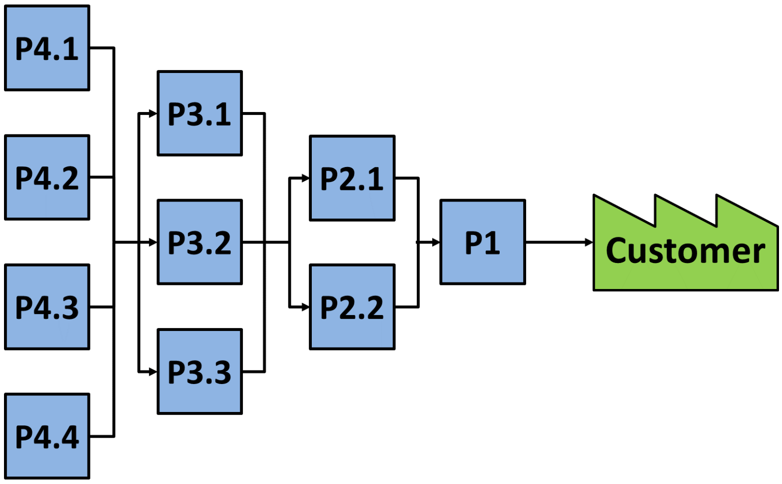


Figure 322: Different takts for parallel processes! (Image Roser)

Please keep in mind that the takt will be different if you have parallel processes. In the example shown the first process P1 has the original customer takt. The second parallel processes P2.1 and P2.2, however, have double the customer takt (assuming the processes have an identical speed). Since they work in parallel, each has to do only half of the parts, doubling the customer takt.

$$\frac{Available\ Work\ Time}{Half\ Customer\ Demand\ during\ Available\ Work\ Time} = Double\ Customer\ Takt$$

Similarly, since each of the three processes P3.1, P3.2, and P3.3 have to produce only one third of the overall quantity, the customer takt triples. Equally for P4.1, P4.2, P4.3, and P4.4 the customer takt quadruples. In general, **if you have *n* parallel processes with identical speeds the customer takt multiplies by *n***.

If the processes do **not** have identical speeds, then you would have to calculate each takt separately based on the number of parts that pass through. For example if P2.1 is twice the speed of P2.2, then 2.1 will make 2/3rd of the parts and P2.2. will make the remaining third. The customer takt of P2.1 will then be the inverse of 2/3rd, namely 3/2=1.5 of the original takt, and P2.2. will have 3/1 = 3 times the original takt. But to be on the safe side I recommend to calculate it separately using the number of parts going through each process to avoid errors. Similar is of course also true if the processes have non-identical work times.

Also, be aware if more than one part is needed for the final product. Assume P2.1 and P2.2 have identical speeds, then the customer takt would double. If, however, P2.1 makes the left fender and P2.2. makes the right fender, you would need two fenders per car and the doubled customer takt would halve again to the original value.

It starts to become real tricky if you have three processes making pistons for a five cylinder engine, and one of these processes is 40% slower (Hint: It is $\frac{13}{25}$, $\frac{13}{25}$, and $\frac{13}{15}$ of the original takt). **In any case, unless you are really into fractions, go the safe way and calculate the number of parts needed from each process, and then calculate the customer takt for each machine separately.**

39.3 An Example

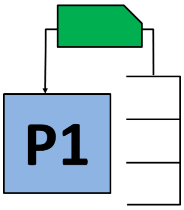


Figure 323: Simple System (Image Roser)

Lets make a simple example. We have one manufacturing system that produces two part types, A and B. We have a flexible manufacturing system whose capacity we can adjust by adding or removing workers in the system.

We want to find out how many workers we need to add to the line next week. Hence, your period of interest is next week. We estimate that the customer orders 4.000 products next week, and we have a 5 day workweek with one shift of 7.5 work hours each. This gives us a total available work time of 37.5 hours or 135.000 seconds.

$$Customer\ Takt\ Next\ Week = \frac{135\ 000 s}{4000\ pieces} = 33.75 \frac{s}{piece}$$

If for example our workers need 60 seconds to produce one part in average (including machine problems and defects), then we would need at least 1.7 workers to fulfill the customer demand.

For the overall customer takt, we did not care if the worker ordered A or B parts, we were only interested in the total sum. However, if we want to adjust the number of kanban for next week, we would have to analyze part A and B separately. Out of the 4.000 parts total, we predict 3.200 to be of type A and 800 of type B. Hence we calculate the two separate customer takts as shown below.

$$Customer\ Takt\ Next\ Week\ A = \frac{135\ 000 s}{3200\ pieces} = 42.19 \frac{s}{piece}$$

$$Customer\ Takt\ Next\ Week\ B = \frac{135\ 000 s}{800\ pieces} = 168.75 \frac{s}{piece}$$

Please note that these takts are larger than the joint takt. These values we can then use for a more detailed calculation of the number of kanban.

39.4 Common Mistakes

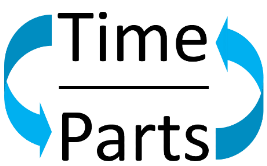


Figure 324: Time over Parts Confusion (Image Roser)

When calculating the customer takt please **make sure that you do not mix up the numerator and denominator**. The customer takt is always a time for one piece, hence the work time is the numerator and the pieces are the denominator. If you mix this up, you calculating the inverse and end up with the throughput – which is also useful but it may no longer match the rest of your formulas.

Figure 325: Micrometer (Image Lucasbosch under the CC-BY-SA 3.0 license)

As for precision, **the customer takt is only as precise as your inputs**. If you know your future demand precisely down to a single piece, I envy you. Otherwise, make sure you leave some wiggle room in your system in subsequent calculations of capacity (For example, kanbans are more robust and automatically include a wiggle room through supermarket inventories). Also, if your demand prediction is fuzzy, you do not gain more accuracy by making your work time estimate super precise.

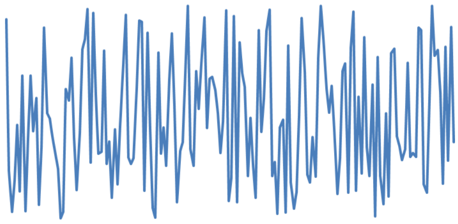


Figure 326: Fluctuation (Image Roser)

Finally, **while the takt time gives you the average time between parts, the true time between parts will fluctuate widely**. A customer may not order a part every 50 seconds, but may order 30.000 on the first of the month and then nothing until next month. The takt time of your process will (hopefully, usually) not fluctuate that much, but even there most parts will be much faster than the average, but every now and then a long delay or breakdown will be much, much slower than the average.

I hope these two posts on takt times were helpful for you. In the next posts I will introduce more important times. In the meantime **go out and organize your industry!**

40 How to Measure Cycle Times – Part 1

Christoph Roser, October 06, 2015, Original at https://www.allaboutlean.com/measure-cycle-time-part-1/

Figure 327: The good old cycle times … (Image unknown author in public domain)

The cycle time of a process is a key to match the supply with the demand in lean manufacturing. Everybody working on a shop floor knows the term. Yet, I still find that people sometimes confuse what exactly it means. **The cycle time is the fastest repeatable time in which you can produce one part.** Hence, in this post as part of a series on manufacturing speed measurements I would like to dig deeper into what cycle times really are, and how to best measure them. As it turns out, there is actually quite some detail on how to measure cycle times, hence I split this post into two parts (second part How to Measure Cycle Times – Part 2), with an additional third post focusing on the details of manual cycle times.

40.1 Definition of Cycle Time

Figure 328: Time is Money (Image geralt in public domain)

Most definitions for cycle time I have found online are rather basic, defining cycle time often as *the time required to complete a cycle* (Merriam Webster). However, for practical terms, this definition is way to broad. A much more useful definition for me is:

The cycle time is the fastest repeatable time in which you can produce one part.

Hence, it is measured as a time per part, and **does not include losses like breakdowns, defects, and other delays** (for more on losses see my articles on OEE). As with most other time measurements, you can also distinguish between the current cycle time you actually have (simply called **cycle time**), and the cycle time you want – the **target cycle time**.

Yet even this will leave some remaining ambiguity. For example, if you have batch processes, is the cycle time the time for one batch, or the time for one part? Depending on what you need the time for, both may make sense. Confusingly, I am not aware of an widely accepted name that distinguishes one from the other. Both are commonly called cycle time, regardless if for a batch or for a single part.

Please be aware that this definition above is far from universally accepted. **Quite a few practitioners define cycle time to include losses. Others call the definition above an**

"effective cycle time". This has significant potential for confusion! I strongly prefer to use cycle time only for times without unplanned losses or delays. In any case, if discussion takt times and cycle times with someone else, please verify what they are talking about! Based on a discussion on the LinkedIn Group TPS Principles and Practice, cycle time is more often defined excluding losses (Many thanks to all who contributed in this discussion).

40.2 How to Measure Cycle Times

40.2.1 The Easy but Terrible Wrong Way!

Figure 329: Wrong Way (Image Eranb in public domain)

Many people simply calculate the cycle time by dividing the working time by the number of parts produced during this working time.

$$Customer\ Takt = \frac{Work\ Time}{Number\ of\ Parts}$$

This is terribly wrong! This is how you calculate the line or process takt time, which includes losses. If you calculate the cycle time using this approach, you include all the losses and breakdowns. Even if you pick a "good day", you still have lots of minor delays, slow-downs, some defects, and so on that will creep into your measurement.

40.2.2 The More Convenient but Slightly Flawed Approach

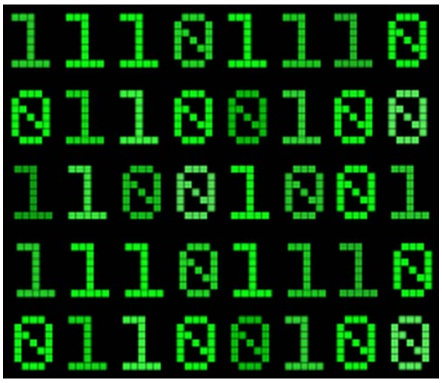


Figure 330: Binary Code Data Representation (Image MdeVicente in public domain)

Another common approach to determine the cycle time is to simply look it up in one of the data sheets. When the machine was built, surely somebody must have set a time into the machine. Similarly, there is often data available on how fast a manual work should be. Often, this number is used without questioning.

While this number is probably closer to the truth, it still is far from good. The speed of machines change over time. The number you have received may no longer be correct. The number may also be only the primary process, but may not include the loading or unloading or other preparation. For example, in an injection molding machine I once had the situation that the "cycle time" included the injection and the cooling, but not the opening, ejection, and closing of the mold, hence the "official" cycle time was too short.

Similarly, for human operations there is often a time available based on MTM or REFA data. However, this usually includes 5% to 25% extra time for toilet or other breaks. While I totally agree to include the time when calculating the **average target speed for the operator**, it must not be included in the **peak speed of the process**. I will write more on that in the near future.

Hence, some practitioners say that you always must measure your data yourself. I am not that hardcore. Measuring it yourself will take quite a bit of time, especially if you have many processes (details see below). If you are short on time (and most people are), you can also use the data found in some documents. But please check if these numbers are approximately in the right ballpark. Also keep in mind that different part types may have different cycle times. I would not trust them without verification, but if the numbers are close enough I sometimes skip the detailed measurement.

40.2.3 The Most Precise but still Imperfect and Time-Consuming Way

The most precise way to determine the cycle time is to measure a number of individual parts. To determine the entire cycle time, you would need to **measure the time between the completion of one part until the completion of the next part for multiple parts**. This is the same as measure the time between the beginning of one part until the beginning of the next part. If it is more convenient, you could even measure the time between one action of the cycle and the same action of the cycle of the next part. I.e. if during the cycle there is a point where a light comes on, or an audio signal is given, or the computer automatically takes a time stamp, then you can also measure the time between successive lights/signals/time stamps for successive parts. In any case the result may look something like a chart below:

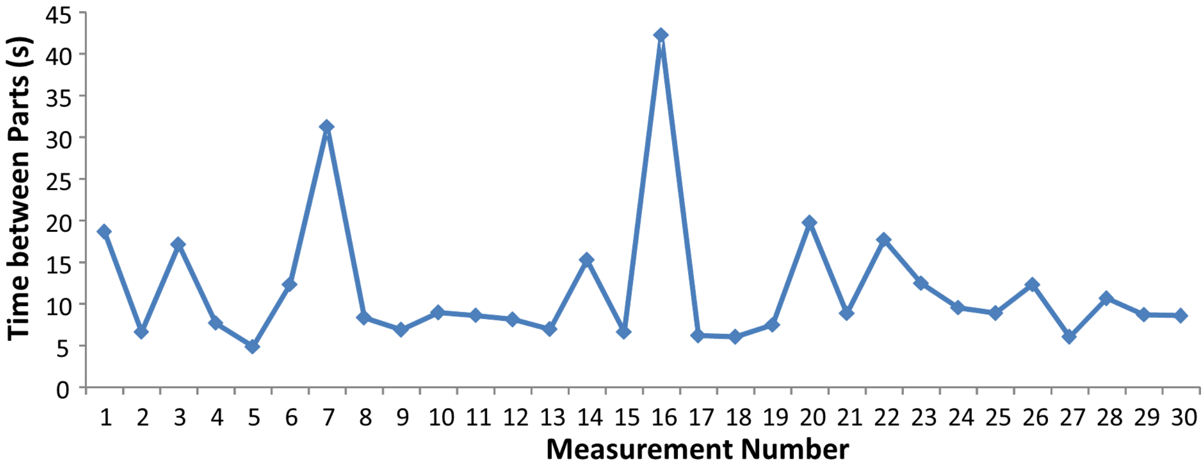


Figure 331: Cycle time graph (Image Roser)

You will have variation. The question is: How to get the cycle time from this data set?

The smallest value in the data is 4.9 seconds. Yet, this is not our cycle time. Our cycle time should be repeatable, and the smallest value is not repeatable. In any case, I also often find that this is a measurement error. Hence, **do not use the minimum as the cycle time.**

What I also see way to often is people simply taking the arithmetic mean, i.e. the sum of all times divided by the number of measurements. Unfortunately, this is then skewed towards a larger value by the larger outliers.For example, if you measure the average wealth of 30 people, and one of them is Bill Gates (worth ca. $ 80 billion), then the average wealth of everybody is at least $2.6 billion, even if all the other 29 people are poor paupers.

Similar for the data above, measurement 7 and 16 seem to be very large. The arithmetic mean of the data set above is 11.8 seconds, and hence above most actual measurements. **Do not simply use an arithmetic mean for cycle times**. Sometimes I see the largest values discarded, and the arithmetic mean of the remainder used. **It is possible to use the mean without these extreme values**, although not my preferred way.

What I often do is to **use the median or an percentile**. The median is the measurement where half of the measurements are larger, and the other half are smaller. A 25th percentile (also known as the first quartile) is the measurement where 25% of the measurements are smaller and 75% of the measurements are larger. This would also work.

Yet even then the results differ. As shown in the graph below, the median is 8.8 seconds, and the first quartile is 7.1 seconds, a difference of 20%. Which one should we use? Or should we use the 10th percentile (6.2s), the 15th percentile (6.6s), or the 20th percentile (6.8s)? By the way, more measurements won't bring the numbers closer together, since this is not a measurement error but caused by the underlying random distribution.

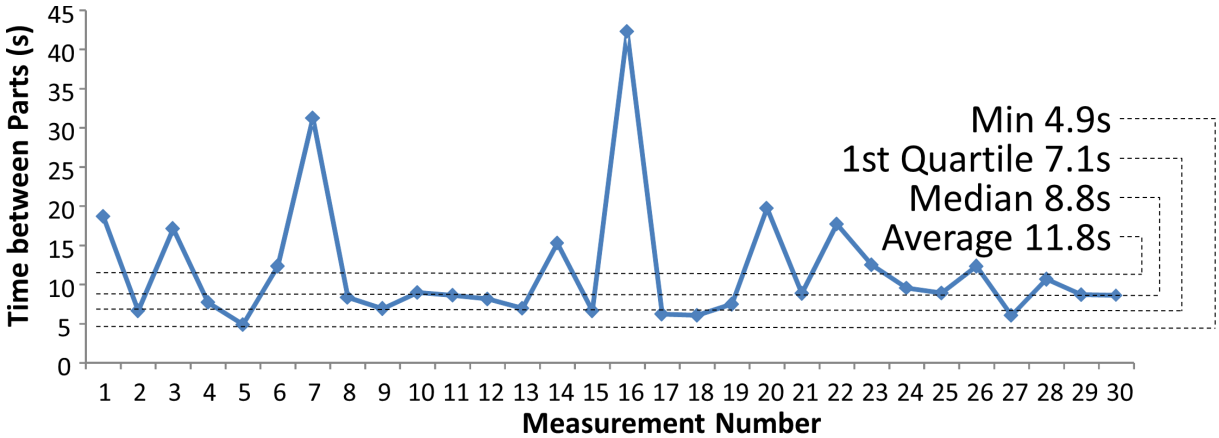


Figure 332: Cycle time graph with Numbers (Image Roser)

Here I don't have a definite answer for you.As mentioned in the heading, this method is still imperfect. If i seem to have few outliers at the bottom (i.e. very small times) I often use the first quartile (i.e. the 25th percentile) or the 10th percentile. If i do have lots of outliers, I sometimes use the median. For example, I once had a system that generated automatic data, but due to a technical quirk often measured two parts with no delay in between. Hence, 1/3rd of my data had a time between parts of zero, and a quartile would then give me a cycle time of zero, which is not useful.

Hence, I cannot answer you definitely which percentile to use. **Plot the data, look at the data and try to figure out what you think your system can repeat if there are no problems.** If you graph the data as shown above, you can also simply put in a line where you think the cycle time fits best. As for the graph above, would you go with the Min, 1st quartile, median, or average value for a repeatable cycle time? For me, the 1st quartile would look best. I will talk a bit more about this problem in my next post.

40.3 Summary

Overall there are three ways to measure cycle times. A really bad one (divide work day by number of parts produced), a mediocre one (look up the [outdated? wrong?] data somewhere), and a time-consuming and still slightly flawed way (measure the individual cycles and take the best quartile or so). However, even with this data, there are still things that can go wrong. In my next post (How to Measure Cycle Times – Part 2) I will talk about the dangers of changing the sequence of the steps within a process, on different part types with different cycle times, and some general comments on the accuracy of cycle times in general. Stay tuned, and in the meantime **Go Out and Organize your Industry!**

41 How to Measure Cycle Times – Part 2

Christoph Roser, October 13, 2015, Original at https://www.allaboutlean.com/measure-cycle-time-part-2/

Figure 333: More on Cycle Times … (Image unknown author in public domain)

This is the second post on how to measure the cycle time of a process. Again, **the cycle time is the fastest repeatable time in which you can produce one part.** Hence, as part of a series on manufacturing speed measurements I continue with more details on what cycle times really are. This is the second post on how to measure cycle times (post 1 here), with an additional third post focusing on the details of manual cycle times coming up next.

41.1 Some sound Advice

41.1.1 A Warning on the Sequence

In the previous post I described one approach to measure the cycle time by taking multiple measurements of the time between parts, where you **measure the time between the completion of one part until the completion of the next part for multiple parts**. For this, however, you have to keep an eye on the sequence of operations.

If you measure the cycle time of an automatic process, the system will (most likely) repeat the steps of the process always in the same order. However, if the process includes manual work, then often operators *self-optimize* their work by fiddling with the sequence.

The operator could do the sequence differently for different cycles. In this case, if you measure cycle to cycle the measurement may be off. Similarly, I have seen many instances where the operator makes semi-batches by doing one step of the process multiple times in quick succession, and then does the other steps in their normal sequence.

The image below shows a simple process, consisting of three steps A, B, and C. We assume that in this process, the sequence can be mixed up (e.g. you have to screw three screws, and the sequence is not important for the final part). The cycle time is measured always from the beginning of step A to the beginning of the next step A.

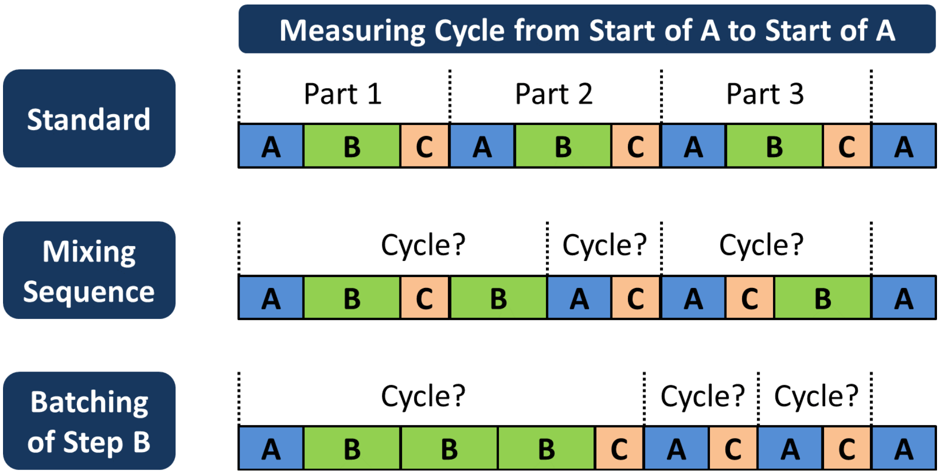


Figure 334: Cycle time variations when measuring from Start of A to Start of A with standard sequence, mixed sequence, or batching (Image Roser)

If the standard sequence is strictly followed, all cycles take the same time, as shown in the first row. However, if the sequence is mixed up, suddenly the cycle time starts to fluctuate heavily despite the same overall time for three parts, as shown in the second row. Same is true if the operator starts batching by doing three steps B in sequence before doing the rest, as shown in the final row.

Despite all steps itself taking the same time, the cycle measured varies significantly if the sequence is not standardized. Your cycle times will fluctuate much more, and make it harder for you to determine what your cycle time really is. Hence, **when measuring cycle times make sure the same sequence is followed for all measurements!**

41.1.2 What to include in the Cycle Time?

Many processes have a mixture of both cyclical work (needed for every part) and non-cyclical work (needed only every few parts). Examples for no-cyclical work are loading a new box of parts, setting up the machine, or exchanging a worn tool. Naturally, **the cycle time should be measured only on the cyclical steps**. However, if you take the median or a lower percentile, any cycles that include non-cyclical work resulting in longer *cycles* are automatically excluded from the resulting cycle time.

41.1.3 A Note on Part Type Variations

Figure 335: Different Screws (Image Ssawka under the CC-BY-SA 3.0 license)

Naturally, not all parts have the same cycle time on the same process. A more complex part may take longer for milling than a simple part. In a perfect world, you would measure the cycle time of every possible part type at every possible process. Using the number of parts for every type you can now generate weighted averages to determine the average speed of your line.

In reality, you probably lack the time to measure every part. Focus on the high runners, and think about where you need accuracy, and where you can get away with less. While I sometimes hear the general requirement that you must measure everything with absolute precision, in practice you may often hot have the time. Try to be as precise as necessary, but don't waste time on precision that is lost anyway in a later calculation (especially if you calculate the number of kanban!).

41.2 Some Statistics – which you probably don't need in Practice

41.2.1 Which Distributions are Common?

Below I will talk a bit about random distributions. Fortunately, you usually don't need to know the exact distribution, unless you really want to use the data for simulations. But first, what type of distributions could you expect for cycle times?

Generally, a random distribution for a cycle time should be continuous and have a range that goes from a non-negative number to infinity. I.e. the cycle time cannot be lower than a certain value, most definitely not less than zero. That rules out for example the normal distribution (or Gaussian distribution). Secondly, the distribution is usually not symmetric but very one-sided towards the lower end. Heavy tails are common (more below).

The following distributions are well suited for cycle times, possibly with an additional offset on the x-axis. Naturally, more distributions are possible.

- Exponential distribution
- Pareto distribution
- Lognormal distribution
- Gamma Distribution
- Chi-Square Distribution
- Weibull Distribution

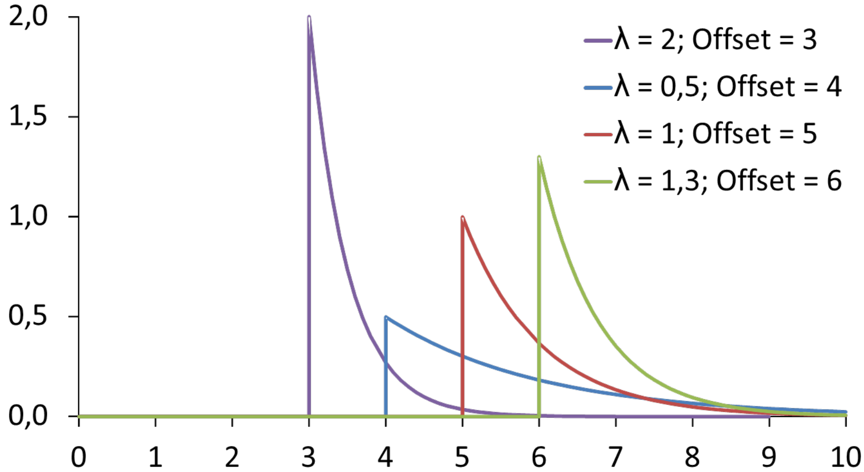


Figure 336: Different Exponential Distributions (Image Roser)

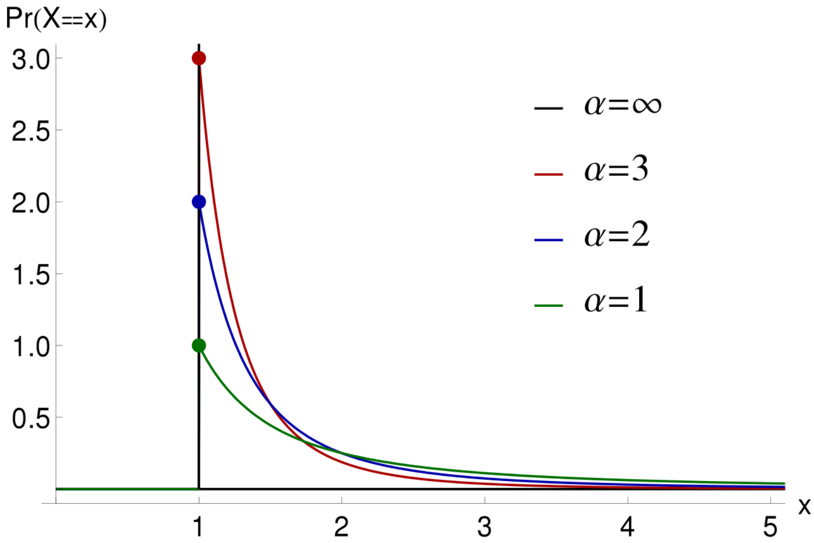


Figure 337: Different Pareto Distributions (Image Danvildanvil under the CC-BY-SA 3.0 license)

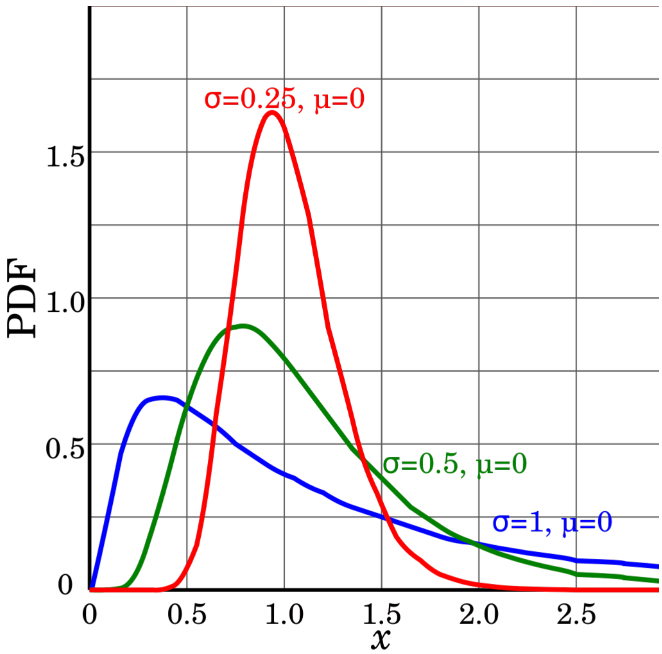


Figure 338: Different Lognormal Distributions (Image Krishnavedala in public domain)

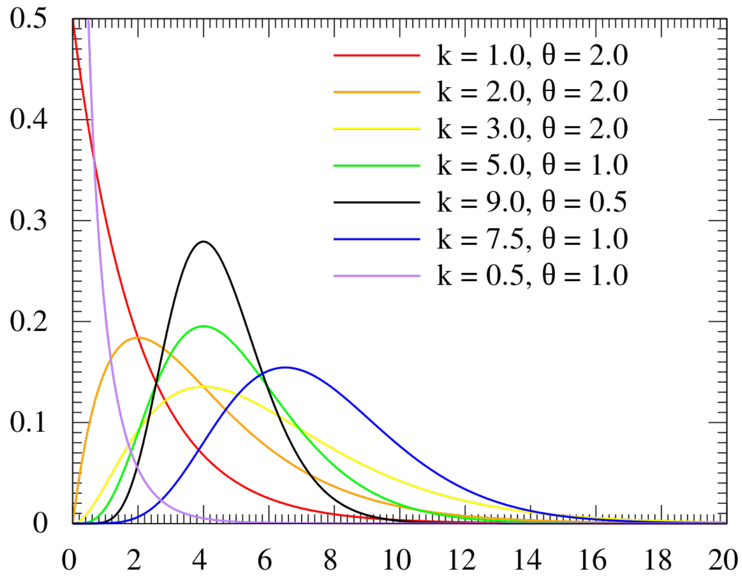


Figure 339: Different Gamma distributions (Image MarkSweep, Cburnet, Autopilot under the CC-BY-SA 3.0 license)

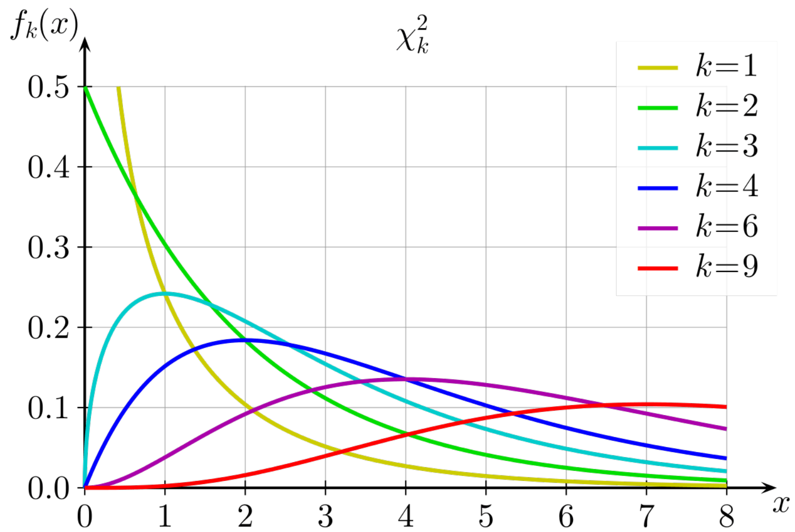


Figure 340: Different Chi-squared Distributions (Image Geek3 under the CC-BY 3.0 license)

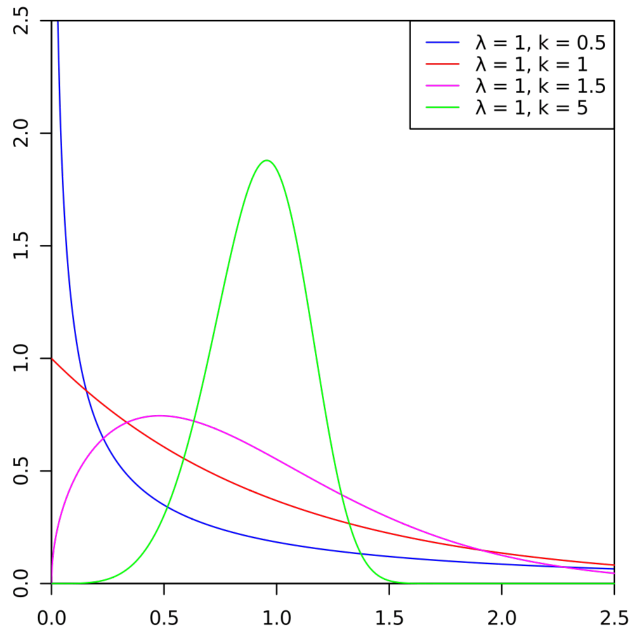


Figure 341: Different Weibull Distribution (Image Calimo under the CC-BY-SA 3.0 license)

41.2.2 On the Precision of Cycle Times

As described in the previous post, the cycle time may differ quite significantly depending on what percentile you use as the cycle time based on multiple measurements. Due to outliers, you should definitely not use the mean. It is better to use the median, the first quartile, or the 10th percentile.

Of course, depending on which method you use or which percentile you calculate, the cycle time may look quite different. This is unfortunately often the reality due to small (and sometimes large) random events forming the underlying random distribution.

The image below shows different percentiles for a standard exponential distribution with $\lambda = 1$. Depending on which percentile you take, the resulting cycle time could be quite different.

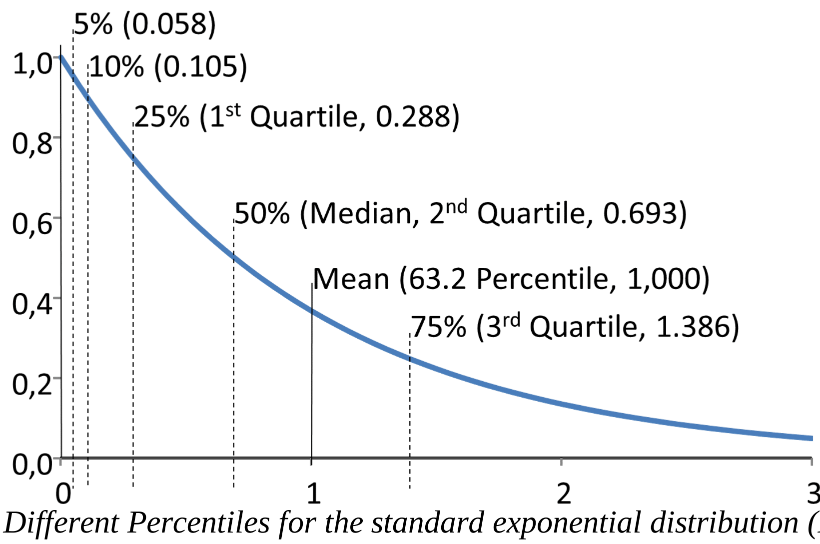


Figure 342: Different Percentiles for the standard exponential distribution (Image Roser)

Importantly, more measurements won't bring these numbers closer together! You are not reducing the standard deviation, but are merely measuring the distribution more precisely.

41.2.3 On Heavy Tails

Figure 343: Heavy Tail Sheep (Image Peter Lund Simmonds in public domain)

Most cycle time distributions are very one sided (meaning most measurements are towards the lower end of the range), but also fat-tailed or heavy-tailed (meaning there are usually rare but comparatively long times between the parts, e.g. if there is a break down and the system stops for minutes or hours).

The graph below shows the probability density function of both a exponential distribution, and a much more heavy tailed Pareto distribution that have the same mean. The Pareto distribution has a much higher probability of very small values (visible in the diagram below) and very large values (too small and too far to the right to be seen in the diagram below). Only between 1.4 and 12.4 is the exponential probability higher. Both have the same mean of 1, but the median of the exponential distribution is only 0.693, whereas the median of the Pareto distribution is 0.892

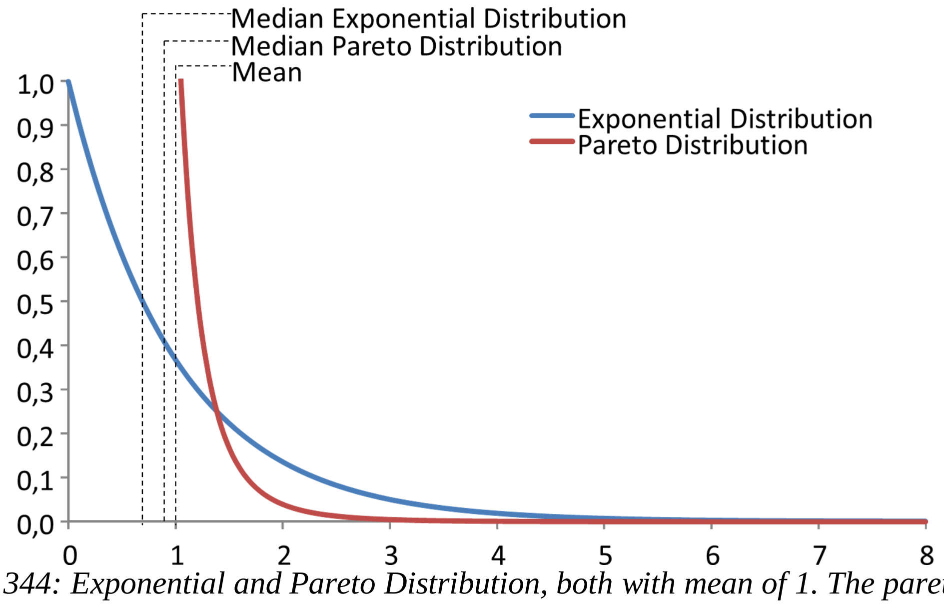


Figure 344: Exponential and Pareto Distribution, both with mean of 1. The pareto has a higher probability for both very small and very large values, and hence is heavy tailed. (Image Roser)

Some highly automated processes have a quite narrow distribution. If the computer takes 3 seconds to inject, 25 seconds to cool, and 5 seconds to eject an injection molded part, the cycle time will mostly be very close to 33 seconds. Hence, the cycle time will differ only by a small percentage regardless if you use the 10th, percentile, 1st quartile, or the median. Other processes that have a wider distribution will have significant differences depending on which approach you use.

41.3 Summary

Cycle times (and other time measurements) are not a precise science, in practice it is usually only something that is (hopefully) good enough. So, if you are looking for the one true way to get the right cycle time – sorry, there is no such thing! I usually base it on the median or 1st quartile of a data set, or on available data with a brief verification. In any case, make sure it is measured as a time per part (and not its inverse), and please do not mix it up with takt times, which includes all losses and other delays.

I hope this post helps you to determine the speed of your system, and to match your supply with your customers demand. Now **go out and organize your Industry!**

42 Cycle Times for Manual Processes

Christoph Roser, October 20, 2015, Original at
https://www.allaboutlean.com/manual-cycle-times/

Figure 345: Even more on cycle times… (Image Blackcat in public domain)

In my last two posts I described how to measure cycle times. However, for manual processes measuring cycle times is quite different, since the humans that are measured usually strongly dislike being measured. Therefore, it is difficult to measure it directly. There is an alternative to calculate it, but this also has lots of pitfalls. Let me explain you a bit about human psychology, and how to measure manual cycle times.

42.1 The Difficulties of using a Stopwatch

Figure 346: The mechanical part is easy… (Image Hydrargyrum in public domain)

Probably one of the first idea many people have when needing cycle times of manual labor is to simply take a stopwatch and measure the times. The basic approach would be very similar to any other cycle time, where you take the mean or a low percentile of the individually measured time between parts (see How to Measure Cycle Times – Part 1 for more).

While this approach is correct in theory, in practice it has many other problems that may cause you to end up with incorrect times. It all goes back to the problem that **most workers do not want to be measured using a stopwatch.**

42.1.1 Legal Problems

Figure 347: Gavel (Image Brian Turner under the CC-BY 2.0 license)

First, in many countries there are government regulations detailing if, when, and sometimes even how you can measure your workers using a stopwatch or with video. In other countries such regulations stem not from the government, but through agreements with unions or workers representatives. In any case, often you are simply not allowed to take the time of workers without clearing it with the workers representatives beforehand. Even if you are legally allowed to measure without consulting the workers beforehand, you still should talk with the workers beforehand to avoid conflict.

42.1.2 Psychological Problems

Figure 348: Pretending to be one while being the other … (Image cynoclub with permission)

I you have cleared the legal requirements, you still have the problem that workers do not like to be measured. They fear (often rightfully so) that any measurement is just done to increase their workload. Hence, whenever someone with a stopwatch is standing behind them, *their … work … will … slow … down … to … a … snails … pace …* – and all of that without you ever noticing it. Workers are very skilled to look quite busy while at the same time significantly reduce their overall speed. The most popular method seems to be to add additional tasks or make the tasks look more complex than they really are.

Professionally trained time takers hence often include an estimate of the workers performance, and adjust the measured times by a certain percentage up or down (usually down). For example with the REFA method, cycle times are adjusted using a **performance index** that usually falls between 80% and up to 135%. Yet this estimate also has a significant margin of error, and is far from accurate. Besides, since it is an estimate, the worker may estimate it quite different than the time-taker. You will get a number, but the employees may or may not agree with you. To avoid conflict, time-takers often tend to estimate on the faster side that makes the worker look better.

Also, you can sometimes have the opposite effect where a worker speeds up if watched to please the observer or management. In any case, if you have to measure the cycle time of a manual process using a stopwatch, then be aware that the resulting number may have a substantial error. As stated in my previous post, **there is no such thing as a true cycle time!**

42.2 Predetermined Motion Time Systems

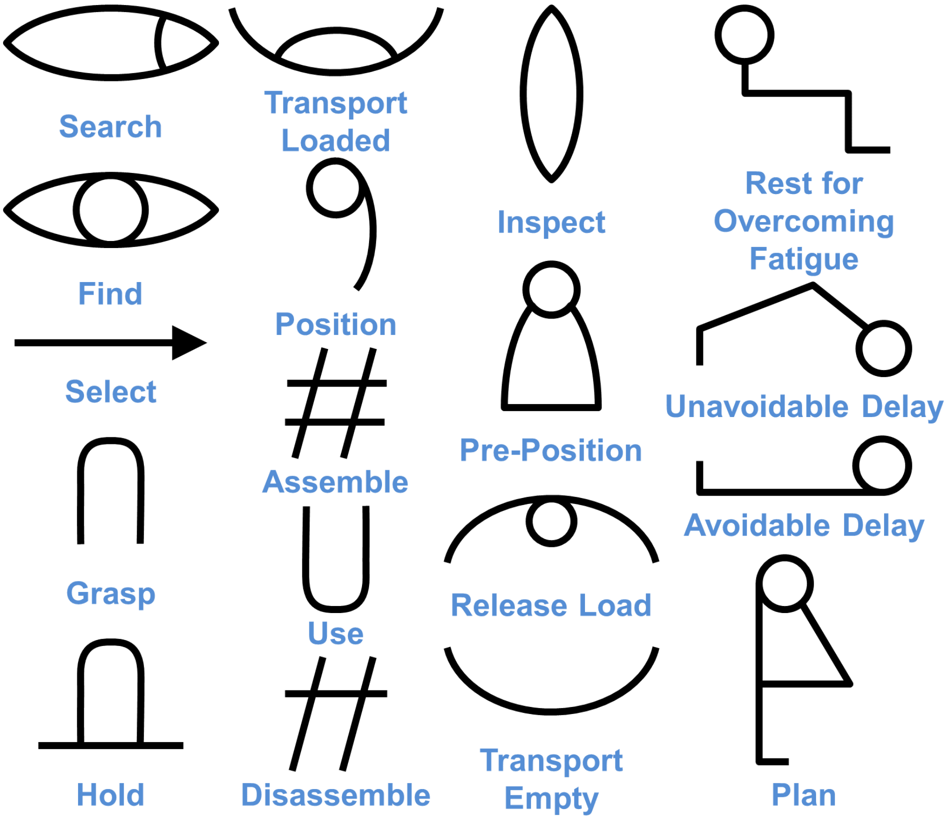


Figure 349: The 18 Therbligs by Gilbreth (Image Roser)

Another approach is a predetermined motion time system. Originally invented by [Frank Gilbreth](), there are nowadays many different systems around, the most popular one being Methods-Time Measurement (MTM).

In this system, the time needed is calculated based on tables. For example if you pick up a coin from a desk, the data table will tell you how long it takes to move your hand from the current position to the position of the coin, another table will tell you the time to pick up a small flat object, and another table will tell you the time to move an object in your hand to another position. The sum of these times is the overall time needed to pick up that coin. Additional tables are for fitting, pressing, looking, walking, and many other movements and actions. These times are often given in a strange time unit TMU (Time measurement unit), where 1 TMU is 1/100.000 hours or 0.036 seconds.

In many companies you will find data where someone has calculated the time needed for your manual process using this system. Yet, there are a few things to know before you use this time. Besides the usual problem of outdated or incorrect data, there are two other major things to consider.

42.2.1 Contingency Allowance


Figure 350: Everybody has to! (Image Roser)

Most predetermined motion time systems include a **contingency allowance** for additional tasks of the workers. These are often grouped into technical contingencies like talking with supervisor, fixing small problems, etc; and personal contingencies like toilet breaks or taking a drink. Usually they are added as a percentage on top of the calculated times from above. The percentage added often depends on the negotiation with the unions, but are on the magnitude of 15%. Other times like change over or maintenance times can also be added, but are often calculated separately from the time per part.

Hence, the time available through a predetermined motion time systems often includes 15% or more for "other" contingencies. This is perfectly OK for calculating the daily quota to determine the performance related pay of the worker.

However, if we calculate the cycle time, this is a (small) problem. We defined **cycle time as the fastest repeatable time in which you can produce one part.** The time calculated abve, however, includes additional times, which we then have to remove again before we can use the calculated time as a cycle time.

For example, if the process takes 40 seconds, then 15% of contingency time is another 6 seconds. Hence, the work takes 40 seconds, followed by 6 seconds break for contingencies. Yet, the worker cannot go to the toilet within 6 seconds between two parts. Rather, he produces 50 parts every 40 seconds, and after 33 minutes of production he takes a five minute toilet break. This is perfectly fine when calculating the workers quota.

However, when calculating the cycle time, have to exclude those contingencies and look only at the best possible time.When discussing this with the workers, be very tactful, least you leave the impression that you want to take that contingency time from the workers. **We definitely do not want to touch the workers toilet break! We do not remove the time from the workers quota, this remains unchanged. But we want to determine the peak speed between the workers contingencies.**

42.2.2 The Intricacies of Performance Based Pay

The second problem with predetermined motion time systems is their accuracy. These tables are based on thousands upon thousands of measurements in a laboratory, where thousands of different people (young, old, man, woman, …) did different movements and had their time taken.

Yet, whenever I observe workers on the shop floor, they usually seem to be able to work much faster than the calculated time. The movements within a process quickly become routine, and they move much quicker than the people in the laboratory. In my experience, 130% of the target throughput is easily possible for most workers. Hence, instead of the calculated 100 parts per hour, they easily get 130 parts per hour done.

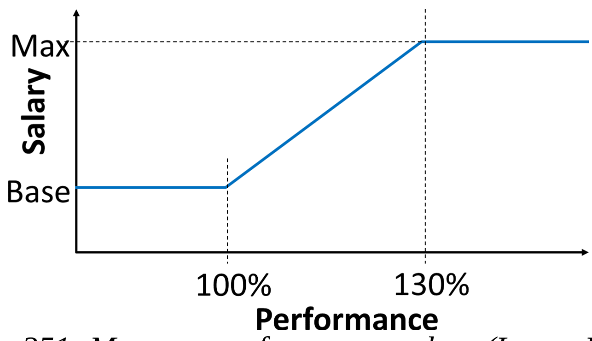


Figure 351: More money for more work … (Image Roser)

I suspect that more would be possible, but performance based pay is often capped at 130% to avoid large quantity of bad quality. If the workers would exceed 130%, it would bring them no extra income, but would include the risk of making the work look to easy. Worst of all, somebody may conclude that the predetermined motion time has to be updated, since the work is now too easy. Hence the workers actively avoid producing at more than 130% performance, and histograms of the parts per day look almost like they are cut off at 130%.

In any case, we want to determine the cycle time. **The cycle time is the fastest repeatable time in which you can produce one part**. Hence, here, too, you should use not the predetermined motion time, but a faster speed to reflect this continuous over-performance. The only possibility to get this is again through estimation, which workers may or may not like.

42.2.3 A Note on Diplomacy on the Shop Floor

For a correct cycle time, you should remove the contingencies and include the faster performance. **You should make it crystal clear that this has no influence on the daily quota and hence performance related pay! The cycle time is only the peak speed, not the average speed with breaks and other interruptions included.**

If you are lucky enough to have a cooperative workers representation, you can explain this to the workers so that they understand that this will not harm them. Instead, the correct cycle time calculation is necessary that the average speed (and hence the performance related pay) can be reached.

Figure 352: Pick your Fights wisely! (Image Samuel William Fores in public domain)

If, however, you and your workers representatives have fallen out and the workers are just waiting for an opportunity fight, then this may not be worth the effort. In this case I would just use the predetermined motion time as is inducing contingencies and all rather than becoming the target of the workers fury. Pick your fights only where absolutely necessary. Cycle times may not be a priority here. Just keep in mind that this manual cycle time is far from where it should be.

This is actually a third option that – depending on the circumstances – may be available. In discussions with the workers you could talk only about times including all losses (i.e. the process or line takt times). These are usually large enough to look non-threatening to the workers. Just keep in mind that the cycle times are probably much faster, but keep that information for yourself. In any case, this won't affect the quotas or the performance based pay anyway.

42.3 Summary

As with the cycle times discussed in the previous posts, **the idea of a single correct value for the cycle time is an illusion. Especially for manual work!** Hence, keep in mind the concerns of the workers when either measuring or calculating the cycle times. If anyhow possible try to work together with the workers, not against them.

This concludes my three posts on cycle times (How to Measure Cycle Times – Part 1, Part 2, and the one you are currently reading). After almost 4000 words on cycle times I personally was surprised how much detail there is on such a presumably simple thing. In any case, I hope this was also interesting for you. Now **Go Out and Organize your Industry!**

43 Pay Attention to Details – Operator Training at Toyota and Scania

Christoph Roser, October 27, 2015, Original at https://www.allaboutlean.com/attention-to-details/

Figure 353: It's all in the details… (Image Mentalitanissarda under the CC-BY-SA 3.0 license)

Often, implementing "lean" means management is picking the latest lean-related buzzword and telling their people to implement it. This is wrong on so many levels. For one, a lean project should always start with a problem, not a solution. On another level, good manufacturing is all about the nitty-gritty details. Both normal operations and improvement projects need a lot of attention to details. Unfortunately, this is frequently lacking in many companies. In this post I would like to show you the level of detail for operator training in some excellent companies.

43.1 Operator Training at Toyota

43.1.1 Training with Pneumatic Screws

Figure 354: (Stock photo, not Toyota. Sorry!) (Image Photographee.eu with permission)

Toyota, like most companies having assembly, uses a large number of screws. Therefore, it makes sense to train the operators in the handling of pneumatic or electric screwdrivers.

Now, in other companies the operator training would be done in 10 minutes by giving the new operator the screwdriver and telling him which holes to put screws in. However, this leaves lot of ambiguity that can cause potential quality problems later on. Is there a sequence of screws that is better than others? What is the best way to hold the screwdriver to avoid its slipping off the screw and scratching the material underneath? What is the best way to make sure the applied torque is neither too small (and hence not good enough) nor too strong (and risking a ripped off screw). What is the easiest way to get the screwdriver on the screw? Finally, how can the screws be attached in the most efficient manner, yielding good quality and using minimal time and effort?

To train their operators in all these details, Toyota has set up separate training stations where operators practice the process in a safe environment. A trainer coaches them on how to hold the screwdriver, shows them all the things that can go wrong, and overall tries to improve the operator from someone holding a screwdriver to an expert screwdriver operator.

Besides training the operator, this also shows if the new operator can handle the operation. While assembly is usually a lower pay grade, it is by no means easy. The operator has to focus despite the frequent repetition of the tasks. If there is a mismatch, it is better for both sides to find that out early in training, rather than later after quality problems.

43.1.2 Training Muscle Memory in Handling Objects

Toyota also has lots of small training on how to handle objects to train muscle memory. The operator practices handling of parts in a simulation environment to make the movements routine. This is similar to you driving a car. You also no longer need to think where the turn signals are and which pedal is the brake; you just do it.

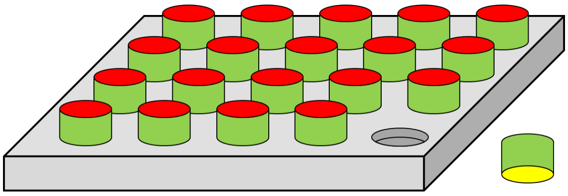


Figure 355: Toyota Flip and Place Game (Image Roser)

One such game is "*Flip and Place.*" There are 20 cylinders on a 40×30 cm board, each in its own 7mm deep indentation. One side of the cylinder is red, the other one is yellow. The goal is to flip them as fast as possible. To optimize your time you have to think about such mundane things as how to grab, hold, flip, and place the cylinder. One of the winning strategies is to pick up the cylinder with one hand, and place it with the other hand, flipping it during the handover process.

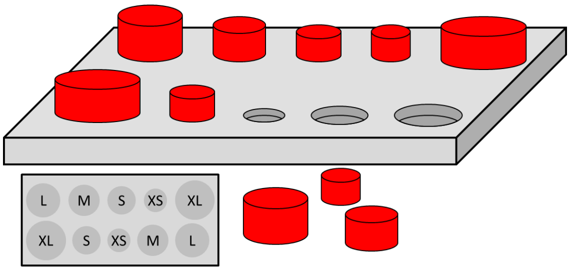


Figure 356: Toyota Gromet Game (Image Roser)

Another game, the "*Gromet Game,*" aims to put 10 pegs of 5 different sizes (from XS to XL) into matching holes. The pegs have only a slight difference in size, but fit only in the hole of the matching size. Please note that they do not provide the helpful size diagram as shown in my image – you have to figure out yourself which peg goes where.

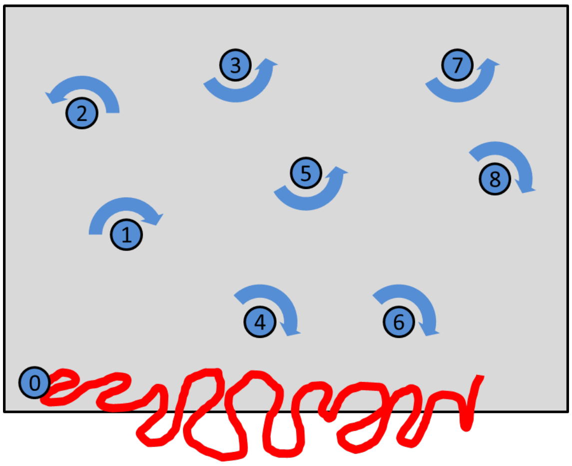


Figure 357: Toyota Rope Game (Image Roser)

Yet another game is the "*Rope Game.*" On a 120cm wide board, 9 pegs are placed. The first peg is connected to a rope. All the other pegs have a number and a rotational direction. The goal is to wind the rope around the pegs in the correct direction as quickly as possible.

Overall, Toyota puts a lot of effort into training their people. This training is usually done NOT at the assembly line, but separately with close supervision. Toyota wants their operators to make the largest steps on the learning curve in the classroom, rather than by trial and error with real products for real customers. After all, you don't want to buy a car from someone that has just assembled a car for the first time ☺.

43.2 Operator Training at Scania

Scania, a large Swedish manufacturer of trucks and buses, also seems to be one of the few companies where operational excellence and lean thoughts are well implemented. During the European Lean Educators Conference 2015, I received a tour of their operator training area in Södertälje, near Stockholm. Since I was allowed to take pictures, I can show you their training in more detail than with Toyota.

43.2.1 Pipe Assembly Training

Figure 358: Pipe Assembly Training Station (Image Roser)

Trucks use a lot of pipes and hoses. There is a dedicated station on how to assemble these pipes.

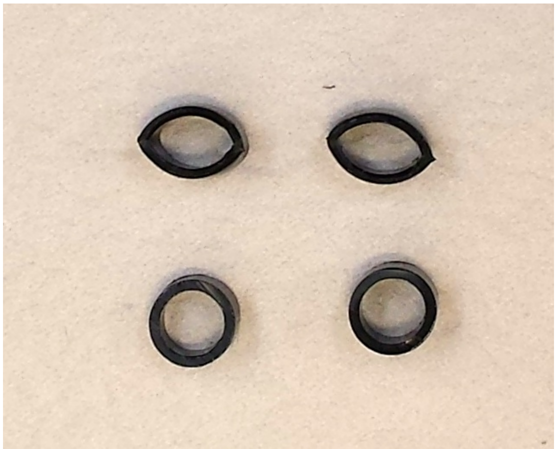


Figure 359: Top bad, bottom good! (Image Roser)

First, the operator is shown all the things that can go wrong. Operators occasionally need to shorten the hoses. Often, they did this with simple tools like bolt cutters or knives. This resulted in somewhat squished cross sections, some small ridges, and possibly also a not-even cut. The picture shows squished cross sections from a bolt cutter on the top, and correct cross sections at the bottom.

Figure 360: Good and bad pipe cutters (Image Roser)

The correct cross sections can be achieved easily using the correct tool. This tool (shown on the left) not only avoids squishing, but also ensures a perpendicular cut, both of which are difficult with bolt cutters (shown on the right).

Now, you may think that simply taking away all bolt cutters and telling the operators to use the right tool may suffice. It does not, at least not for an excellent company. Having experienced the difference makes it much more likely that the operator remembers the importance of using the correct tool.

Additionally, at the station, the haptics of assembling pipes are not simply explained; instead, they are experienced. At this training station, the operator also learns how a good connection feels, and how to distinguish it from a bad connection.

43.2.2 Cable Tie Training

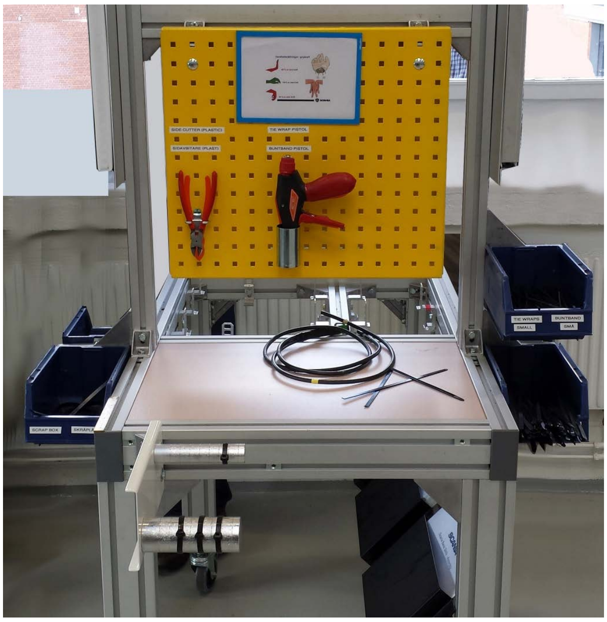


Figure 361: SCANIA cable tie station (Image Roser)

At another station, the operator learns how to correctly attach cable ties. Again, this sounds simple, but there are many details to pay attention to, all of which are remembered better if experienced rather than heard. Hence, the operator first learns about different types of ties (heat resistant or not, specialty ties, etc.) and then practices using cable ties on different aluminum poles.

Again, the training starts with the things that can go wrong. If the cable tie is tied by hand, it will not be strong enough and can slip. In the picture you can see three cable ties, only one of which is properly tightened.

Figure 362: Two loose, one tight (Image Roser)

Cutting off the end of the tie is also difficult using a simple bolt cutter. There may be an edge sticking out. If the cut is not even, there may be a sharp edge that can scratch and injure a person. The image also shows the same three ties as before, only one of which is good.

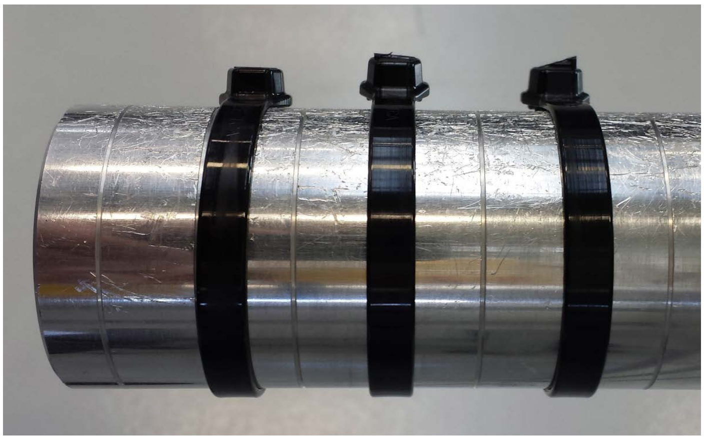


Figure 363: Cable ties: left good, others not! (Image Roser)

To correctly tie the cable tie, a special tool is used (having the lovely Swedish name, *buntband pistol*). This tool not only applies the correct torque, but also cuts the remaining tie evenly.

43.2.3 Screws and Nuts Training

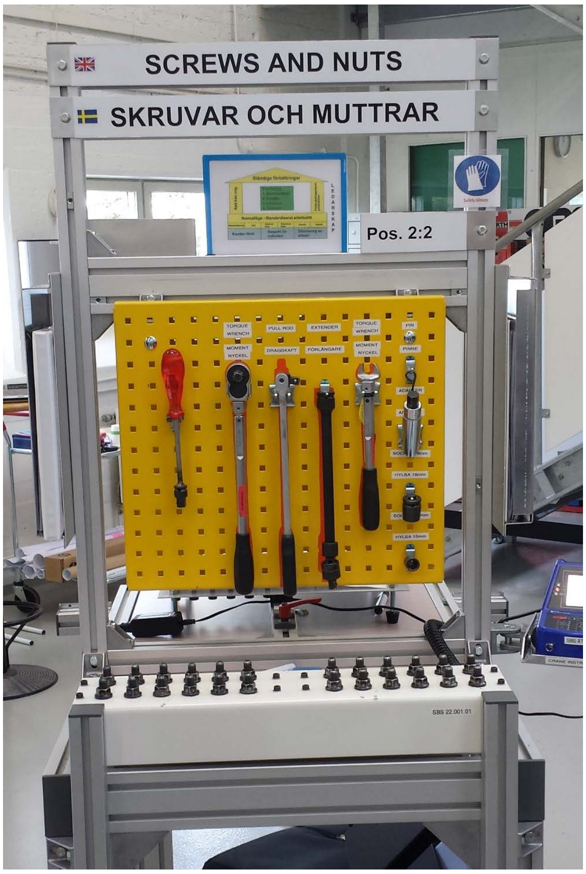


Figure 364: Screws and nuts training (Image Roser)

Finally, there is also a screws and nuts training station. With screws, one of the important things is the torque applied on the screw. As before, the operator first learns how NOT to do it.

In particular, the trainer asks the operator to apply a certain torque to the screws. The trainer measures the torque on a display out of view from the operator. As it turns out, the operator is usually far off the required torque, applying either too little or too much. This is often especially surprising to more experienced operators who thought they had the feeling for the correct torque.

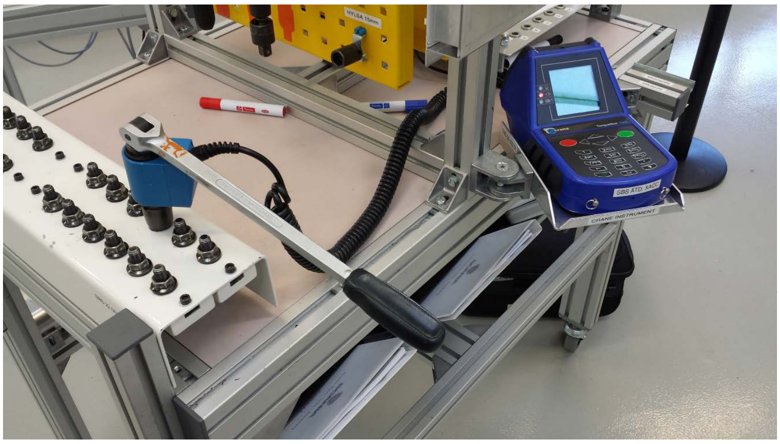


Figure 365: Applying and measuring torque (Image Roser)

Of course, this becomes much easier with a special torque wrench. However, even then it is possible to mess up. The torque wrench clicks when the correct torque is applied. However, if you continue to pull, it will exceed the torque. Similarly, if you “click” a few more times, you add more torque to the screw than necessary. Here again, the operator learns through experience.

43.2.4 Other Training Areas

Figure 366: Electrical connections training (Image Roser)

Figure 367: Logistic Training Area (Image Roser)

Without much explanation, here is the logistics training area and the electrical contact training area at Scania. They use the same principle as the stations above.

43.3 Summary

In a truly good manufacturing company, attention to such tiny details can make the difference between average quality and exceptional quality. By providing operator training in a simulated environment, quality can be improved. Additionally, efficiency is also improved, since operators can be taught how to do things more efficiently and hence faster.

Yet, the above descriptions can give you only ideas on how to improve your own system. If you merely copy the above – regardless if Toyota or Scania – then again you are not paying attention to details. Your manufacturing system may have completely different needs and requirements, and the above may or may not match your needs. There are few shortcuts in lean. Don’t just copy the above stations; make your own journey.

However, there are a few things that will help. First, you should start by showing bad examples. Learning from mistakes is much easier than learning from good examples. You should also orient the training to the operator needs. It is easy to overload the operator with too many requirements, and you may end up with none being followed. This of course also requires that you understand what the critical points of the process are. Finally, you should mirror the training station as much as possible to the real line. Use the same tools and equipment, and try to make it as similar as possible.

As always, I hope these best practices I have seen at Toyota and Scania help you in your daily work. Now **go out and organize your industry!**

P. S. Many thanks to the kind people of Scania for their excellent tour of their training facilities! The photos are published with their kind permission. Also many thanks to Toyota for providing tours of their plants.

P.S. 2 A Russian translation by Valery can be found here: Обратите внимание на детали — обучение операторов на Toyota и Scaina

44 The Three Fundamental Ways to Decouple Fluctuations

Christoph Roser, November 03, 2015, Original at https://www.allaboutlean.com/decouple-fluctuations/

Figure 368: Waves on shore (Image mattbuck under the CC-BY-SA 4.0 license)

Manufacturing systems have fluctuations. Material may arrive sooner or later. Production may be fast or not. The customer may order more or less. Generally, the less fluctuations you have, the more efficiently you can produce. Toyota puts in an enormous effort to control fluctuation, but even they have fluctuation. In this post I would like to show you the **three basic ways how you can decouple fluctuations: inventory, capacity, and time**.

44.1 A Few Sources of Fluctuations

Fluctuations can come from everywhere. Your supplier could be early or late, bring too little or too much, have good quality or not. Customers are also known for random behavior, ordering more, ordering less, canceling an existing order, changing quantities, moving delivery dates forward or back. You also have fluctuations in your own system. Machines may be faster or slower than usual, or may have a breakdown altogether. Your operators may be trained or not, ready to work or sick at home. Supporting processes can also cause changes to the production program if a product is not yet designed yet or the work standards are missing. Overall, there are many sources of fluctuations.

In this post I will focus on fluctuations in the material flow, especially toward the customer. However, keep in mind that there are many other types of fluctuations as well (e.g., within quality or profit).

44.2 The Three Ways to Decouple Fluctuations

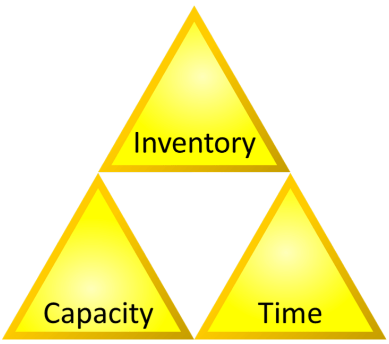


Figure 369: Triforce Inventory Capacity Time (Image Roser)

There are three fundamental ways how you can decouple fluctuations: inventory, capacity, and time. Each of them has different advantages and disadvantages. Depending on your exact situation, a mix of these three may be best for you. Let’s go through this triforce of inventory, capacity, and time.

44.2.1 Inventory

Figure 370: How long does it last? (Image Axisadman under the CC-BY-SA 3.0 license)

Inventory is probably the first thing most people think of when considering decoupling fluctuations. You just add a buffer stock between your processes. If you temporarily need more than what you can produce, you take parts out of the inventory. If you temporarily produce more than what you need, you increase the buffer stock.

Using inventory is probably the easiest way to have a structured decoupling of fluctuations. You can add it pretty much between every process to buffer the fluctuations between the processes. This makes it also one of the most popular ways to decouple fluctuations.

Figure 371: Gold Bullion Missing (Image Apollo2005 under the CC-BY-SA 3.0 license)

The downside of inventory is the cost of the inventory. Traditional cost accounting looks primarily at the cost of capital. Unfortunately, this is only a small part of the overall cost. There are many more costs, like insurance, storage cost, handling, administration, obsolescence, defects, deterioration, and increased lead time. Many of them cannot reliably be calculated, hence cost accounting just leaves them out. But they are still there. Overall, **you can expect to pay between 30% and 65% of the material value per year** just for the privilege of having the material. For more on this, see my post on [The Hidden and Not-So-Hidden Costs of Inventory].

Additionally, **inventory can cover fluctuations around the mean demand, but not long-term changes**. If your customer continuously wants more than what you can produce, your inventory is going to run out eventually. If your customer continuously orders less than what you produce, your inventory will explode. In the latter case, the great advantage of a pull system is its ability to limit the maximum inventory (see [The (True) Difference Between Push and Pull] and [Why Pull Is So Great!] for more details). Overall, inventory alone is rarely the answer to your problem of fluctuations in demand and supply. You also need to adjust capacity.

44.2.2 Capacity

Figure 372: Just add a few people and machines… (Image John Oxley Library in public domain)

Another way to decouple fluctuation is by adjusting your capacity. If your customer wants more, you just ramp up the working hours and produce more. If the customer wants less, you just send people home and stop the machines.

I guess you can already see the difficulties with this approach. Few operators are willing to be called in on a moment's notice and sent home a little later – and rightfully so! **The problem with adjusting capacity is the delay between the decision to increase or reduce capacity, and the actual increased or reduced capacity.** In Europe, flexible companies can set working hours one week in advance, while less flexible companies set working hours one month in advance or more. Sometimes smaller changes on a short notice are possible with the good will of the operators.

If you need larger increases than possible with your workforce, you have to hire more people. However, it will take probably months before you see a noticeable effect. If you need more machines, it may take even longer. To install a new custom made set of machines easily takes 6 months. If you build a new plant, measure the delay in years.

Same if you want to reduce your capacity. If you have to fire your workers, this may take months or even longer depending on your local labor laws. Getting rid of old machines is faster, but used machinery has quite a markdown on price.

Additionally, with inventory you could create a pile of finished goods at one spot at the end of your value chain. With capacity, however, you need to adjust the entire value chain up to the new capacity. If you forget to increase capacity in one process, your entire system will not be able to produce more than the bottleneck process. Please keep in mind that the bottleneck could also be your supplier, which has to make the same move up or down as you do. If you forget to decrease capacity in one process, the problem is smaller, but you still have people or machines waiting for work.

On the plus side, **changes in capacity may be cheaper than by increasing inventory**. Having your operators work a few hours more per week does not add much to the cost of the product, since most of the labor cost is not fixed but variable cost. In fact, it may make things cheaper since your fixed costs get distributed over more products.

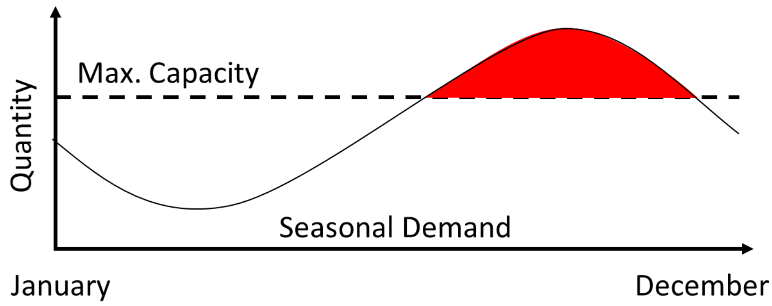


Figure 373: Generic Seasonal Demand Curve (Image Roser)

Overall, changes in capacity are slow but economical. Hence, they are best used if there is a known long-term behavior or trend. If your sales increase by 5 percent every year, then you can expect how much capacity you need next year. If your demand shows a seasonal curve, you send people on holiday in the off-season and have them work when you need their time most.

44.2.3 Time

Figure 374: I want my stuff! (Image David Shapinsky in public domain)

The third way to decouple fluctuations is by time. This is – if you so will – the default option. If you didn't manage to decouple using buffer or capacity, eventually somebody has to wait. This may be either the customer (if demand is larger than capacity) or your operators and machines (if demand is less than capacity).

Hence, as far as decoupling goes, **decoupling through time is the easiest way to decouple, since it happens automatically. Unfortunately, it is often also the least desirable way to decouple.** You don't have to do anything; somebody just has to wait. In fact, many companies that put in an enormous effort to decouple using inventory or capacity still sometimes have to let the customer wait.

The tricky side of the decoupling through time is the cost associated with it. If your operators have to wait, this cost is easy to calculate. Additionally, you can still try to send them home early or use the time to do other things that create value for them. Some companies (e.g., Toyota, Scania) have opted to use the time for improvement activities even if the slump lasts for months (e.g., by sending their operators through training and by improving the processes).

"I Like a Little Competition"—J. P. Morgan

Figure 375: I Like a Little Competition (Image Art Young in public domain)

The cost of letting your customer wait, however, is more difficult to assess. If you have a powerful monopoly customer, letting them wait can quickly become expensive. Many automotive manufacturers are not shy about requesting money for line stoppages caused by the supplier, which can quickly reach millions of dollars. If on the other hand you are the monopoly supplier … well … tough luck for the customer. He can't really go anywhere else. Maybe some of you remember the quality of service and prices of the Bell Systems phone network before the break up of Ma Bell into little bells in 1984? Or the service of the Deutsche Telekom before 1989 (although it seems some of the Deutsche Telekom haven't noticed yet that they are no longer a monopoly…).

In many cases, these waiting times are used systematically to decouple fluctuations. This is true for companies that sell customized made-to-order products or have market power over their customers. For example, if you order a new Toyota, they will tell you when it fits in their production schedule. Hence, you, the customer, have to wait rather than Toyota stocking up millions of vehicles just in case.

44.3 Summary

Most companies use a combination of the above three to decouple fluctuations. Inventory is best used for short-term fluctuations due to its large cost. Slower acting but cheaper capacity is best used to cover larger or longer fluctuations that ideally are predictable. Decoupling through time is the default resort for companies whose market position cannot afford it, and a useful tool for those companies that can afford it.

Of course, do not forget that there are also ways to reduce fluctuation in the first place, as, for example, by working with smaller lot sizes or order sizes (ideally one-piece flow), cooperating with suppliers, etc. (See Introduction to One-Piece Flow Leveling for more.)

How is the situation in your company? Where would you use inventory or capacity, and where could you use time? Think about it when you **go out and organize your industry!**

45 All About Andon

Christoph Roser, November 10, 2015, Original at https://www.allaboutlean.com/andon/

Figure 376: A light in the darkness, guiding you toward efficiency… (Image Batholith in public domain)

Andons are systems to alert operators and managers about current problems in manufacturing. The system automates the information flow in case of problems. An Andon system usually consists of the actual Andon, sometimes called an Andon board. Often, additional input and output devices are possible, the most famous being probably the Andon line, a cord that can be pulled to alert others about a problem. In a second post I will talk about How to Use an Andon – and How Not To.

45.1 Origin of the Term

Figure 377: Writing letters during the Edo period. (Image Kusakabe_Kimbei in public domain)

> *Andon (行灯, あんどん) fixed paper-enclosed lantern; paper glued over a wooden or metal frame housing an (oil) lamp. Originally portable, later mainly with a wooden stand.*

The term *Andon* comes from Japanese paper lanterns used for lighting since the Edo period. As such, it is one of the different traditional paper-covered lanterns and lights, others being Bonbori (雪洞) or Chōchin (提灯).

The term was used by Toyota for their signal system to improve their response time. However, the idea of using signals and cords is older than Toyota. A very similar system was already used in Ford factories before 1930, as described in Ford Men and Methods by Edwin P. Norwood. Back then, any worker could stop the line by pulling a cord if the problems overwhelmed him (thanks to Mark Warren for pointing out the book to me).

45.2 The Purpose of an Andon

45.2.1 Accelerating Information Flow

The main purpose of Andon is to **improve the flow of information in case of problems**. All factories have problems that may delay or stop production (yes, even Toyota). A good factory has fewer problems, can fix them faster, and tries to eliminate the root cause of the problem. Andon can help with that process by standardizing and accelerating the information flow, and hence enabling a faster response with less effort wasted on conveying the information.

45.2.2 How It Should Not Be…

Figure 378: Let’s fix that! (Image DVIDSHUB under the CC-BY 2.0 license)

But before we go to the good factories, let’s talk first about the … normal … factories. In the West, a popular way to combat production problems is traditional firefighting: find somebody that can fix the symptoms so the work can continue. However, it will often take some time before the operator notices or escalates the problem. It will take more time to find somebody who can help. And, depending on the availability of the firefighter, it may be fixed sooner or later, usually by de-prioritizing something else. Of course, fixing here means, more often than not, fixing only the symptoms and not the cause.

Does this sound familiar? Unfortunately, this wasteful process is still far too common in manufacturing. In fact, it feels like many people justify their purpose through firefighting, and don’t even want to have a normal, smooth process. If there are no fires, then there is no need for heroes who put them out. In movies, the hero is rarely the engineer and designer who prevented the catastrophe from happening in the first place. Yet, many careers are built by being a hero…

45.3 How an Andon Works

45.3.1 Input for the Andon System

Figure 379: One Station Andon cord (Image Roser)

An Andon accelerates the information flow related to slowdowns and stops of the production system. As such, it has inputs and outputs. Information about problems is put into the system. This can happen manually. Most famous is probably the **Andon cord**, also known as the Andon line (also in Japanese) or Andon rope. This is a rope hanging from the ceiling. If the operator encounters a problem, he pulls the rope, which gives a signal to the Andon that there is a problem. Usually a second pull cancels the signal and tells the Andon that the problem is solved.

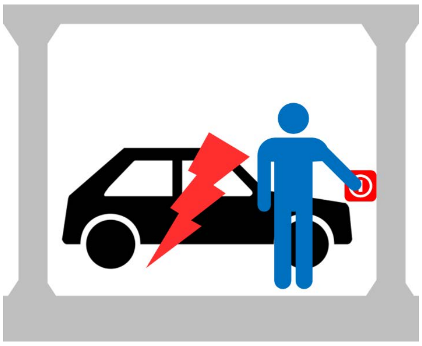


Figure 380: Andon button (Image Roser)

The cord is probably best known, but it does not have to be a cord. It could also be an **Andon switch** or an **Andon button**. A cord has the advantage that on a larger assembly line, it gives easy access to the signal line over a longer distance, whereas with a button the worker may have to walk over to it before pressing it. Of course, for smaller work spaces, a button or switch will be just fine since the worker is not walking around anyway.

Figure 381: Andon cord with multiple stations (Image Roser)

Ideally, every station at the value stream has its own button or cord. This way, the system knows not only that there has been a problem, but where the problem occurred. It is even possible to have more than one cord or button. For example, you could have a yellow cord if the operator has a problem but he is not yet sure if he can fix it in time without stopping the line. If he could not fix the problem and has to stop the line, he pulls the red cord to signal a line stop. One option for the line stop is also to keep the line moving until the product has reached the end of the individual station. Only when the "time is up" does the line stop completely. This allows calling for help while the line still moves, and hence creates less inconvenience for other stations. It also allows a faster start after the problem is fixed, since the next product will be arriving almost immediately.

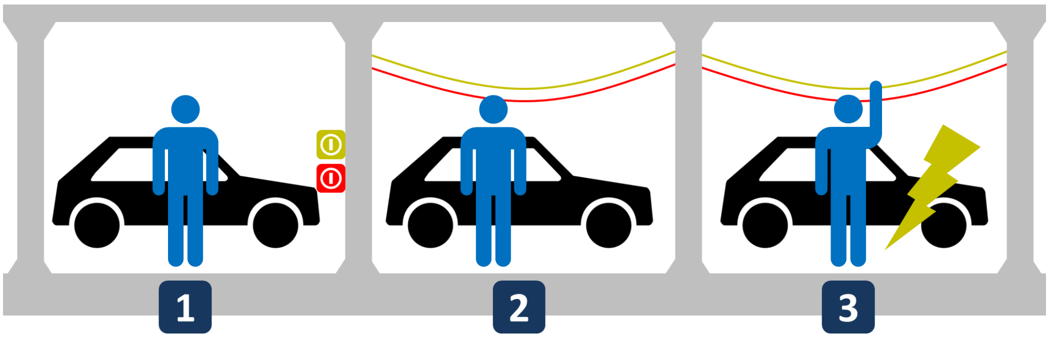


Figure 382: Andon system with multiple stations and multiple cords or buttons (Image Roser)

However, make sure you don't overdo it with the number of lines and the quantity of input. One line is usually a good starting point, more than three lines is excessive, and you don't want the operator to type in a problem report while the line is waiting for him to actually fix the problem!

Of course, there could also be an **automatic input into the Andon system**. For an assembly line, the system could sense if all necessary operations have been completed. If there are still open tasks when the time is up, it means the worker is either falling behind or forgot something. In any case, it is a problem and a signal can be sent automatically. Similarly, for an automatic or semi-automatic machine, sensors and programmed logic can detect a current or even a potential upcoming slowdown or stop. This information is then also forwarded into the Andon system.

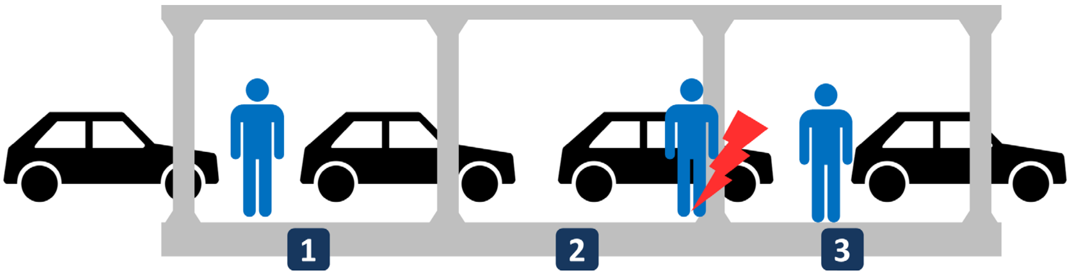


Figure 383: Andon system with multiple stations and detection of falling behind (Image Roser)

Additionally, many Andon systems also automatically measure things like production speed, actual and target quantities, and other parameters relevant to the performance of the line.

45.3.2 Output of the Andon System

The Andon system receives data on the production performance from different sources like sensors, programs, or manual inputs. This data is then displayed, usually in a visual manner involving lights, but also possibly in numbers or even audio signals or through mobile phone networks. As such, Andon can be part of visual management.

Figure 384: Stack light (Image Ktm250-1150gs under the CC-BY-SA 4.0 license)

Probably the simplest Andon system is a stack light or industrial light tower on top of a machine. One or more lights indicate the current status of the machine. Even combinations are possible (green light on, yellow is blinking). Common colors are green for regular operations, red for larger problems or defects (or, alternatively, a call for assistance), orange for warnings, blue for a request for assistance, and white if all the other colors are not enough for you 😛.

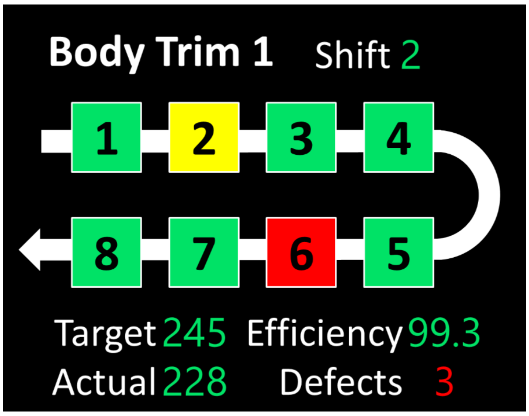


Figure 385: Andon Board (Image Roser)

More closely associated with Andon, however, are Andon boards. These summarize the information about the status of the production system on one board. This board can be created using different lights and LED number displays. Alternatively, you can also simply use a large-screen monitor and program all the display functions into the software. While the monitor is fancier, at Toyota I usually see old-school mechanical constructs for the Andon boards.

This board should display the relevant information from the Andon system. Usually, it shows the **status of the different processes in the system, and an actual and target production value. It may show defect quantities, efficiency, or material supply issues**. You can add anything that you think is useful. You can also add **sound signals**. At one Toyota line, I have seen different chimes used for different stations on the line. Hence, in case of problems, you don't even have to look but already know where the problem is. As usual, both with visual and audio signals, don't overdo it. Try to focus on the important things.

One of the advantages of an Andon system is that you are not limited to one board. I know one plant manager who installed a smaller version of the **Andon board in his office**. At another plant, they had an automatic escalation of production problems. After a two-hour stop, the shop floor section manager **automatically received an SMS on his mobile phone**; after four hours, the production manager got an SMS; and after eight hours, the plant manager automatically got an SMS, day or night. Note: Before you copy that, try to estimate how many nights of sleep you get before setting up a thirty-minute stoppage alert.

Figure 386: Keep Calm and Stop the Line (Image Roser)

Additionally, if there is a problem that cannot be fixed within the cycle time, **the Andon system can automatically stop the line or the process**. For example, if the operator pulls the red Andon cord, the line stops until the problem is fixed. This is one of the outputs of an Andon system, and also one of the automatic responses that a good Andon should make in case of problems.

Of course, there are more responses necessary, but unfortunately most of them are not handled by an automatic system, but by a human. This is actually where most (Western) Andon systems fail. More on this in a second post about How to Use an Andon – and How Not To, so stay tuned. In the meantime, **go out and organize your industry!**

46 How to Use an Andon – and How Not To

Christoph Roser, November 17, 2015, Original at https://www.allaboutlean.com/mess-up-andon/

Figure 387: One Station Andon Cord (Image Roser)

In my last post, All About Andon, I detailed how the mechanical side of an Andon signaling system works, including Andon cords, buttons, and boards. In the Western world, the mechanical side of an Andon system usually works pretty well. However, in most cases, the usage of the Andon is poor to nonexistent. Hence, in this post I tell you how to actually work with an Andon, and then I will give you a rant why companies so often mess it up!

46.1 Quick Recap about Andons

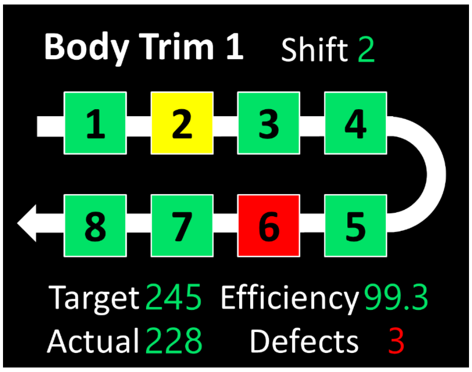


Figure 388: Andon Board (Image Roser)

An Andon is a system to aid the information flow regarding the status of the production system. Operators pull a cord or press a switch if there are upcoming or actual problems. Similarly, machines and processes can send a signal if something is wrong. This information is then shown through lights, numbers, and sounds to alert others about the problems.

46.2 OK, My Andon is Blinking. What Next?

Well … get moving! A blinking Andon is a sign of a smaller (yellow) or larger (red) problem. Someone somewhere needs help, either to prevent a line stoppage or to get the line going again in case of a stop.

46.2.1 Who Should Help?

Figure 389: Let's give them a hand… (Image Cherie A. Thurlby in public domain)

At Toyota, the organizational structure on the shop floor consists of small teams of four to five operators with one team leader. The operators do the actual work, and the team leader covers their bases. If someone has to take a toilet break, the team leader keeps the line working. If there is an absence, the team leader covers it (and the team leader of the next team now assists two teams). If there is time available, the team leader takes care of little things including smaller maintenance issues. And, most importantly for our Andon, **the team leader is the first responder to help an operator in trouble**.

Since the team leader is usually no more than fifty feet away from the operators, he can respond quickly and assist the operator even before the line stops. It may take a team leader about fifteen seconds to reach the operator, out of a typical time between cars of one to two minutes at Toyota. In many cases, the team leader prevents a yellow Andon alert from becoming a line-stopping red alert.

If the line stops completely, other operators (who have now time available) can come to assist in solving the problem. Hence, in the case of a line stoppage, there is a lot of manpower available to help fix the problem.

Depending on the type of the problem or the duration of the stoppage, others may be called in to help out (e.g., for a quick transport of material from the warehouse to get things going again).

46.2.2 What Happens Next?

Eventually, the line gets moving again. At Toyota, this usually happens fairly quickly. In the Western world, the problem would be considered "solved" since the line is moving again. Not so at Toyota. Getting the line moving again just fixed the symptom. The bigger goal is to solve the root cause. What caused the problem? How can we prevent it from happening again? Do we need a change or adjustment in the tools? Do we need a change in design? Do we need to update the work standards?

Again, in the Western world, there is a tendency to put a lot of engineering manpower into anything that is changed on the shop floor. At Toyota on the other hand, I regularly see quick fixes using duct tape and string (not on the cars, of course, but on the tools). They are quick to install, and they solve the problem.

When Toyota builds a new plant, the assembly line has lots of stops in the beginning. Whenever there is a problem, the line is stopped. In the first weeks, it probably stops more than it runs. However, **they work continuously on fixing the causes, not only the symptoms!** Within a few months, the new assembly line will work close to or at the regular legendary Toyota efficiency.

Figure 390: Even fancier than a real Andon… (Image Powerhauer under the CC-BY-SA 3.0 license)

Hence **the value of an Andon system lies in how you work with the system. How do you use the accelerated information flow about shop floor problems to create a lasting fix for the problems?** Without that, the Andon is nothing more than an expensive disco light. Unfortunately, in the Western world, this usage is often lacking. Let me give you a rant with more details on this:

46.3 How to Mess up an Andon System

46.3.1 Not Stopping the Line…

Figure 391: Keep Calm and Stop the Line (Image Roser)

Pulling the (red) Andon cord will stop the line. This prevents problems from overflowing to the next station and allows the fixing of issues where they occur, not afterward.

However, in many factories, both workers and management have been conditioned for decades that *the line must not stop. Never, ever stop the line. If the line stops, we lose money*. This conditioning is hard to overcome. Even though not stopping the line actually leads to more stops, there is still the mental roadblock against stopping the line to fix the problem.

If the new idea of an Andon comes around (*Oooh … a Japanese word … must be good!*), managers will tell their operators to pull the cord and stop the line. However, in all likelihood, operators will be hesitant to do so. And, often rightfully so. While the managers tell them to stop the line, their gut may still be against line stops. Even if they understand the benefit, the gut still thinks otherwise.

Figure 392: Must … not … eat … (Image zest_marina with permission)

Imagine me looking at a piece of chocolate. Of course, my head tells me: "*Chris, you are too fat anyway. You should not eat that chocolate …*" Take a guess what happens next to the chocolate. Hint: it involves guts.

Overall, **both operators and managers may be hesitant to stop the line, defeating the purpose of the Andon.**

46.3.2 Leaving the Operator Alone with His Problems…

Figure 393: A little help please … (Image alex.pin with permission)

Above, I described you how Toyota organizes the response to help the operator in fixing the problem and addressing the root cause. Unfortunately, such a response is difficult to organize with the stretched manpower available in most Western factories. Whereas at Toyota there is one team leader for every four to five operators, in many Western plants the first responder has to cover twenty to thirty operators or more. And this is on top of all the other issues and problems he has to take care of, from ERP system paperwork to restocking the coffee machine.

Simply speaking, **nobody has time to help the operator!** If this happens a few times, the operators will quickly learn that there is no point in pulling an Andon cord; it is easier to simply push the problem downstream.

46.3.3 Not Thinking Things Through…

Often, higher-ups decide they need an Andon to have a better performance, since Toyota has them, and … you know … the power of Japanese words in manufacturing … and stuff … Oh, and it has to happen yesterday at the latest!

Figure 394: More of this please … (Image AndrewHorne in public domain)

I have seen **lots of money and time wasted on expensive Andon systems that nobody wanted, nobody had time to think through, and nobody ever looked at.** For example, the $30,000 multiple large monitors under the ceiling that were never turned on because the workers' representatives objected. For example, the nice large LCD displays in every team meeting corner (about eighty altogether in the plant), which I have not seen used in two weeks on the shop floor. For example, the many lines where the operators quickly learned that they are not really supposed to stop the line but rather to push the problem downstream (because that's what the reaction of the managers taught them, even though the managers said otherwise).

46.4 Summary

The value of an Andon system is in using it! Like most other lean ideas, the implementation is more than putting up some lights, boards, or cards; it instead requires changing the way we work. Putting up some cords and lights only gives you information. It is up to you to act on it. Failure to use the information will not improve your system – no matter how fancy the Japanese name is.

As always, I hope this post was insightful, and I look forward to reading your comments here or on LinkedIn, Twitter, or elsewhere. No go out, fix a problem, and **organize your industry!**

47 What Is Your Production Capacity

Christoph Roser, November 24, 2015, Original at https://www.allaboutlean.com/production-capacity/

Figure 395: Three Hourglasses (Image mdgrafik0 in public domain)

Your production capacity is one important aspect of your production system. The capacity has to match your demand. If your demand is higher than your capacity, then you will not be able to supply the customer. On the other hand, if your capacity is higher than the demand, then you will have lots of idle workers and machines, which is not good either. The name is actually a bit of a misnomer, since capacity is the *ability to contain things*, whereas for a production system we are much more interested in the number of parts that are completed. In any case, capacity is important!

47.1 The Easy Way: Total Production Quantity During a Time Period

One of the easiest ways to measure capacity is to simply use the **total production quantity for a given time period**. For example, if your plant can produce an average of 20,000 gizmos per week, then your total capacity is 20,000 gizmos per week. So far, no surprises.

You can also divide the total time by the total quantity, and get what I call the line takt or system takt (see also How to Determine Takt Times). Hence, this system takt is also a measure of the capacity, which has to match the customer takt, a measure of the demand. Confusingly, many practitioners also call this the (average, total, …) cycle time, which I find confusing, as for me the cycle time is without losses, but the takt time includes losses.

47.2 What Is My Quantity?

Figure 396: Look at what we produced… (Image Lewis G P in public domain)

The quantity should be the quantity that you can realistically produce, including all time lost for changeovers, maintenance, breakdowns, missing parts, and other delays. Hence, for a system working at full capacity, it is the average quantity produced in a given time period.

If your system is working at less than capacity, however, you cannot take the total production quantity. For example, if you produced 20,000 gizmos per week, but half of the time your people were idling, then you cannot use the 20,000. Same goes if only half of your people work while the other half idles, or if you fill their time with some secondary tasks like weeding the parking lot (yes, I have seen a plant doing just that).

Now, you could just assume that if half of your people are idling when making 20,000 gizmos per week, then your total capacity would be twice that: 40,000 gizmos. This is probably not true. If there is not enough work around, then people automatically work slower than normal. Hence, your total capacity would be quite likely more than 40,000 per week. This could be 30% on top or more, but this is hard to estimate. The best way is still to take a fully loaded system and count the parts during a given period.

47.3 Can I Calculate My Quantity?

Figure 397: REFA time study and Stopwatch (Image Tasma3197 under the CC-BY-SA 3.0 license)

Another possible option is using calculations to determine the total quantity. Some plants use predetermined motion time systems like MTM or REFA to calculate the time a worker needs for the tasks. Others use the cycle time divided by the estimated OEE. Simulation has also been used to measure plant capacity. I generally advise against that. These methods are far too imprecise to give a good estimate of the production capacity. **If you have a plant, use real numbers of the plant running at full capacity.**

Of course, if you do not (yet) have a plant, you cannot measure the plant (yet). For example, if you build a new greenfield plant, restructure a line, or generally plant to significantly change your system, you can test the capacity only after installation and ramp up. If you need the capacity beforehand, you have to calculate. Keep in mind that this is usually a very imprecise approach. If you have other similar plants, use the experience from these plants when creating your capacity estimates.

47.4 Assumption for the Working Time

Figure 398: Clocking out at the end of the shift (Image Ministry of Information Photo Division Photographer in public domain)

The working time during a time period should be similar. Your capacity will differ if your plant runs on one shift or two shifts per day. Naturally, if you work longer, you can produce more. This assumption is usually not a problem, since it is simply included in the assumptions. Every foreman worth his money assumes that in two shifts he can make twice the parts as he can make one shift. For practical purposes this is usually also precise enough, even though production during shifts are not necessarily identical.

Figure 399: Working hard … or hardly working? (Image Lewis G P in public domain)

For example, some night shifts may be more productive since no manager is around to mess things up. Yet, in other plants night shifts may be less productive since no manager is around to keep them working. I have seen people on night shifts sleeping when they should be working. But again, unless you have more detailed data, the assumption of a linear relation between work time and quantity is usually good enough.

For the time, I usually simply take the total available time with people present. For example, if a shift is 7.5 hours, then a five-day work week with one shift is 37.5 hours. In rare cases I have seen plants taking out things like maintenance time or changeovers. This is possible, but not necessary. It all depends on what you use the capacity measurement for. If you make 20,000 gizmos per week **without maintenance**, then your capacity for the next four weeks is 80,000 gizmos **without maintenance**. Both sides of the equation have to have the same assumptions for the time. If you calculate capacity during a two-shift week without maintenance times, and then apply it to a two-shift week with maintenance, you will be waaaay off. Just keep it simple.

47.5 Assumption for the Work Content

Figure 400: I count two vehicles… (Image Tzorn under the CC-BY-SA 3.0 license)

The second assumption is often overlooked – **the work content for one part should be similar for all parts**. If my capacity is 20,000 gizmos per week, I assume every gizmo takes approximately 1/20,000 of the working time during the week. However, if I have some easy-peasy gizmos that just fly off the line and other heavy-duty gizmos that keep my people busy for hours on end, then I cannot simply just put them together.

Figure 401: Say what ??? (Image talitha with permission)

If your products have quite different work content, then the calculation becomes more tricky. In fact, usually too tricky for upper management. If your boss asks you what your capacity is for next week, saying, "*Either 5,000 large ones or 30,000 small ones or anything in between depending on the mix,*" is usually not a career building answer .

Luckily, you can do an additional assumption of a similar product mix. If you measured your capacity with a certain mix of high- and low-work content products, then this capacity assumption is valid as long as you have a similar product mix. Hence, answering your boss with "*20,000, sir,*" is a much better career-building answer, with the unspoken underlying assumption of a similar product mix.

Overall, I usually try to assume a similar mix or similar product work content to make my work easier. If both of these assumptions do not hold true, I am forced to do it the hard way.

47.6 The Hard Way: More Precise but Cumbersome

If both assumptions of similar work content or similar mix fail, the capacity has to be calculated based on the individual mix. You would need the system takt for the major product (groups) going through the system. In other words, you would need to know the average time between parts for both low-work-content and high-work-content parts, including the losses.

Before calculating the takt times for every single product you make, try to group them into groups with similar work content. This makes it much easier. You will lose a small bit of precision, but this precision is lost anyway due to the fluctuations between otherwise similar weeks.

Figure 402: All are different. Some more than others… (Image Ssawka under the CC-BY-SA 3.0 license)

You then need to calculate the takt of each group. What is the average time between the completion of the parts, including all losses. In other words, assume a small part is completed on average every 5 seconds, and a large one every 20 seconds (i.e., the takt time). You then can simply choose two production quantities, which, multiplied with the takt times, must give you the total work time available. For example, you could make 15,000 small ones in 20.8 hours, and fill the remaining 16.2 hours with 3,000 large ones. Or you make 25,000 small and 500 large for again 37.5 hours total. That way you can calculate the capacity for each mix you would like.

When calculating the takt time (time between parts including losses) for your product groups, keep in mind that many manufacturing systems fluctuate heavily over time. If you get a "good hour," your result will be quite different from a "bad hour," as will the capacity estimate. Try to get as much production data as you can. Also make sure to include all losses.

When looking only at the parts per hour, it is easy to overlook longer breakdowns or interruptions where nothing got produced. In other words, assume in the morning you produced 1000 small parts per hour, in the afternoon you did 250 large ones, and in between you had a two-hour maintenance. You need to include the maintenance in the total estimate, ideally proportional to the total production time for small and large parts.

47.7 If you can't measure your work at all …

Sometimes you have products (or services) that vary widely in their work content. Additionally, there may be "surprises" that cause unforeseen work (Changes in design, product doesn't work yet, production is more difficult than expected …). Overall, you do not really know your work content very well. Now you could manage to standardize your products at least somewhat, although this is often difficult.

If you do lack reliable data about the work content, the best approach is usually an expert estimate. As you surely known, an *expert estimate* is a wild guess by someone that has at least some familiarity with the system. While this is rather imprecise, for some products it may be the only way to guesstimate the work content and hence the production capacity.

It is still worthwhile, though, to have an upper limit on the quantity or amount of work in the system at the same time. This limit turns your production system into a pull system

(see The (True) Difference Between Push and Pull).

47.8 Summary

I hope the last parts were not too confusing for you. Again, calculating by product type makes it much more tricky. I myself also much rather prefer the assumption of similar parts or similar product mix. Even if it is a borderline case, I still prefer one of these assumptions over the hassle of getting product-specific data including all losses, and then try to figure out the capacity depending on the mix. Unfortunately, sometimes it cannot be avoided (e.g., if you try to figure out the capacity of a maintenance guy). He can do many small things or a few big things before the end of his shift. It gets even more complex if experienced maintenance guys can do lots of different things, and newer ones not yet. And, all of this doesn't even include customers that are willing to pay a higher price if there is a (perceived) shortage of goods. In any case, go out and match your capacity to your demand when **you organize your industry!**

P.S.: The post is based on an interesting question I got from Andy Higgins (name mentioned with permission). Thanks, Andy 🙂!

48 American Automotive Market Strategy of Toyota and Others

Christoph Roser, December 01, 2015, Original at https://www.allaboutlean.com/automotive-market-strategy/

Figure 403: Major Car Makers (Image Roser)

The largest ten car makers sell over 200 different car models on the US market. Without vans, SUVs, and sport cars, there are still 100 consumer cars left. Toyota has the largest number with a total of 14 models, yet they still have an excellent market strategy and very little self cannibalization. BMW has much fewer models, yet still manages to cannibalize itself. GM has 13 models and also steps on its own toes, while completely missing another market segment. This post is based on a master's thesis of one of my students, Amir Javanshir, and the detailed source is at the end of the article.

48.1 About the Data Source

Mr. Javanshir collected tons of data of the available models on the US automotive market. He compared the price with a technical index consisting of the width, length, and height, and the weight, displacement, and power output. Each of these indices was normalized between 0 and 1, i.e. the car with the smallest length got an index for the length of 0, and the longest car got the index 1. All other cars were distributed between 0 and 1 proportionally to their length. The tech index is constructed from the following variables.

- **Size index**, consisting of
  - **Width** (excluding mirrors): Smart 1.56m to Audi A8 1.95m
  - **Length**: Smart 2.69m to Daimler S Class 5.25m
  - **Height**: Audi A5 1.37m to Fiat 500l 1.67m
- **Engine index**, consisting of
  - **Displacement**: BMW i3 0.7l to Chevrolet SS 6.2l
  - **Power output**: Toyota Prius 73PS to Daimler S Class 449ps
- **Weight**: Smart 880kg to Daimler S Class 2145kg

The indexed width, height, and length were multiplied in a size index. The indexed displacement and power output were multiplied in a engine index. Finally, the size index, the engine index, and the weight were multiplied in a technical index, ranging from the smart at 0.075 to the Daimler S class at 0.871. A total of 100 vehicles have been included in the analysis. The makers and brands are listed below. The data is from the beginning of 2015.

- US makers: General Motors (Buick, Cadillac, Chevrolet); Ford Motor Company (Ford, Lincoln); Chrysler Group (Chrysler, Dodge, Fiat)
- Japanese Makers: Toyota Motor Corporation (Lexus, Scion, Toyota); Nissan Motor Company (Infiniti, Nissan); Honda Motor Company (Acura, Honda)

- German makers: Volkswagen Group: (Audi, Porsche, VW, not including ultra-luxury Bentley and Lamborghini); Daimler (Mercedes-Benz, Smart); BMW Group (BMW, Mini, not including the ultra-luxury group Rolls Royce)
- South Korean Makers: Hyundai-Kia Autom. Group (Hyundai, Kia)

48.2 The Clustering

Using some clustering analysis tools and some manual optimization generated nine different classes of cars. Interestingly enough, almost all classes were doubled. For each "normal" car segment except subcompact, there was a corresponding luxury segment. Similar specs, but fancier and hence a higher price. The overall segmentation is shown below, including some cars that where outside of any segmentation.

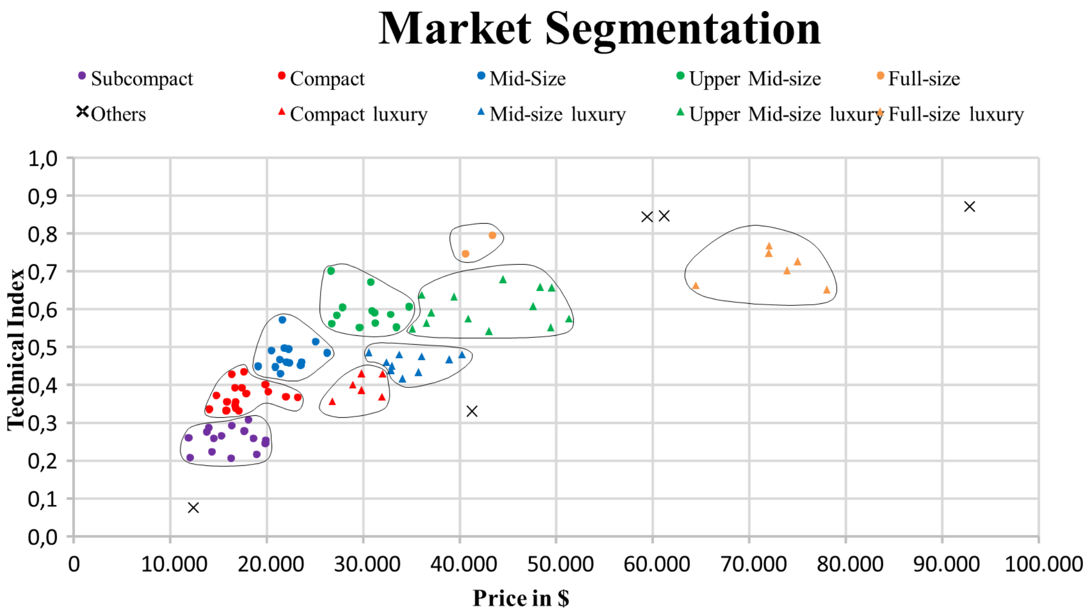


Figure 404: US Automotive Market Segmentation (Image Avir Javanshir with permission)

48.3 BMW Group

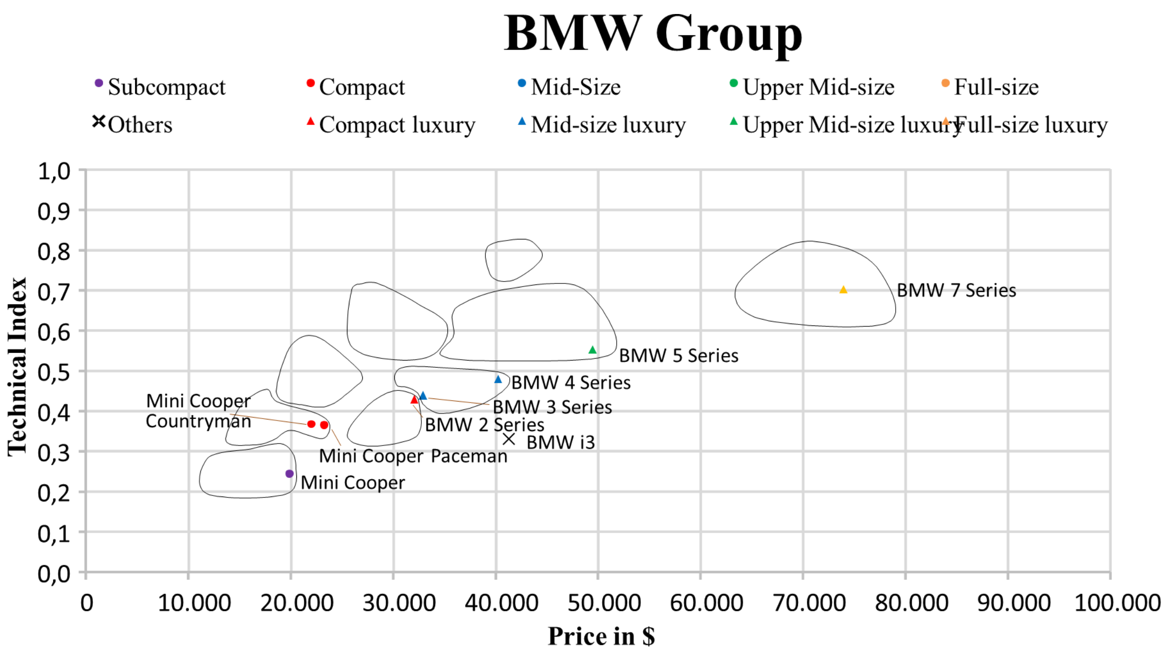


Figure 405: US Automotive Market Segmentation BMW (Image Avir Javanshir with permission)

Figure 406: BMW 2 series top and 3 series bottom (Image nakhon100 under the CC-BY 2.0 license)

The BMW Group has already two interesting overlaps. First, the BMW 2 series and 3 series. For almost the same price, you can upgrade your two-door BMW 2 to a four-door BMW 3. As with any cannibalization, some customers may strongly prefer one over the other, while others could pick either one.

The second cannibalization is even more pronounced: the Mini Cooper Countryman and the Mini Cooper Paceman. They have nearly the same specs, nearly the same price, and a very similar styling. The only difference is that the Countryman has four doors, whereas the Paceman has only two. Unsurprisingly, most customers opt to get four doors for the price of two.

48.4 Volkswagen Group

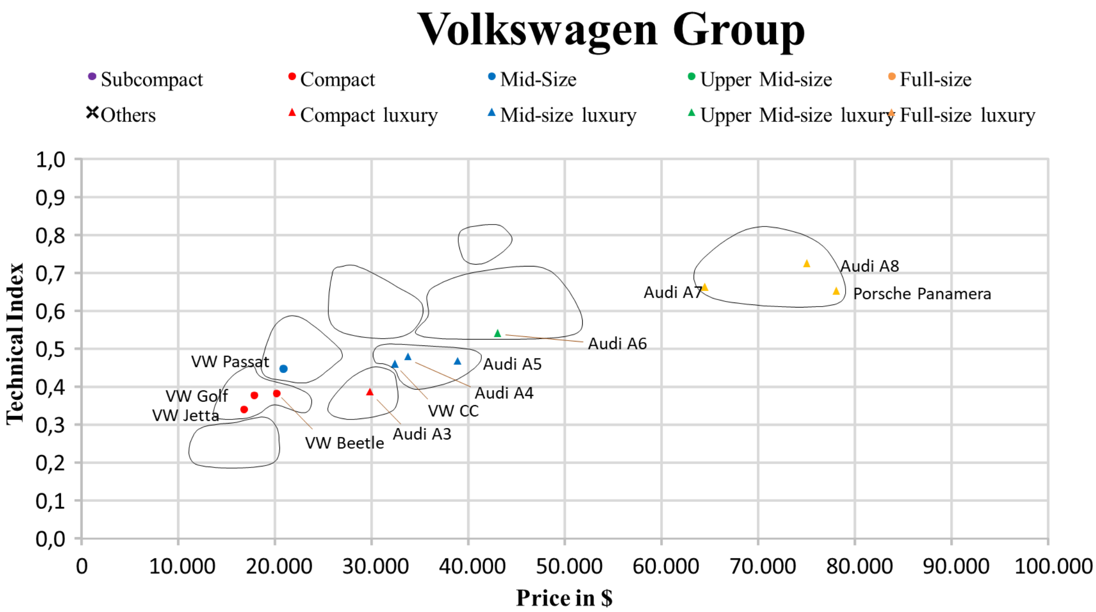


Figure 407: US Automotive Market Segmentation VW (Image Avir Javanshir with permission)

Figure 408: VW CC top and Audi A4 bottom (Image Thomas doerfer under the CC-BY 3.0 license)

Even before the Dieselgate, Volkswagen was a weak brand on the US market. An average VW model sold only 72,000 times in a year, which is less than any other large maker. Generally, they manage to keep their volume brand, Volkswagen, and their premium brand, Audi, separate – except for the VW CC and the Audi A4. For some reasons, the VW CC is rather expensive. For only a little bit more money, you get a premium A4. Again, unsurprisingly, most customers choose the (almost) free upgrade.

For being the second largest car maker, it is also surprising what they do NOT offer. There is no VW brand model available above the Passat or CC. The upper-mid-size and the full-size vehicle categories are not covered at all. Hence, there are no options within the VW brand for people who want a large car but can't afford an Audi. Quite a gap in my opinion. But then, after the Dieslgate, VW probably has other problems to take care of instead of fixing their market strategy.

48.5 General Motors

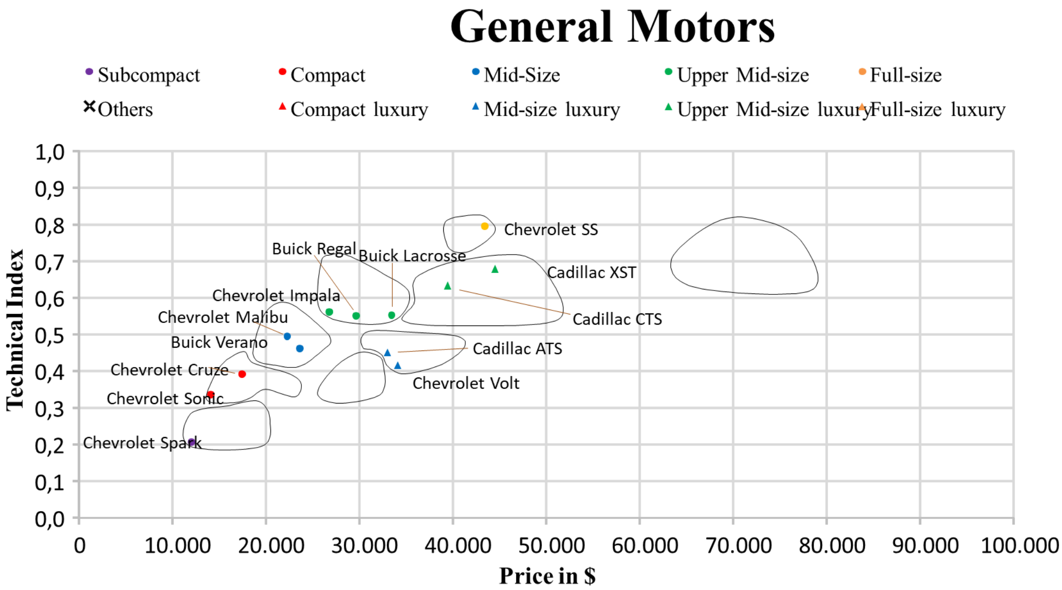


Figure 409: US Automotive Market Segmentation GM (Image Avir Javanshir with permission)

Figure 410: 2011 Buick Regal, 2010 Buick LaCrosse, and 2010 Chevrolet Impala (Images IFCAR in public domain)

GM has the largest market share of the US market with almost 18%. Yet, even though it manages to keep its premium-brand, Cadillac, separate in the luxury segment, it has no offers in both the compact luxury and the full-size luxury segments.

Additionally, there are three very similar cars in the upper-mid-size segment: the Buick Regal, the Buick LaCrosse, and the Chevrolet Impala. These cars are based on the same platform and have similar performance. The only small distinction is the price. Two of them even appear under the same brand. There is a risk of cannibalization among these three vehicles.

Figure 411: 2012 Buick Verano top, 2013 Chevrolet Malibu bottom (Images IFCAR in public domain)

There is a second, even more significant cannibalization: the Buick Verano and Chevrolet Malibu. They have very similar technical specs and also very similar prices. Again, there may be a high risk of cannibalization in the mid-size segment of GM.

Overall, GM has a rather crowded strategy, while missing the most profitable full-size luxury segment. But then, they were rather occupied lately with their ignition key scandal (see also my post [Culture of Quality – A Comparison of Toyota and GM Recalls]).

48.6 The Benchmark (again): Toyota Motor

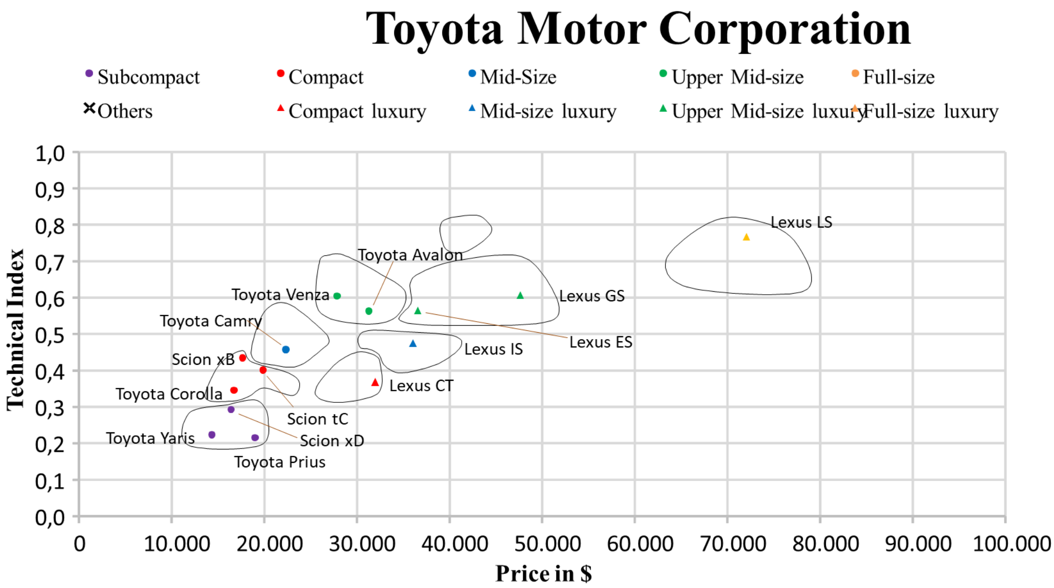


Figure 412: US Automotive Market Segmentation Toyota (Image Amir Javanshir with permission)

Toyota has more models on the US market than any other maker, a total of 14. You would expect that they step quite a lot on each others toes, but no. A detailed look at their product placement strategy shows a near perfect result. None of the models are anywhere close to another from Toyota. The premium segment is entirely covered by their premium brand, Lexus. The volume segment is also covered by their volume brand, Toyota, except for the small full-size volume segment. A third brand, Scion, is aimed primarily at younger customers.

This strategy pays off for Toyota. An average-volume model sold 180,000 vehicles per year, more than any other maker. The luxury models also sold well with an average 30,000 vehicles per model and year. This is second only to BMW with 31,000 units.

48.7 Summary

It is clearly visible which companies put effort in their product-placement strategy (Toyota), and which ones not so much. While generally a new model is aimed to take away share from the competitor, many models instead cannibalize their own maker's share. The above analysis is based on the US car market, but a similar analysis can also be done for almost any market. You know your own products better than anyone else, and hopefully also have a good understanding of your market. Does your company cannibalize itself? Is there a major segment you missed? If so, can you work on fixing these oversights? It helps you to **organize your industry!**

48.8 Sources

Amir Javanshir: Produktbezogene Marktsegmentierung des US-amerikanischen Automobilmarkts und anschließende Untersuchung der Firmenstrategien, Masters Thesis, Karlsruhe University of Applied Science, March 2015

Javanshir, Amir, and Christoph Roser. "Produktsegmentierung Des Amerikanischen Automobilmarktes – Kannibalisierung und Fehlende Strategien." Sonderdruck Arbeitskreis Automobilwirtschaft, 2016.

49 Why Do We Have Inventory?

Christoph Roser, December 08, 2015, Original at https://www.allaboutlean.com/why-inventory/

Figure 413: Typical Full Warehouse (Image Axisadman under the CC-BY-SA 3.0 license)

Inventory is expensive. Depending on your environment, inventory will cost you between 30% and 65% of its value. Toyota is known for (among other things) small inventories. Whereas Western companies often have weeks' or even months' worth of inventory, Toyota's inventory is measured in hours.

It is no surprise that inventory reduction is high on the list for many companies. In fact, the term "lean" by itself implies lower inventories. But why do we have inventory in the first place? And why is (too much) inventory considered evil in lean manufacturing? In this post I would like to tell you the reasons why we have inventory in the first place, and why too much is bad. In my next post I will explain what happens if you simply reduce inventory, and discuss in more detail better approaches on how to reduce inventory.

49.1 Why Do We Have Inventory?

Figure 414: Question Mark (Image Horia Varlan under the CC-BY 2.0 license)

There are three reasons why we have inventory. For simplicity's sake I include all parts that are needed for manufacturing in inventory, including raw materials, work in process, and finished goods. In order of priority, these three reasons for inventory usually are:

49.1.1 Decouple Fluctuations

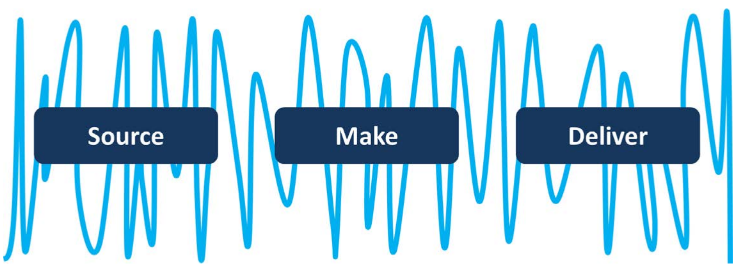


Figure 415: Source Make Deliver Fluctuations (Image Roser)

The primary reason is to decouple fluctuations. Fluctuations are any unexpected changes in your value stream. This includes **suppliers** (delayed shipment, bad quality, …), your **own value chain** (machine breakdown, workers calling in sick, mix up in the schedule, capacity constraints, …), and your **customers** (order early, order more than expected, order less than expected, changing orders …). All of those mess up your plans. A buffer inventory will keep your customers happy and your workers busy, even if there are (smaller) fluctuations. If you need more than expected, you decrease your buffer stock; if you need less than expected, you increase your buffer stock.

Of course, inventory is only one way to decouple fluctuations. The others are capacity and time (see The Three Fundamental Ways to Decouple Fluctuations). However, ramping capacity up and down quickly is difficult, and there are usually upper and lower limits as well. As for time, if you can let the customer or your workers wait, this will be an option. However, often this is not possible. In sum, **inventory usually is the workhorse to decouple short-term fluctuations.**

If you would have no fluctuations whatsoever, you could order every part to arrive on time (or in Japanese English: Just *in* Time or JIT) for processing, have it processed right away, and ship it out immediately. All parts would never be idle but always on the move. In this case you would need (almost) no inventory. The only inventory required would be the one you are currently working on.

49.1.2 You Need Something to Work

Figure 416: Blacksmith working (Image Jeff Kubina under the CC-BY-SA 2.0 license)

This brings me to the second reason why you need inventory: You actually have to have a part if you want to work on a part. At a bare-bone minimum, the part you are working on needs to be there. However, usually only very, very few parts in your inventory are currently worked on. With respect to inventory cost, this part is usually negligible.

49.1.3 Cost Reduction

Figure 417: Piggy Bank (Image Ken Teegardin under the CC-BY-SA 2.0 license)

The third reason for inventory may be due to cost reduction. One possibility to reduce cost is batching. For example, when shipping parts, it may not always be sensible to ship each part individually. If you order screws, you do not order a screw every 45 seconds, but you order a box of 3000 screws per week. Hence, you have in average 1500 screws lying around even without fluctuations. Similar batches may apply to other transport or selected processes.

Similarly, you may buy more when it is cheap, and use or sell the material when prices go up. This is, in effect, also an inventory to reduce cost. In both cases you can save money, although you will also create cost due to an increased inventory. Ideally there is a trade-off. In reality, the cost of inventory can rarely be estimated accurately. The estimation of the benefit of batching may be more accurate.

49.1.4 Relevance of These Three Reasons for Inventory

In value stream mapping, you can calculate a timeline with the percentages of value add and waiting time. Usually, the fraction of parts actually worked on is somewhere around 0.05% or less (unless you have batch processes). The other 99.95% of the parts are waiting. Hence the parts actually worked on is usually the smallest fraction of your inventory by far.

As to how the remaining 99.95% percent of your inventory is used, it depends on your system. This inventory is used both for batching and to cover fluctuations. In fact, the same part may serve a dual purpose as a batch and a fluctuation buffer. If you are at the beginning of your batch, and, due to fluctuations, need more, you can simply use more from the batch. Only if you are at the end of the batch, there are no more parts left to cover fluctuations. Overall, **most of our inventory is there to buffer and to batch.**

49.2 Why Is Inventory Evil?

Figure 418: Inventory is burning money (Image www.tOrange.us under the CC-BY 4.0 license)

As described in my previous post on The Hidden and Not-So-Hidden Costs of Inventory, simply having an inventory costs you between 30% and 65% of your inventory value per year. The main causes are:

- Cost of capital
- Taxes and insurance
- Storage cost
- Handling cost
- Administration
- Scrapping and obsolescence
- Deterioration and theft
- Cost of delayed response time

Figure 419: Grapevine snail (Image Jürgen Schoner under the CC-BY-SA 3.0 license)

Probably the most underestimated one is the cost of delayed response. The lead time increases proportionally with the inventory. This relation is known as Little's Law. The more inventory you have, the more sluggish your system becomes.

- It takes longer for an order to be produced and delivered to a customer.
- If a downstream station detects defects, more parts have to be fixed or scrapped.
- If there are product changes, it will take longer to flush out the old parts in the system (or you have to throw out more).
- Generally, any change in production will take longer to become effective.

49.3 What is a Good Trade-Off between Too Much and Too Little?

Figure 420: Scales (Image Maksym Yemelyanov with permission)

From the above discussion, the goal is clear. **You should have an inventory that is large enough for your system to function properly, but not too large with the costs outweighing the benefits**. The problem is finding this sweet spot. Manufacturing is usually a complex system with many different influences. It is all but impossible to determine this sweet spot theoretically. Rather, you have to find it by lowering your inventory and observing how your system reacts. On a side note, the typical status in many Western companies is, in my point of view, too little inventory rather than too much if the abilities of the system are taken into account.

Another complication but also opportunity is that the manufacturing system is not static. You can improve it and allow it to function with less inventory. You can also let it slide, resulting either in worse performance or a higher inventory needed, or both.

49.4 Summary

Inventory is necessary to buffer fluctuations, for batching, and (last but not least) to actually have something to work with. Yet, too much inventory will not only increase cost, but also worsen a lot of other measures related to lead time. You would need to find a trade-off in the middle between. In my next post I will talk about the effect of simply reducing inventory without addressing these underlying reasons, and describe in more detail sensible ways to reduce inventory. Until then stay tuned and **organize your industry!**

50 How to Reduce Your Inventory

Christoph Roser, December 15, 2015, Original at https://www.allaboutlean.com/reduce-inventory/

Figure 421: Inventory (Image Axisadman under the CC-BY-SA 3.0 license)

Reducing inventory is one of the goals of lean manufacturing. In my last post I described why we need inventory in the first place, and why too much inventory is bad for you. Now let's look at how we can achieve a good inventory level. First, an important statement: **Inventory is not a lever that you can pull. It is more the result of other good lean improvements.** In fact, merely pulling this lever and reducing inventory will actually make things worse. To gain the true benefits of lower inventory, other measures have to be taken. In this post I would like to describe what happens if you simply reduce inventory, and how to do it to achieve a lower inventory without causing mayhem in the process.

50.1 Simply Reducing Inventory Will Achieve the Opposite

Often, upper management decrees that the inventories have to be reduced. "*Inventory is expensive. Toyota has little inventory, and we want to be lean, hence we reduce inventory*." Middle management then follows these wishes and order less parts, hoping that the inventory will go down.

However, this inventory has a function. These parts serve a purpose, namely to buffer and to batch. If we simply reduce the number of parts, they can no longer fulfill their function. The number of missing parts will increase, as will the number of unfulfilled customer orders. Hence both your productivity and delivery performance will go down.

Figure 422: What you want … (Image Juergen Brauckmann in public domain)

And now for the double whammy: Your parts will not be missing equally. Most raw material will still arrive on time. Except, the one part missing means you often cannot use any of the material. If you wanted to produce 1000 products, each product needs 100 different parts, and one part is missing…Congratulations! You just increased your inventory by the material for 1000 complete products (minus one part). Hence, **simply decreasing inventory may actually increase your inventory due to missing parts, on top of a worsening productivity and delivery performance.**

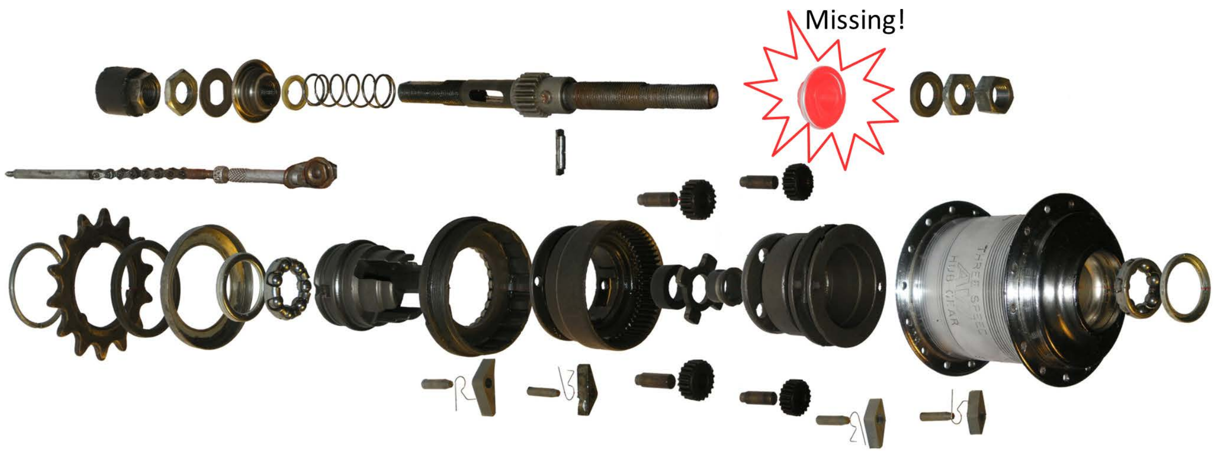


Figure 423: What you have … (Image Keithonearth under the CC-BY-SA 3.0 license)

50.2 Inventory Reduction is an Outcome, Not an Input

Of course it can save money to have a smaller inventory. However, a smaller inventory is more of a result than a lever you pull. To reduce your inventory, you need to reduce your fluctuations. Depending on the source of your fluctuations, this may be difficult. However, there is often one source of fluctuation that can easily be reduced simply because you artificially introduced it in the first place: your batches!

50.2.1 Reduce Inventory by Reducing Batch Size

Having a batch size larger than 1 is nothing other than an intentionally introduced fluctuation. In the image below, the inventory levels over time are shown for a batch size of 20, 10, and 5. Unsurprisingly, the inventory levels are lower for lower batch sizes. In fact, the average inventory in the example below is almost exactly half of the batch size (i.e., the average inventory is 10, 5, and 2.5 for the batch sizes 20, 10, and 5).

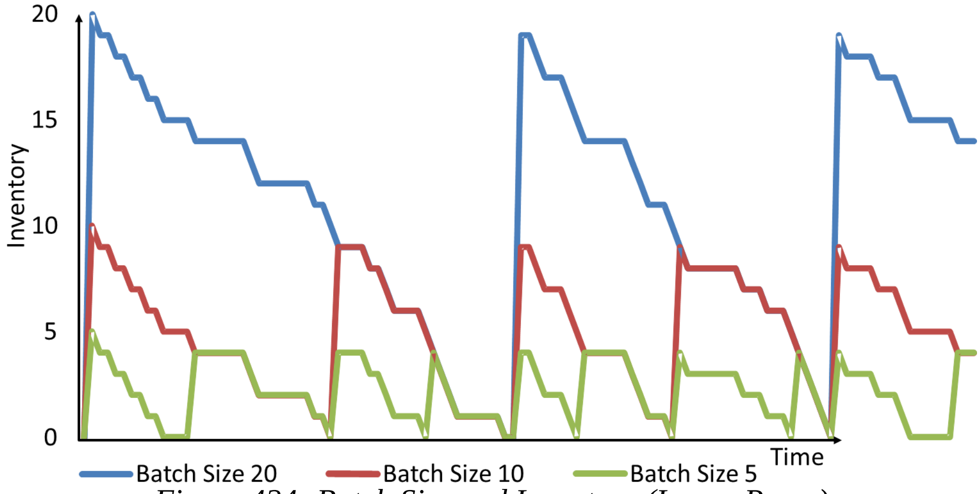


Figure 424: Batch Size and Inventory (Image Roser)

Hence, reducing the batch size is one of the easiest ways to reduce inventory. The above example is a bit of a simplification for only a single batch. However, you probably have multiple batches. Overall, if you halve your batch size and keep the number of batches constant, then you have halved your inventory. Reducing batch size is one of the easiest ways to reduce inventory.

However, before you simply reduce your batch size to the perfect number of 1, keep in mind the reasons why we have inventory in the first place. These batches can save money. For example, your shipping costs or changeover costs may not be zero, and may increase with a smaller batch size. **While I would err toward a smaller batch size, I would not completely**

neglect these costs. It may be beneficial to reduce these costs (e.g., through a SMED workshop) before reducing batch sizes.

50.2.2 Reduce Inventory by Reducing Other Fluctuations

Secondly, your inventory – batched or not – buffers against fluctuations. If you reduce your inventory – regardless if through smaller batch sizes or otherwise – you will eventually have no longer enough to buffer your fluctuations. To reduce the inventory you would have to reduce the fluctuations.One great tool here is pull, which besides reducing fluctuations also gives an upper limit to the inventory. In fact, many activities in lean have as one side effect a reduction in inventory.

By the way, a goal of zero inventory is nonsense. As described above, too little inventory decreases productivity and delivery performance, and may even unintentionally increase inventory.

Figure 425: Not enough water… (Image Case, William Howard in public domain)

If you are into lean, you probably have heard the worn-out metaphor of the ship floating on water with rocks below. It is mentioned in pretty much every beginner lean course. The water stands for inventory, the rocks for problems, and the ship for your production system. You should lower the water/inventory until you see the rocks/problems, and then fix them before you lower the water even more.

Personally, I am not too fond of this metaphor, as there are too many discrepancies. For one thing, a ship likes to have lots of water under its keel, and the water does not cost the ship anything. In lean, you want to be as close to the rocks as possible. But then, maybe I have heard it just way too often…

In any case, **you want to reduce inventory to a level where the problems are still manageable, and – more importantly – fixable. If you find a problem, you need to eliminate the root cause so it does not happen again. This is easier said than done and is usually a lot of hard work.** Depending on the source of fluctuations, you could try to work with your suppliers to ensure a more reliable delivery (usually works only if you have power over them), try to understand your customers better for a more accurate prediction of demand, improve maintenance or availability of your system, or a host of many other things. It depends on where your fluctuations come from, and which one you can influence or at least predict. Reducing inventory by reducing fluctuations is one of the reasons Why Leveling (Heijunka) is Important.

If there are more problems than you can handle, then you would actually need to increase inventory. My gut feeling is that in many Western companies this is the case. Inventory was reduced to rock bottom, resulting in bad performance and lots of firefighting. **Too little inventory can be as bad as too much!**

50.3 How to Get to a Low Inventory Level

50.3.1 Achieve Adequate Inventory Level

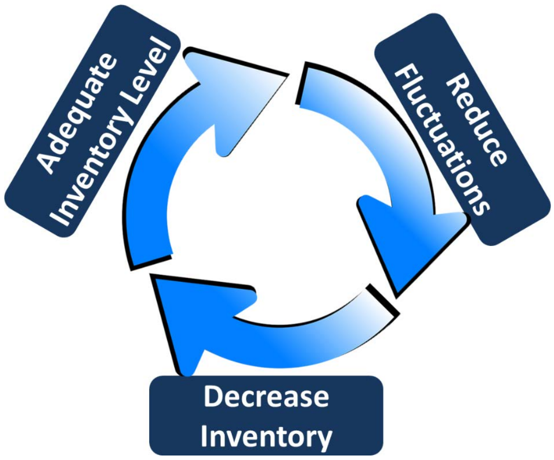


Figure 426: Inventory Reduction Circle (Image Roser)

To improve your inventory sensibly without causing chaos, it is advisable to make smaller steps. First, you would need to know if your current inventory level is adequate for the abilities of your manufacturing system. Please do not confuse adequate with desirable. Before we become better, we first need a working current system. If problems related to inventory (missing parts, missed deliveries, …) overwhelm you every day, then you have too little inventory and should increase it. My gut feeling tells me that this is the case in many Western companies.

Yes, you heard me right. **It may be good for you to increase inventory**. At the same time I am fully aware that – depending on your bosses – this may damage your career. Even if it is the right thing to do, increasing inventory is a *no-go* in many companies. And I can't blame you if you like your career more than the success of the company. Yet, it will make good manufacturing more difficult.

Of course, no amount of inventory will fix all problems – it will actually make problems on its own. Hence, the right inventory does not mean it will be problem-free, but rather that you will have a few problems that you can work on improving.

50.3.2 Reduce Fluctuations

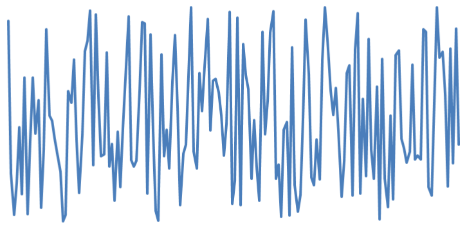


Figure 427: Fluctuation (Image Roser)

Once you are at the right inventory level, reduce fluctuations in your system. This includes both those that are self-made (usually the easier one, batch size) and those that are forced on you. Many lean activities have as a primary or secondary effect a reduction in fluctuations. But please note that reducing fluctuations is usually easier said than done.

If you start with adequate level of inventory, the problems that are popping up will show you where to start. At the same time, you should have the time to fix these problems in a way that they will no longer happen. Just waiting for the late material to arrive or the overdue delivery to be shipped will fix the problem, but it won't prevent it from happening again.

50.3.3 Decrease Inventory

Once your system is improved, there should be less problems popping up. If so, you can reduce inventory. If it works, great! Go on and reduce fluctuations on the next problems that pop up. If your problems become too big, you would need to increase inventory again to get to a workable level. In any case, you would need to repeat the cycle again, starting with an adequate inventory level.

50.4 How Low Can I Get?

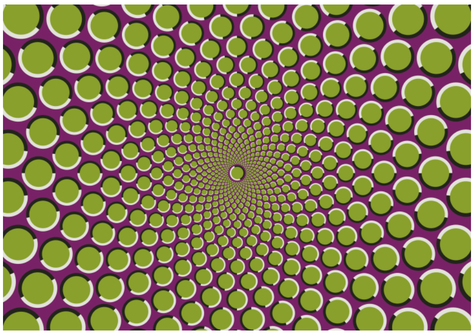


Figure 428: Motion Illusion Star (Image Fiestoforo under the CC-BY 3.0 license)

Theoretically, you could have an inventory of one piece per process. All your people or machines are busy. Ordered parts arrive exactly when you need them, and products are completed exactly when your customer needs them. It is beautiful, but it is an illusion. There will always be fluctuations, and hence you always need more inventory than one piece per machine.

The lower you get your inventory, the more difficult it will be to reduce fluctuations even more. In fact, just standing still will be a lot of work. At one point, the benefit of lower inventory is no longer worth the effort to obtain it. At which inventory level this will happen is difficult to tell. It also depends on your power over suppliers or customers. If you are a car maker, you can dictate the conditions to your suppliers, and your customers have to wait for you. If you are a small company, it will be much harder to convince your suppliers to improve delivery performance. As always, put your effort into the biggest problems you have. Now go out, reduce fluctuations, and **organize your industry!**

51 Lean for Refugees

Christoph Roser, December 22, 2015, Original at https://www.allaboutlean.com/lean-for-refugees/

Figure 429: Refugees in Hungary (Image Gémes Sándor / SzomSzed under the CC-BY-SA 3.0 license)

Europe is currently experiencing a refugee crisis. Hard numbers are difficult to obtain, but it is estimated that one million refugees arrived in Germany in 2015. Government authorities were ill-prepared to handle and organize these people. Significant resources have been put in, but they never seem to be enough. The organizational processes are not yet functioning well.

As it happens, I am an expert in improving organizational and other processes. I decided to help, and together with two other professors, founded an initiative, **Lean for Refugees**. We are politically neutral, volunteering our time to organize these processes so we can help both the refugees and the government. Let me give you an overview of what we have done so far.

Update: As the crisis has passed (for now) we have scaled back our activities. The site lean-for-refugees.de is now offline.

51.1 Who We Are

We are three professors and a few volunteers who spend our time helping the authorities organize the processes around refugees. For this we started a small initiative, Lean for Refugees.

Figure 430: Banner Lean for Refugees (Image Lean for Refugees with permission)

Prof. Dr. Constantin May	**Prof. Dr. Christoph Roser**	**Prof. Dr. Andreas Syska**
Ansbach University of Applied Sciences CETPM	Karlsruhe University of Applied Sciences AllAboutLean.com	Niederrhein University of Applied Sciences

51.2 What We Are Not

The refugee crisis is dividing Germany and Europe. Some people would like to let everybody in, and then some more, whereas others would prefer to build a wall that puts the Berlin Wall to shame. Society, with the help of politics, has to come to a consensus for this problem. However, this consensus is not a problem we can help with. We are experts on lean, not politics.

So, first, **we stay neutral, and, more importantly, stay out of the discussion of who can come in and who not.** So, please no hate mail for being too left or too right! In any case, regardless of what the consensus and the laws are or will be, they have to be implemented. And that’s where we come in.

Second, there are limits to what we can do. As you will see below, some laws are difficult to implement. Different software systems are not always compatible, bug free, or user friendly. **We cannot change laws to suit the process. We cannot fix or change a Germany-wide software program.** But even with these limitations, there is still lots of potential for improvement.

Finally, **we do not aim for perfection**. Our goal is merely to make the situation better than it is now. We would rather take many **small steps in the right direction** than one big step for a supposedly perfect solution that does not work in the end.

51.3 Who We Worked With

Figure 431: Sign LEA Mannheim (Image Roser)

Altogether we spent almost three days in the LEA Mannheim (*Landeserstaufnahmeeinrichtung*, State Office for initial registration). This is one of the state of Baden-Württemberg offices that gives refugees their initial registration papers called BüMa (*Bescheinigung über die Meldung als Asylsuchender*, Confirmation of Registration as Asylum claimant). These are sort of a ID substitute for refugees. With those, the refugees are entitled to benefits and they can apply for asylum, which is a separate process.

There are approximately 250 to 500 refugees arriving in Mannheim per week, which is also approximately the speed at which the office can hand out papers. However, since the capacity was ramped up just recently, there is approximately a 5-week backlog of unregistered refugees in Mannheim (and similar in most of Germany), hence the need to improve capacity. The actual asylum claim process has a much larger backlog of multiple months.

51.4 The Current State

We started (as with pretty much any lean activity) with understanding the processes. The refugees are transported by bus from their lodging to the LEA and then back. The actual process has three major steps:

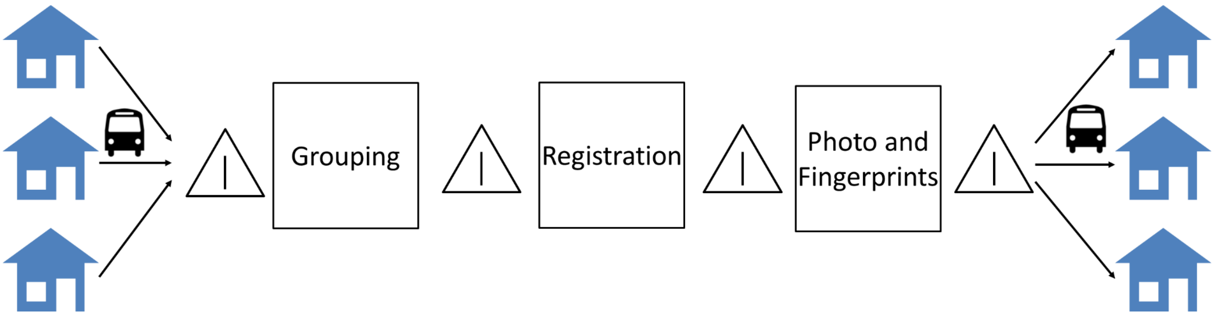


Figure 432: LEA Current State Process overview (Image Roser)

51.4.1 Grouping (Optionierung)

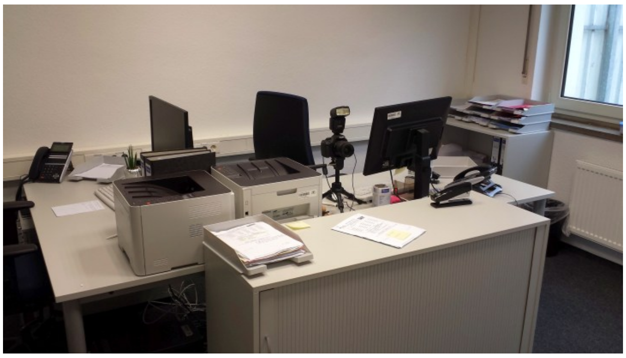


Figure 433: Categorizing (Image Roser)

The first step selects groups or individuals from the mass of refugees waiting. The registration is done, if possible, in family groups (father/mother/uncle/aunt/children…), but also individuals without relatives. The challenge is to determine the relation between the people, their ages, and if they have already been registered. A photo is taken and the number of people is added in a database, "EASY," that aims to distribute the refugees evenly across Germany.

51.4.2 Registration (Aufnahme)

In a second step, the actual details of the refugees are registered. Name, origin, language, date of birth, religion, etc. are first written down using a multilingual registration sheet. Afterward this info is put in a software system, MigVIS. Unfortunately, this is not standardized across Germany; different states and federal agencies have individual and incompatible solutions.

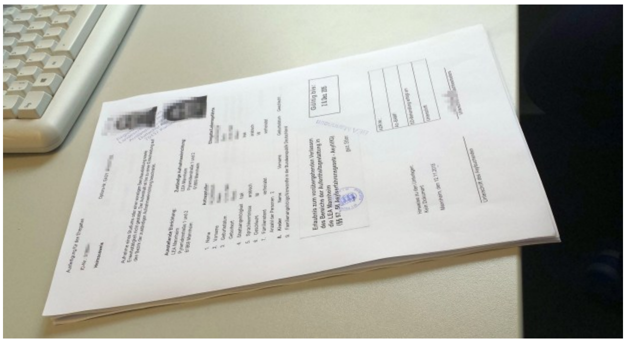


Figure 434: Sign here … 17 times (Image Roser)

With the ultimate accuracy of the German bureaucracy, this results in 17 pages of print outs that have 24 seals on them, each of which has to be signed by the refugee. Luckily, for every additional refugee in the group there are only 4 more pages and signatures per person. These are the registration papers (BüMa), a consent form in German, a consent form in their native language, and bilingual legal instructions, all of which have multiple copies for the refugee, the federal office for refugees, the state office for refugees, the health office, the state government, etc.

51.4.3 Photo & Fingerprints (Erkennungsdienst)

Figure 435: Fingerprinting Refugees (Image Roser)

The last step before the refugee gets his papers is another photo and fingerprints. The photo has to be without head scarf, which is a problem for some women. The fingerprints are easy, as most refugees have lots of practice in giving fingerprints. According to German news, some refugees get fingerprinted up to 8 times by different agencies while in Germany.

51.4.4 Current State Summary

Based on what we observed, and together with the employees from the LEA, we created a swim lane diagram, including problems and potentials. Like most value stream diagrams, these are only useful for the people who made them; for others, it is only to impress. Hence, **be impressed!** On a side note, I usually prefer to have no more than 15 to 30 blocks on a value stream map to keep it manageable. Yet, this was moderated by another volunteer, and I do not mess with other people's style of moderation while doing a workshop. In any case, the results were good (and impressive ☺).

Figure 436: Current State Refugee Registration (Image Roser)

51.5 Potentials

We found lots of improvement potentials (even without changing software or laws ☺).

- Many processes had a lot of waiting time. Especially the photo and fingerprint was 30 minutes of work, followed by 30 minutes of waiting for the next refugees.
- The refugees were brought into the offices from the waiting rooms 4 or 5 times. Each time involved a lot of searching.
- There were no visualizations for the refugees, to explain the process and guide them along.
- Many of the refugees arriving by bus did not meet the conditions for registration (i.e., accompanied minors need a statement by the youth welfare office, all family members that are fleeing together have to be present, …).
- The whole process is a batch process for multiple groups of refugees.

51.6 The Future State

Based on this, we developed a future state. Using a conservative estimate, we believe that we can improve throughput by at least 50%. The most important improvement ideas are below:

- Most significantly, we split the processes in smaller steps that are easier to learn and provide a better-balanced workload.
- We divided the steps into front-office and back-office steps. We want to pull refugees from the waiting room only twice, once for registration, and once for signatures, fingerprints, and receiving documents.
- We wanted to improve the process of bringing refugees from their lodgings so we have to send back fewer refugees without registration due to lack of papers, etc.
- We made lots of little improvements, from a camera that zooms on faces automatically to having printers that handle two types of paper.
- We visualized using icons and multiple languages.

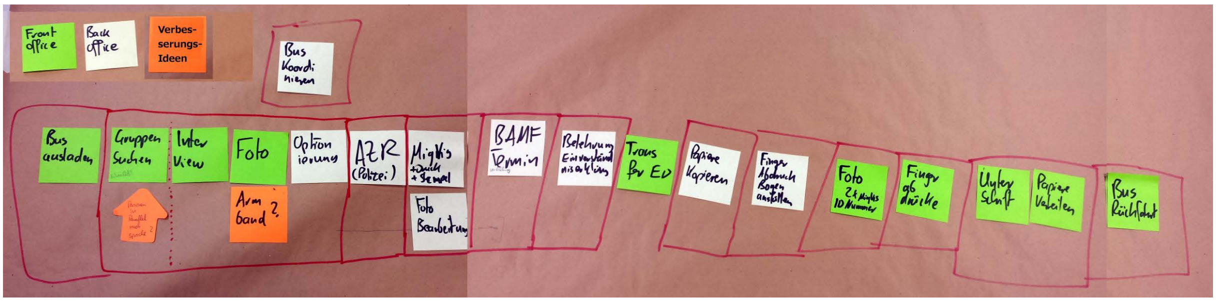


Figure 437: LEA future State (Image Roser)

51.7 Next Steps

We are currently planning a new workshop for early 2016. Since the LEA is moving into a new building, the workshop content depends on the still unknown moving date.

- If the workshop is well timed with the move, we want to implement the new flow in the new offices, including visualization.
- Otherwise, we look at the boarding of refugees in the lodgings, including visualizations.

51.8 New Product for Workshops: Write On CILing Sheets

Our war room in the LEA didn't have flip charts. I tried a new product here for the first time, and liked it quite a lot: **Electrostatic flip chart foil**. It is like a 60 centimeter wide and 20 meter long Saran Wrap in white or with squares. It clings to the wall, and you just cut off a desired length horizontally or vertically. Normal white board markers can be used on it. It is even dry-erasable, although this did not work well with a textured wallpaper underneath. The product is called **Leitz EasyFlip**, but at the time of writing it was unavailable on Amazon.com, but available on Amazon.de. There are also other similar products available. You can also see it in the war room image below on the left.

51.9 Summary

Figure 438: Our war room (Image Roser)

Overall, we had great fun and the warm fuzzy feeling of doing good. The entire workshop was done without the help of computers (except for e-mail communication). All ideas were developed on paper. A more detailed description of the processes (in German) can be found on Lean for Refugees. We are looking forward to the next workshops. I will post updates here too. In the meantime, **go out and organize your industry!**

51.10 See also

Roser, Christoph. “Lean for Refugees – Erste Workshops Erfolgreich Abgeschlossen.” Yokoten 5, no. 1 (2016): 20–21.

52 A Critical Look at Industry 4.0

Christoph Roser, December 29, 2015, Original at [*https://www.allaboutlean.com/industry-4-0/*](https://www.allaboutlean.com/industry-4-0/)

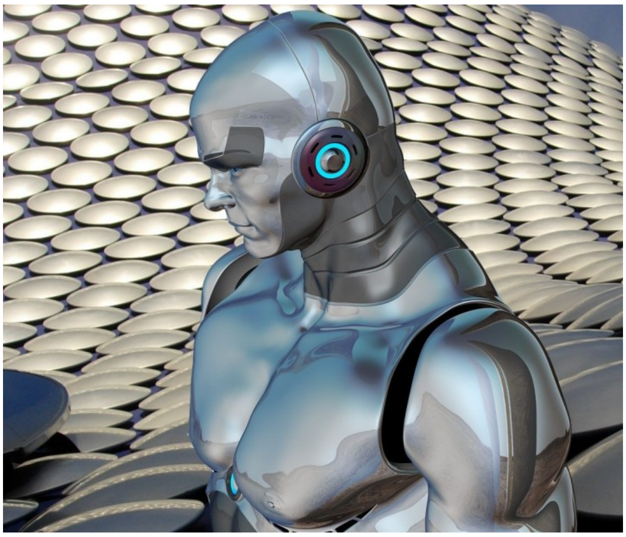


Figure 439: Modern Man with Background (Image DrSJS and Mcginnly in public domain)

One of the hottest buzzwords right now (at least in Germany) is Industry 4.0. However, it's a bit fuzzy what Industry 4.0 is, exactly. In this post I would like to talk about Industry 4.0. **This includes very little about all the promises of a wonderful future – you can read that elsewhere. Instead, I will try to give you the big picture.** I will talk about how Industry 4.0 came into existence, why it is so popular, what the true current benefit of Industry 4.0 is, and why you should pay attention to clothes.

52.1 How Industry 4.0 Came into Existence

Around 2011, the German research union for economy and science (*Forschungsunion Wirtschaft-Wissenschaft*) approached Chancellor Merkel. Their proposal was to start a research program for computers in industry, funded by the government, to maintain the technological edge for the German industry. Its name? *Industrial Revolution 4.0.*

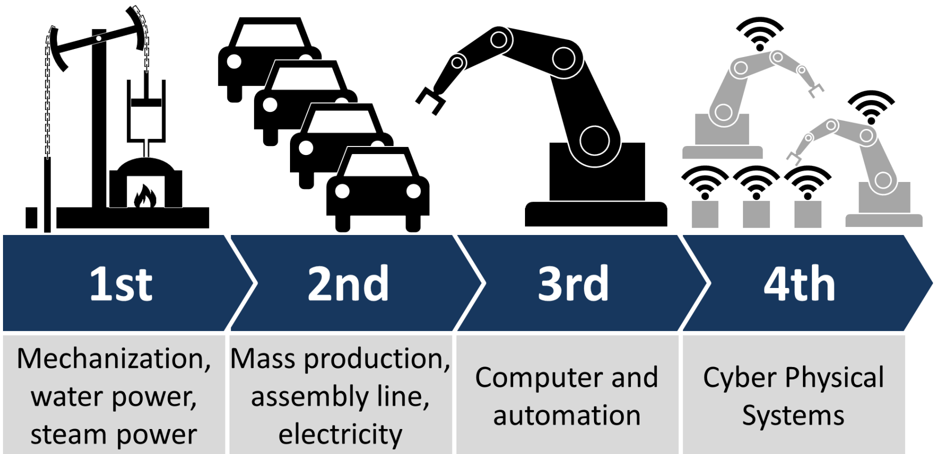


Figure 440: Industry 4.0 (Image Roser)

The idea behind it was that we are currently experiencing the fourth industrial revolution. According to their reasoning, the **first** industrial revolution was of course the Industrial Revolution between 1760 and 1820ish, which brought us steam power and mechanization through spinning mills (see, for example, my post [How a Little Bit of Industrial Espionage Started the Industrial Revolution](#)). The **second** industrial revolution was mass production, starting around 1870, but best known through the assembly lines of Henry Ford 1913. The **third** industrial revolution was the introduction of computers and automation in manufacturing from 1950 onward. They argued that we are right now at the beginning of the **fourth** industrial revolution: cyber-physical systems.

Please bear in mind that the numbering of industrial revolutions is rather confusing. For example, the European Parliament declared in 2007 that renewable energy is the third industrial revolution. I found sources up to an seventh industrial revolution (replicating machines). In any case, the numbering is far from generally accepted.

Figure 441: No revolution on my watch! (Image Armin Linnartz under the CC-BY-SA 3.0 Germany license)

But back to our *Industrial Revolution 4.0*. Merkel was in favor of this program, except for the name. Under no circumstances would she fund a revolution in Germany. After a bit of head scratching, they took out the revolution of the *Industrial ~~Revolution~~ 4.0*, resulting in the much less revolutionary *Industry 4.0*.

After cleaning up these problems with the nomenclature, the program received the go-ahead. The research program was funded with 400 million euro and announced to the public at the Hanover Fair (Hannover Messe) in 2011.

52.2 Money, Money, Money…

Figure 442: Euro coins and notes (Image Avij in public domain)

As it turned out, nobody was quite sure what Industry 4.0 actually is. Everybody agreed that it is something with computers in industry. Yet, since Industry 4.0 came with 400 million euro of government research funding, academia and industry were scrambling to put their topic on the agenda to get a piece of the pie. Resulting topics include anything even loosely related to computers in industry. This includes Big Data, 3D printing, facial recognition, the Web 2.0, autonomous vehicles, anything with cloud computing, and many more.

You can read quite long documents about Industry 4.0, which say pretty much the same on every page using different words: **it is something with computers and industry!** I totally agree that usage of computers will increase, and that this will reshape the way we make things. However, the actual content of industry 4.0 is very vague and fuzzy, with few results to show.

52.3 Internet of Things and Cyber-Physical Systems

Figure 443: Internet of Things (Image jeferrb in public domain)

One of the more promising topics is cyber-physical systems, or the closely related Internet of Things (IoT). The idea is to digitally connect machines and even parts. Hence, information about the current status should be available much more readily, and large quantities of data are provided for analysis.

The hardware is already mostly there. Wired and wireless networks can connect machines and systems. Radio Frequency Identity Chips (RFID) allow each part to transmit its identity wirelessly to a computer. Implementations are still a bit buggy, but overall it works.

The software systems that use these data, on the other hand, are still far from their potential. You could say we are missing the “*killer app*“. The visions are there. For example, it would be possible for machines to recognize an upcoming breakdown and signal for countermeasures beforehand. Inventories could be monitored in real time, rather than struggling with the difference between ERP systems and reality. The parts could plan their own production sequence using swarm intelligence.

It is estimated that this would bring benefits of over 270 billion euro per year in Germany alone (estimate of the Fraunhofer Instituts für Arbeitswirtschaft und Organisation [IAO] and BITKOM). However, we are still quite a bit away from cashing in on this.

52.4 A Déjà Vu?

Figure 444: Please let it work this time! (Image Piotr Marcinski with permission)

Based on my long experience in manufacturing, I cannot help but have a déjà vu. Manufacturing is difficult. There is a near-endless stream of problems and issues that need to be solved for a shop floor to function. There are few managers that do not wish for these problems to simply go away. It's no wonder that technology that promises all problems will go away sells well. The idea that computers will solve the problems for you already helped to sell NC machines, robots, and ERP programs. Unfortunately, it did not solve the problems. It may have made a few things easier, but it also created other problems.

Same for Industry 4.0. **Despite all their fancy names and buzzwords, I strongly believe that for a long time to come humans are crucial to solving shop floor problems.** The help of computers will increase, but it will be not revolutionary. There will still be lots of problems for humans to solve, not the least the problems that are created by the use of computers in the first place.

As for Industry 4.0, people are now also starting to wonder if there will be any applicable results. Quite a few articles describe Industry 4.0 in a negative light as *CIM reloaded*. It seems Industry 4.0 is mostly committee meetings, recommendation reports, distribution of research funds, and academic prestige.

52.5 A Look Back at Previous Hot Topics

Industry 4.0 is not the first buzzword looking at computers in industry. There were quite a few that have all promised a lot about computers in industry.

- **Digital Manufacturing** during the 1970s: Something with computers in manufacturing, but not much came out of it
- **Computer Integrated Manufacturing (CIM)** during the 1990s: Also quite a disappointment compared to the promises
- **Digital Factory** from 2000: Results unclear
- **Factory 2.0** from 2005 onward: Initiative of the European Union, pretty much forgotten
- **Smart Factory** from around 2007: Program of the University of Stuttgart, sort of merged with Industry 4.0

I would wager that if we look back in a few years, Industry 4.0 will have been a lot of hot air. It will also have funded quite a bit of research. In this, research it is a bit like advertising. Half the money spent on advertising is wasted; the trouble is we don't know which half. Although, **in research probably more like 90% the money spent is wasted, yet not spending would be disastrous**.

52.6 The Big Benefit of Industry 4.0!

Figure 445: Made in Germany! (Image Roser)

The one thing that Industry 4.0 does well is to sell! Industry 4.0 is a German research program that promises on things becoming better. However, since these promises are rather vague and its implementations insubstantial, many people are wondering what Germany knows that the rest of the world doesn't.

Planeloads full of academia and industry experts from all over the world arrive in Germany to study Industry 4.0 (Actually, one of the best presentations on Industry 4.0 I have seen is from a Japanese journalist, Toru Kumagai, based in Munich). This leads to lots of exchanged business cards and contacts. And, for a salesperson, any contact is a potential sale. Many products, especially software, are sold as supporting Industry 4.0. It is no surprise that the members of the Industry 4.0 executive committee include SAP, Siemens, and Deutsche Telekom.

Figure 446: The emperor's new clothes… (Image Elnur with permission)

But as I said above, we Germans don't know that much more than the rest of the world. It feels like the tale of **the emperors new clothes**. There are many articles on how wonderful everything will be with Industry 4.0, but if you really look, there is not yet much there. Yet, a lot of people praise the *new clothes* Industry 4.0!

There are also research programs in America that look into computers in industry. However, while the German Industry 4.0 is driven by the government, the American projects are funded more through industry. Hence, my feeling is that these American programs are more substantial than the German ones (or maybe the **American emperor's new clothes** just look much more fancy when seen from a distance 😉).

In any case, I hope you do know the status of your clothes 🙂. Now go out, patch a few holes, and **organize your industry!**

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54 Author

Figure 447: 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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