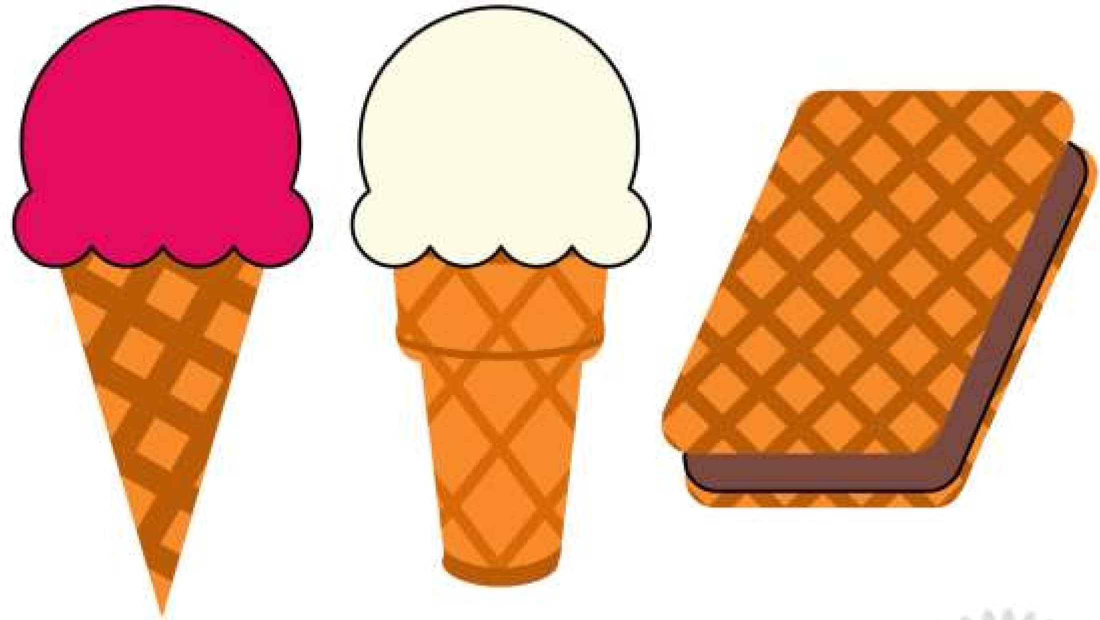
Collected Blog Posts of AllAboutLean.com 2022

Christoph Roser



Other Books by Christoph Roser

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

All About Pull Production: Designing, Implementing, and Maintaining Kanban, CONWIP, and other Pull Systems in Lean Production, AllAboutLean Publishing 2021, ISBN 978-3-96382-028-1 (Also available in many other languages.)

Fertigungstechnik für Führungskräfte. 3. überarbeitete Auflage, 274 pages, AllAboutLean Publishing, 2022. ISBN 978-3-96382-062-5 (Manufacturing fundamentals textbook for my lectures, in German)

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

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

Collected Blog Posts of AllAboutLean.com 2015, AllAboutLean Publishing, 2020. ISBN 978-3-96382-013-7

Collected Blog Posts of AllAboutLean.com 2016, AllAboutLean Publishing, 2020. ISBN 978-3-96382-016-8

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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.

Preface to the 2020 Collection of Blog Posts

2020 was again very productive, and I wrote another 53 blog posts. With the help of some WordPress programming, I also simplified the creation of this collected blog post volume, but it is still a lot of work to get all the images right and to give proper credits to the authors of other images. But the Corona pandemic gave me plenty of time. I also was able to work on my other book *All About Pull Production*, an extensive volume on pull production. At the time of writing, the proofreading process is nearly completed, and this comprehensive volume on pull production should be available soon. Hence, I took the liberty of listing it already in the *other publications* section.

As promised in my previous preface, I submitted 334 blog posts as book sections to my university publication database in 2020, as well as the seven books that contained them (plus some other conference and journal articles). With 373 publications in 2020 I was easily the most published author at my university 😎.

It took quite some time, but eventually someone noticed my creative output… and immediately concluded that this can't be right and took them out of the statistics. Luckily, I was able to convince them that all was proper, and these are indeed publications (although admittedly it is a bit of a stretch to call them academic publications–but then, they aren't shabby either!). Hence, my statistics is back up where it should be.

Table of Content

1 50 Years after the Death of Lillian Evelyn Gilbreth

Christoph Roser, January 2, 2022 Original at
https://www.allaboutlean.com/50-years-after-the-death-of-lillian-evelyn-gilbreth/

Figure 1: Lillian Moller Gilbreth in 1921 (Image Richard Arthur Norton in public domain)

Fifty years ago today, Lillian Evelyn Gilbreth (May 24, 1878 – January 2, 1972) passed away. She was an early pioneer in optimizing and streamlining work, which is especially remarkable in a time when women were supposed to be at home in the kitchen instead of pursuing science and engineering. I already wrote briefly about her, her husband, and Frederick Winslow Taylor in my post The Tale of Taylor and Gilbreth. I also have her portrait, among other key people in the history of manufacturing, hanging in my office. Let's have a look at the life of this very remarkable and outstanding woman!

1.1 Early Life

Figure 2: Lillian-Gilbreth as a Child (Image Purdue University Libraries in public domain)

Lillie Evelyn Moller was born on May 24, 1878, in Oakland, California, to a successful family of German ancestry. Her parents were Annie (née Delger) and William Moller, who sold building supplies. The second oldest of nine children, she was first educated at home, but later did very well in school and graduated with exemplary grades in May 1896. Her father was hesitant to send her to college, but Lillie was able to persuade him. In 1896 she started studying at the University of California.

As it turned out, Lillie also excelled in college. She obtained a bachelor's degree in English, but also studied Spanish and psychology. She won a prize for poetry. When she graduated, she was also the student speaker at the commencement in 1900, the first woman to do so at the University of California.

Figure 3: Lillian graduating in 1900 (Image Purdue University Libraries in public domain)

These intellectual pursuits suited her, and she did not want to become a housewife. She moved to the other side of the USA and enrolled in graduate school at Columbia University in New York City. She also started to use the more formal name Lillian instead of her actual birth name, Lillie. However, because she got sick with lung problems, she had to move back to California, and received a master's degree in literature from University of California in 1902.

Next she started a Ph.D., also at the University of California. During that time she got married to Frank Bunker Gilbreth in 1904 and moved to New York. Even though she completed her Ph.D. degree and her dissertation, she was not awarded a degree due to a technicality (residence requirements for doctoral students). However, in 1915, after her marriage, she obtained a Ph.D. in applied psychology at Brown University.

1.2 Family Life

Figure 4: The Gilbreth Family 1922 (Image Partners for Life in public domain)

During her Ph.D. studies, Lillian also traveled in Europe. During this time she met Frank Bunker Gilbreth in Boston in June 1903. (Lillian's travel companion was a cousin to Frank). They got married in October 1904 and lived in New York, then later in Rhode Island and New Jersey.

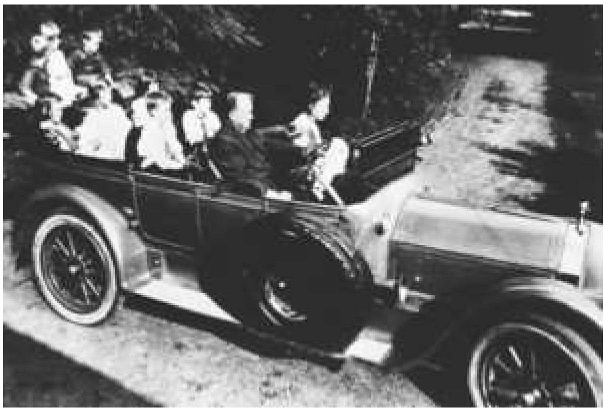

Figure 5: Gilbreth Family in car (Image Thomas Y. Crowell Company in public domain)

Frank and Lillian wanted to have a big family, and, oh boy, yes they did. Some popular sources refer to twelve children, and there is a book and two movies about their lives titled *Cheaper by the Dozen*.

Figure 6: The Gilbreth Family in 1924 (Image unknown author in public domain)

Depending on how you count, however, you may end up with anywhere between eleven and thirteen children. One was stillborn without even a name, and another one died young at age six. Since two died before the last eight were even born, at most you will see eleven children on family photos (see here for a list of children). Anyway, having never given birth myself, I think thirteen children is nevertheless quite an achievement!

1.3 Working with Frank

Figure 7: Frank Bunker Gilbreth Sr. (Image unknown author in public domain)

Figure 8: Frederick Winslow Taylor (Image unknown author in public domain)

Frank Gilbreth was a pioneer in scientific management and motion studies. He and his wife pioneered the study of work using photography and film, which in the 1920s were still cumbersome tools. They worked in the same field as [Frederick Winslow Taylor](), albeit their opinions clashed heavily.

In my view, while Taylor is more famous, the Gilbreths actually did better work. Taylor fudged his numbers to suit his desired results, and had enormous difficulties with differing opinions. See below for one of Gilbreth's original videos, which are still highly interesting.

The Video by Axbom Innovation AB is available on YouTube as "Frank and Lillian Gilbreth original films" at https://youtu.be/9fQJfap7SAQ

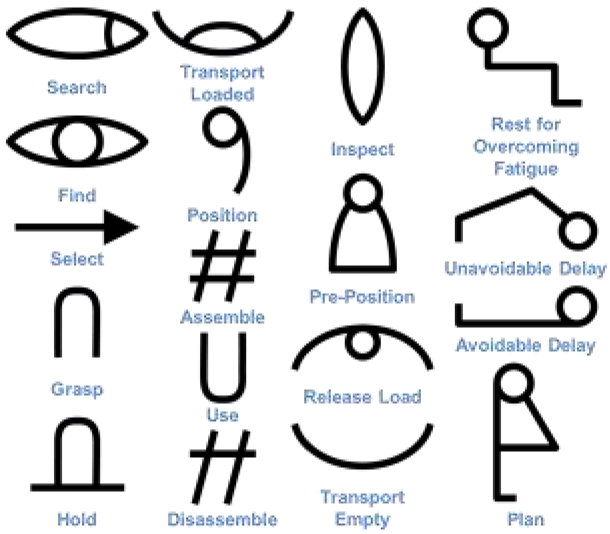

Figure 9: Eighteen therbligs (Image Roser)

Frank and Lillian's work and consulting was much more applied. Especially Lillian focused on the highly important human side of work, researching and consulting both industrial psychology and human fatigue (nowadays called ergonomics). A lot of their methods are still in use today (for example, the familiar scene of surgeons getting their tools handed by assistants rather than turning around looking for tools themselves). This shortens the duration of the surgery and increases the chances of survival.

One important part of their work was time motion studies, where Gilbreth developed eighteen therblings for different tasks to estimate the time of a manual process. Nowadays these are no longer used and have been replaced by MTM (Methods Time Measurement). They also published numerous books and papers together, although often Lillian was omitted as a (co-)author.

Frank died of a heart attack in 1924. This put Lillian in the difficult position of both running their consulting company AND caring and providing for eleven children between the ages of one and nineteen. It did help that they also used the same ergonomic and efficiency methods from industry in their private household, and they detailed timetables for who was allowed to use which bath and when, combined with standards to reduce movement and hence waste during hygiene and household tasks.

1.4 Solo Career

Figure 10: Lillian around 1930 (Image Harris & Ewing in public domain)

Losing her husband and business partner put Lillian in a difficult spot. The industrial world in 1924 was still very much male dominated, and most businessMEN didn't know how to deal with a capable woman in industry. Their three biggest clients did not renew their contracts after Frank died.

As a result, she focused on (or was pushed toward) industrial areas where businessMEN of that time had no clue and desperately needed help: the design of household appliances and kitchens. This is almost ironic, since Lillian despised housework and left this to hired help.

She was heavily involved in the design of the modern kitchen, and is credited for inventing the foot-pedal trashcan, wall mounted light switches, and shelves inside of the door of a refrigerator.

She also advised for the government during World War II, and was a good friend of President Herbert Hoover. She was an accomplished speaker and also a lecturer, and in 1935 a professor at Purdue University as well as other universities.

1.5 Death and Legacy

In 1968 at the age of 90, Lillian's health started to fail, and she retired to a nursing home. She died fifty years ago today on January 2, 1972 from a stroke.

Lillian was groundbreaking in the field of industrial engineering and as a general role model for women in industry. Many awards are named after her. She is shown on a US mail stamp in 1984, and in 1995 was introduced to the National Women's Hall of Fame. Her life and her achievements are much more than what I can fit in a blog post, and she deserves her own book (a book on The Gilbreths by James Gifford is in the works). Now, **go out and organize your industry!**

2 Alec Baldwin and Workplace Safety

Christoph Roser, January 11, 2022 Original at https://www.allaboutlean.com/workplace-safety-1/

Figure 11: NY Ambulance (Image Chris Sampson under the CC-BY-SA 2.0 license)

On October 21, 2021, actor Alec Baldwin handled a prop gun on a movie set that fired and killed cinematographer Halyna Hutchins and injured director Joel Souza. And, as far as I know, it was not even Alec Baldwin's fault. While the investigation is still ongoing, it looks like a lot of safety regulations were ignored or applied sloppily. Accidents in manufacturing and other industry also often have not a single cause, but multiple points of failure, before somebody gets hurt. A good reason to look deeper at workplace safety. This first post looks in more detail at the events on the film set, and a second post looks generally at workplace safety.

2.1 The *Rust* Shooting Incident

Figure 12: Alec Baldwin (Image Gage Skidmore under the CC-BY-SA 2.0 license)

On October 21, 2021, actor Alec Baldwin was on the set of the movie *Rust*, a Western movie where an outlaw (played by Baldwin) set out to rescue his son from a murder charge. As is common with Western movies, guns play an important part in the story. Overall, the movie industry frequently uses weapons. Anybody with a sliver of knowledge on gun safety knows that pointing a gun at somebody is a big no-no, as there may be an accidental discharge (a gun firing while it is not intended) or a negligent discharge (a gun firing due to an operator error). Pulling the trigger in such a situation is even worse, because then it is neither accidental nor negligent anymore. Yet, pointing a gun at someone and pulling the trigger is a common occurrence in the movie industry. Since the people on set do not have a death wish, there are many stringent rules to prevent accidents and injuries.

2.2 Gun Safety on Movie Sets

Figure 13: Iconic prop gun from James Bond (Image mrgarethm under the CC-BY 2.0 license)

It is common to use replica guns that look like guns but cannot hold ammunition or fire a blank or a bullet. These are used for rehearsals, and whenever no actual "bang" is necessary. But other guns are functioning. Often, these are modified so that they cannot be loaded with a cartridge that has an actual bullet, but may contain some explosives, often much less than a normal cartridge. Most people would call these cartridges blanks, although in filming, blanks refer to dummy ammunition that holds no charge (although at close distance they can also be dangerous). Even when using real guns on movie sets, only such blanks are allowed. Real bullets are not allowed on set (with very few exceptions). In the filming industry, they also use the terms *cold gun* (which has no charge inside whatsoever) and *hot gun* (which contains some sort of explosives). Even then, if a hot gun is fired in the direction of the camera or crew, a safety screen is set up to protect the people downrange.

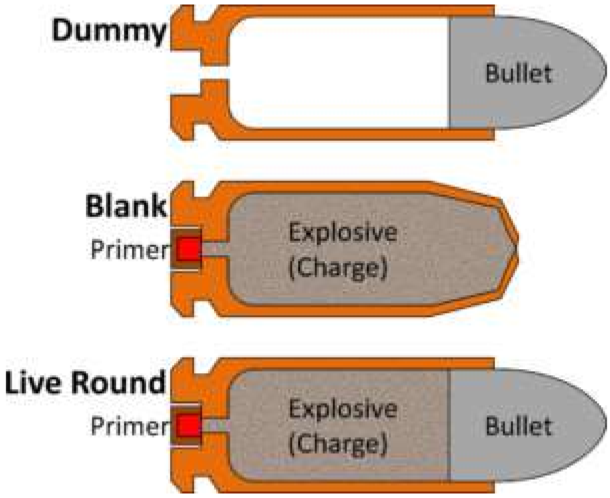

Figure 14: Dummy, Blank, and Live Ammo (Image Roser)

The person in charge of guns is the armorer, who has to ensure that guns and blank ammo are locked away, and that guns are *cold* and in proper condition, with nothing stuck in the barrel (shining a light through or using a wooden stick to poke through). The armorer also trains the actor in proper gun handling. The armorer retrieves the gun only when needed, and loads the gun with blanks only shortly before the filming. Together with the assistant director, they have to ensure that a gun is cold or hot, and they give it directly to the actor before the filming. Cold guns can also be "fired" into the ground as another redundant safety check. Overall, there are many redundant measures to ensure gun safety in the film industry – and I did not even get into the paperwork of it all.

Hence, accidents are rare on movie sets (Wikipedia has a list of prop weapon accidents, most of which seem to be bladed weapons). The last famous actor who died in a gun accident on set was Brandon Lee, nearly thirty years ago in 1993. The scene required an actor to shoot Lee with a blank (powder) cartridge. However, a bullet from a previous misfire was stuck in the barrel, and the armorer failed to check if the barrel was clear. The blank cartridge had enough energy to propel the stuck bullet out of the barrel and kill Brandon Lee.

2.3 What Went Wrong on the Set of *Rust*?

Figure 15: Movie set (different movie) (Image Roser)

On the set of *Rust,* many things went wrong. Gun safety was very sloppy, and before the fatal accident there not one, not two, but three accidental firings of a gun. Three times a gun made a "bang" when it should not have (two times with Baldwin's stunt double, and once with another woman who injured her foot by the discharge). Seven stage crew members actually walked off the set due to gun safety concerns as well as issues with their payments. They were replaced with non-unionized workers, and the filming continued. The deadly accident happened on the same day that these workers walked out.

Figure 16: A colt.45 Revolver, similar to the one in the accident. (Image Metropolitan Museum of Art and in public domain)

The events leading to the accident are still under investigation, but allegedly some of the crew used guns from the set to shoot at beer cans with live rounds in their spare time, only hours before the accident. Live rounds may have been mixed with dummy rounds and blanks on set. Obviously, a proper check for the state of the gun was not done. Armorer Gutierrez Reed handed the gun to assistant director Dave Halls, who handed it to Baldwin and announced the gun as a "cold" gun. This cold gun supposedly did not contain any explosives, but actually DID contain a charge and probably also a bullet. When Baldwin drew the gun for a rehearsal, a single round fired, killing cinematographer Halyna Hutchins and injuring director Joel Souza. Supposedly, Baldwin did not even pull the trigger.

A lot of failures came together to lead to the death of Halyna Hutchins. Prop guns should not have been used for private target practice. Live rounds should not have been on set. At least two people should have verified that the (supposedly) cold gun contained no charges before handing it to Baldwin. Following any of these steps could have prevented the death. Additionally, the three (!!!) previous accidental discharges on the same movie set, including one injury, should have given them a clue that something was seriously going wrong, and an investigation should have started. In fact, even a single discharge should have resulted in at least a more stringent adherence to the safety standards.

I actually feel sorry for Alec Baldwin. He received a (supposedly-but-not-really) cold gun. He was holding the gun when it killed his coworker. All the legal investigation notwithstanding, this must be a heavy burden on his mind. The legal fall-out is ongoing. Armorer Gutierrez Reed is accused of sloppy safety standards, but she claims she is being framed. Director Dave Halls' attorney claimed sabotage by someone putting live bullets on set. Certainly, there is more to the story in the future. For me, the biggest problem is why there were three near misses or minor incidents, but apparently nobody did anything to prevent further events! **There were quite literally three warning shots before Halyna Hutchins died!** Anyway, in my next post I will look at safety in manufacturing and other industries. Now, **go out, make sure your people are safe, avoid handling live firearms if you can, and organize your industry!**

3 On Workplace Safety

Christoph Roser, January 18, 2022 Original at https://www.allaboutlean.com/workplace-safety-2/

Figure 17: Injury Fork Lift (Image HalfPoint with permission)

In my last post I looked in detail at an example of a workplace accident with Alec Baldwin, where a misfire in a gun killed a coworker. It seems quite a few failures and oversights had to come together to result in the accident. This is the same in industry. A major injury is rarely the result of a single mistake. Modern industry has plenty and often redundant safety mechanisms to prevent accidents. Yet accidents do happen. Let's look deeper into workplace safety!

3.1 Introduction

Figure 18: Harry McShane, 1908. (Image Lewis Wickes Hine in public domain)

Workers want to have a safe workplace. This is true regarding injuries, but also general and long-term health risks, both physiological as well as psychological, although this post focuses more on injuries. In any case, workplace safety should be an important topic for workers.

As for employers, the picture is more mixed. Historically, a lot of employers saved money on safety, and any risk of accident was the risk for the employee. Machines were often better treated than employees, since an employee was easily replaceable, whereas a machine costs money to fix or replace. Especially in poorer countries, this may still apply. One historic example shown here is the sixteen-year-old Harry McShane, who lost his left arm from the shoulder down in a machine in a spring factory in 1908. The employer paid neither compensation nor any hospital bills.

In the civilized world, governments have since then stepped in and enforced health and safety regulations. In the US there is, for example, the Occupational Safety and Health Administration (OSHA), but most countries have one or more similar organizations, although not all of them are always effective. But if this works, it makes poor safety much more expensive for the employers. Employers who slack off on health and safety often face high punitive fines. As a curious result, in some plants management pays much more attention to health and safety than the employees.

3.2 Preventing Accidents

In industry, you should prevent or minimize risks. There are quite a few overarching health and safety management systems that give you lots of details on how to do this. In Germany, for example, there is a free download for the OHRIS system. This post is only a brief introduction, and if you are serious about safety you should not rely only on this blog post!

Figure 19: Door open, machine off (Image Glenn McKechnie under the CC-BY-SA 2.0 license)

This may start with first applying all legally required measures. Next, you should find out any risks that still exist, and reduce or eliminate these risks. Depending on the severity of the potential accident, you may use redundant measures to reduce the risk for your employees. Ideally, the process is changed so that a risk is completely eliminated. For example, a CNC milling machine may be completely enclosed, and work only if the doors are properly closed. This prevents broken tools or metal chips from injuring bystanders.

If it is not possible to eliminate the risk, you should reduce the risk. This often involves training on proper health and safety procedures. For example, a lathe operator must not wear loose clothing and must have short hair or the hair put up to prevent entanglement with the lathe that otherwise leads to some of the most gruesome deaths in industry.

Figure 20: Safety gear (Image Compliance and Safety LLC under the CC-BY-SA 3.0 license)

If things do go wrong despite these actions, the next (and often the last) effort to mitigate the damage is the personal safety equipment (safety shoes, glasses, and the like).

And, if even that did not prevent injury, you better know where the next first aid kit is, hope that it is up to standard, and know how to use it.

3.3 Managing Accident Prevention

Figure 21: Workers in Factory (Image Nopphon1987 with permission)

A key part in preventing accidents are both the workers AND the managers. The workers should follow safety protocol, and report or stop if anything is amiss. Managers and workers together should improve the safety of the workplace.

And, managers should verify that technical solutions for a safe workplace are functioning (sometimes the workers disable them for convenience ☹), that the workers indeed follow the safety standards, and that they wear their personal protective equipment.

Figure 22: Worker Ear protection (Image Elnur with permission)

If the worker fails to follow safety protocol, managers need to enforce it, first nicely, later not so nicely. In Germany, where firing an employee is legally difficult and hence rare, repeated failure of an employee to follow safety protocol is not only a cause for terminating employment. Managers MUST terminate the employment for the safety of the employee. There have been cases where an employee repeatedly violated safety rules, and management did nothing. When the employee eventually got injured, management was on the hook and legally liable for not firing the employee. Like most processes in industry, the ultimate responsibility lies with management for setting up a system that works.

3.4 How to Identify Safety Risks

How do you identify safety risks? That is easy. They are often marked in red. Whenever a person bleeds or otherwise gets injured, then you have a safety risk. It is often said that safety rules are written in blood – since the rule was created after a person (or multiple people) got injured or died.

Since it is preferred to prevent an accident with foresight rather than preventing a reoccurrence in hindsight, learn from the mistakes of others. Most safety rules, regulations, and best practices were learned the hard way when someone got injured. Follow these rules to prevent injury in your plant.

Figure 23: US Airways Flight 1549 (Image Greg L under the CC-BY 2.0 license)

In some industries this is a major activity. If a plane crashes or even has only a near miss, the Federal Aviation Administration (FAA) and other similar bodies investigate thoroughly what exactly went wrong, and how to prevent it from happening again. (Movie tip: *Sully* with Tom Hanks covers the crash and investigation of US Airways flight 1549 in the Hudson River. However, the film very unfairly portrays the National Transportation Safety Board [NTSB] investigators as the bad guys, when in reality they were much more supportive and understanding).

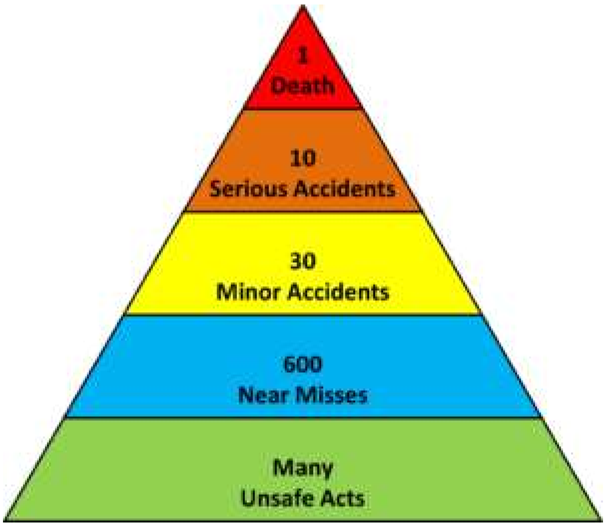

Figure 24: Accident Triangle (Image Roser)

Even better, accidents often don't happen by surprise, but have a sequence of dangerous situations, near misses, and minor events that precede them. This relation is often presented as an accident triangle, showing how many near misses or close calls lead to how many minor accidents, major accidents, and facilities. One example is shown here. Don't get too hung up on the numbers, as different studies have different numbers (it seems working in confined spaces will kill you quicker if something goes wrong, whereas the UK is generally better at preventing fatal accidents [or under-reports the non-fatal ones]).

But the idea is clear, lightning does not strike from a clear sky, but often has many close calls that precede it. The deadly firearm accident on the movie set with Alec Baldwin had two misfires (near misses) and one injured foot (minor accident) before eventually someone died. **There were literally three warning shots before the cinematographer died!** Don't make the same mistake. Act on near misses and minor incidents, or sooner or later one of you people will be dead.

Anyway, this was only the briefest of introductions on workplace safety, a – literally – life-or-death topic. Now, **go out, ponder where your plant had its last near miss, prevent it from killing someone next time, and organize your industry!**

4 How to Estimate Value Add for Manual Work – How to See Waste!

Christoph Roser, January 25, 2022 Original at https://www.allaboutlean.com/estimating-and-seeing-waste-in-manual-work-part-1/

Figure 25: Worker Value Add assembling example (Image Roser)

One of the necessary tasks in becoming leaner and improving your industry is to eliminate waste. I like to use a simple approach for measuring waste in manual work to know how good (or bad) the current situation is. To explain my approach I commissioned a few animations. Let me proudly present my approach and my animations, so you can also estimate the efficiency of manual lines when you are on the shop floor.

4.1 Introduction

You are all familiar with the lean concept of waste (muda) as part of the trinity of waste, overburden, and unevenness (muda, mura, muri). You probably know the seven types of waste (although some count eight types or more). Sometimes there is a distinction between avoidable waste (e.g., defects, which should be eliminated) and unavoidable waste (e.g., transport, which should be reduced, but it is hard to produce anything with zero transport).

Figure 26: Seven Trash Cans Labeled (Image Thomas Söllner with permission)

4.2 The Trickiness of Distinguishing Waste from Value Add

Waste is sometimes also contrasted with value add, which is anything that creates value for the customer. Either your people are creating value for the customer or they are not. This sounds simple in theory, but in reality it is sometimes hard to distinguish waste and value add. For example, if you build cars, you need to attach wheels to the cars. The value for the customer is that the car has wheels. Transporting the wheel around is of no value to the customer. Attaching it to the rest of the car is. But then, is the value in screwing in the screws, or merely in tightening them the last quarter turn. Would all those excess turns of the screw be a waste? Can you do it with even less screws? Or could you skip an entire tire?

Figure 27: Wheels with 3, 4, and 5 lug nuts (Image Bindydad123 under the CC-BY-SA 4.0 license, and (Image PXHere in public domain)

Figure 28: All waste? (Image ed_davad in public domain)

Even more extreme, if you are a retail or logistics company, you do add value for the customer by providing products to them. But in conventional lean wisdom, all transport and inventory is waste, but clearly the customer is paying for the service.

Overall, you have to think about what your company does that adds value to the customer. At the same time, do not think too hard about it, because then you would start questioning everything. While this is okay in principle, it also has to be practical. If your boss wants you to reduce waste related to attaching wheels to cars, you probably should not suggest flying cars or anti-gravity transportation…

It becomes even more difficult if you do not know the products or process very well – for example, if you are only a visitor to a plant. However, in this case I use a rough estimation to measure the efficiency in manual operations. Let me explain:

4.3 Observing Value Add and Waste

I use a simplification to decide if something is waste or value add, and then use a quick-and-dirty estimation to measure what percentage of the time a worker adds value. My simplifications for processes that I am unfamiliar with is that **whenever the worker touches the part, it is value add.** For example, if the worker adds components to the main part (e.g., during assembly) or removes stuff (e.g., during machining), it is probably (hopefully) value add. Nevertheless, use common sense. If the worker is touching the part but it is obvious that it is waste, then it is waste. Similarly, if the worker is not touching the main part, but nevertheless you believe this to be value add, then it is value add. But for most observations, this "touch-no touch" distinction is good enough for an estimate.

The images below show an example from my animation. In the background you will see a sign that tells you if it is value add or if it is waste, and which type of waste it is. In reality, of course, you do not have such a sign, but for training purposes it helps immensely.

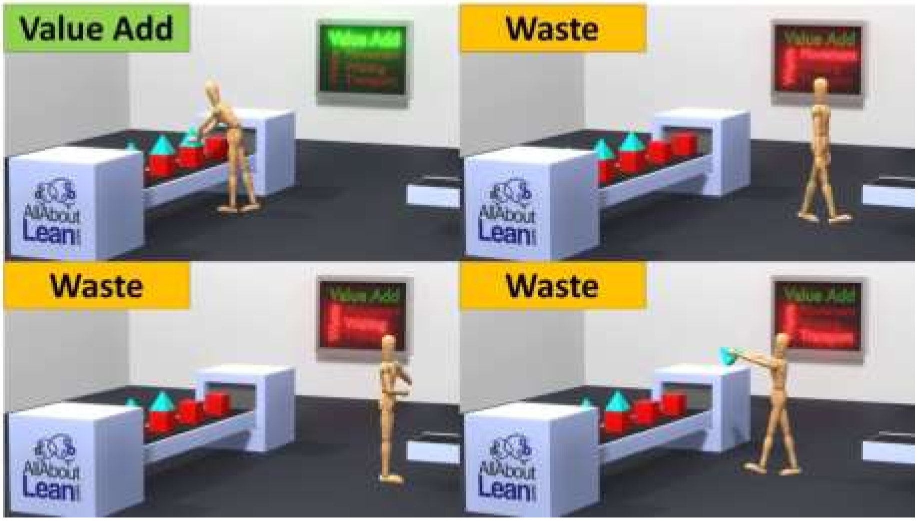

Figure 29: Worker Waste Value Add Overview (Image Roser)

Again, **this is a simplification!** It is easy to imagine situations where the worker touches the main part, but only to fix a problem or because a component does not fit well. Hence, this method is not perfect and tends to overestimate the value add slightly. On the other hand, you can use this approach even if you are unfamiliar with the process, or if you can observe it only from some distance. Both are common for visitors and tours. So now you can estimate when a worker is adding value and when not.

4.4 Measuring Value Add and Waste

This gives the next step: you can **count how often you see a worker adding value and how often not**. If I see a worker, I wait briefly to understand what he is doing before determining if it is value add or not. Usually, I use a three-second delay. In my head, I count to three, and on "three" I determine if the action at "three" is value add or waste. You can even count the same person repeatedly at different times. To do the actual measurement, I simply count instances of observing value add and instances of observing waste. This counting is a simple list of dashes as shown below.

Figure 30: Adding Value and Waste Counter (Image Roser)

This brings me to my animation below. This animation is admittedly quite wasteful, but in my next post I will have two more animations with improvements. Look at the animation loop and count to three. At "three," is the stick figure adding value or doing waste? The sign in the back helps you in this training animation, but of course in reality there would be no such sign. Hence, focus on the person, and after three seconds decide if it is value add or waste. Try to really focus on the timing at "three." If the worker just added value, but turned around at "three," then it is no longer adding value. If the worker walked a long distance, but at "three" just started touching the part, then it is adding value, even if he wasted a lot of time beforehand. Count every time you see a value add or a waste at this "three" spot in time.

Figure 31: Waste Value Add Animation Example 1 Wasteful (Image Roser), also available at https://youtu.be/lRIBU3xFIyI

Now you have a random sample of a few observations, always deciding if it is value add or waste. Of course, more is better. Using these numbers we now can calculate the percentage of the time a worker is adding value (number of observations of value adding divided by total number of observations) or waste (number of observations of waste divided by total number of observations – or simply the remainder to 100%). And, voila, you now know the percentage value add of the manual labor at this line or station.

If you do this measurement for the animation above, then you will get the percentage value add. I did the calculation for you, and it is a measly 17.4% value adding time, with the remaining 82.6% of the time being wasted (24.4% movement waste, 22.2% waiting waste, and 36.2% transport waste). Depending on how many measures you took, you should get numbers somewhere on this magnitude.


Figure 32: Hyundai moving walkable platform assembly line (Image Carol M. Highsmith in public domain)

These counts can easily be done on the fly during a plant visit, and it may take less than ten minutes to observe a line. If I do it in reality I may have a total of ten to forty observations. You can measure them for the entire plant overall, or separately for different lines or cells.

Keep in mind it is a rough estimate. However, I definitely prefer my own rough estimate over any "official" value add numbers I get, which are most likely "optimized" to look good. I don't believe 120% value add just like I don't believe 115% OEEs, and I have seen them a lot ☹. In my next post I will show you what values to expect, and also two more very similar but more efficient animations. Now, **go out, measure your efficiency, and organize your industry!**

5 What Percentage Value Add to Expect for Manual Work?

Christoph Roser, February 1, 2022 Original at [*https://www.allaboutlean.com/estimating-and-seeing-waste-in-manual-work-part-2/*](https://www.allaboutlean.com/estimating-and-seeing-waste-in-manual-work-part-2/)

Figure 33: Worker Value Add Reaching for Part (Image Roser)

In my last post I described a quick-and-dirty approach to estimate the percentage of value add (i.e., the efficiency) of manual work. While the value is only an estimate, it is a measurement that you can take quickly and easily even in passing for a manual workplace. You simply count when a person is adding value and when not (i.e., waste). This post will look into more detail on what numbers to expect, and what to do next if you want to increase this percentage of value adding time. Let's have a look:

5.1 What Values to Expect

Having measured the percentage of value add as per my last post, what percentage of the time do you want your employees to be adding value? This is simple. The true north of value adding is 100%. Unfortunately, you will never reach 100%, and it is a constant struggle to even stay somewhere near it (unless, of course, you fudge your numbers).

So what values can you expect? I did this analysis for plenty of automotive plants in Japan, including Toyota. The graph below shows an overview. You can see that the best plants approach 80%. In average, Nissan was the best-performing company with around 70% value adding time across two plants, although the Takaoka and Tsutsumi final assembly line easily outperformed it with 75–80% value add. (For more on these plants, see my [Grand Tour of Japanese Automotive.](#))

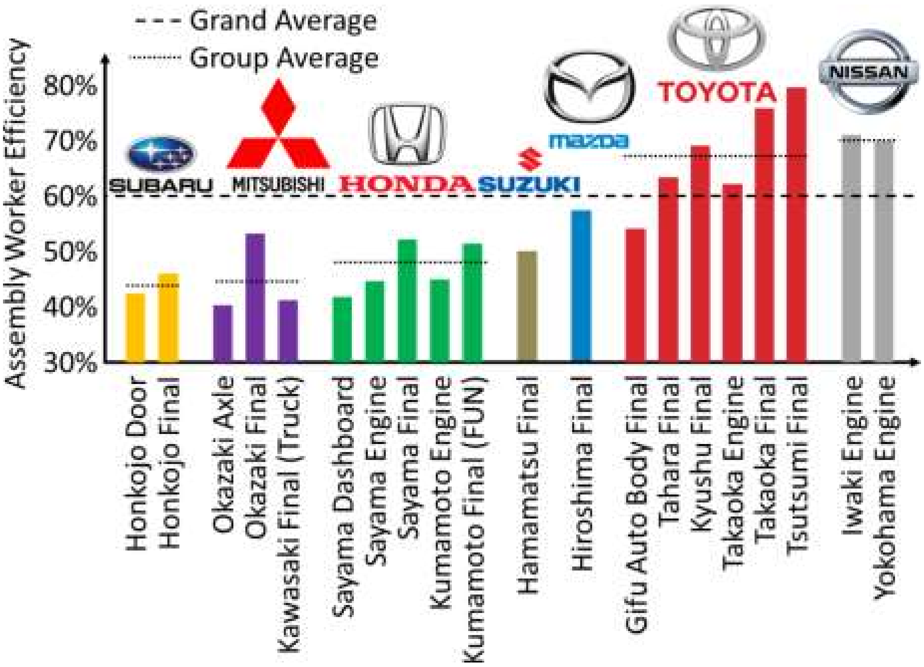

Figure 34: Japanese Automotive Efficiency Comparison (Image Roser)

Hence, the benchmark is probably a percentage of value add of around 80%. However, you cannot measure all plants on the same scale. A high percentage of value add is easiest when you have a highly repetitive task with short cycle times and very similar products. Automotive final assembly lines usually fall under that category.

Figure 35: Truck Assembly Line (Image zanskar with permission)

The graph above, however, also includes some other vehicle lines. The final assembly line at Mitsubishi Kawasaki has a value add of only 40%. However, this line does not produce passenger cars, but instead trucks. The cycle time is much higher, the product variety and the work content varies much more, there are more instances where multiple workers have to work together for heavy parts, and overall it would be much more difficult to reach the same percentage value add. My guess is that a top-of-the-line truck assembly line may have a 60% value add. Similarly, Honda Kumamoto is also not passenger cars, but motor bikes. Here, too, you find more variety, although the cycle time is comparable to passenger cars. Benchmark here would be for me around 70% value add.

The graph above shows not only final assembly lines, but also subassembly lines (e.g., engines, axles, doors, and dashboards). These have often similar complexity and cycle times as the final assembly line, but the percentage value add is usually much less than the corresponding final assembly line. The difference is not the product or the speed, but management attention. The closer the manufacturing is to the final product, the more focus the line will receive from management. Often, final assembly lines are much more optimized than subassembly lines … and to a degree this is justified since the final assembly line has (usually) a much larger impact on the bottom line than the subassembly line. If you could improve the efficiency of your final assembly line or your subassembly line by 10%, which one would it be? Often, it is the final assembly line. However, I would not adjust my expectations down juts because management decided to look elsewhere.

Figure 36: Production line at Trumpf (Image Trumpf with permission)

These examples here are still all highly standardized products with a fast takt time. At the other end, you will find extremely customized products with extremely slow takt times, as for example machine tools (takt time 8 hours) or shipbuilding (takt time in months). In this case, even an efficiency of 50% would be quite good. Or you surely have seen construction sites where many more workers are standing around or generally doing waste instead of actually adding value.

Figure 37: Sleeping Worker (Image FyeNaparat with permission)

Expecting from a machine tool maker the same 80% value add as from an automotive assembly line would be unfair to the machine tool builder. Even if they could optimize their production process to 80% value add, the optimization may cost much more than the benefit of the value adding time. The best-of-bench comparison depends heavily on the product type and the assembly line.

This leaves the question: **Which target is right for you? That is easy: If it is a problem, then the target is always better than what it is currently. If it is not a problem, then put your focus on the areas that are a problem.** (This also works for other targets, too. 😊)

5.2 Becoming More Efficient

Becoming more efficient means to increase your percentage of value add, which means to reduce waste. In my last post, I presented a short animation loop of an assembly process with plenty of waste, and only 17.4% value add. Here it is again:

Figure 38: Waste Value Add Animation Example 1 Wasteful (Image Roser), also available at https://youtu.be/lRIBU3xFIyI

Here is a very similar animation, but this time the waiting time is eliminated. Have a look at the animation, and see or even measure how much less waste there is. I also did the measurement, and this animation above has only 20.9% value add, with a whopping 79.1% waste (35.6% movement waste and 43.6 transport waste). Still, it is better than the animation in the last blog post.

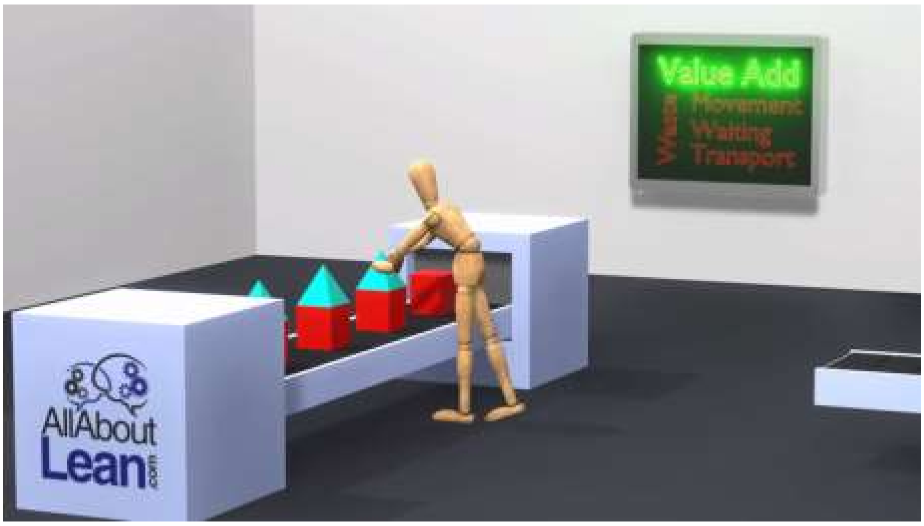

Figure 39: Waste Value Add Animation Example 2 No Waiting (Image Roser), also available at https://youtu.be/wOukCSP7i5Y

Finally, the last of three animations, where the waste is reduced even more. The parts are now much closer to the assembly line. The worker does not need to turn around or walk, but merely grabs the next roof from the subassembly line above. This reduces waste (of course assuming that you repeat the task often enough to justify the effort of installation of an overhead conveyor). You can count the value add in these animations yourself, and calculate the percentage of value add. Here, too, I did the measurement of the percentage value add. This animation is much better, with 44.8% value add. The remaining 55.2% of waste are 19.0% movement waste and 36.2% transport waste. If you measure it yourself, you should get similar numbers. Still, quite a bit away from Toyota with up to 80% value adding time.

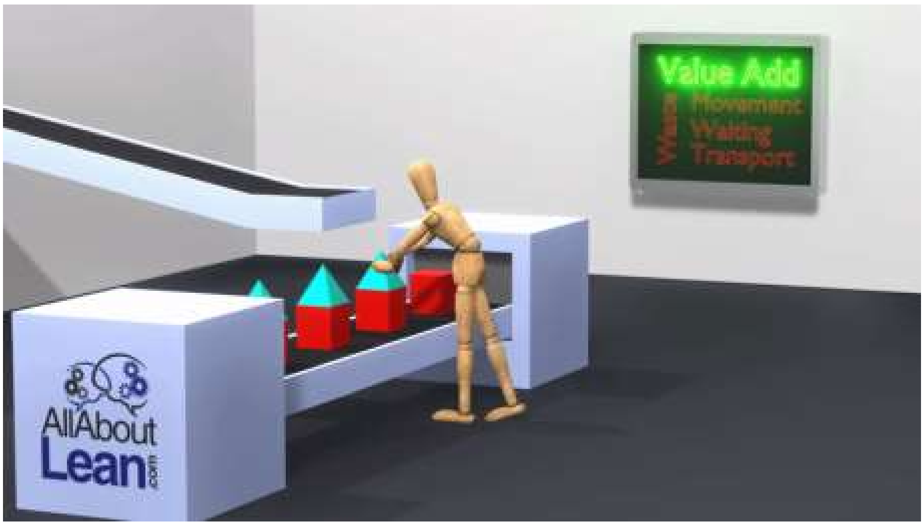

Figure 40: Waste Value Add Animation Example 3 Efficient (Image Roser), also available at https://youtu.be/Q3xZ-XjzSR8

Overall, it is quite possible to measure and understand waste and value add quickly for manual work in manufacturing. This is the first step in improving your system and becoming more efficient. I hope this approach helps you in also understanding and improving your own production. Now, **go out, understand the waste, reduce it, and organize your industry!**

6 AI in Manufacturing: Hype or Helpful?

Christoph Roser, February 8, 2022 Original at https://www.allaboutlean.com/ai-in-manufacturing/

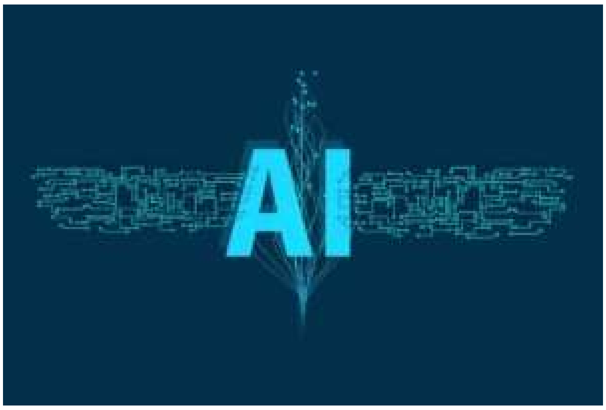

Figure 41: Artificial Intelligence (Image Gerd Altmann in public domain)

There is a big hype on anything related to computers in manufacturing. I have written quite a few cautionary articles on the Industry 4.0 bandwagon. This post looks more in-depth into artificial intelligence (AI). I believe there are possible applications of AI in manufacturing, but at the moment these are still uncommon. In this post I would like to talk a bit about the hype, but also present a few examples of where it actually works. Let me show you:

6.1 Introduction

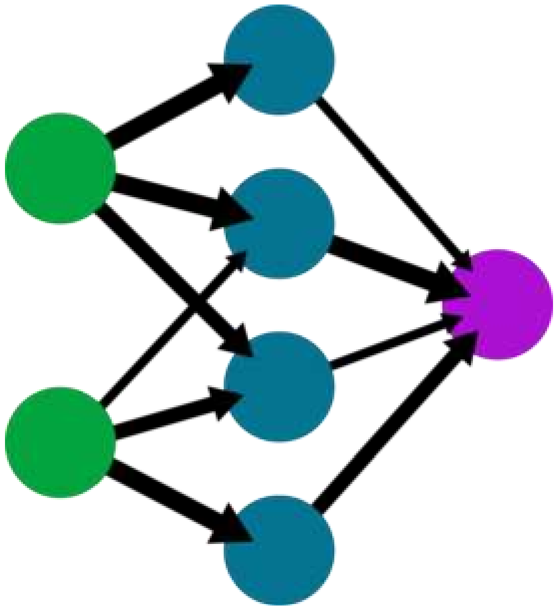

Figure 42: Neural networks are common tools in AI (Image Wiso in public domain)

Artificial intelligence is intelligence from machines, as opposed to humans or animals. This definition, unfortunately, has some gray zones. Do you need intelligence to calculate the square root of 15 129? Certainly! But a computer can do it much faster, and will give you the result (123) before you even read the second digit in this number. However, this does not mean that the computer is intelligent. Instead, another human has programmed the logic on how to calculate square roots, and the computer merely follows this logic. This is not commonly considered artificial intelligence. For another example, take chess computers. Any decent program nowadays can beat most human players. However, (with a few exceptions) most chess computers simply use raw computing power to analyze millions of possible future chess moves, then pick the most promising one. While some consider this already AI, for me it is still merely good calculation.

Figure 43: Can it learn? (Image Russell Lee in public domain)

I personally consider artificial intelligence a computer system that is able to learn. For an AI, it is not a human that provides the rules, but the system generates its own rules based on the data provided. However, I am also fully aware that plenty of AI researchers would disagree with this definition. But then, it seems plenty of AI researchers disagree quite a bit with each other when defining their field, and there are numerous conflicting definitions out there by people who know much more about AI than I do (for more definitions, check Wikipedia).

6.2 How Big Is the Hype?

Figure 44: Blah Blah Blah (Image studiostoks with permission)

Artificial intelligence is definitely a hot topic. There are over 3 million academic papers on Google Scholar mentioning artificial intelligence, including 200 000 review articles. Slightly over 1 million academic articles are on manufacturing alone, of which 22 000 are summary reviews. It is definitely a hot topic (with few exceptions described below). The media picked the topic up even more, and Google News returns over 100 million news articles on artificial intelligence. I am certain you also come across AI-related news regularly. But for all its hype, I have not yet seen much AI in manufacturing or logistics.

China is trying to become a major player in the topic of AI, and they also publish a significant number of papers. Their privacy laws (or lack thereof) provide them with plenty of data to train their neural networks and other algorithms. In 2021 alone they published over 500 articles on AI in manufacturing. However, despite all the publishing, few of these articles have any practical application; they are merely theoretical and abstract research far removed from the reality on the shop floor. Besides, most papers are very fuzzy on the details of the data they use, and to other researchers it feels more like an unknown and unverifiable black box. Overall, there are still very few real-world applications of AI on the shop floor that are not merely demonstrations or just for show.

Figure 45: Sneaky AI Consultant (Image bramgino with permission)

Consultants and other service providers are always in the search of a hot new buzz word to distinguish themselves from the competition (e.g., "Industry 4.0"), and AI is no exception. Quite a few consultancies are pushing AI as a sales argument, yet the actual work is still done using conventional math done by analysts. In many cases, AI is merely a sales argument. Plenty of AI in the presentations, but little in the actual implementation. It feels like a common mistake also found in lean: the client starts with a solution (artificial intelligence here or kanban in lean) and is looking for a problem to solve. Please, always start with a problem, and don't limit yourself to selected solutions, as you may miss out a better solution that is merely not on your radar from the beginning.

6.3 Artificial Intelligence Is Tough

Figure 46: Businessman in a Maze (Image ra2studio with permission)

Artificial intelligence is not easy. Highly complex problems are often tough to do. Take for example the self-driving car. Billions were spent on research, and yet there are no fully autonomous cars available yet for the mass market. And, in my view, navigating the production plan on a shop floor is probably just as complex as navigating a land vehicle. Similarly, there are also high expectations on reliability and performance. A self-driving car that does not crash 95% of the time is not good enough, as is a production system that produces the right stuff 95% of the time. In my view, artificial intelligence is still limited to specific nice applications, although this niche is getting bigger.

6.4 Where Can Artificial Intelligence Already Help? Implementation Examples

A lot of artificial intelligence seems to be for now a hype, or at least merely promises of something in the future. However, there are existing and successful applications of artificial intelligence in manufacturing. These do what AI's (in my view) often do best: they look at large amounts of data and try to make sense of it. In a sense, AI is good with big data, where the normal methods often fail. Let me show you a few successful applications of AI in manufacturing that I have come across.

Figure 47: Amazon bin Image (Image Amazon with permission)

One of these is optical recognition. Optical character recognition is common nowadays, and you may already have software on the computer or mobile you're reading this article on. (It is so common that some researchers no longer consider this to be artificial intelligence). But there is plenty more optical recognition needed in industry. For example, Amazon uses AI to identify the number and type of items in a shelf segment (a *bin*) of their movable storage shelves (the *pods*). The image on the left is such a image for the AI to analyze. The AI needs to compare the image with the items that are supposed to be in there, including their quantity, and flag any discrepancy. (More on my blog post The Inner Workings of Amazon Fulfillment Centers – Part 5.)

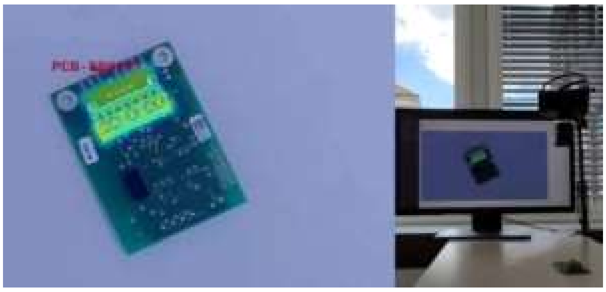

Figure 48: Heatmap example (Image Julian Senoner with permission)

Another example is finding defects on electronic circuit boards and similar applications. Julian Senoner and his team at EthonAI are using artificial intelligence for more than just detection of whether a printed circuit board is (most likely) correct. If the product is faulty, the AI also generates a heat map to indicate for the user which part of the printed circuit board is flawed.

Recognizing patterns does not need to be limited to optical recognition. The Atlantis Foundries in South Africa previously used conventional optimization to reduce their defect rates. Through hard work they got their defect rates down from 15% to 6%. However, this was still not good enough. They used the help of an AI consultancy, which analyzed a whopping 185 process variables using plenty of historic production data using artificial intelligence. First the AI learned how to predict quality. Based on this the AI made recommendation on what settings to use to improve quality. The defect rates went down below 2%, and even had an unheard-of zero defects for three months in a row. (Many thanks to Anton Grütter from the Lean Institute Africa for telling me about this in the first place).

Overall, artificial intelligence seems to be useful if you have plenty of data on lots of repetitions (i.e., many variables measured for many products made) that AI can learn from, and where 100% accuracy is not essential (AI make mistakes too). Often these are narrow problems like selected quality issues, but unsuitable for wide or highly complex problems (what product should I make when). (The keywords here are *weak AI* versus *strong AI.*) Also, don't expect AI to tell you why it made that decision, as most neural nets do not give you that information (the keyword is *explainability*). In any case, don't just throw AI at any problem you have, and magically expect a solution. Start with the problem! If you have more examples of artificial intelligence actually being used in manufacturing, please do let me know in the comments below. Now, **go out, use your intelligence (artificial or otherwise) and organize your industry!**

6.5 Selected Sources:

- The Economist: Can China create a world-beating AI industry?, January 22, 2022
- Julian Senoner, Torbjørn Netland, Stefan Feuerriegel, Using Explainable Artificial Intelligence to Improve Process Quality: Evidence from Semiconductor Manufacturing, Management Science, December 09 2021 (not the example in the blog post above, but similar)
- Foundry of the Week: Atlantis Foundries, Foundry Planet
- Industry 4.0 or Lean 4.0?, Interview with Anton Grütter on the Atlantis Foundries

7 A Few More Turns on the Changeover Wheel – Part 1: Creating a Sequence

Christoph Roser, February 15, 2022 Original at https://www.allaboutlean.com/changeover-wheel-1/

Figure 49: Girl with Ice Cream (Image Andrey_Kuzmin with permission)

The changeover wheel is a visualization of a good changeover sequence. In this series of posts I will go deeper on how to use such a changeover sequence in planning your production sequence. The concept itself is simple, but there are still some pitfalls in using it. This first post looks deeper at generating a first sequence. My next post will then optimize the sequence, where we will also learn why you probably should not shoot for the perfect solution, but merely for good enough.

7.1 Introduction

Figure 50: Older Couple Eating Ice Cream (Image manpeppe with permission)

I have written about changeover sequencing and its prioritization before. In this post I will go into more detail on the changeover wheel, an illustration of the changeover sequence. In my previous posts I used the example of ice cream (since I like ice cream), hence let's continue with the ice cream example, but this time let's make it a bit more complex. Let's assume you have a machine that can make different types of ice cream. There are three different variables that can be influenced:

- The **waffle**: Is it a cone, a cup, or a sandwich?
- The **flavor**: Vanilla, raspberry, or chocolate
- The **size**: Small, medium, or large

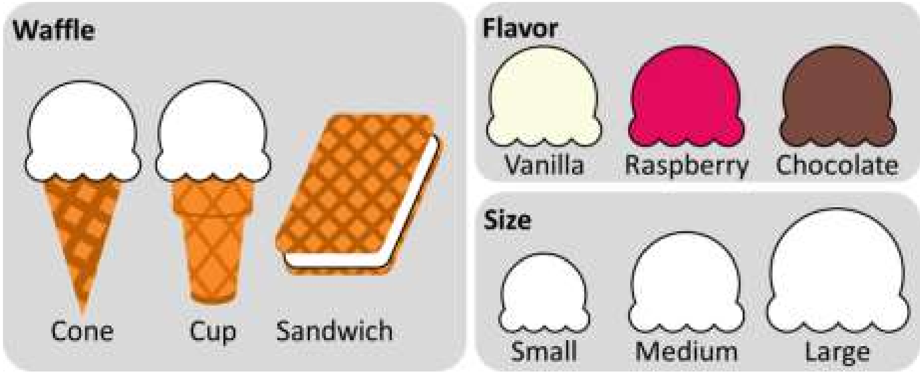

Figure 51: Ice cream variables (Image Roser)

This gives us, for this example, a total of 3x3x3=27 different products, assuming all combinations are actually produced. In industry, you often find similar systems with multiple variables that influence your product. The product could even have more variables. It could require two different tools to change, using different diameters of wire, or using different glues or different components. I'll stick with the ice cream example here since it provides a very nice visual.

7.2 How to Create the Sequence

Now you have to think about the sequence. You should include all products that you may produce on this system. The goal is to have **a sequence with the least total changeover time** that includes all products. Usually, we measure the time since it is easiest, but what we really want is the cost. In some cases, looking at cost may lead to different sequences than if you look only at time. For example, changing the flavor takes less time, but it does waste some ice cream that is washed down the drain. Is this wasted ice cream more relevant than the longer time for the waffle changeover? It could be. In our example, it is not (merely to keep the example simple). But your changeover may not be as simple as this ice cream example here.


Figure 52: Sequence of Nuts (Image Roser)

Now you could take all products and arrange them in a sequence. However, this is cumbersome, especially if you have many different product variants. I find it easier to go by variables. Take the most cumbersome type of changeovers, and arrange them in a sequence. In our example, the most cumbersome change is the change of the waffle type. You would have to remove a mechanical tool from the machine, add the new tool into the machine, adjust all the settings, bring the tool to the right operating temperature, and you are ready to go. Hence, we first sort our product groups by the waffle type.

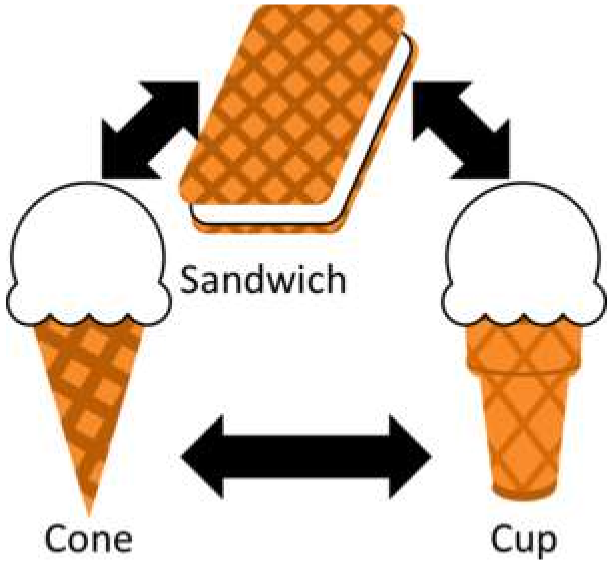

Figure 53: Ice Cream Waffle Sequence (Image Roser)

The sequence of the waffles in our example does not really matter. Changing from a cone to a cup and vice versa is very similar. Changing from a cone or cup to a sandwich or vice versa requires more time. But since we have only three waffles, the sandwich is always preceded or followed by a cone or cup, and hence the sequence does not really matter. If we would have two different sizes of sandwiches, however, we should keep the sandwiches together. Again, the goal is to have a (in our case, waffle) changeover sequence with the least total changeover time.

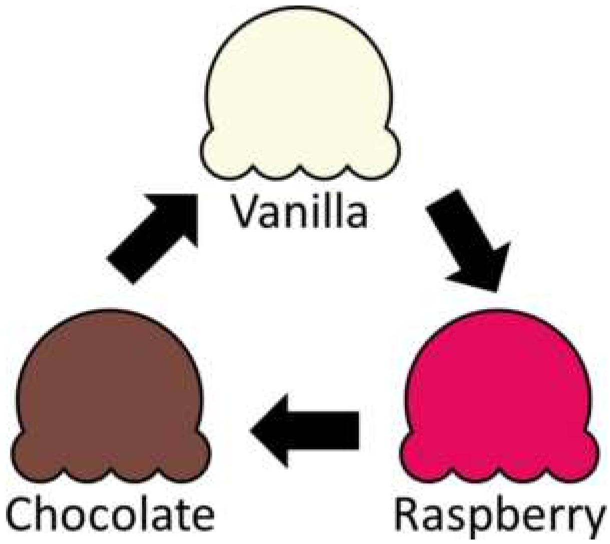

Figure 54: Ice Cream flavor Sequence (Image Roser)

The second most complex variable in our example is the flavor. Changing the flavor requires exchanging the tanks with the ice cream and also requires cleaning of the machine. Here the sequence matters quite a bit. In many changeovers involving color, the change is from light to dark. A speck of vanilla ice cream won't be noticeable in chocolate ice cream, but a speck of chocolate ice cream will stick out quite a bit in vanilla ice cream. Hence, going from light to dark often requires less cleaning effort. Therefore, we would like to always change the flavors from vanilla to raspberry to chocolate. After chocolate we have vanilla again, although this changeover requires more cleaning effort.

Finally, there is the size of the ice cream. In our example, this is the easiest variable to adjust. We merely change a setting in the program on how much we have to extrude. The changeover time is not quite but close to zero, and it is our least important variable. It also does not matter if we change from small to medium to large or any other sequence, as it will make no difference whatsoever.

The entire changeover wheel could look like something below. It starts with a small vanilla cup (at the top), followed by medium and large vanilla cups before changing to raspberry, etc.

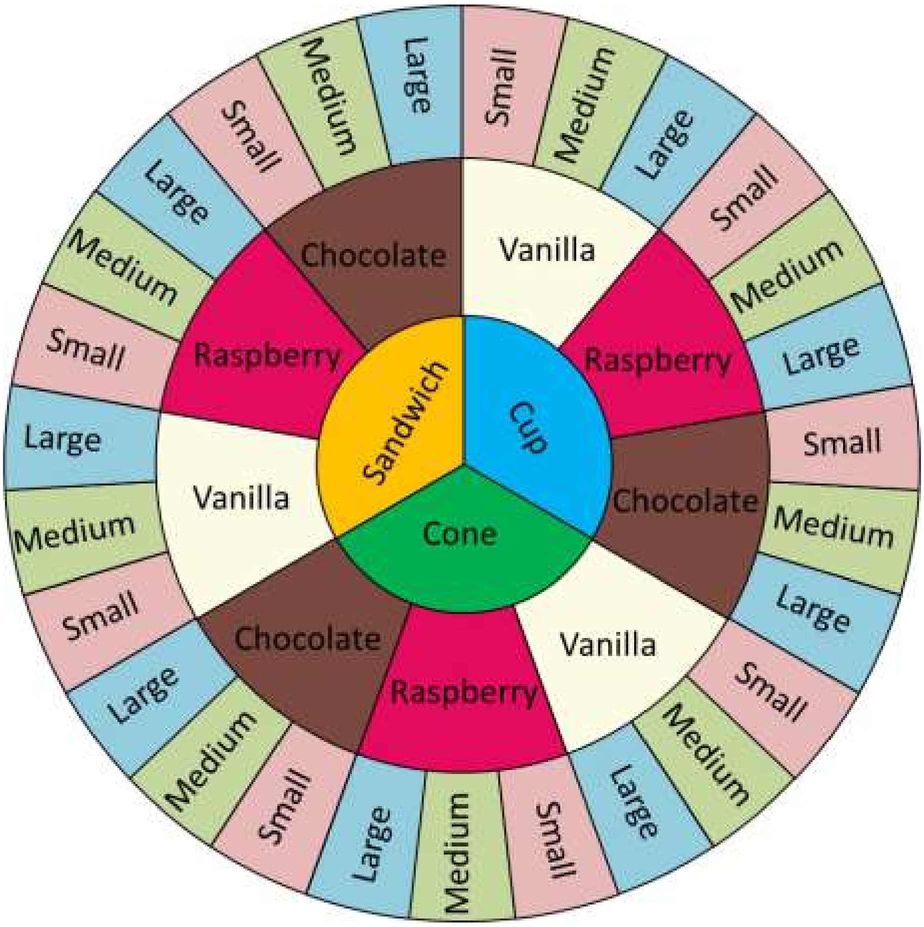

Figure 55: Three Variable Ice Cream Changeover Wheel (Image Roser)

Overall, we sort our variables by their changeover duration, and start with the biggest factor first (in our example, the waffles). Within this biggest factor (waffles), we then sequence the next biggest factor (in our case, flavors). We go through all variables, until we get to the variable that have actually a changeover duration of zero (in our example, the size is close, albeit not quite zero). Within the sequencing for each variable, there are also different situations. The sequence could matter (like the flavors in our example from light to dark), or does not matter (like the size in our example). This will give you a changeover sequence (or a changeover wheel), but – attention! – this is only the first step. In my next post I will show you how to optimize the sequence. Even if the changeover wheel above looks very neat, there is still a lot more potential for improvement! Now, **go out, create a changeover sequence, and organize your industry!**

PS: This blog post was inspired by a master thesis by my student Milena Oberle: "*Entwicklung eines Steuerungskonzepts zur Stabilisierung volatiler Auftragsfolgen einer variantenreichen Mischfertigung unter Berücksichtigung der zukunftsweisenden Erfolgsfaktoren einer Smart Factory*", Hochschule Karlsruhe, 2022.

8 A Few More Turns on the Changeover Wheel – Part 2: Improving the Sequence

Christoph Roser, February 22, 2022 Original at https://www.allaboutlean.com/changeover-wheel-2/

Figure 56: Bearded Man eating Ice Cream (Image photosvit with permission)

In my last post I looked at how to create a changeover sequence. However, this was only the first draft of such a sequence. For a truly good sequence, you need to spend some more time optimizing the sequence. Try to get a better sequence, even though it is impossible to find the perfect solution even for a moderate number of products. I also give a suggestion on how to visualize a changeover wheel in Excel.

8.1 Introduction

Figure 57: Ice cream variables (Image Roser)

Just a brief recap, in my last post I created a changeover sequence for an ice cream machine, where you could change the waffle (cone, cup, sandwich), the flavor (vanilla, raspberry, chocolate), and the size (small, medium, large), for a total of 27 products. I sequenced the products starting with the most cumbersome part of the changeover (the waffle), followed by the flavor (light to dark), and finally the easy-peasy change of the size.

8.2 Optimize the Changeover Sequence

Figure 58: Mom and daughter eating ice cream (Image oksix with permission)

Sequencing one variable after another sounds straightforward, but the devil is in the details. In reality there are often more complications. What if the slowest changeover in the second largest variable takes longer than the fastest in the largest variable? What if, in our example, changing from chocolate to vanilla takes longer than changing from a cone to a cup? What if a smaller variable influences the time it takes for a longer variable to change?

Also important: If you change two variables at once (e.g., changing both the waffle and the flavor), is this in parallel or consecutively? In other words, is the changeover duration the sum of the two individual changeovers, or is it the longest of the two individual changeovers? Do you change the flavor while also changing the waffles, or do you first change the waffle and then the flavor?

Even if one variable change is independent from another variable change, there is probably still quite a bit of potential to improve. Below on the left is the basic, non-optimized changeover wheel from my last post. Now compare it with the changeover wheel on the right. It still has all the 27 product types, it still has all the same sequences for each variable, but it has much fewer changeovers. For example, in the first wheel above we changed flavors a total of nine times. In the wheel below, we have only six changeovers for the flavor. The number of changeovers has been reduced by one-third, saving time, effort, and wasted ice cream for cleaning during changeover!

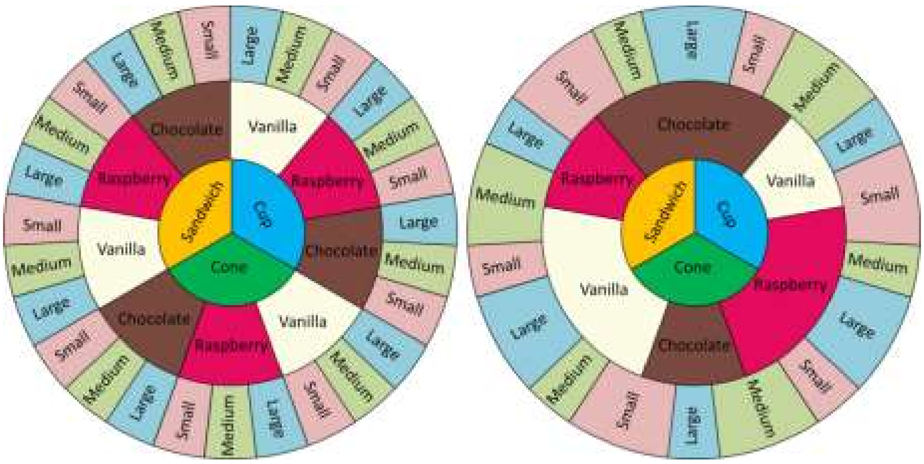

Figure 59: Three Variable Ice Cream Changeover Wheel Original and Refined (Image Roser)

Similarly for the size of the ice cream. In the first wheel, we changed the ice cream size a total of 27 times. In the second, optimized changeover wheel, we changed the size only 18 times. While the size of the product was our least significant variable, it does save some time. This could get even more complicated if one variable affects the effort for another variable. For example, what if changing the waffle type would take longer if it is a large ice cream portion?

Again, your goal is to **get the sequence that takes the least time for the changeover effort**. To be more precise, it should take the least cost for the changeover effort, including not only time but also energy, people involved, wasted material, and any other cost that goes into the changeover effort. There is an optimal solution out there. If you have some variables where the sequence does not matter or where the changeover time is zero, then you probably have multiple optimal solutions. The challenge is finding it.

Figure 60: Sequence of Nuts (Image Roser)

The first challenge is to have all the data… which you probably don't. For optimizing the changeover sequence, you are probably relying on the gut feeling of the people who do this (and please, **DO involve the people that do the changeover into the sequencing of the changeover!**). This is, for most companies, probably the most sensible approach. You may not get the optimal solution, but hopefully you get something close with a reasonable effort.

Even if you have all the data, it is not easy to find the optimal solution. The number of possible sequences (in mathematical language: the permutations) depends on the number of products you have. For n products, the number of sequences is n!, where the "!" is not an exclamation mark but a mathematical operator for factorial. For example 3! = 1*2*3 = 6. And this number of permutations goes up at an eye watering speed! For 5 product variants, it is still a manageable 120 possible sequences. But for our example with 27 different product types, we could make 27! = 10 888 869 450 418 400 000 000 000 000 combinations. Even a computer that could test one million sequences per second would still take magnitudes longer than the existence of the universe to check them all. And that is for sequencing a measly 27 products.

Figure 61: NASA Galaxy (Image NASA in Public Domain)

If you have 100 different product types (which is by no means rare), you have 100! = 93 326 215 443 944 200 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 possible changeover sequence combinations. For a measly 172 products, my Excel can no longer even calculate the number of possible sequences. The point I am getting at: You cannot do an exhaustive comparison of all sequencing combinations. No matter if you are human(s) or a computer, **you have to take shortcuts to determine the sequence**. **Don't aim for perfection, but for something good enough.** If you find the perfect solution long after our sun has burned out and the universe has ended, then your changeover sequence is no longer necessary.

8.3 A Note on Visualizing the Changeover Wheel

Creating the changeover wheel is not easy. Visualizing it is not easy, either. Creating multiple overlapping circular graphs is a bit tricky in Excel. There is one chart option called "sunburst," which looks like it is perfectly suited to create changeover wheels. The sunburst below is a display of a calendar year including quarters, months, weeks, and days.

Unfortunately, by default the Excel sunburst sorts the entries by size, where the largest entries come first and shorter ones afterward. The sunburst below starts in December, followed by October (more days than November). The shortest month February ends the year. In short, the sequence is completely messed up, and I have not found any way to stop Excel from automatically doing this. (Damn you, Microsoft. So tantalizing close to the perfect solution, and yet utterly useless for my purposes…)

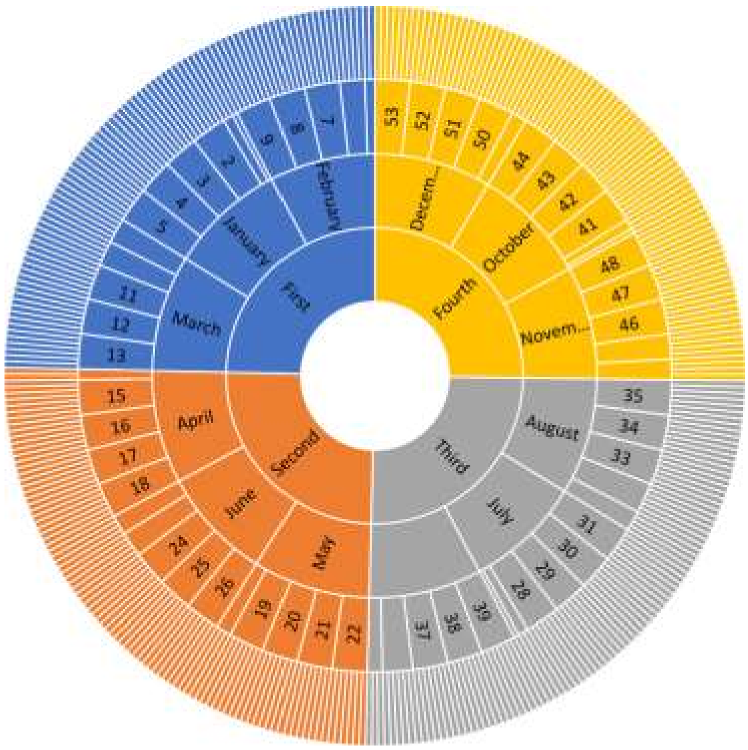

Figure 62: Excel Sunburst Calendar Year (Image Roser)

To my knowledge, the best way to create a changeover wheel in Excel is to use a doughnut or pie chart, with multiple such charts on top of each other to represent the different variables. It is a bit of work, but doable. There are also custom solutions out there, but I did not look into those.

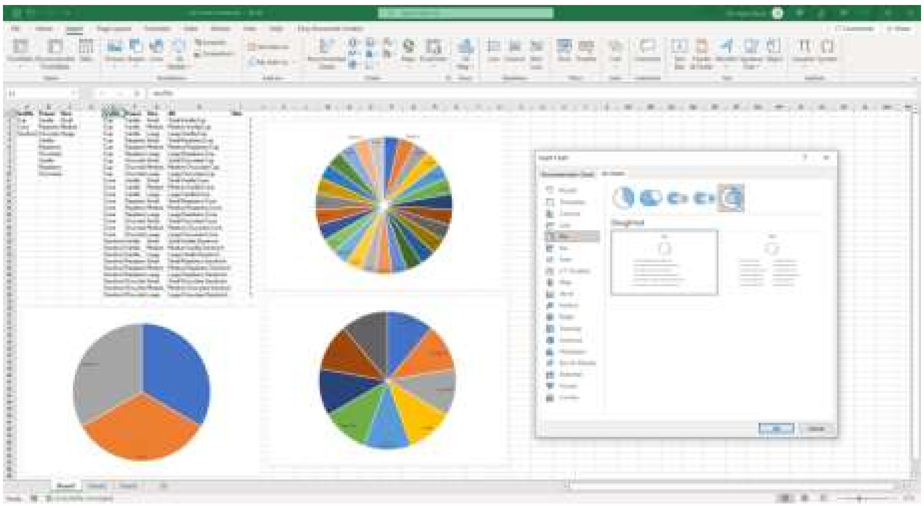

Figure 63: Excel Screenshot Doughnut Chart (Image Roser)

In any case, don't get stuck on the wheel. A simple excel table is also perfectly adequate, as long as you remember to start at the top again when you get to the bottom. In this series of posts I simply use a wheel because it is a better visualization. In my next post, I will show you how to properly use a changeover wheel, as there are some pitfalls too. Now, **go out, optimize your changeover sequence (but don't take eons to do so), and organize your industry!**

PS: This blog post was inspired by a master thesis by my student Milena Oberle: "*Entwicklung eines Steuerungskonzepts zur Stabilisierung volatiler Auftragsfolgen einer variantenreichen Mischfertigung unter Berücksichtigung der zukunftsweisenden Erfolgsfaktoren einer Smart Factory*", Hochschule Karlsruhe, 2022.

9 A Few More Turns on the Changeover Wheel – Part 3: Prioritizing Jobs

Christoph Roser, March 1, 2022 Original at https://www.allaboutlean.com/changeover-wheel-3/

Figure 64: Ice cream truck (Image Rixie with permission)

In my last posts I talked on how to set up a changeover wheel or, more generally, a changeover sequence. Next I will show you how to use a changeover wheel. You have to fit you prioritized production into the sequence. The idea is simple, but there are some pitfalls as well as some tricks to make it easier. I will talk more about the pitfalls in my next post. Let's have a look on how to fill the changeover wheel with actual production jobs.

9.1 A Brief Recap

We will continue the example from the previous posts of an ice cream maker with three types of waffles, three flavors, and three sizes. This gives us a total of 27 different products, which we fit into a changeover wheel. The following explanations will use this changeover wheel for the examples too.

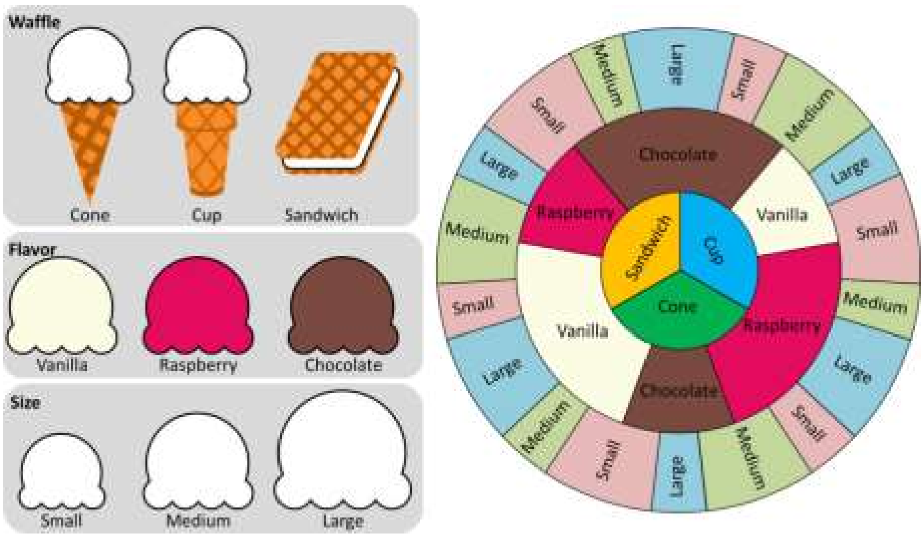

Figure 65: Changeover Wheel Overview (Image Roser)

9.2 Set Capacity of the Wheel

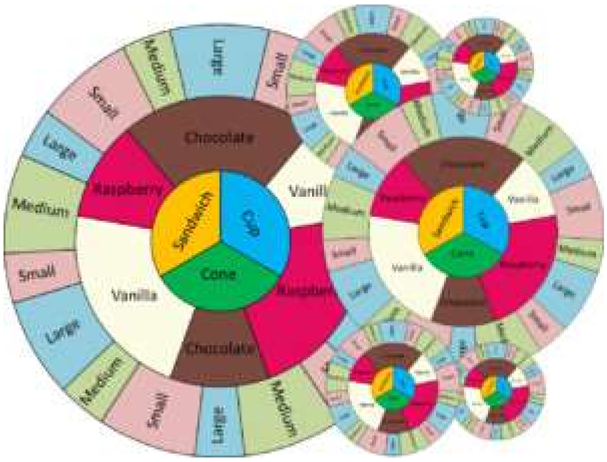

Figure 66: Changeover Wheel Different Sizes (Image Roser)

The first step is to define the capacity of the wheel, or – more precisely – how many hours should the wheel cover. This is directly related to reducing fluctuations. The more frequently you "turn the wheel," the less time until you produce a product again, and the smaller the fluctuation.

Let's start with a negative example. Assume you have defined the changeover sequence. You could now just stuff every possible demand or order into the wheel, and start producing. However, this would create a lot of headache later on. If your demand fluctuates over time, sometimes it will take a lot of time to turn the wheel (if customers order a lot), and sometimes you turn it quickly (if customers order little). If you have demand for 100 tons of ice cream during the summer, it will take a long time until the wheel is turned and you can produce a product again. You need large inventories to buffer these large fluctuations in the production (make a lot of one product, and then nothing of this for a long time).

Figure 67: Lots Of Ice Cream (Image feel_berry with permission)

If you have been reading this blog for some time, you probably know that smaller batches more frequently are generally advised in lean manufacturing to reduce fluctuations and become more efficient. This is one part of the problem if you just stuff everything into the wheel. The bigger problem, however, is that the fluctuations themselves are fluctuating. In summer you need a lot of time to turn the ice cream changeover wheel, and in winter it goes much quicker. Yet, you need to be prepared for the worst, so even when the demand is low and the wheel turns quickly, you still need inventory to decouple larger turns. (This example here is not ideal, because the seasonality of the ice cream is well understood and the system can change seasonally.) But the main point stands: **Do not put all demand into a single turn of the wheel!** Instead, define the wheel to be a certain size, and put in only the most important demand until you reach this goal and then turn the changeover wheel.

Figure 68: Large Ice Cream Cone (Image Zoran Photographer with permission)

So, how many hours' worth of production should your wheel have before you turn it again? A smaller size (a quicker turn) creates less fluctuations and allows you to reduce buffer inventory. A larger size (a slower turn) requires less effort for changeover since you produce more per changeover. These two factors decide how big a changeover wheel should be (i.e., how many hours of production should go in before you turn the wheel again). This question is closely related to the question of a good batch size for changeover. Be aware that sometimes shop floor people go overboard with large wheels to reduce the changeover effort. Conventional lean wisdom, however, goes for the smaller wheel. This would also be my recommendation. Make the wheel as small as you can get away with. It could be a week worth of production, or a day, or a shift, or just a few hours, before you turn the wheel again.

Figure 69: Mini Ice Cream Cone (Image ProjectManhattan under the CC-BY-SA 3.0 license)

Please note that there is not really a lower limit of the wheel size. You can easily make wheels smaller than what you need to produce each product only once. You simply do not produce all products in a single turn. Also, ideally the size of the wheel is defined as a production duration (including changeovers). However, if your batches are somewhat similar, you could also define the size of the wheel as a number of batches. There may be slightly more fluctuations if the baches need different time, but it is so much easier to simply count batches instead of determining the time needed for each batch. Your choice.

9.3 Fill by Priority

Figure 70: Different ice cream (Image elenathewise with permission)

Now you simply take the possible orders for production and sort them by priority. The most urgent job goes in the wheel first. But here, too, are some pitfalls. If your most urgent job is a batch of *medium vanilla cones*, you place this one first. But if you have additional open jobs for batches of the same *medium vanilla cones*, you should not also place them just because they are the same type as the most urgent job. These additional jobs should wait until it is their turn, even if it is the same product.

This is also shown in the example below. We have eleven possible batches that could be produced, which were sorted by priority. The most urgent batch is a *medium vanilla cone*. So we place this one first on the wheel. We have the same *medium vanilla cone* in the list twice more (Indicated with an ice cream cone in the list for your convenience). However, we do not simply place them all merely because it fits the changeover sequence. It also has to fit the priority! If you place these additional two batches right away, you may delay a more urgent batch, leading to a stock out.

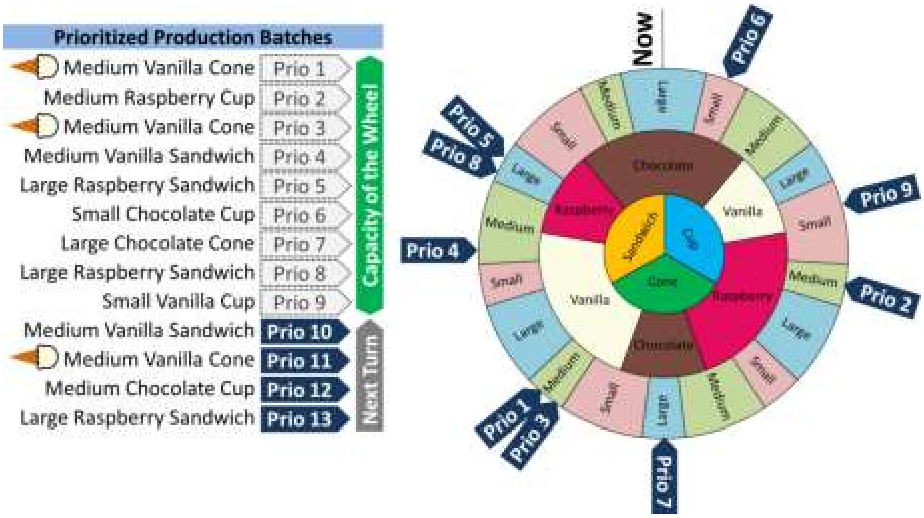

Figure 71: Changeover Wheel Prioritized with Jobs and Icon (Image Roser)

As it happens, the third most urgent batch is again the *medium vanilla cone*, so it gets placed on the wheel too. After placing the nine most urgent jobs, we have filled the capacity of the wheel. The last instance of the *medium vanilla cone*, however, is only prioritized on position 11, and hence has to wait for the next turn of the wheel. Same applies to the large raspberry sandwich, which made it on priority positions 5 and 8, but priority 13 has to wait for the next turn.

So this is the basics on how to fill the changeover wheel with production jobs. There are a few possible modifications and options, more on these in my next post. Now, **go out, sequence your production, and organize your industry!**

PS: This blog post was inspired by a master thesis by my student Milena Oberle: "*Entwicklung eines Steuerungskonzepts zur Stabilisierung volatiler Auftragsfolgen einer variantenreichen Mischfertigung unter Berücksichtigung der zukunftsweisenden Erfolgsfaktoren einer Smart Factory,*" Hochschule Karlsruhe, 2022.

10 A Few More Turns on the Changeover Wheel – Part 4: Options for Prioritizing

Christoph Roser, March 8, 2022 Original at https://www.allaboutlean.com/changeover-wheel-4/

Figure 72: Ice Cream Factory (Image Zyabich with permission)

In my last post of this series on the changeover wheel and changeover sequencing, I showed you the basics on how to use a changeover wheel or changeover sequence. In this post I will look at a few options and modifications that are sometimes used too.

10.1 A Brief Recap

We will continue the example from the previous posts of an ice cream maker with three types of waffles, three flavors, and three sizes. This gives us a total of 27 different products. We created a changeover sequence (the changeover wheel) and added production jobs in sequence of priority.

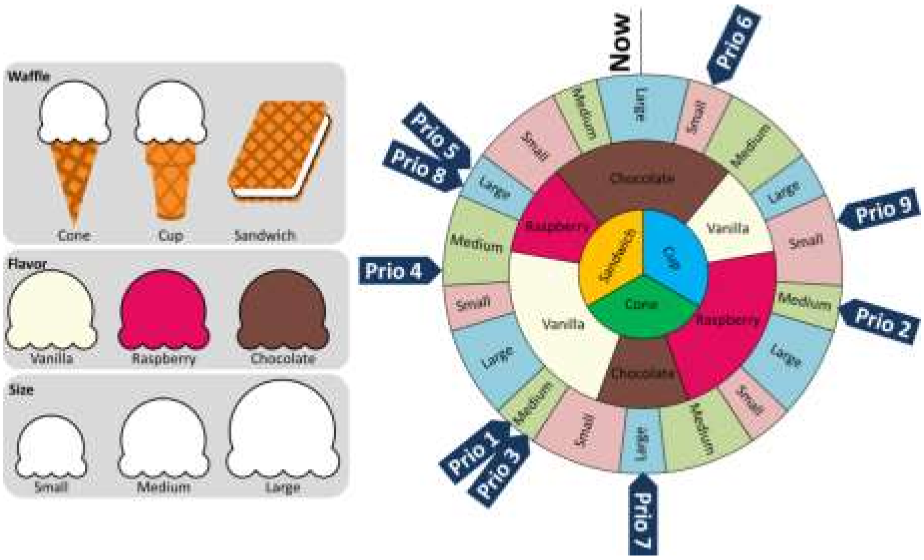

Figure 73: Changeover Wheel Product Types and Sequence (Image Roser)

10.2 Option: Adjust to Reduce Changeover Time

My recommended way is to fill the changeover wheel simply by priority of the jobs. However, there is also a modification possible. Out of all your possible and prioritized jobs, there are some that you must do during the next turn of the changeover wheel. These are necessary, and if you don't do them you may run out of ice cream… and nobody wants that! However, there are other possible jobs that are less urgent, and you either could do them this turn or wait for the next turn. In the graph below I have labeled them "necessary" and "optional."

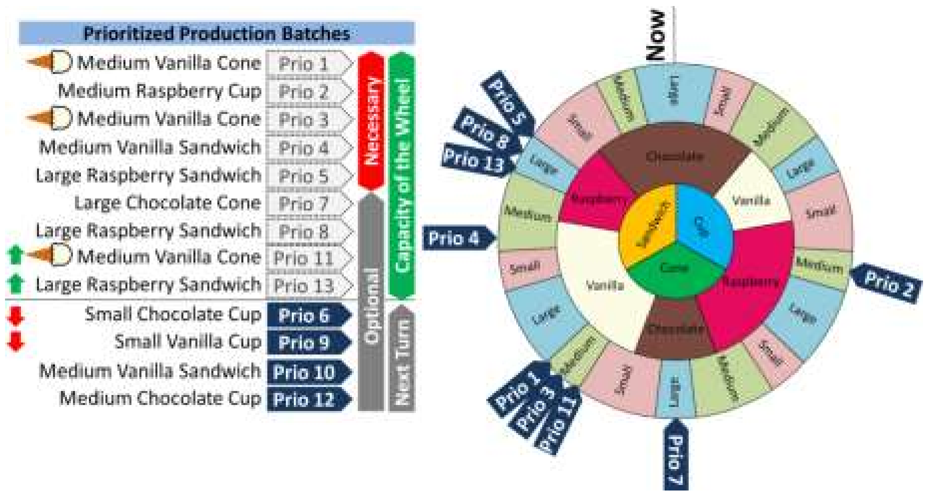

Figure 74: Changeover Wheel Prioritized with Jobs Optimized (Image Roser)

Obviously, you must fit the necessary jobs in your wheel. (If you can't, then you may have capacity issues, which is a different problem from the sequencing.) But among the other jobs, you may pick and choose which ones fit best in your sequence. In the example above, I have moved Prio 11 and Prio 13 up, since I am doing these product types anyway. To ensure I do not overload the capacity of the wheel, I moved jobs 6 and 9 down. Jobs 6 and 9 are optional, and I can do them this turn or during the next turn of the wheel. By doing them next turn, I save some changeover effort, since I go directly from raspberry sandwiches (jobs 5, 8, and 13) to raspberry cups (job 2) without ever having to switch the flavor to chocolate or vanilla. Much less wasted ice cream.

Figure 75: Out of stock? (Image Roser)

But again, you can do this only if you are confident that you are not running out of the de-prioritized products. In effect, you accept a slightly smaller risk of a stock out for a reduction in changeover effort… AND quite a bit of management decision making! If you manually switch things around, you have to… well… manually switch things around. This can be quite a bit of effort, and also can be another potential source of mistakes. Especially for these reasons I usually avoid messing with the sequence besides the priority. But, if you want to do this, it can work.

10.3 Always Plan an Entire Changeover Wheel

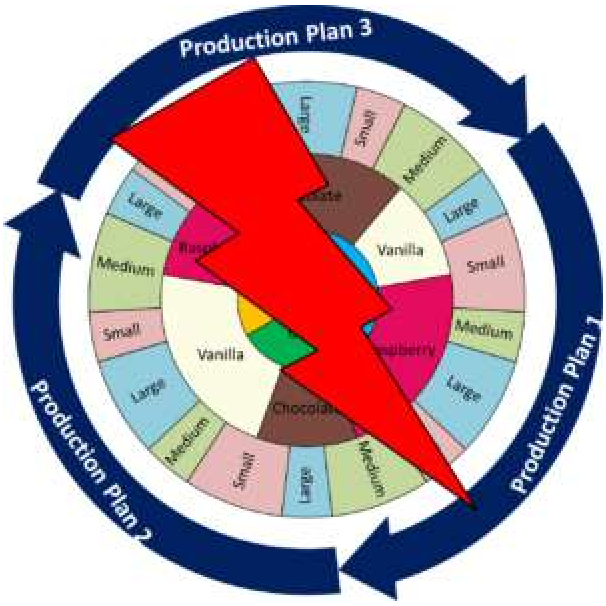

Figure 76: Changeover Wheel Production Plan Bad Segmentation (Image Roser)

The first point is a pitfall. You should **always plan an entire changeover wheel or sequence!** Do not plan only segments of the wheel. This is tied to the different parts of the wheel having different workloads. If you decide to fill jobs for only part of a wheel, as shown here, it will be tricky to decide how much capacity (jobs or production hours) to allocate for this part of the wheel. This is difficult.

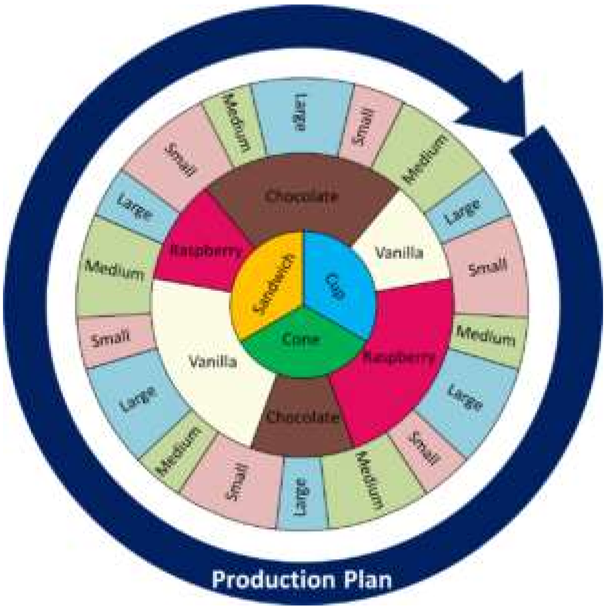

Figure 77: Changeover Wheel Production Plan Entire Wheel (Image Roser)

You could eyeball it and say, "If my entire wheel is three hours of production, then each one-third segment should be 1 hour." This sounds logical, but it is not! How do you know that the demand of the customer distributes evenly around the wheel? It could be that your first third are all slow runners, and you are wasting your precious capacity with jobs that you need only far in the future. When you finally get to the second or third segment with all the urgent high runners, you may lack the capacity to produce them. You produced a lot of goods that you need only much later, but you are now short on the products that you need soon. Hence, always plan an entire changeover wheel or changeover sequence! Never plan only part of a changeover wheel.

Figure 78: Changeover Wheel Production Plan Multiple Wheels (Image Roser)

On the other hand, you can without problem plan multiple wheels ahead of time. For example, if your wheel is 3 hours, and you have 15 working hours per day, you can without problem plan 5 changeover wheels in one go, and be done for the day. This may reduce planning effort and is also more flexible on the planners agenda, since they have to do it only once every five turns instead of planning every turn. On the other hand, it reduces your flexibility a bit, since changes in demand for the 2nd, 3rd, 4th, and 5th turn are not taken under consideration.

10.4 Re-Planning

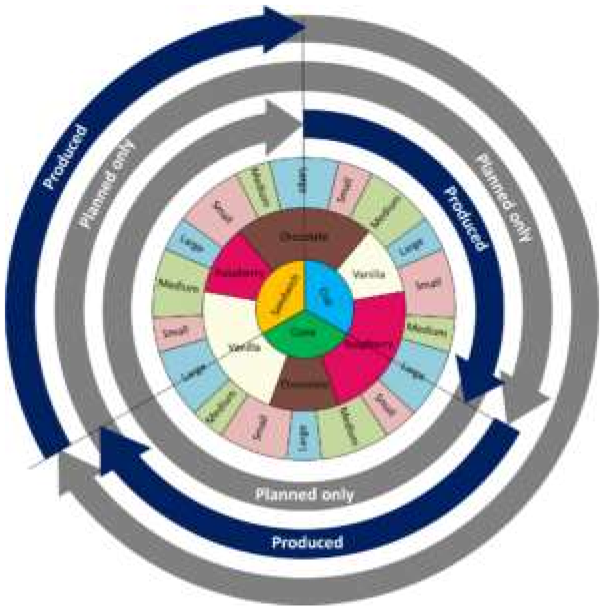

Figure 79: Changeover Wheel Production Plan Frequent Replanning (Image Roser)

The more often you plan, the quicker you can adjust to changes in demand. But always plan an an entire changeover wheel! However, it is possible to plan more frequently than a turn of the wheel. This is illustrated here, where the managers re-plan for every change of the waffle type (i.e., they re-plan three times per turn of the wheel. But again, they MUST plan the entire wheel). They only choose to change the plan when they redo the planning. This is necessary to make sure the available capacity is indeed used for the most important products.

Of course, this is a lot of effort and management overhead. I see two possible situations where you can do that. First, if you have a sufficiently advanced ERP system that can do the planning automatically, then it is no sweat on your brow, you just let the computer worry about all the planning. Do this only if you have a high level of trust in your computer system. Actually, let me rephrase this: do this only if **the people that are using the ERP system every day for planning** have a high level of trust in your computer system!

The second reason to re-plan is probably more common. Something unexpected happened, the customer is yelling at your boss, your boss is yelling at you, and you need to change the production plan to make your boss and your customer happy (or at least less angry) (or at the very least angry against somebody else…). In this case, re-plan the entire changeover wheel (changeover sequence) to incorporate the latest information (the yelling). Discard the previous plan that has not yet been started.

As so often, what started as a one- or two-blog post series is getting quite lengthy when I start to go into the detail. And we are not yet done. In my next post I will look at more things that you can or should consider for the changeover wheel. Now, **go out, fix your sequence to make your boss and your customer happy, and organize your industry!**

P.S.: This blog post was inspired by a master thesis by my student Milena Oberle: "*Entwicklung eines Steuerungskonzepts zur Stabilisierung volatiler Auftragsfolgen einer variantenreichen Mischfertigung unter Berücksichtigung der zukunftsweisenden Erfolgsfaktoren einer Smart Factory,*" Hochschule Karlsruhe, 2022.

11 A Few More Turns on the Changeover Wheel – Part 5: Frequently Asked Questions

Christoph Roser, March 15, 2022 Original at https://www.allaboutlean.com/changeover-wheel-5/

Figure 80: Happy Couple Eating Ice Cream (Image grkic with permission)

In my last two posts I talked on how to set up a changeover wheel or, more generally, a changeover sequence. Next I will show you how to use a changeover wheel. The idea is simple, but there are some pitfalls as well as some tricks to make it easier. Let's have a look.

11.1 A Brief Recap

We will continue the example from the previous posts of an ice cream maker with three types of waffles, three flavors, and three sizes. This gives us a total of 27 different products. We created a changeover sequence (the changeover wheel) and added production jobs in sequence of priority.

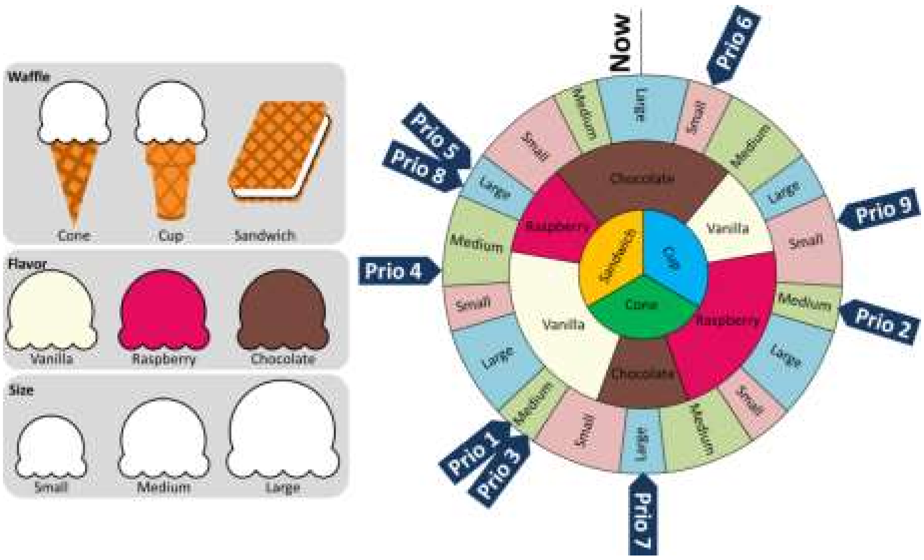

Figure 81: Changeover Wheel Product Types and Sequence (Image Roser)

11.2 Make-to-Order vs. Make-to-Stock

Figure 82: Made to order (Image desertsolitaire with permission)

For many organizational tasks, it does make a difference if a product is produced for inventory (make-to-stock) or for a specific customer order (make-to-order). Does this make a difference for the changeover wheel? Probably not. You have your list of possible jobs ordered by priority. It is possible that a make-to-order job has a higher priority, but other than that it is simply put in the list of open jobs.

When filling the changeover wheel with orders (as discussed in the previous post), you simply put in the job where it fits best when its priority comes up. There may be a minor extra effort if your make-to-order job is so special and rare that this type of product is not yet on the changeover wheel. In this case, you have to see where it fits in best in the current sequence. I have sometimes heard suggestions like making all make-to-order jobs first, and then using the normal changeover sequence for the make-to-stock products. This would accelerate the make-to-order jobs slightly, but would generate a lot of additional changeover effort. Usually, this is not worth it, unless the job is ultra urgent and must be done right away. On a side note, if all (or most) of your jobs are ultra urgent and must be done right away, then don't bother with the changeover wheel, since the ultra-urgency defeats any other sequencing approach like a changeover optimization. But if this is the case, then your shop floor is messed up anyway and has other fundamental problems.

11.3 Freeze Sequence As Needed for Logistics and Preparation

Figure 83: Changeover Wheel Production Freeze (Image Roser)

The first point is obvious. When you plan your production, your logistics and other processes (e.g., preparing tools) need time to get ready. If you decide right now to produce large chocolate ice cream waffles, your production will be unable to do so right away. There will be a lag, where logistics gets the raw materials and your workers get the right tool from the storage. Only after these preparations can they actually do the setup and produce your product. I am sure your shop floor already has something similar. In effect, you should **make your plan long enough beforehand to give logistics and other processes time to prepare.**

Depending on your shop floor, such a freeze of the production plan can take hours, days, or sometimes even weeks. You should not change production during this period, as logistics will not have time to react. The example shown here is for a three-hour production plan freeze so logistics can do their thing.

Also, make sure to freeze enough time for logistics to do their job reliably. If there is an emergency, logistics can hurry up, and in your factory surely they have done so in the past. However, this does not mean that they can always hurry up. If you always cut the logistics time to the bone, then you will get hurt!

Be aware that this period for the production plan freeze is measured in hours. The changeover wheel is merely a sequence, and depending on your demand fluctuations, the same period could cover a smaller or larger segment of the changeover wheel. It is not the number of slots that are relevant, but the time needed to cover the slots for this turn of the wheel. This time can be different both for different parts of the wheel and for different turns of the wheel if the customer demand changes.

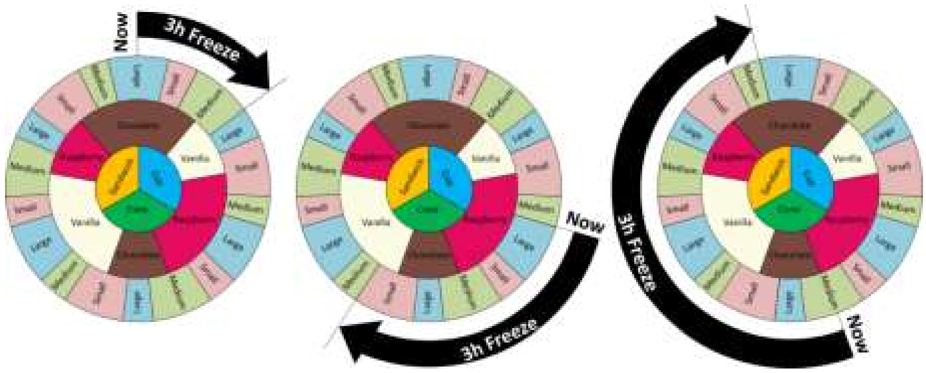

Figure 84: Changeover Wheel Multiple Production Freeze (Image Roser)

11.4 Where to Start the Wheel?

Another common question is where to start the wheel? There are two feasible approaches. First, you can **start the changeover sequence where the last sequence ended**, as shown below. This is the easiest way. In the example below, the first possible product in the sequence is always a *large raspberry cup*.

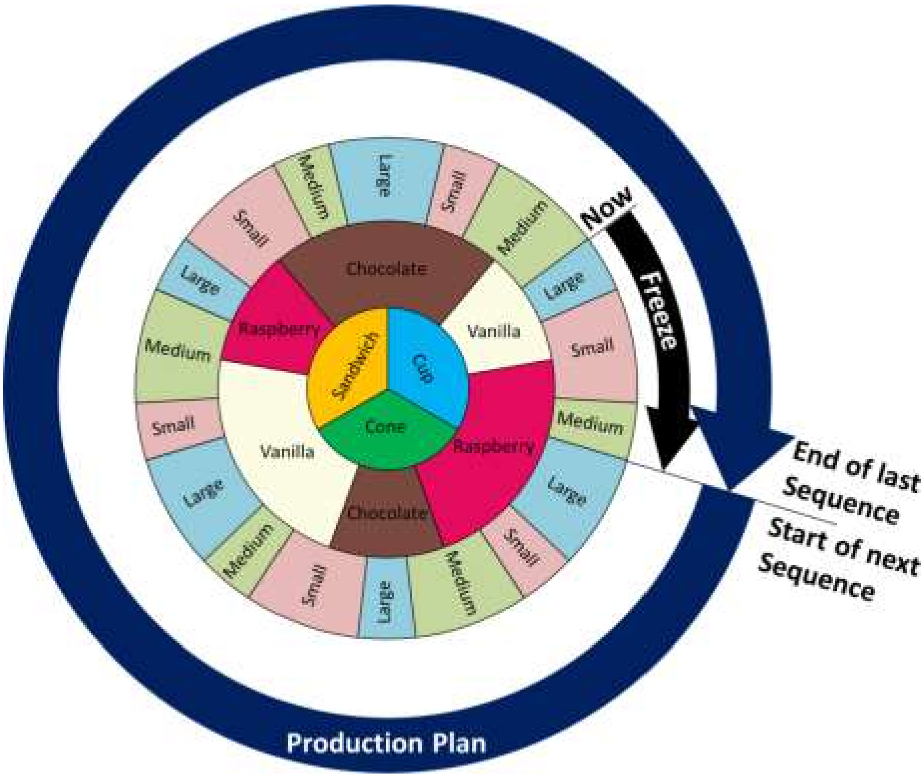

Figure 85: Changeover Wheel Where to Start (Image Roser)

Alternatively, you prioritize your jobs and fill the wheel normally. Then you **start the changeover sequence with the highest priority job you have in the wheel**. This is shown below with both the original and the adjusted wheel. This way you can accelerate the production of the highest priority job … but at the cost of delaying the other jobs that are at the end of this updated changeover sequence. In the example below, we start the sequence not at the *large raspberry cup*, but start with the *medium vanilla cone*, since this is our highest priority job we have available for the next wheel. This would accelerate the production of this *medium vanilla cone*, since it is now next in line.

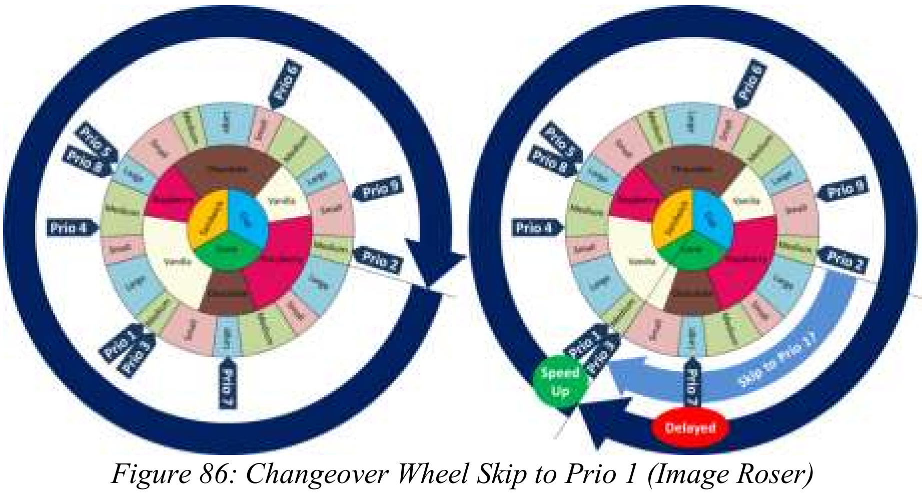

Figure 86: Changeover Wheel Skip to Prio 1 (Image Roser)

While this is nice for the Prio 1 job, it is not so hot for the job at the end of the revised changeover sequence. The *large chocolate cone*, which normally would have been first in the sequence, is now the last in the sequence. This product has to wait additionally for almost an entire changeover sequence. If this is okay, then you can do that. If not, then you may have a problem later on with this product. Plus, you have a bit of additional decision making overhead. I personally would prefer to just start the sequence at the same spot every time, as this is the easiest. **Adjusting the start should be reserved for emergencies**, as it has additional problems like running out of stock that is now at the end of the sequence. If you change the start of the sequence once, you then have to always start the sequence again at the new spot, or also face additional possible problems if you change the start of the sequence back to the original start after the emergency. It is possible but can be messy.

A question that may pop up is if, after filling the sequence with jobs, you can start at the first actual job, and skip all products that have no jobs associated with it for this turn of the wheel. In the example shown below, we would skip the start from the *large raspberry cup* to the *large chocolate cone*. However, this makes no difference whatsoever. If you start the sequence as originally planned with the *large raspberry cup*, it would also just skip the products without jobs, and the first job is the *large chocolate cone* anyway. This is the same if you change the start of the sequence. Honestly, it makes no difference, and is just wasted management effort.

Figure 87: Changeover Wheel Skip to First Entry (Image Roser)

This post concludes now this five-post series on the intricate details of the changeover wheel or changeover sequence. As with many lean tools, you should do the changeover sequence only if it brings you a benefit that is worth the effort, not merely because you can. Now, **go out, sequence your changeovers, and optimize your industry!**

P.S.: This blog post was inspired by a master thesis by my student Milena Oberle: "*Entwicklung eines Steuerungskonzepts zur Stabilisierung volatiler Auftragsfolgen einer variantenreichen Mischfertigung unter Berücksichtigung der zukunftsweisenden Erfolgsfaktoren einer Smart Factory,*" Hochschule Karlsruhe, 2022.

12 How Managers Drove Boeing into the Ground…

Christoph Roser, March 22, 2022 Original at https://www.allaboutlean.com/boeing-management/

Figure 88: Plane Crash Clip Art (Image SlawaB89 with permission)

Boeing is a well-known maker of large commercial aircraft. If you fly occasionally, you almost certainly have been on one of their planes. Lately, however, Boeing is better known for quality issues and crashed planes. It seems that management at Boeing skimped on quality to save cost and make deadlines. In this post I want to look closer at the management of Boeing, especially in relation to the safety of the Boeing 737 MAX 8. Besides using different news sources, this article is mostly based on the book *Flying Blind* by Peter Robinson (source below).

12.1 Boeing 737 MAX 8 Crashes

Figure 89: Lion Air Boeing 737-MAX8 (Image PK-REN under the CC-BY-SA 2.0 license)

In 2018 and 2019, two rather new Boeing planes (both shown here) of the type 737 MAX 8 crashed under very similar circumstances. Lion Air flight 610 crashed on October 29, 2018, near Jakarta shortly after take-off. Ethiopian Airlines Flight 302 crashed on March 10, 2019, in Ethiopia. Both planes reported some sort of control problem before the planes took a nose dive straight into the ground. All 346 people died; there were no survivors. Other pilots also reported similar problems with the MAX 8 planes.

Figure 90: Ethiopian Airlines Boeing 737 Max8 (Image LLBG Spotter under the CC-BY-SA 2.0 license)

As a result, many aviation authorities grounded this type of aircraft shortly after the Ethiopian crash, until the cause of the accident was better understood (with the US Federal Aviation Administration FAA noticeably lagging behind). Other pilots reported near misses due to similar problems with the same model of aircraft.

By March 18, 2019, all 387 Boeing 737 MAX 8 planes in 59 airlines were grounded, plus another 400 or so newly manufactured ones were awaiting delivery. Only after twenty months, at the end of 2020, did the first aircraft of this type start to fly again.

12.2 A Bit of Boeing Company History

Figure 91: Boeing Logo (Image Boeing for editorial use)

Boeing had an excellent reputation with regard to safety. There was a saying “If it ain’t Boeing, I ain’t going.” The company was run by engineers, and safety was a high priority. The entire Boeing culture revolved around building excellent planes. Quality and safety issues reported upward were taken very seriously, and managers spent a lot of time on the production floor.

This changed in 1997 when Boeing merged with McDonnell Douglas. McDonnell Douglas was a very different type of aircraft company, run not by engineers but by accountants. The bottom line was most important. Despite that, McDonnell Douglas was struggling. Robinson writes that the merger probably saved McDonnell Douglas from bankruptcy. It was said that “McDonnell Douglas bought Boeing with Boeing’s money.” After the merger, the two management styles collided. Boeing management had been described as “boy scouts,” whereas McDonnell Douglas managers were called “hunter-killer assassins.” Hence, it did not take long before Boeing was run mostly by former McDonnell Douglas managers.

And with that, the entire culture of Boeing changed. There are reports of people being pressured NOT to report quality and safety issues. It seems people who did got fired. Making the deadline and saving cost had the highest priority. Safety was not even mentioned in the annual proxy statements between 2010 and 2014. In 2010 Airbus launched the A320 NEO family of planes, which was a direct competitor to the Boeing 737. Boeing managers were under pressure to design a new plane to compete with Airbus. Designing a completely new plane would have been quite expensive, and may have required re-licensing of the pilots, hence Boeing decided to update the 737.

12.3 A Bit of Boeing 737 Design History

Figure 92: Boeing 737-100 (Image Aero Icarus under the CC-BY-SA 2.0 license)

The first version of the Boeing 737, the Boeing 737-100, had its maiden flight in 1967, fifty-five years ago. Since then, many upgraded versions of the plane have been developed, with the current fourth generation being the 737 MAX series, including the MAX 8. Over time, fuel efficiency became more important to the airlines. Newer, more fuel efficient engines are often larger than older engines. But this was a problem for the Boeing 737.

While the original turbines of the 737-100 were almost completely under the wing, the increasingly larger engines of the successor models no longer had enough space under the wings. To fit these larger and more fuel-efficient engines, Boeing moved them forward and up. Below is a drawing of the second generation 737-400 and the latest generation 737 MAX 8, with the engine highlighted in color. You can clearly see how the engine became larger and moved forward and upward. To save space, the MAX 8 engine is also somewhat flatter at the bottom when seen from the front. The engines of the third generation were somewhere in between the second and fourth generation shown here.

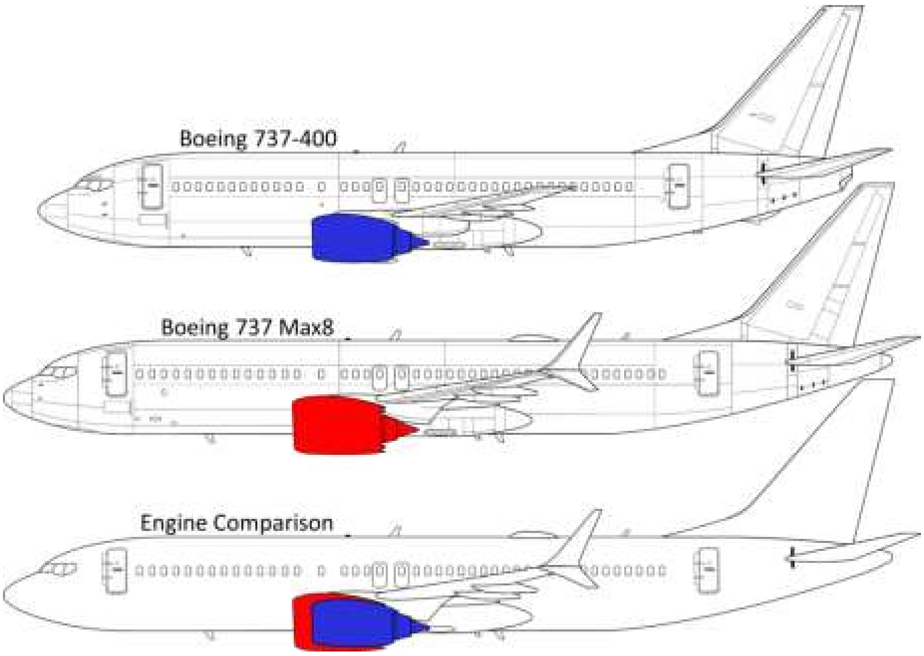

Figure 93: Boeing 737-400 and Max8 Engine Comparison (Image Scott, modified by Roser with permission)

Sketch of the 737-400 and 737 MAX 8 with the engines highlighted. The last sketch is an approximate overlap of the engines over an MAX 8 body.

Some people had already commented that the fifty-five-year-old airframe had reached the end of its life, and a new design would have been better. The increasingly forward and upward position of the engine increased the risk of an unintended upward pitch in certain conditions (i.e., the plane starts to climb). To prevent this, a *Maneuvering Characteristics Augmentation System* (MCAS) software was added for the Boeing 737 MAX 8. This software detects if the plane has an unintentional climb, and would counteract this by steering the plane back downward.

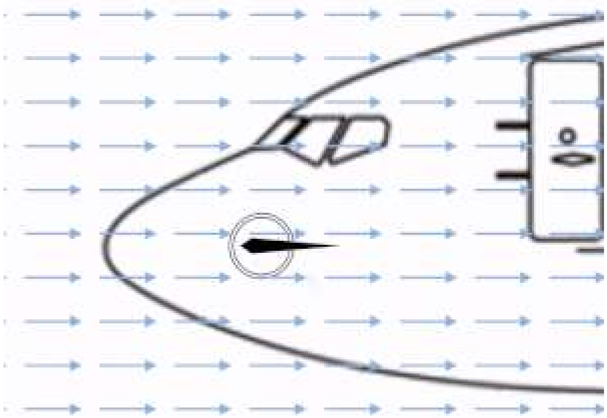

Figure 94: Angle of attack sensor animation (Image Julien.scavini and Christoph Roser under the CC-BY-SA 4.0 license)

It does this by collecting data from the plane, including its angle of attack sensor. This angle of attack sensor is a small wing at the sides of the cockpit that always stays with the airflow as shown in the (simplified) animation here. These angle of attack sensors are somewhat sensitive, and anything from a bird strike to a Mylar balloon can throw them off. Hence, there are usually at least two sensors, one on each side of the cockpit.

For some reason (Cost? Deadlines?), Boeing decided that **the MCAS system would use data only from ONE angle of attack sensor**. And this is a big NO-NO in aviation. Planes are built around redundancy. The failure of a single device must not cause problems, and redundancy is required to keep the plane airborne and safe. The MAX 8 did not have this redundancy, and a failure of this single angle of attack sensor would throw off the entire MCAS system. And this is what happened. The angle of attack sensor malfunctioned, and the MCAS believed that the plane was in an unintentional climb, overrode the pilot decision, and steered the plane back down toward horizontal… except due to the malfunctioning sensor it was not horizontal but downward. A lot downward! Both planes flew straight into the ground despite the pilots' best efforts.

Another part of the problem was that the Lion Air pilots did not know of the MCAS, nor did other pilots of the MAX 8. The handbook mentioned the MCAS, but only in the appendix, and only explaining the abbreviation. **The pilots were never trained on the MCAS** and – crucially – how to turn it off. When designing the plane, Boeing promised that pilots would not need any additional training for the MAX 8 if they were certified for the predecessor model. Yet, adding a new software module would require additional training, especially if the module (like the MCAS) could override the pilots' decision in controlling the plane. Hence, the MCAS was kept under wraps and the pilots did not know about the system. This shocked a lot of pilots when it came out, and further undermined trust in Boeing.

After the first crash, pilots learned about the system, and the Ethiopian Airlines pilots actually were able to turn it off. Unfortunately, they needed to turn it off **within the first 10 seconds** of it malfunctioning, which would be extremely fast and nearly impossible to do if the pilot first had to identify the problem and figure out what to do. By the time the Ethiopian Airlines pilots turned it off, they were already in an unrecoverable dive.

As with most accidents, they could have been prevented. But the fault, in my opinion, does not lie with the pilots, but with the design, which in turn seems to be caused by neglecting safety in favor of profit and meeting deadlines. As one person said, "Boeing got away with murder."

12.4 The Role of the Federal Aviation Administration (FAA)

Figure 95: Seal of the United States Federal Aviation Administration (Image US Government for editorial use)

The FAA would be the oversight body to prevent makes of aircraft and other aviation companies from prioritizing profit over safety. Unfortunately, there was a lot of pressure on the FAA to make the plane happen and to look the other way. In fact, the FAA rewarded its employees if they made an airline more profitable, and they publicly shamed inspectors that caused trouble for the airlines. An FAA boss even told his people that their bonus depended on Boeing making its deadlines. Boeing was deep inside the FAA. The FAA was a "tombstone agency," acting only if someone died. Anyhow, it seems that after two crashes, the FAA is tightening its certification process.

12.5 Is This an Isolated Incident?

It does not seem so. Certainly, these two crashes were the most dramatic accidents. But another plane, the Boeing 787 Dreamliner (maiden flight 2009), also made headlines with lithium-ion batteries catching fire. The problem is supposedly fixed, and no plane crashed. There were also reports on quality problems in building planes, from metal chips around wires to forgotten tools inside of planes. The latest model, the MAX 10 (a longer version of the MAX 8), is also rushed. Of particular concern is the end of 2022, after which new cockpit safety features are required by the FAA for aircraft models. It seems the MAX 10 may miss this deadline, and may require a different cockpit… which in turn would require more pilot training and increase cost even more. At the time of this writing, Boeing lobbyists are working hard to get another extension beyond the FAA deadline.

So, there seem to be lots of management shenanigans impacting the quality of the products at Boeing. Would I still fly in a Boeing? Yes, since air travel is still one of the safest forms of travel, even on a Boeing. However, if I have the option, I would prefer an Airbus. One side note, it seems that due to the power of unions in Europe, employees can speak much more openly and raise safety issues easier at Airbus than at Boeing. Anyway, this blog post turned out to be much longer than I planned, but I hope it was interesting to you. Now, **go out, travel safely, and organize your industry!**

PS: The day before I published this article, another Boeing 737 crashed. China Eastern Airlines Flight 5735 plunged almost straight into the ground. There were no survivors, all 132 people on board died. This was a Boeing 737-800, from the previous generation of 737's before the Max8, and it did not have a MCAS system. The cause of the crash is still unknown, could be anything from a suicidal pilot to maintenance issues. Investigations are ongoing. The airline grounded its fleet of 737-800's for now.

12.6 Sources

Besides many articles in different newspapers, I especially recommend two sources, a book and a movie. The book provides an especially good look at the behavior of Boeing management.

- Robison, Peter. 2021. Flying Blind: The 737 MAX Tragedy and the Fall of Boeing. New York: Doubleday.
- Downfall: The Case against Boeing. Netflix documentary from 2022. Directed by Rory Kennedy

13 50 Years of SAP–Blessing or a Curse?

Christoph Roser, April 1, 2022 Original at
https://www.allaboutlean.com/50-years-of-sap-blessing-or-a-curse/

Figure 96: SAP Logo (Image SAP for editorial use)

SAP is turning 50! The company was founded on April 1, 1972, exactly fifty years ago. Nowadays it is one of the largest software companies worldwide, and their products are found in many, MANY companies, although not every user seems to love the product. For me, this is a love-hate relationship. You can't live with it, but you can't live without it either. Let's use this anniversary to have a look at the company and its software that is widespread in industry, as well as some general musings on ERP systems.

13.1 The Company

On April 1, 1972, five former IBM employees – Claus Wellenreuther, Hans-Werner Hector, Klaus Tschira, Dietmar Hopp, and Hasso Plattner – founded SAP. The name originally stood for *SAP Systemanalyse und Programmentwicklung GbR*. In English this would be "System Analysis and Program Development." Later the company was renamed *SAP GmbH Systeme, Anwendungen und Produkte in der Datenverarbeitung* ("Systems, Applications, and Products in Data Processing"). Nowadays SAP is no longer an abbreviation but the full name of the company.

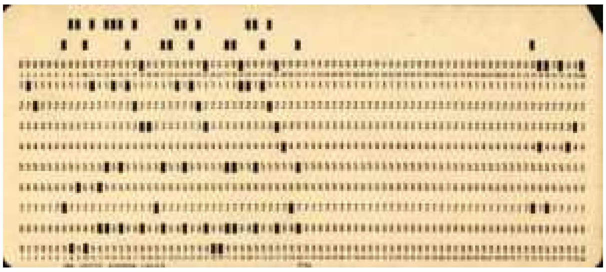

Figure 97: An old punch card, NOT at SAP (Image Pete Birkinshaw under the CC-BY 2.0 license)

Their idea was to use computers to manage the finances and other data of companies. Different from IBM at that time, however, they decided not to use punched cards to store data, but to interact with the user through keyboards and monitors. While this is the norm nowadays, back then it was a major step forward. Instead of punched cards, they managed data in real time, and the abbreviation "R" for "Real Time" was used for the name of their software SAP R/1, and later R/2 and R/3. Their first product was developed at their first client in the chemical industry, but was also designed to be universally applicable across many industries. Their latest package is called SAP S/4HANA, although the older SAP R/3 dating from 1993 is also still in common use.

Figure 98: SAP main modules (Logo SAP for editorial use, Image Roser)

The main product of SAP is its Enterprise Resource Planning (ERP) software. This business management software aims to manage all data in a company. The main modules of SAP are FI (Finance), CO (Controlling), MM (Materials Management), SD (Sales and Distribution), PP (Production Planning), QM (Quality Management), PM (Plant Maintenance), and HCM (Human Capital Management). But many more industry sector solutions and business modules exist.

This software turned out to be quite popular. The revenue of SAP grew, on average, over 40% every year between 1980 and 2000, although this has slowed down markedly, and the average growth between 2010 and 2020 was only 9%… which is still pretty decent. SAP is also able to make a quite nice profit out of it. The net profit margin in 2021 was 18.9%, and usually around 15% for the last ten years on average. This is quite good compared to many other industries. Like any large company, there are also some scandals, and there are reports that SAP did industrial espionage, bribery, and other shenanigans. But our focus here is on the software.

13.2 Limitations of ERP Software

The task of an ERP software can be gargantuan. It tries to manage all data related to a company, from infrequently changing employee records and intellectual property databases to the constantly changing number of parts you have on the shop floor. As such, it has great potential, but also lots of risk. In particular for managing the material on the shop floor, I had lots of problems with SAP when I used it in industry. ERP software like SAP wants to tell you what you can do with the available materials, and when you should do what. There are lots of academic models for this, but especially the early models had one major limitation: **they assumed unlimited production capacity**. If you have ever been in charge of a shop floor, you know that unlimited capacity would solve a lot of problems. Unfortunately, you do NOT have unlimited capacity, and any assumption in this direction would give you lots of problems.

Newer models aimed to improve this and include capacity limitations in the modeling of the production plan. However, it still feels highly cumbersome, and is not always working very well. One problem I had was that updating the available capacity was quite time-consuming, especially since unforeseen events could change the situation quickly. Naturally, if the data in the database was not correct, the resulting model was also flawed.

Figure 99: Missing material… (Image Roser)

Keeping the data up to date was also a challenge in other areas. When building a product, we consumed raw materials and created products. ERP software updates the database accordingly. Our problem was that the production record was added to the database at the end of the shift, and hence the updating of the record was delayed. The ERP system always believed there were more parts than what we actually had, which made it very difficult to determine if we had the material to produce what we wanted to produce. **Incorrect material availability data** was a constant hassle when I was working with my ERP system. A more frequent update would have reduced the gap, but a real-time data update is still quite visionary (although RFID and other technologies have new possibilities here). Of course, garbage in… garbage out… but I have yet to see a plant where this data maintenance was done satisfactorily.

Figure 100: SAP screenshot (Image Rwj dk under the CC-BY-SA 3.0 license)

Another issue I have with SAP is the interface. The software originated fifty years ago, and **the user interface still looks and feels decades old**. A lot of data is required, and it is far from intuitive what data should be entered where, when, and how. Using SAP was – at least for me – always a pain.

Another problem I had was with access permissions. I constantly ran into problems where I did not always have the rights to access the data that I needed. Yes, I know, this was also a self-made problem, but I was unable to get the access rights. Luckily, an older colleague in a completely different department still had those rights, and was able to export the data into Excel for me. Talking with other ERP users, I found that this seems to be a common approach: **you need to export the ERP data into Excel if you want to make any kind of non-standard analysis**. Alternatively, you had access to programmers that could implement the functionality for you… but due to the cost and time involved, this was also rarely an option for most users.

13.3 Enormous Complexity

One challenge for ERP in general and SAP in particular is the complexity of the data in modern industry. You need to invest a lot of time to keep the data up to date. Even with the best intentions, mistakes will happen, which can lead to unintended consequences. When I was managing a small team that planned production using SAP, I also planned a few parts myself to know what I was talking about. Yet for one setting I had no idea what to add, and it was a mandatory setting field (indicating that it was important). The interface was of no help and very cryptic. So I asked my people. They all told me that they always put in a certain setting. But they all told me a different setting to enter! And none of them could explain to me what this setting does or why they used this particular setting. The only answer I got was, “We’ve always done it that way, and it’s never caused problems.”

It seems that no one understands all of SAP anymore, and even consultants know only their subsection. I have been told SAP even programmed a wrapper around the software to make the usage easier. Since the wrapper then also turned complex, they programmed a second wrapper around the wrapper. Overall, SAP is a Moloch that is hard to control. The complexity also makes it difficult for companies to switch to other ERP software (or vice versa), since the databases are not really compatible, and transferring the data to a new software would be a huge undertaking with a large risk of problems.

13.4 A Single Point of Failure

Figure 101: Auto accident in Toronto, Canada, 1918. (Image James Salmon in public domain)

This high level of complexity combined with the software managing many crucial aspects of a company creates a single point of failure. If everything works, good. But if SAP breaks, the entire company can grind to a standstill. In 1999 Hershey was unable to deliver their products after a change to SAP… shortly before the Halloween, the most important days for any candy manufacturer. In 2000 Nike accidentally produced thousands of shoes… of the wrong type, after an ERP upgrade. In 2006 Cadbury Schweppes also produced way too many perishable goods due to an ERP problem, also creating a huge loss. My own university was unable to pay their bills for three months after switching to SAP. You will find plenty of similar expensive "glitches" if you google for them. Overall, any kind of ERP upgrade or change makes most responsible managers quite nervous, since it can break the entire company.

13.5 Can't Live with It, Can't Live without It…

So, would the world be better off without ERP and SAP software? Probably not. It seems to be a typical case where you can't live with it, but you also it can't live without it. The complexity and quantity of data in a modern enterprise is enormous. Managing it by hand or by Excel is rarely a good solution (although in some cases it may work). Hence, we need a software to help us with managing the data. But using the software does not make the complexity and problems go away. Pretty much every SAP (or generally ERP) user I've talked to complained about their software and its performance (not only SAP). But not having it would probably make it much worse. I personally have worked mostly with SAP, and have little experience with ERP programs from their main competitors, Microsoft, Oracle, IBM, and others. Hence I don't know if they are better. I do know that smaller companies often prefer smaller software packages from providers within that industry (e.g., an ERP software specialized for waste management), as they may be cheaper and better suited to their (specialized) task. Anyway, congratulations to SAP on their 50th birthday. Now, **go out, make sure your ERP system has accurate data, and organize your industry!**

14 On Standard Tools and Standard Solutions…

Christoph Roser, April 5, 2022 Original at
https://www.allaboutlean.com/standard-tools-and-solutions/

Figure 102: Tool Box with Tools (Image AndreyPopov with permission)

On the web and in print, you find frequent mention of a "lean toolbox," "lean toolbook," or similar. These books do have their use, and at least one of them is written by an author that I highly respect. Many other lean books also focus on the different tools and methods. But focusing on a set of tools can also be quite misleading. Hence, I wrote this blog post as a word of warning. Every master needs their tools, but the tools do not make a master!

14.1 Standard Tools for Standard Solutions

Figure 103: Selection of screwdrivers (Image Roser)

A "tool box" somehow implies standard tools. For example, a screwdriver. There are standard screwdrivers that will fit standard screws. However, this is quite a simplification. Even among screwdrivers, there are many different types. There is the slot head (ugh, don't use these). There are Phillips and Pozidriv heads. You probably also have a Torx, and maybe some more like a hex wrench and an Allen key (internal hex) or even more.

Figure 104: New and damaged Pozidriv (Image Roser)

Hence, you already have a multitude of different "standard" tools. If you are repairing mobile phones or other electronics, you will have even more. Just for fun, I have assembled a (absolutely not complete) list of screwdrivers below (sorted by the number of positions you can insert the screwdriver into the screw). All of these do exist, are used somewhere, and are (with few exceptions, like the cross and slotted/Phillips) not compatible with each other. In particular the group that is often bunched together as cross-heads or cross-tips look like they are suitable, but they are different standards! If you mix them up, you will damage the screw and the screwdriver and, in the worst case, get stuck with a screw that you can no longer turn.

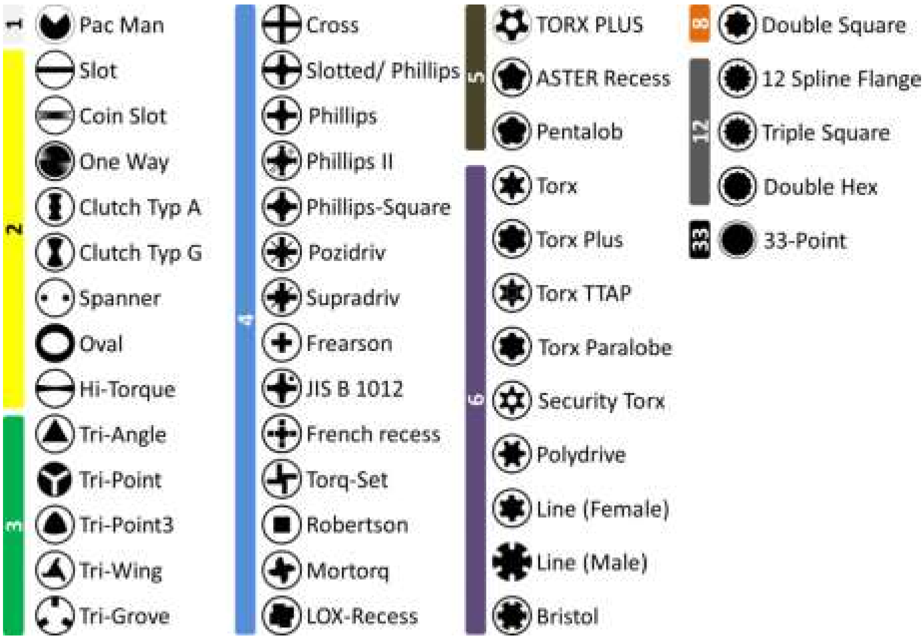

Figure 105: Selection of screwdrivers (sorted by number of positions they can be inserted) (Image Roser)

In terms of lean tools, the number of tools listed is usually fewer than the screwdrivers above. Nevertheless, they also may have a specific purpose. For example, you all know kanban. But kanban only works for make-to-stock items, and not for make-to-order items (in which case CONWIP or POLCA may be better). Even if you have make-to-stock items, Kanban may not be the right tool, and a reorder point system is sometimes preferable. And even if kanban would be the best tool, then there are still different variants of kanban (Triangle, Two Bin, and so on). For more on different ways to pull, check out my book All About Pull Production.

Overall, there is rarely a "standard tool" that fits your problem, since your problem is probably not a "standard problem" to begin with. If all of your problems would be as equal as Torx screws, problem solving would be easy. However, the nature of your problems and their causes are probably quite manifold, and a standard solution rarely fits well. This brings me to my next point:

14.2 Adapt Tools for Your Purpose!


Figure 106: Selection of tongs from a blacksmith (Image Roser)

A standard tool may not fit, but you may be able to use the idea and adapt it to your specific problem. Let's take an analogy from industry again. A blacksmith uses a pair of pliers (or thongs) to hold the workpiece. For this, blacksmiths usually have plenty of different pliers. But even then, the smith may in some cases modify the pliers to fit his purpose better. A smith once told me that. ideally, every workpiece should have its custom pair of pliers.

Figure 107: Injection Mold (Image MobiusDaXter under the CC-BY-SA 3.0 license)

Or for another example, let's use injection molding. Injection molding is certainly common in industry, but it still requires a lot of adaptation and customizing to make good-quality and cost-efficient parts. This ranges from the design of the part for molding, the design and building of the mold itself, to the settings for running the injection molding machine, and more. Even if you consider injection molding a standard solution, it is not a fire-and-forget solution, but an a-lot-of-effort-to-make-it-work solution. Both the problem and the solution are just more complex than a screwdriver where you simply need to find the matching screw.

The same with lean. Even if you consider some lean tools as standard solutions, you still need to heavily modify and adapt the solution, figure out all the minor problems with it, and put in a lot of effort so the solution fits the problem like a glove, and not a one-size-fits-all hat that never fits. Even if you want to use a normal kanban system, you still have to decide on how many cards, where they go, how to transport them, where to store them, and many more decisions. And that is only for a common implementation. You may even have trickier challenges, like for example the overhaul of an aircraft engine. For a complete overhaul, the engine is taken apart, its parts sent through the material flow, and then put together again. Try to use kanban for that! (Hint: It does not work, as it is usually not a make-to-stock production).

14.3 Tools Do Not Make the Master

Figure 108: Two sculptures of Lucille Ball. The first one (left) was so bad that they had to replace it. (Not by Michelangelo 😐) (Images Adam Moss under the CC-BY-SA 2.0 license)

As I said above, tools can certainly help in your work. But it is not the tool that makes the master! Michelangelo became great not because he bought good chisels! Michelangelo was great because he could use chisels so well (and many other instruments of art and science).

To become great, you need a couple of ingredients. Talent certainly helps. The right environment and support is also necessary. But most of all, it is practice! It is sometimes said that you need 10 000 hours to become an expert, but that claim has no scientific basis. (Side note: By that number I am also an expert on sleeping, eating, and sitting on a chair 😮). Regardless, you need to practice to become good at what you do. More is better, and the learning curve never ends (it juts becomes somewhat flatter).

14.4 Don't Forget the Philosophy

Figure 109: PDCA Circle (Image Roser)

And finally, don't forget the philosophy behind it. If you mechanically try to copy the movements of a great sculptor, you won't become great. You need to understand not only the movements to make art, but also the philosophy behind it. Same in lean. Just using the tools is not enough; you need to understand the purpose and the philosophy around it. And – at least for me – this is often the hardest part. In particular for lean, one of the important philosophies is Plan-Do-Check-Act (PDCA), but there are more. One day, when I have really understood lean, I will try to write those philosophies down. But I think I need more practice before that…

Now, **go out, practice lean by doing it until you become even better than you already are, and organize your industry!**

15 250 Years after the Birth of Eli Terry

Christoph Roser, April 12, 2022 Original at https://www.allaboutlean.com/eli-terry/

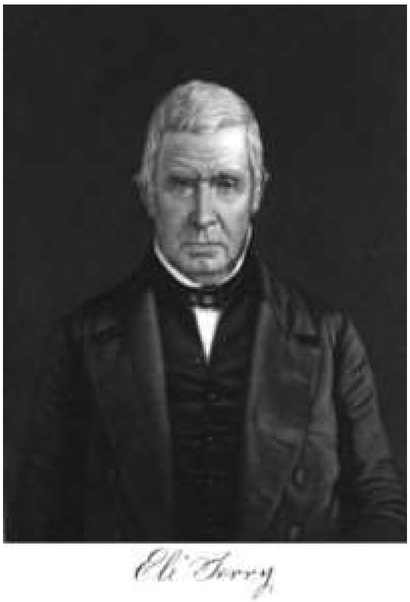

Figure 110: Eli Terry Portrait with Signature (Image Samuel Sartain in public domain)

Two hundred fifty years ago today, clockmaker Eli Terry was born on April 13, 1772 in (what is now) South Windsor, Connecticut, USA. He was one of the earliest industrialists using mass production with interchangeable parts in the USA, contemporary with the better-known muskets of Honoré Blanc in France (ca. 1785), and long before John Hancock Hall at the Harpers Ferry Armory (ca. 1824). His name is known mostly to nerds in manufacturing and horology, but I believe his achievements deserve recognition. Hence I will go back in history to look at his life.

15.1 On Clocks…

Figure 111: The largest church clock in Europe is in Zürich (Image Roser)

Measuring time has always been of interest to humanity. From the sun (or its shadow) to water clocks, marks on candles, hourglasses with sands, to mechanical gears. But these required effort and often were quite expensive. Clocks on church towers and other public buildings were sort of a service to the public so everybody could check the time. A clock at home was affordable only to the rich. Clockmakers in America started making clocks from the 18th century onward.

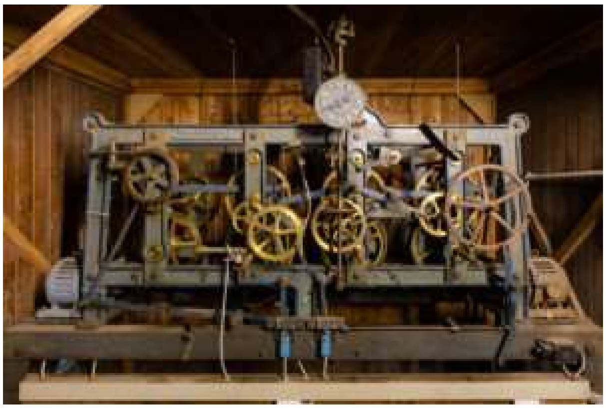

Figure 112: A mechanical metal church clock (Image Dietmar Rabich under the CC-BY-SA 4.0 license)

Since metal was rather expensive back then, many clocks were mostly made of wood, and only crucial parts were made of metal. Even then, the components for clocks were painstakingly filed by hand, and fitted together with even more frequent adjustments and filing. It was a luxury piece affordable only to the wealthiest, and custom made on order. A skilled clockmaker was able to make around six to ten clocks per year, with a clock costing around €400–900 in nowadays prices.

15.2 The Early Years of Eli Terry

Figure 113: Wooden gear milled by Eli Terry (Image TomVaughn under the CC-BY-SA 4.0 license)

Eli Terry was born on April 13, 1772, to Samuel and Huldah Terry in South Windsor, Connecticut, USA (at that time his birthplace was part of East Windsor). He apprenticed as a clockmaker. Unusually, he apprenticed both for brass and wooden clocks. Afterwards, in 1792, at age twenty, he started his own business in Plymouth, Litchfield County, making clocks slowly and laboriously by hand just like every other clockmaker of his time.

However, in 1795 he developed a simple machine that mechanized the cutting of the gears. Rather than making the gears (painstakingly) individually, the machine milled a tooth for multiple gears at once using a circular saw. The machine then moved to the next position for a tooth and cut another tooth. A whole batch of gears was produced simultaneously and quickly.

Since wooden gears required less precision than metal gears, almost by accident, this made his parts interchangeable. In turn, this allowed him to produce many more clocks than before. But this still pales in comparison to the mass production that he was to venture into.

15.3 Mass Producing Clocks

In January 1806 Terry expanded and built a small factory. This factory was water powered, and is considered the first water-powered shop in the US. Terry improved on his tools using different jigs and fixtures. He substituted water power for apprentices, and used journeymen to finish the gears. He also installed water-powered saws and lathes to speed up production even more.

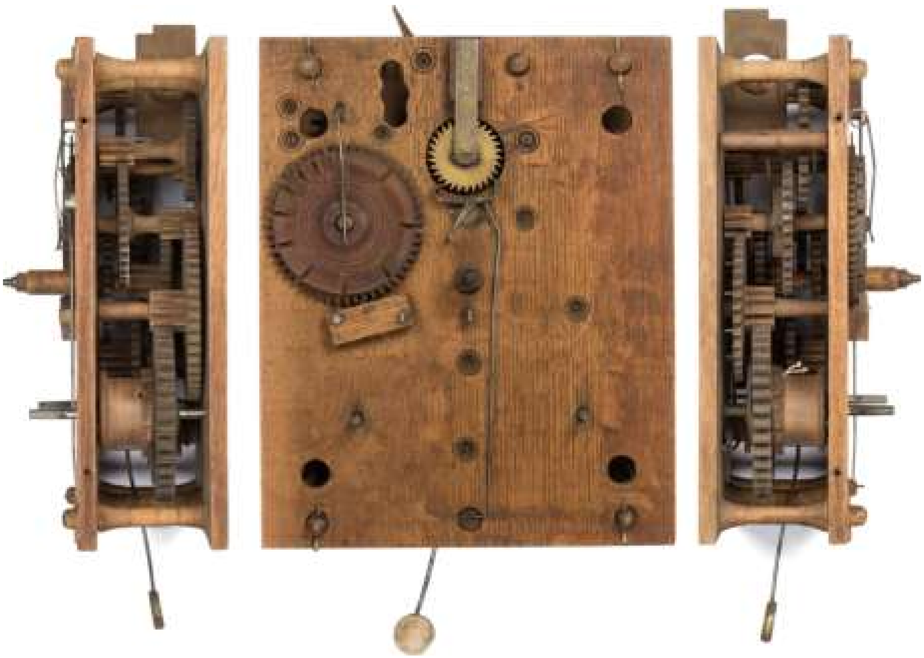

Figure 114: Wooden clockworks of Eli Terry design from around 1820 (sides and front). Exact maker unknown, may be a copycat product. (Image Deutsches Uhrenmuseum under the CC-BY-SA 4.0 license)

He then promised two merchants that he would produce an unheard number of 4000 clock movements within three years. A conventional clockmaker would need more than 400 years to make this number of clocks! And Terry promised it in three years! A very bold statement. Especially since his factory was too small. He needed to expand even more. In June 1806 he established a much larger factory. The ramp-up was not easy, and it took him two years to get everything running smoothly.

But then his output took off like the world had not seen before. He was able to produce 3000 clocks per year, not only tremendously faster than other clockmakers, but also tremendously cheaper! His factory was a stunning success, and was a license to print money. But that was not what Terry wanted. After he fulfilled his contract of 4000 clocks, he sold the factory to his assistants in 1810 at age thirty-eight. Afterwards he retired with a modest fortune to do what he loved… tinkering with clocks.

15.4 Coming Out of Retirement

Figure 115: Eli Terry clock (Image JVGJ under the CC-BY-SA 3.0 license)

In 1812 he came out of retirement and started another clock factory, with a focus on ease-of-use, machined parts, interchangeability, and low cost. From 1814 onward, Eli Terry mass-produced truly interchangeable clockworks and clocks, one of the first examples of true interchangeability in the world and almost certainly the first in the USA. Soon hundreds of men worked for Terry in his factory.

This revolutionized clockmaking in the USA. While before a clock cost around \$20–\$40 (roughly \$400–\$900 in today's currency), Terry managed to drop the price to around \$10, and later even lower to \$5. While wooden clocks were a luxury item before, they became standard for the middle class by 1830. By then, pretty much no small clockmaker was left in the business, as Terry and his three largest competitors produced 15 000 wooden clocks every year from 1820 onward.

15.5 Patents

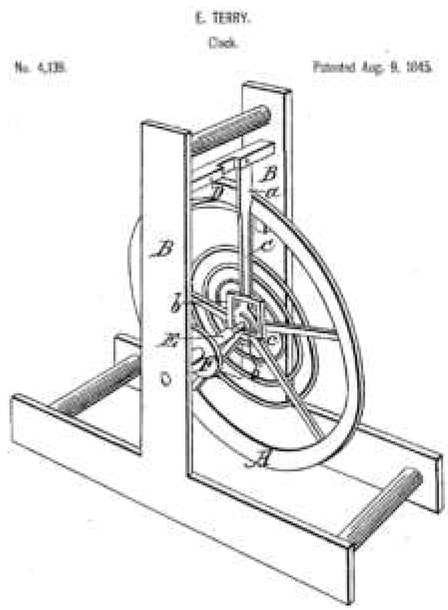

Figure 116: Eli Terry patent office drawing (Image Eli Terry in public domain)

During his tinkering, he improved the mechanism of the clocks. He received at least five patents throughout the years and had the first US patent for a clock, trying to secure his intellectual property. However, like many other inventors, he found out the hard way that having a patent and benefiting from a patent are quite different. Other clockmakers soon copied Terry's design, and a whole industry was created that supplied parts and built clocks based on Terry's ideas.

Some copycats even advertised their plagiarism as "Patent Clocks"! In some cases Terry took action, and for example he successfully sued the Reeves & Co company that plagiarized his clocks, forcing them out of business and had their stock of unsold clocks destroyed. But his work continued to be copied.

15.6 Retiring Again

Terry became very rich with his business. However, it was not what he wanted, and in 1820 he retired (again) (other sources say 1833). He did what he forced others to quit, making custom clocks by hand. His workshop was one of the last traditional clock shops, as he had forced everybody else out of the business. He died on February 24, 1852, at the age of eighty-one. Three of his sons followed in his footsteps and also became clockmakers.

Overall, he destroyed old-style clockmaking, but at the same time he made clocks affordable for everyone using mass production and interchangeable parts. He was definitely a pioneer in manufacturing! Now, **go out, follow his footsteps by making your products less expensive, and organize your industry!**

16 Material Flow and Traffic Flow – An Analogy

Christoph Roser, April 19, 2022 Original at https://www.allaboutlean.com/material-flow-traffic-flow/

Figure 117: Traffic Jam (Image B137 under the CC-BY-SA 4.0 license)

In lean, the concept of "flow" is important. But what is it? In this post I would like to look deeper into this important concept using another flow we are all (much too) familiar with: traffic flow!

16.1 The Analogies

Figure 118: Traffic and Material Flow Analogy (Image Victor Kibiwott under the CC-BY-SA 4.0 license)

There are a lot of similarities between material flow and traffic flow. Both parts and cars have to go from one location to another, because the parts or the passengers are needed somewhere else.

Usually, this travel is a waste and should be avoided, or at least reduced. Most people usually don't take the scenic route on their daily commute. The critical factors are a combination of time and cost, where less is better in both cases. With traffic, drivers want to spend little time in traffic but sometimes also want to avoid toll roads. Same with material. It should arrive fast, but air mail may be too expensive depending on the circumstances.

Figure 119: Empty Road (Image mark-weaver in public domain)

These travel times fluctuate. Sometimes the roads are free, but sometimes there is a traffic jam or another type of gridlock. Parts may arrive quickly, or are sometimes a bit delayed. For material flow this can happen both between factories (where we often have road transport, i.e., traffic again) or within the factories. Hence, the travel time fluctuates. Often, however, it is important for both the parts and the vehicles to be at a certain location at a certain time. Being too late is not good. Material that arrives too late often causes other delays. People who arrive too late may miss a connecting train or be late for an appointment. Hence, there is often a time buffer. Both parts and people are planned to arrive early to ensure that they are not late. The earlier they are, the less likely they will be late. At the same time, parts and even more so people don't want to sit around for a long time until they are needed. Hence, you need a trade-off between ensuring being on time and not waiting around for too long.

Figure 120: Part not found… An empty standard EUR pallet with a bit of plastic on top, transparent background (Image Roser)

There may also sometimes be mistakes. A wrong part may be delivered to the wrong location. I once drove two hours in the wrong direction since there were two towns of the same name. (Luckily, since it was a mini one-day holiday, we just enjoyed the other town, which was also nice). Maybe you went out to an appointment only to learn that the appointment was yesterday. Similar does happen with parts. Overall, there are a lot of similarities between traffic with people and transport of material.

16.2 The Differences

Figure 121: Annoyed Tired Young Man in Traffic (Image monstArrr with permission)

However, there are also some differences. Probably the biggest one is that we have our own will, and we care a lot about wasting time in traffic. Parts, on the other hand, do not care. Not at all. A part does not mind sitting in a warehouse for three years; a person, on the other hand, would mind quite a lot. Perhaps you've had kids in the back seat asking every five minutes, "Are we there yet?"

As an effect, a person will try to improve the situation. If there is a road closure, the person will try to reroute to reduce the additional delay due to the closure. A part will wait stoically forever. To improve the flow of parts, some overarching entity (a person in logistics or similar) needs to take care of the material flow. Traffic is mostly self-organizing. The government provides the roads and other infrastructure like bridges, and the traffic will organize itself using the available infrastructure. (Although, admittedly, sometimes the infrastructure could use an overhaul. Complaining about bad roads and bridges is popular in many countries.)

16.3 How to Reduce Traffic or Material Flow (In Other Words, How NOT to Do It)

Figure 122: This is an "expressway." (Image NWACHUKWUEBUKADAVID under the CC-BY-SA 4.0 license)

Before I talk about how to improve the situation, just for fun, let's talk about how we can make it worse. I DO NOT want to make it worse, but sometimes you can get good insights from such a thought experiment (sometimes called reverse brainstorming, or negation). The obvious is to take away infrastructure. If roads and bridges are closed, traffic will take longer. That is obvious, and probably not a great insight.

However, traffic will also get worse if a lot of vehicles are on the road at the same time. During rush hour, the infrastructure is hard pressed to handle the traffic, and a 15-minute drive can turn into a 45-minute torture quickly. This is not obvious in material flows, but also true. If you have too much material en route at the same time, it may overload the corresponding infrastructure for transporting and handling the material.

Another not-obvious analogy is increasing fluctuations. Watch the red cars in the video below (with thanks to Florian Palatini for his LinkedIn post on "What causes Traffic Jams"). One vehicle frequently overtaking and merging to become faster may slow everything else down, possibly even a lot more. It may not be obvious, but this also applies to material flow. Naturally, prioritizing one part over another accelerates one part, but increases delay for the other one. However, due to the additional effort in changing the sequence, the delay may be bigger than expected, and the average speed of all parts goes down.

The Video by yourslife partner is available on YouTube as "What causes traffic jams" at https://youtu.be/2Loi9YyOz4k

Figure 123: All rules are optional… (Image Timmylegend under the CC-BY-SA 4.0 license)

The last way to reduce flow is to ignore rules. The more people ignore traffic rules, the more chaotic it will be, and the more fluctuations will increase. Some vehicles may not arrive at all due to accidents. If you really want to mess up our traffic, make all rules of the road optional. (Okay, please don't! This is only a reverse brainstorming example.)

16.4 How to Improve Material Flow

Figure 124: Öresund Bridge in direction to Kopenhagen (Image Hajotthu under the CC-BY-SA 4.0 license)

So how do you improve flow? You should strive to have a fast transfer time (both people or parts) and also reduce fluctuations. You can probably get the largest improvement by providing AND maintaining infrastructure–although this may also be the costliest approach. Make sure you have proper space and tools for handling the material flow, and that they are in good working condition.

Try to level your material flow. Toyota prefers much smaller trucks more frequently than large trucks infrequently, as this improves material flow altogether.

The same with prioritization. While you may need to prioritize some parts sometimes, know that this will increase the chaos and increase the fluctuations for the other parts, potentially even much more than you expect.

Finally, have good standards that are used (the "rules of the road," if you will). This greatly helps with consistency and reducing fluctuations, allowing you to have shorter AND less fluctuating material flow delays. Overall, while the analogy is not perfect, I think there are quite some learnings we can take from traffic flow and apply it to material flow. Now, **go out, get your parts flowing consistently, and organize your industry!**

P.S.: This blog post was inspired by a post by Florian Palatini on "What Causes Traffic Jams." Many thanks, Florian!

17 Evolution of Process Placement at Toyota – Part 1

Christoph Roser, April 26, 2022 Original at https://www.allaboutlean.com/toyota-process-placement-1/

Figure 125: Ammonite Fossil (Image James St. John under the CC-BY 2.0 license)

When setting up a new production – or even when rearranging an existing production – one important decision is how to arrange your processes. I have written a lot on line layout, but this post will look at how the arrangement of lines evolved at Toyota. Some of their insights are now accepted wisdoms in lean, but many companies still struggle with it. This post also looks into the manning of machines, especially multi-machine handling. The blog post is based on the appendix in the Toyota Handbook from 1973.

17.1 One Person per Process

Figure 126: One process per person (Image Roser)

Toyota started out like many other companies, as a job shop. They had different processes, and one person was assigned one process. This is common, as it is the most intuitive way to set things up. The worker puts a part in the machine, starts the machine, and waits for the machine to complete its task before removing the part and adding the next part. The benefit of this approach is that it is easy to set up. It is also perceived to be easy to control, but as we will see later with the arrangement in sequence, there are better options.

In any case, this is often not a good way to organize machines. The obvious problem is that the workers have to wait, which is idle time and one of the seven types of waste (muda). It costs the company money, with no benefit for the customer and hence no benefit for the company.

Figure 127: Ford piston shop 1917 (not Toyota) (Image Ford in public domain)

When Toyota started out, they had their parts in boxes on the floor, which resulted in quite a bit of walking and searching. Ergonomics was not really considered, and the workplace was set up simply however the machine was designed. The workspaces were at different and often uncomfortable heights. A separate quality inspector was in charge of quality, before the material was moved to the warehouse and later to the assembly line. The attitude at that time was that a station with few completed goods was slacking off, and workers always tried to have a pile of completed products to show how much work they did. It was believed that "the more you have, the better."

If you are at least somewhat familiar with lean, the above paragraph should have set off multiple alarm bells in your head. Yes, even Toyota started out not lean (at least partially because they invented lean as they went along improving their production system). This example here is for the machining division, but they found similar situations in many locations in different plants.

17.2 Multiple Processes per Person

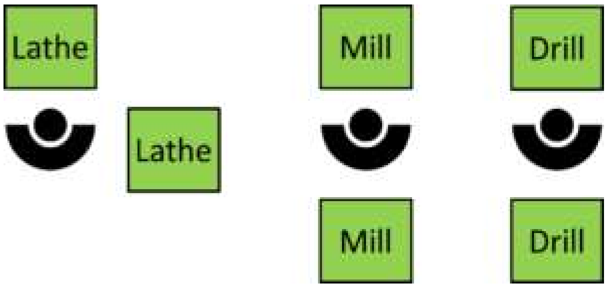

Figure 128: Two processes per person (Image Roser)

The intuitive next step is to have one person handle multiple machines. While one machine is processing, the other machine is loaded or unloaded. This reduces the waiting time and hence the waste. The first picture here shows workers handling two machines. The two machines could be cattycorner or opposite to each other. The "corner" solution may have less walking or moving of the operator. The "opposite" solution may have easier access for inbound and outbound material. Either way works, and your situation will determine which one is better.

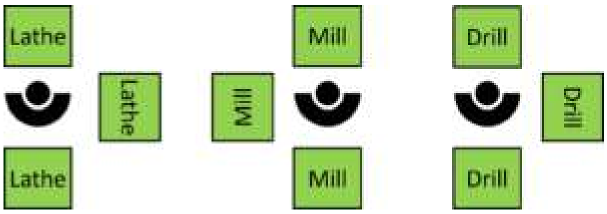

Figure 129: Three processes per person (Image Roser)

You can also try to have a worker handle three machines, as shown here. Depending on the arrangement of the machines, the material flow of inbound and outbound parts may be a bit more challenging, especially for larger parts.

You could also imagine workers handling four, five, and six different machines. This also raises the question of the material flow. As for the number of machines, theoretically, a worker can handle a large number of processes, with the drawback that these processes may have to wait a long time for the worker come back.

17.3 Number of Processes for One Person

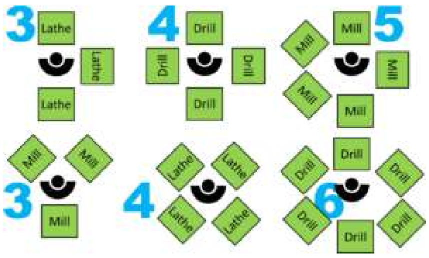

Figure 130: Process Placement Variants (Image Roser)

This brings up the question: how many machines should you have for a worker? This could depend on the work content for loading/unloading, and the actual machining time without a worker. If you have too many machines, the machines have to wait for the worker. This would under-utilize the machines, which is not ideal. If you have too few machines, the worker has to wait for the machine. This would under-utilize the worker, which is also not ideal. In lean, the time of the worker is considered much more valuable than the time of the machine. **If you have a choice, you should rather have the machine wait for the worker than the worker for the machine**.

Now, you could think that the ideal situation is a perfect match: the worker never has to wait for the machine, and the machine never has to wait for the worker. **This thinking is a common pitfall!** First, consider fluctuations (or mura if you will). Due to fluctuations, sometimes the machine is faster, sometimes slower. Even more so for the worker, who sometimes is faster and sometimes is slower (maybe he got disrupted, or there was a side job that needed to be done like taking away packaging material, etc.). Since the time of the worker is more valuable and (usually) more expensive, the machines should be faster. Even with some (normal) fluctuations, the worker should not wait for the machine. Instead, the machine should wait for the worker. Only for larger and unusual fluctuations (e.g., a breakdown) should the worker wait for the machine.

Figure 131: The customer takt defines the speed (Image Vladimir Voronin with permission)

Now you could think, *Okay, I will set up the system so that the worker is almost always busy, and the machines may have occasional waiting times due to fluctuations.* Better, but still one major flaw: your target speed is not the worker utilization. **Your target speed is the** customer takt**!** You should set up the entire system to match the customer takt. Of course, within this customer takt your worker should still not be idling, but the guiding target is the customer takt! For a more detailed explanation on how Toyota matches the production system to the customer takt, see my post on the Standard Work Combination Table.

In my next post I will continue the story of how Toyota evolved over time, starting with some highly suggested features for multi-machine handling. Your company probably also did not hit perfection on the first try, but needed multiple iterations and continuous improvement. And, since no company is ever perfect, this need for continuous improvement never stops, not even at Toyota. Now, **go out, evolve your company, and organize your industry!**

17.4 Source

Toyota Motor Corporation. 1973. Toyota Production System Handbook, Appendix. Translated by Mark Warren.

18 Evolution of Process Placement at Toyota – Part 2

Christoph Roser, May 3, 2022 Original at
https://www.allaboutlean.com/toyota-process-placement-2/

Figure 132: Nautilus Shell (Image Chris 73 under the CC-BY-SA 3.0 license)

Toyota did not start out as a lean company, but evolved over time. This was also not an automatic process. It needed a lot of care and attention, as well as continuous improvement and PDCA. This is the second post of this short, two-post series on the path of Toyota from a messy and hard-to-manage job shop to a much more efficient flow shop.

18.1 Highly Suggested Features for Multi-Machine Handling

One person per machine is easy. One person for multiple machines is a bit more difficult. Now the worker has multiple responsibilities. This requires better training, as the worker must be qualified on all processes he is taking care of. It is also a bit more of a balancing act. One feature that greatly simplifies this approach is to **have the machine stop automatically**. It is no problem if the machine waits for the worker to start the process. There is no harm to the product if it sits idle in front of the machine. However, it is a much larger problem if the machine waits for the worker to STOP the process. If the worker is delayed, the product may be damaged or completely ruined.

Figure 133: Roast Beef (Image Steve Johnson under the CC-BY 2.0 license)

Just imagine making roast beef. If the beef sits in the fridge, a one-hour delay does not hurt the beef. If the beef is in the oven, a one-hour delay is the difference between a nice meal and the charred remains of former food. Hopefully, it does not burn your kitchen down, either.

The work is also greatly simplified if the worker does not have to come back to the machine during one operation. If the worker has to come back to change a tool, or to set up the part for milling from a different side, or any other task during the processing of one part, this greatly complicates the work sequence for the worker. If possible, automate these intermediate steps as much as possible.

18.2 Arrangement in Process Order

One flaw that Toyota observed with this setup of one person handling multiple similar machines was a pile-up of completed goods. This multi-machine handling improved efficiency, but the system was not yet set up to handle these larger quantities of finished or semi-finished goods. In lean terms, there was no flow. The material was sitting around instead of moving to the next location.

Figure 134: Three processes per person in Sequence (Image Roser)

A possible solution would be to beef up logistics for a faster material handling… but Toyota found a much better solution: it arranged the processes in the order of which the parts were processed. Instead of one operator handling two or three lathes, another another or three drills, and another two or three milling machines, they had one operator handle the entire sequence. They changed their job shop into a flow shop, or at least into work cells.

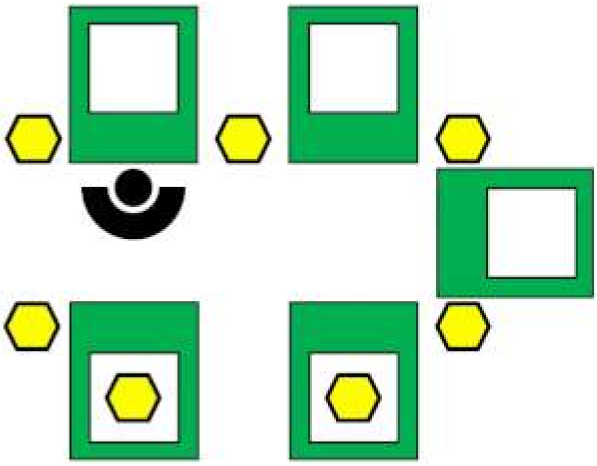

Figure 135: Animated example of a chaku chaku line (Image Roser)

This had significant benefits. The handling of the material was much reduced. Originally the worker was taking the part out of the machine for logistics to bring it elsewhere (next process? warehouse?…) so another worker could put the part back into the machine. Now, the worker removed the part from a machine and added it right into the next machine. Excess handling and transport was significantly reduced. The piles of material between the different machines disappeared almost completely. Lead time was reduced, cost was reduced, and the process became much more … lean. Instead of the shop floor looking like small isolated islands with little connection to each other, it became a basic flow shop.

Since the worker was in charge of a sequence of processes, this also almost accidentally improved the quality. Any problem caused by one process for a subsequent process was noticed right away, and was noticed by the same worker. This shorter feedback loop made it much easier to improve quality.

18.3 Arrangement in Flow

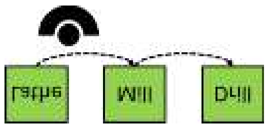

Figure 136: Processes aligned in a line (Image Roser)

Finally, Toyota arranged these processes in a line. This had the drawback of increasing the walking distance of the worker slightly. However, it solved another problem for Toyota: the overall target for the speed was based on the customer takt. However, it was difficult to set up the processes so the workload for one worker was exactly one customer takt (adjusted for the losses, i.e., adjusted using the OEE). They had many work cells where they needed fewer than one worker to match the customer takt.

Figure 137: Ford final assembly 1917 (not Toyota) (Image Ford in public domain)

For example, if a cell needs only 0.4 workers to match the takt, then you have to round up. (Note there are some exceptions where you can have a worker shift between cells, but this is tricky and also often wasteful.) You need 0.4 workers, but you have to place 1.0 workers in the cell. You waste 60% of the time of one worker. In longer lines where the processes are arranged linear (or U-shaped), you can have multiple workers in the same system. This makes it much easier to have a consistent workload for each worker, with the leftover free time usually pooled at the last worker.

In fact, many different ways of setting up the workers are possible, where you can adjust the number of workers to the customer demand. If the customer has a higher demand (a faster takt), you add workers into the system; if the demand goes down again (a slower takt), you remove workers again. Possible approaches are chaku-chaku lines, bucket brigades, rabbit chases, or one-up-one-down approaches.

This was roughly the evolution of Toyota from a very inefficient job shop to a much more efficient flow shop. Sure, you could optimize the job shop, but if you do not make the transition to a flow line, you will miss out on a lot of improvement potential.

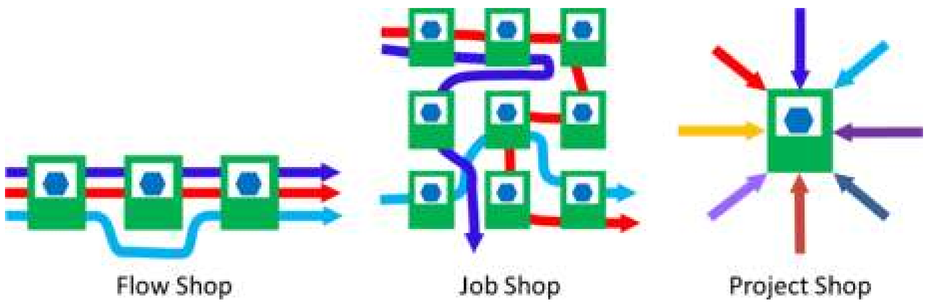

Figure 138: Flow shop, job shop, project shop (Image Roser)

These two posts gave a quick review of the evolution steps at Toyota from a messy job shop to a much better flow shop. However, the evolution does not stop here, and Toyota always continues to improve. It also was not necessarily a straight road, and Toyota tried some different approaches that did not turn out well and were reversed. I hope your company is also able to continuously improve, even if not every try is a success. Now, **go out, evolve your company, and organize your industry!**

18.4 Source

Toyota Motor Corporation. 1973. Toyota Production System Handbook, Appendix. Translated by Mark Warren.

19 The Problem of Industry 4.0: Data! – Part 1

Christoph Roser, May 10, 2022 Original at *https://www.allaboutlean.com/industry-4-0-data-part-1/*

Figure 139: Industry 4.0 and Data Network (Image microphoto1981 with permission)

Industry 4.0 is still a hot topic, even over ten years after the term was coined. Unfortunately, very often I find it to be much more hype than content. The examples where it actually worked well are few and far between, and the examples where *not much* was hyped as groundbreaking are way too frequent. In my view, a large problem of Industry 4.0 is the data, especially the data structure and the problems with analyzing the data. Hence, (yet another) short series of post warning on the difficulties of Industry 4.0 with a focus on the data.

19.1 Industry 4.0 – A Recap

Industry 4.0 is the fourth industrial revolution, after the first (the big one) with mechanization and steam power, the second with mass production and electricity, and the third with computers. The idea is to use computers in networks to leverage information for better speed, cost, quality, and safety (with a lot of buzzwords like cyber-physical systems, internet of things, big data, artificial intelligence, digital twins, smart factories, and many more). Depending on who you ask, the definition of Industry 4.0 may be quite different.

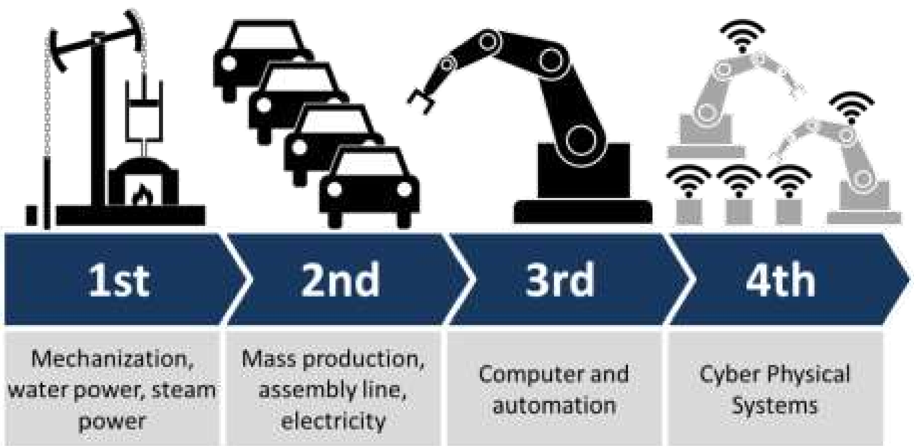

Figure 140: Industry 4.0 (Image Roser)

I have written quite a few posts with a critical look at Industry 4.0, trying to see What Works, What Doesn’t, Comparing It to Lean, and analyzing the data to see if it is a revolution (spoiler: no, or at least not yet), and I even had a series of posts for our Van of Nerds tour looking at the state of Industry 4.0 in Germany. Overall, I usually find much more hype and far fewer examples that actually work.

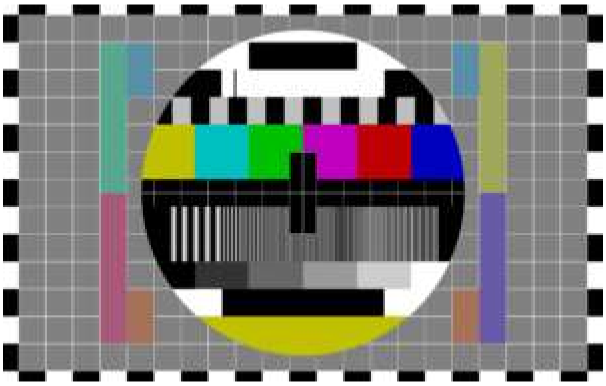

Figure 141: TV Test pattern (Image unknown author in public domain)

There seems to be a number of different causes for these many failures. Often, I find that Industry 4.0 is done not to solve a problem, but merely to do Industry 4.0. Lean improvements should always start with a problem to solve or improve, and doing something merely for the sake of doing something is unlikely to improve anything. Another problem is that the complexity of Industry 4.0 is often underestimated, and due to the fundamental differences in different factories with different products, it is hard to scale the system. You cannot just copy the software from a factory making cars to another factory making ice cream. The exception here is logistics, where the problem of moving things from A to B are similar in many factories. And another issue is the complexity of the data… which is the focus of this blog post.

19.2 On Data Complexity

Figure 142: Connected City (Image World Image with permission)

Industry 4.0 is very loosely defined. Pretty much anything with computers related to manufacturing could be seen as Industry 4.0 (although according to the diagram above, only computers would be Industry 3.0). The scale of the complexity also varies widely. I advocate to keep the problems small and manageable, because this will greatly simplify things and make a successful implementation much more likely. Smaller implementations are, for example, installing a new robot or even a cobot (collaborative robot – although this again would be industry 3.0), or using AI to analyze camera pictures to detect errors or to understand the inventory, or using RFID chips to analyze the inventory. The more complex the problem, the more challenging the implementation. Depending on the complexity, the following points on data may apply to a varying degree.

Figure 143: Amazon Manual Storage (Image Álvaro Ibáñez under the CC-BY 2.0 license)

Yet if you listen to (some) consultants, the holy grail of Industry 4.0 seems to be everything connected to everything else (internet of things, cyber physical systems, etc.). Everything collects data and sends it around on the cloud. This is most impressive… if it would work, which it usually does not. The closest I have seen are Amazon fulfillment centers (see my series on Amazon Fulfillment Centers). But I know of many more attempts that failed, usually because the people in charge underestimated the complexity. These "everything with everything else" attempts often have the largest issues with handling the data, and they get hit in full force by the effects outlined below. Hence again my advice: Keep it simple!

19.3 Merging the Data

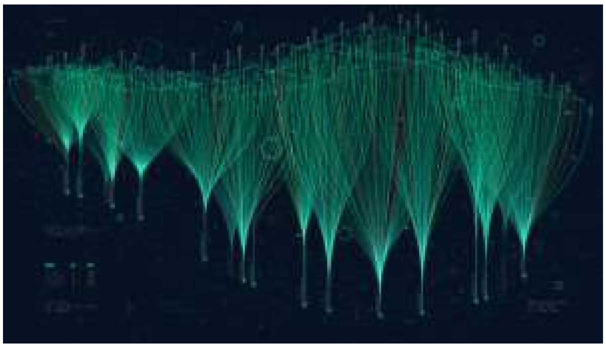

Figure 144: Industry 4.0 Merging Data (Image Max776 with permission)

The first step is often to get the data together in a common database. This is often easier said than done. You may have many different machines by different makers, which may have different data structures. Somehow you have to get all of these data into a joint system. Imagine a professor (like me) giving homework and then receiving Word documents, PDFs, Excel files, and PowerPoints. While it is not a problem for grading, it would be a problem to put them all together in a single file. It is often similar in Industry 4.0.

Even if it is the same data structure, the details of the format may still be different. If I give my students homework and tell them to deliver it in Excel, it may still be in many different structures. One student has column A as the time, another one as an index. Putting it together in one file is still a lot of work. In industry 4.0 it is even more complex, as the data is often more complicated than a simple Excel file. There may be lots of unintended consequences.

Figure 145: ERP System Illustration (Image TarikVision with permission)

As an example, think of the last time your company updated their ERP system. Going from one software to an upgraded software from the same maker should be no problem, right? You merely run the software update. If you have ever done that, then I am sure you winced. There are a myriad of things that can go wrong, and such “simple” ERP software upgrades are never simple, requiring extensive testing and trial runs to at least reduce the chances of a total company meltdown due to a ERP software problem.

You may also consider if you want to merge the raw data, or if you want to get pre-processed data. I often prefer to have all the raw data, but this is probably more a personal preference, and especially for larger systems the raw data can become quite big.

Overall, merging the data is a mess, and this does not even touch the potential problem of the ownership of the data and the willingness of one company to share the data with another company. For example, many modern machines can collect processing data, which is then sent to the maker to analyze predictive maintenance and other service problems. However, many companies (especially automotive) turn this data stream off right away, since they do not want the machine tool maker to know what and when they produce.

In my next post I will talk about cleaning up the data and subsequent steps. Until then, **stay tuned, and go out and organize your industry!**

20 The Problem of Industry 4.0: Data! – Part 2

Christoph Roser, May 17, 2022 Original at
https://www.allaboutlean.com/industry-4-0-data-part-2/

Figure 146: Connected Data Industry 4.0 (Image LoveVector with permission)

In my last post I started to look at the difficulties of handling data in Industry 4.0. I looked especially at the complexity and the often underestimated problem of merging data from different sources or machines. This second post of this two-post series finishes up this topic and will look at the also important and often underestimated task of cleaning up the data.

20.1 Cleaning Up the Data

Figure 147: Cleaning Up Data (Image Roser)

Once you have gathered all your data from different sources, you need to clean up the data. For example, if you collect data on machine stops, one machine may define a stop as a turned-off machine, whereas another machine defines a stop as any time not producing, whereas another machine may define a stop as merely waiting for parts. If you merge data from different machines, such different definitions can make or break any analysis. Usually they are a lot of work to sort out and clean up. I have the feeling that some non-data people believe an analysis is merely putting an Excel formula over the data, but in my experience these types of cleanup can take much, MUCH more time than the actual analysis.

Maybe I am an optimist, but I assume all data to have a meaning. Unfortunately, the meaning is by no means always clear, and even the one you actually need. Having data does not always mean having **useful** data. Often, a lot of work has to be done to turn a random collection of data points into some useful coherent data set.

Figure 148: Here's your data… (Image FerranRelea under the CC-BY-SA 3.0 license)

And this does not even include the possibility of faulty data. This even predates computers. For example, Charles Babbage (mathematician, philosopher, inventor, and mechanical engineer, 1791–1871) wrote, *On two occasions I have been asked, "Pray, Mr. Babbage, if you put into the machine wrong figures, will the right answers come out?" … I am not able rightly to apprehend the kind of confusion of ideas that could provoke such a question.* This holds still true nowadays: **Garbage in, garbage out!**

Maybe you have worked with an ERP software that has lots of data. But all too often, an analysis is completely flawed merely because the data in it is wrong. One intern in my former company once had to analyze the space needed for storage. He pulled the size of the storage for the different parts from the ERP system and analyzed… completely overlooking that the data was garbage. O-rings were stored on pallets, engine blocks in small boxes, and the data was a mess. He had to manually go through all the data to clean it up.

Figure 149: This needs good data! (Image Siyuwj under the CC-BY-SA 3.0 license)

By the way, having good data is not cheap. It is said that automotive companies pay around €50 000 just to maintain the data for one part number over its lifetime (not development or production, merely keeping the data up to date). Due to the complexity of their products, automotive companies are usually better at this, but even makers of washing machines or bicycles pay around €8000 per part number to keep the data at least somewhat straight. It is hard to estimate how much it costs to keep the industry 4.0 data for a plant aligned, but I believe the cost to be eye-popping. Again, not for installing sensors, hardware, or for software licenses, but merely to keep the data in the software at least somewhat clean. And this cost is usually not on the radar of most promoters of Industry 4.0…

20.2 Doing All of That Continuously

Figure 150: Lindt Data Panel (Image Roser)

Only after you have merged the data and leaned it up (weeks later) you can do a proper analysis. However, the power of Industry 4.0 is not in having the data analyzed half a year later; the power lies in having the analysis real time or at least very soon. Overall, you have two options. You can merge and clean up the data whenever you need an analysis. Or you set up the system to continuously clean and merge the data automatically. Doing it whenever needed is easier, but you have to do it again for every new analysis. Doing it continuously is much harder, as you need to program and set up the data collection and the data processing; but once it is cleaned up, it does not need to be cleaned again, and hopefully the data streams are usable as is (at least until the next machine is added or another machine or sensor is changed). Just like cleaning your home, cleaning it once is easy, but keeping it clean all the time is much more difficult…

20.3 Understanding the Data

Figure 151: Magnifying Glass On Data Charts (Image sasirin pamai with permission)

Finally, now you can start to analyze and understand the data. This can be anything from an Excel file with a manual analysis to a analysis of variance (ANOVA) to artificial intelligence (AI). This is where the Industry 4.0 people get excited again, but without all the merging and cleaning, it would be a futile exercise. Sure, the algorithm would give you a number, and if management wants a number, they will get a number. But… is it a correct number or is it widely off? Again, **garbage in, garbage out**! If you want data-based decision making, your data better be good! Are you leading the data, or are you led by the data? On a side note, especially in lean it is often difficult to get good data on the benefits of lean, even though they are there. Besides, a lot of your data will never get used. I had one example from maintenance, where they found out that they use less than 15% of the data they have. This is also somewhat understandable, as for example an automotive factory produces over 20GB of data per day, with an increasing trend.

20.4 Some (Theoretical) Attempts to Tackle the Problem

Figure 152: Theory on Blackboard (Image photosvit with permission)

This problem of messy data in different formats is not new. For example, there is the *Reference Architectural Model Industrie 4.0 (RAMI 4.0)*. This is a construct trying to organize the many different data levels related to Industry 4.0. It is a top-down approach to manage data, and like many top-down approaches in Industry 4.0, it never seems to reach the bottom for usefulness. I have not personally worked with RAMI 4.0, but I am not holding my breath. This problem is also related to the *I4.0 Maturity Index*. These initiatives seem to have originated in Germany, and suffer from the German Industry 4.0 tendency to wrap a theoretical construct around something but neglect the actual functionality.

Anyway, my summary is that using data, especially from different sources, is quite a pain. And again, I recommend you to keep your Industry 4.0 approaches small and the scope of the problem manageable. If you try to fix everything, you won't get anything done. If you don't even know what you are trying to fix, you will just get something that probably is not really useful except for glossy public relation fliers. Now, **go out, look for a manageable problem, do the diligent PDCA, and organize your industry!**

P.S.: Many thanks to Xie Xuan for some pointers 😐.

21 The Modern Way to Buy Screws

Christoph Roser, May 24, 2022 Original at
https://www.allaboutlean.com/the-modern-way-to-buy-screws/

Figure 153: VMI screws Inventory (Image Roser)

Screws, or more generally fasteners, are a main staple in most industries. Recently I visited a factory and saw a nice way to automate the procurement of screws and other fasteners. This Industry 4.0 solution is part of a vendor-managed inventory (VMI), where you not only buy the screw, but also the service of always having enough screws, and let the vendor manage the hassle of making sure there are enough screws. I found the example in this factory quite neat, and hence decided to tell you about it. Let me show you.

21.1 The Reorder Point Method

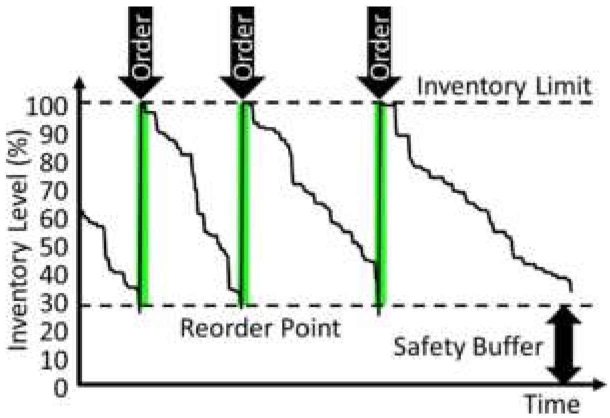

Figure 154: AllAboutPull Reorder Point (Image Roser)

The example I will show you is weightLOG®2 from the Swiss SFS group, which, among other things, makes fasteners. The theoretical basis of this vendor-managed inventory is very simple: it is a reorder point. You have your target inventory. Whenever your inventory falls below the reorder point, you order enough products to fill up the inventory again to the target level. This is a simple approach commonly found in industry. It is also a pull system. You can find more about it in my book All About Pull Production.

In theory, it is easy. In reality, however, you face the challenge of knowing how many products you have currently. You could simply use your ERP data… but we all know how accurate that is. It usually works better for larger and more expensive products, as it is easier to count engine blocks than it is to count screws. Hence, your ERP data is probably off, which could lead to excess inventory (not so good, but then, it is only screws) or a lack of inventory (which is bad, because a missing cheap screw will stop your assembly line).

It would be much more accurate to actually check the physical inventory instead of trusting the digital twin. But then, this is extra work for someone checking how much stuff you have. Again, this is easier for large and more expensive components than it is for screws. Some companies automate this using RFID or similar technologies, but again both the expense and the need to physically attach the RFID chip to the product makes it unsuitable for screws.

21.2 Order by Weight

The solution used by SFS was to check the weight. For this, they created a box that can automatically measure its weight, and send this information to headquarters. The smallest box measures 25g to 8kg ±15g, the larger box has 80g to 20kg ±40g. They also have larger solutions for 1kg to 100kg ±200g, 4kg to 800kg ±800g, and even a full pallet with 4kg to 2000kg ±800g.

You can see the diagram of the box below, as well as photos from different angles. The measurement comes from a integrated scale underneath each box. This scale through a cable channel is measured by some electronics in a box. This box also contains the battery and a BLE 4.0 (Bluetooth Low Energy) sender, which connects to a gateway or controller and from there to the mobile phone GSM network. In front of the box is a small label. A plastic protrusion protects the label from bumping into something and accidentally initiating an order.

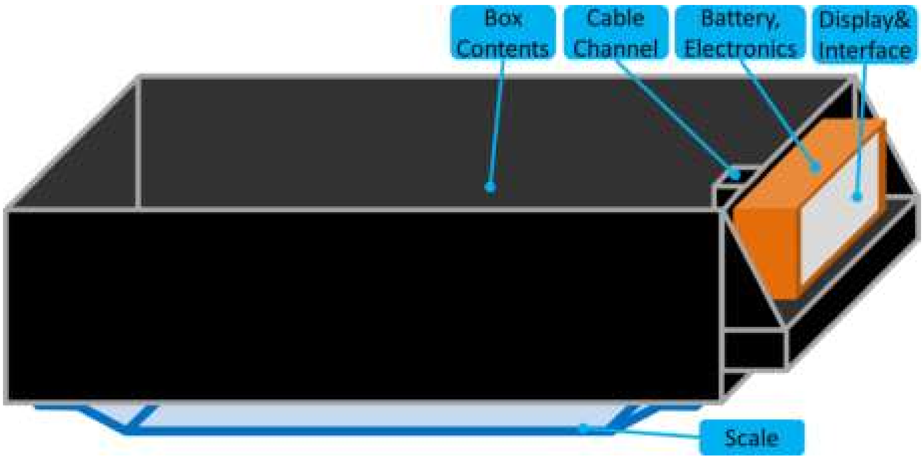

Figure 155: VMI Screws Box Diagram (Image Roser)

Figure 156: VMI Screws Boxes Overview (Image Roser)

Figure 157: VMI Screws Detail Inside Box (Image Roser)

Figure 158: VMI Screws Detail of Scale (Image Roser)

The label has, of course, all the information on the parts in the box (in the image below, a M3x8 screw). It also tells you the target inventory (here 275) and the reorder point (here 150). But besides the printed info, it also is interactive. If nothing is happening, then all should be fine. If the WLAN symbol is blinking, then an order has been issued. If the truck is blinking, then an order is already dispatched and on its way to the customer (i.e., you!). Behind the WLAN symbol is a button that can, for other models (the *pushLOG*), be pressed if you want to order manually, but this is inactive here.

Figure 159: VMI Screws Label Options (Image Roser)

21.3 The Order Cycle

The normal order cycle is simple. The box measures its weight at regular intervals. If the weight indicates that the content is below the reorder point, an order is issued to get the weight (i.e., the quantity) back to the target. This happens if the weight is below the limit for three measurement cycles. Hence, lifting the box up (and giving the scale a signal of zero) won't automatically order more parts. In regular intervals, the orders are put together and a pallet of screws of all types is sent to the customer. If the weight approaches a critical lower limit, they even have a rush order mode.

An employee of the vendor shows up and distributes the pallet contents to the different boxes. The new parts are added on top of the old parts, which is not really FIFO, but seems to be okay for screws. (They also offer a TurnLOG, where the box has two compartments to have a better FIFO sequence, similar to the two-box system).

In the factory I visited, they had a weekly delivery (collect orders until Thursday afternoon, pallet arrives Monday afternoon, boxes refilled on Tuesday), which suited them well for the quantity they needed. Larger factories may, of course, have more frequent orders. The factory had one central shelf for the vendor-managed inventory, but here, too, you may have multiple shelves in different locations all over your factory, as long as you allow the vendor access to your site.

21.4 Bugs and Kinks

Figure 160: VMI Screws Weight Error (Image Roser)

Of course, no system is perfect. For example, the scale has difficulties measuring weights below 100g. However, having an extra 100g of screws hopefully won't break your budget. Or, the batteries were promised to last forever, which happened sooner than they expected. Luckily, the battery idle voltage and under-load voltage is also transmitted wireless to the vendor (along with the weight, the time of the last connection, the RSSI signal strength, the firmware version, and the box type). Another problem was that an employee with a stronger grip and larger hands accidentally but frequently pressed the button when handling the boxes, hence accidentally ordering more screws.

Figure 161: VMI Screws Overfilling (Image Roser)

During my visit I also saw a few boxes that looked quite empty – which was somewhat okay since the workers also had a inventory of screws at their workspace. I also saw one box (shown here) that seemed to be overly full, with bags of still-packaged washers on top of the box.

Another problem was that initially employees left the screw shovel on top of a box… which of course changed the weight of the box. Yet another problem was that initially the shelf (also managed by the vendor) had a small protrusion to keep boxes from slipping out. However, if the box was paced too far forward, it stood on this protrusion, and lifted the scale off the shelf. This resulted in a wrong weight measurement and unnecessary orders as illustrated below. They redesigned the shelf since then.

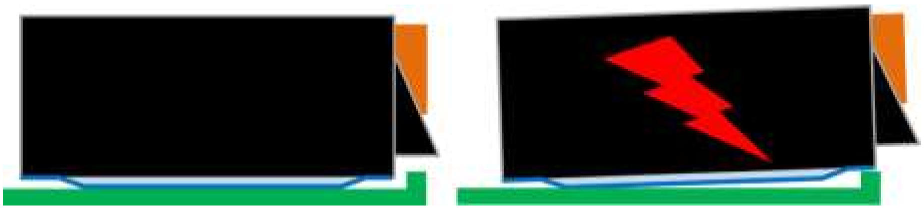
Figure 162: VMI screws Wrong Place on Shelf (Image Roser)

Despite all of these kinks, the plant quite liked this approach to the vendor-managed inventory of screws and other fasteners. Naturally, this is not free, but makes each screw somewhere 8–12% more expensive. However, now you no longer have the hassle of keeping track of your screws. They also haven't really had issues with missing screws, which is the whole point of this exercise. The system also requires trust in your vendor to deliver good quality and to bill correctly only for the consumed screws. SFS also offers third-party products in the same system, but this company was somewhat hesitant about that.

21.5 Alternatives


Figure 163: SFS PushLOG with two compartments (Image Roser)

SFS WeightLOG is a pretty neat system. STS also offers TurnLOG, where you order simply by turning a divided box around, pushLOG where you push a button, and more. This ensures a better FIFO sequence. But there are also many other options. You can also go non-digital with a classical two-bin kanban, but then you have to send the empty boxes (or at least the signal) back to the vendor. But there are many more digital solution. For example, Bossard also offers a similar Smart Bin. Just by googling I also came across Stockvue and their smart scales, eTurns and their SensorBins, MettlerToledo and their SmartShelf, KVT and their smart bin, and many more. I have seen myself in detail only the SFS, but overall I thought this is a quite neat Industry 4.0 solution. Now, **go out, let your trusted vendor take care of your parts inventory, and organize your industry!**

P.S.: Many thanks to Claudia Wagner and her team at Uster Technologies for showing me around in their plant, and for Torbjørn Netland for hosting me at the POM of the ETH during my sabbatical and making the contact to Uster.

22 Where to Start Your Kaizen?

Christoph Roser, May 31, 2022 Original at
https://www.allaboutlean.com/where-to-start-your-kaizen/

Figure 164: Kaizen Word Cloud (Image dizainstock with permission)

To become lean, you need to improve your factory. Continuous improvement (kaizen) consists of many smaller and/or larger improvements. However, often the first challenge is where to start this improvement. Let me dig deeper into the possibilities and challenges of picking improvement projects, with a particular focus on systems that have multiple independent production lines, which makes everything trickier.

22.1 Introduction

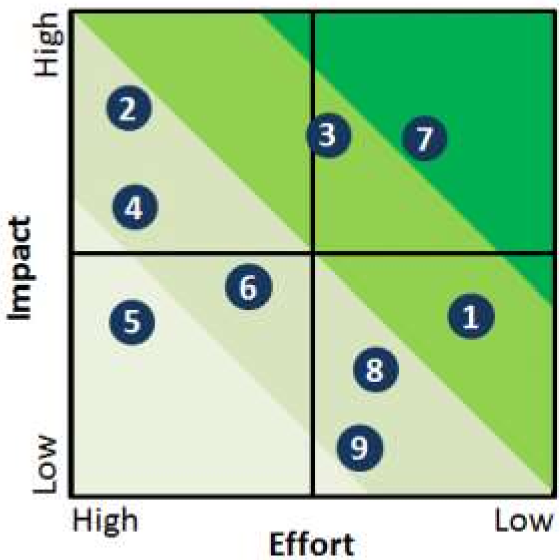

Figure 165: Impact-effort matrix (Image Roser)

I have written about managing lean projects before. I find it very important to limit the number of active projects to something manageable, especially for the critical capacity (i.e., the shop floor manager) who has to be involved in them all. If you have a number of possible projects, an impact-effort matrix is often a good way to narrow it down and select a manageable number.

But this sometimes leaves the problem of picking good candidates for improvement projects. In this post I will show you a few ways to find improvement projects for consideration.

22.2 Your Boss

Figure 166: Manager and Crystal Ball (Image AndreyPopov with permission)

The easiest way to find out what to do is to simply ask your boss. He may just tell you what you have to do. However, this is a flawed approach (even though some bosses like it a lot). It rests on the underlying assumption that The Boss Knows Best … or Does He? In reality, however, bosses are so far away from the shop floor that they do not have a good understanding of the shop floor. Even if they are closer to the shop floor (good!) the people on the shop floor may be better informed. The exception is of course a new employee who does not know or understand the shop floor yet.

Luckily, better bosses won't just tell you what to do, but involve you in the decision-making. Better bosses tap your knowledge to get a better result from your work. However, they should not leave everything to you. Just saying "do whatever you want" is not good either.

Ideally, the boss gives you a direction, sometimes with more and sometimes with less guidance, but always with support. This brings me to my next section.

22.3 The Overall Direction

Figure 167: Safety Quality Cost Time (Image Roser)

In lean, it is really helpful to work in the same direction of improvement over a longer period of time. This direction could be managed by a Hoshin Kanri. While details differ from company to company, it is usually a variation or selection of cost, quality, time, and safety. Here, too, if you want to improve it all, you may not get good improvement in any of those areas. Which one is truly most important area in need at your company? And "all of the above" is not really a valid answer, as this merely means everything is equally unimportant…

22.4 Single Material Flow

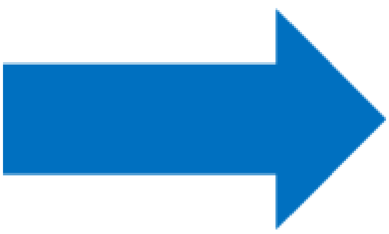

Figure 168: Single Blue Arrow (Image Roser)

If your priority is cost, time, or quality, then you should follow the value stream looking for waste, unevenness, and overburden (don't forget the last two). What areas in the value stream give you problems in your selected area for improvement? (If it is safety, work on the accident-prone areas).

Finding improvements for cost, time, or quality is easiest in a single value stream. If all (or most) of your value add goes through a single final line in your system, then you can just follow the line backwards looking for problems. The image below shows the Toyota Motomachi line, and while the line looks complicated, it is all a single merging value stream. Only a small fraction of the value add of the plant does not go through this single dominant line (for example, spare parts).

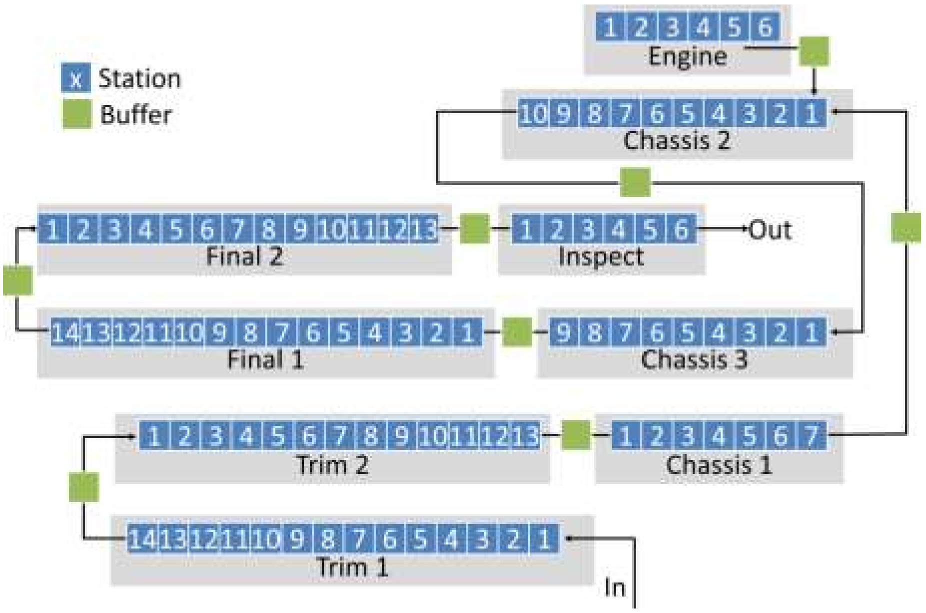

Figure 169: Layout Motomachi Plant Rotated (Image Roser)

22.5 Multiple Material Flows

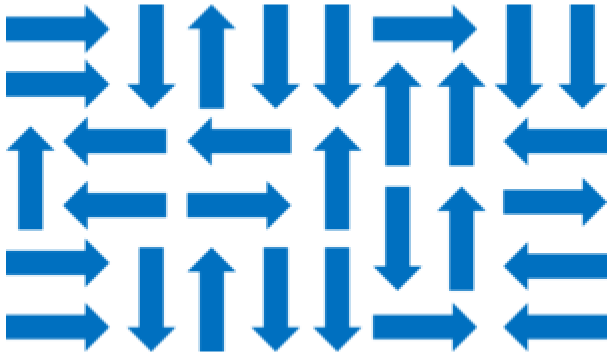

Figure 170: Many Blue Arrows (Image Roser)

Often, a plant has this single dominant line. However, many plants have multiple lines, and it may not always be clear where to start with kaizen. One example I visited recently had a whopping fifty different value streams, where each line attributes for roughly 2% of the value add of the plant (visualized below). These value streams making plastic parts were usually two injection molding machines in sequence with some additional processing and logistics in between. While there was some flexibility, most products could be produced only on one or two lines.

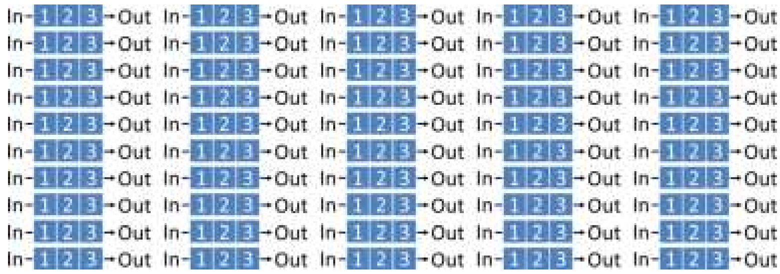

Figure 171: Fifty different value streams of equal importance… (Image Roser)

Here it is much trickier to decide where to do improvements. First, it is hard to decide which line to start with. All of the lines will have waste, fluctuations, and overburden. But which one is the most important one? Secondly, no matter which line you start to work on, it will influence only roughly 2% of the value add of the company. Instead of having one large and powerful lever like the single line-plant further above, you now have a multitude of smaller levers. Whereas the single value stream is a chain with a weakest link (quality, cost, time), now you have fifty chains, each again with a weakest link.

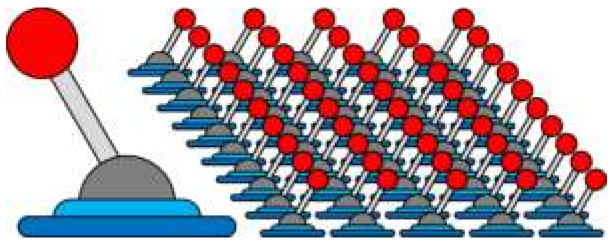

Figure 172: One Big 50 Small Levers (Image Roser)

Now, the worst thing you could do is not do anything. While by not doing anything you don't do anything wrong, you also do not improve either, and instead things will gradually get worse. You can worry a bit about which lever of the fifty is most beneficial, but at one point you have to invest time and money to pull this lever. And, chances are, there may have been another lever that was more significant, and you missed it. That is life, but it is better to do a smaller improvement than to do none at all.

A large lever in a plant with a single line is often large because the lever has many beneficial side effects along the line. It is also benefiting the majority of the products. An improvement in plant with multiple smaller lines will have much less beneficial side effects, and also affect a much smaller part of the products … **while still having potentially the same cost and effort!** You get much less bang for your buck, or for your efforts and time. The exception would be logistics, because improving logistics may improve the entire plant, even if it has multiple smaller and independent value streams.

As for finding relevant lines with good improvements, try to do your best to estimate the impact and the effort. If your target is quality, find out which products have the most frequent or most costly defects, and look at the lines producing them. Similarly for time, find out which products are often out of stock (for make-to-stock [MTS]) or have a bad delivery performance (for make-to-order [MTO]). If cost is your issue, look for products where your produced value is larger. Find possible improvements, compare them with the estimated effort, and pick the most promising ones, even though the underlying data is wobbly or fuzzy. Not doing anything would be the worst.

On a side note, small improvements that are little to no effort can be done regardless. If the workers want a better shovel to handle small parts, or if a tool is worn out, just fix the issue. At Toyota, small improvements are done anyway, without any cost and benefit analysis. Now, **go out, improve your value streams, and organize your industry!**

P.S.: Many thanks to Jonathan Folberth for the discussion that sparked this blog post.

23 Virtual Reality Factory for Training and Teaching

Christoph Roser, June 7, 2022 Original at https://www.allaboutlean.com/virtual-reality-factory/

Figure 173: Virtual Reality Vector Graphic (Image Paulina 26 with permission)

The COVID-19 pandemic and its distancing made teaching quite difficult. On-site trainings on the shop floor especially were no longer possible. **Torbjørn Netland**, Head of Chair of Production and Operations Management (POM) at ETH Zurich took this challenge as an opportunity and brought the factory to the students virtually. Let me show you his success.

23.1 Introduction

As mentioned in my previous posts, learning lean is best done by doing. Unfortunately, this is not always feasible for larger groups of students. Still, visiting and observing the shop floor is highly beneficial. Seeing the actual work, watching the value add and the waste, and following the material flow is very insightful and aids in understanding the system.

Yet, with COVID-19 this was no longer possible. Plants locked down, and external access was given only to essential suppliers and service personnel. Students ranked very low in their need to be on the shop floor, and companies tried to protect the health of their employees. For almost two years, plant access for students was not possible.

23.2 Exploring the Shop Floor Virtually

Figure 174: Torbjørn Netland (Image Torbjørn Netland with permission)

Prof. **Torbjørn Netland**, Head of Chair of Production and Operations Management (POM) at ETH Zurich, and also a fellow nerd from my Van of Nerds, and my host for my sabbatical at the ETH in 2022, was inspired by this problem and set out to bring the shop floor to the students virtually. He recorded 360° videos on actual shop floors, and created a virtual and interactive environment for the students.

23.3 The Gear

Figure 175: Ricoh 360° Camera (Image SimonWaldherr under the CC-BY-SA 4.0 license)

First, they needed the videos. For this they used a 360° camera. These are now readily available for consumers, costing around €500, depending on how fancy you want it to be. They can record photos and videos, and due to their multiple lenses they can record 360° all around.

If you watch such a photo or video on a normal viewer, the image looks terribly twisted as shown below. However, if the computer knows that it is a 360° video, the computer can stitch the image back into a sphere, and you can look in any direction. On a normal monitor you can turn by pulling the image with a mouse. YouTube has a filter option to search for 360° videos. However, it gets even cooler if you have 3D virtual reality glasses.

Figure 176: 360° Picture Universität Landau (Image Nadine Schlegel under the CC-BY-SA 4.0 license)

Figure 177: Woman with Virtual Reality Glasses (Image HammerandTusk in public domain)

You have probably seen those 3D virtual reality headsets. A good one also costs around €500, but if you want to supply every student with such a headset, it will quickly get very expensive. Luckily, a mobile phone can usually take care of the digital side, and the optics is not that expensive. Torbjørn provided his students with simple cardboard VR glasses to which they can add their mobile phone, as shown below. At roughly €10 per headset (custom printed in Switzerland), each student can get and keep their headset.

Now, you simply turn your head to look in another direction. For most people, this quickly feels quite natural (although a small percentage of the population gets seasick from VR glasses, and they have to use a normal monitor with a mouse).

Figure 178: ETH Virtual Reality Headset (Image Roser)

23.4 The Sites

Figure 179: Assembly line workers (Image bibiphoto with permission)

Next, they needed locations to take videos. Many factories are hesitant to let others take pictures or videos on the shop floor. However, Torbjørn has some good contacts, and found factories that permitted the taking of videos for training within the ETH. These videos are for internal use only, and hence full access to the videos is unfortunately only for ETH students. But I have seen the videos, and they are really good!

23.5 The Interaction

They got the videos, they got the gear, but the big effort is in making these videos interactive. Each video contains text boxes "floating in space" with additional information and explanations. Throughout the video there are also questions for the students to answer. Below is a screenshot of such an interaction.

Figure 180: Video Factory learning Screenshot (Image Torbjørn Netland with permission)

Keep in mind that this is still actual active learning, albeit with some gamification. This is not "Netflix and chill," but requires some work by the participants. The students have to pay attention, observe the videos, and then answer the questions. If they look in the wrong direction, they have to watch the video again. Below is a short video by Torbjørn showing the approach. See also his site factoryvr.ch.

The Video by POM_ETH Zurich is available on YouTube as "Teaching Operations Management with Virtual Reality" at https://youtu.be/3mUghoxnWLU

23.6 Quotations and Awards

Figure 181: Torbjørn and VR Glasses (Image Torbjørn Netland with permission)

This approach to a virtual factory course was well received and praised by the students. Below are just two out of many quotes from the hundreds of students that took the class so far.

- *The VR experience was tremendous! Just the right context, content and a very interactive delivery.*
- *I personally loved it, it is such an easy way to bring the production to the class!*

The students were impressed, and the companies where the videos were taken also used this for internal training. Additionally, Torbjørn and his team applied for different teaching awards using this concept, and won quite a few of them. Below is the (continuously growing) list of awards for this teaching concept.

- Gianluca Spina Award 2018 for Teaching Excellence and Innovation.
- 2020 Reimagine Education Bronze Award in Virtual/Augmented Reality.
- The Nigel Slack Teaching Innovation Award at EurOMA 2021.
- Top Three finalists of the KITE Award of the ETH Zürich

23.7 Academic Publications

As this is an university, the approach was also presented academically. Here is a selection of papers on this concept.

- Netland, T.; Lorenz, R.; Kwasnitschka, D. and Senoner, J. (2021), An VR app to teach operations management. The 28th EurOMA Conference. Nigel Slack Teaching Innovation Award.
- Netland, T., Fleischner, O., Brown, K., and Maghazi, O. (2020) Teaching operations management with virtual reality: Bringing the factory to the students. Journal of Management Education, 44(3), 313–341. (an earlier version of this paper was presented at EurOMA 2018)
- Netland T., Lorenz R., and Senoner J. (2019) Teaching Lean with Virtual Reality: Gemba VR. in: Rossi M., Rossini M., Terzi S. (eds.), Proceedings of the 6th European Lean Educator Conference. ELEC, Milano, Italy, 12-13.11.2019, Lecture Notes in Networks and Systems, vol 122. Springer, Cham.
- Gottini, G., Solari Bozzi, L., Kunde, M., Lorenz, R., and Netland, T. (2021) Creating VR content for teaching operations management. Whitepaper, ETH Zurich, Zurich Switzerland.

Overall, it is a novel way to bring the shop floor into the virtual classroom. This will be useful even after the COVID-19 pandemic is over. Now, **go out, look at your shop floor, and organize your industry!**

P.S.: Many thanks to Torbjørn Netland and his team at the Chair of Production and Operations Management (POM) at ETH Zurich for hosting me during my sabbatical and for giving me access to the videos.

24 How to Look Good at the Cost of Your Successor (Please Don't!)–Part 1

Christoph Roser, June 14, 2022 Original at https://www.allaboutlean.com/look-good-at-cost-of-successor-1/

Figure 182: Dog Peeing on Stone Stack (Image humboldthead under the CC-BY 2.0 license)

This post series will be an unusual one. I will tell you how to look good in manufacturing at the cost of your successor. Of course, I do NOT want you to do that. Not only will there be no improvement, but instead the plant will be worse in the long run at the cost of a short-term benefit. This is a somewhat sarcastic post on the dirty tricks you can use to look good, while at the same time driving your (future) plant into the ground. The responsible managers of course will be somewhere else before the inevitable happens. Even though the approaches below are bad for the plant, I am sure some managers will use this as a checklist. But I hope that even more people will see it as a list of warnings for bad managers.

24.1 The General Idea

Figure 183: Business fraud (Image Brian Jackson with permission)

Managing is not easy. Making the right decisions and improving your company is difficult, especially if the available information is uncertain and incomplete. Sometimes, managers find it easier to simply pretend to do good and fudge the numbers instead of improving the bottom line. I have written about this before, for example How to Misguide Your Visitor, or a whole series on Lies, Damned Lies, and KPI on how to fudge numbers, the effect of number fudging (it promotes liars), and possible countermeasures (e.g., go to gemba).

This post looks at another shady trick, where you save money now at the expense of the future of your company. For continuing success, you need to invest into the future of the company. Failure to do so will save you money now, but will damage or even destroy the company later. Unfortunately, some managers are more interested in their career than in their company. To be fair, some companies are also more interested in their company than in their people, hence often this is also a case of mutual disrespect. It seems like this is more likely to happen in publicly traded companies, where the quarterly stock performance is more important than the long-term outlook. Privately owned companies, often owned by the same families for decades, seem to have a much longer-term view.

Figure 184: Garbage in a Forest (Image MOs810 under the CC-BY-SA 4.0 license)

All these dirty tricks below save money now, but the damaging effect will be visible years later. Even better when the damage cannot be properly estimated now or even later. In any case, by then the manager is long gone, presumably promoted for saving so much money. Ugh! Anyway, let's talk how to drive the company into the ground while a manager jumps up.

24.2 Maintenance

Figure 185: Red Oil Can (Image unknown author in public domain)

Maintenance is a prime example where the benefit of the expense is delayed. You reduce the number of people (labor cost) or give them additional tasks, reduce their qualification (cheaper labor), cut the spare parts inventory (less tied-up capital), and more. At first glance, you have saved the company some money. However, the long-term outlook will be worse. If you cut maintenance like this, the machines will still work… now, since the current machine performance depends on past maintenance. But it will be much worse in the future. Depending on your plant, it may take one year, three years, or even more than five years, before the number of breakdowns increase, the spare part availability goes down, and generally up-time and quality becomes worse. In my experience, this is a popular way to cut costs in quite a few plants.

24.3 Quality

Figure 186: Boring Inspection (Image SeventyFour with permission)

Similar to maintenance, saving money on quality can also be seen only much later. This, however, depends on your customer. Some customers (for example, automotive companies) regularly check quality, and will rip your head off (verbally and legally) if your products are not up to expectations. Private consumers especially do not have the ability to test, nor do they have a large sample size to evaluate quality. Even worse when the parts are made in another country with a different legal system, or where the legal system may even support companies to evade responsibility. Some countries even have a reputation for bad quality.

Figure 187: Broken Washing Machine (Image diego cervo with permission)

For example, if your washing machine breaks, are you just unlucky, or are there thousands of other customers who suffer from a low-quality product? You will know only over time from anecdotal evidence on social media. Even then, it will be much more difficult to get compensated (*Sorry, your warranty has expired…*). It would be different for a laundromat-chain with thousands of washing machines, as they know quickly if products are bad, and for them it is worthwhile to make a stink about it. They also have much better chances of getting at least some sort of compensation (free maintenance, reimbursement, replacement,…).

Figure 188: Unhappy Woman with Mobile Phone One Star Rating (Image Krakenimages.com modified by Roser with permission)

In general, customers who order many parts from you will find quality problems quicker and can put much more pressure on you than customers who order few items from countries with a dubious legal customer protection. A shady manager can save a quick buck in a company with a good reputation for quality by using cheaper parts and materials, loosening tolerances and standards, reducing testing and easing testing criteria, and then leaving before the customers take notice and the reputation of the company nosedives. I am not going to name examples, but it has happened, is happening now, and will happen in the future. You probably know a few examples yourself.

In my next post I will continue with many more areas ripe for such manipulation, like service, research and development, improvements, and training, before my last post finishes this series with the worst one (employee motivation) and the one easiest to spot (sell the plant and rent it back). Keep on reading for lots of more possibilities for skullduggery. Hopefully, these do not happen at your plant, although chances are that in at least some areas the cuts may be larger than sensible, although nobody really knows how much the future impact really will be. Now, **go out, do actual improvements instead of just pulling expensive money from the future, and organize your industry!**

25 How to Look Good at the Cost of Your Successor (Please Don't!)–Part 2

Christoph Roser, June 21, 2022 Original at https://www.allaboutlean.com/look-good-at-cost-of-successor-2/

Figure 189: Dog peeing Fire Hydrant (Image MarkBuckawicki in public domain)

This is the second post in this short three-post series on how to look good while driving the plant into the ground. Again, the following is intended more of a warning on how NOT to do it, even though I fear some may use it as a checklist. My hope is that even more see the signs and can stop it, or at least not reward the person in question for this type of skullduggery. I will also talk briefly about how to recognize and counteract this type of behavior for the long-term health and success of your plant. In the last post I gave a brief introduction, and then talked about looking good now in maintenance and quality at the cost of the future performance. Let's continue the different areas that are vulnerable to such shady tactics.

25.1 Service

Figure 190: Grumpy Customer Service Representative (Image Andy Dean Photography with permission)

Service is almost the same as quality. Here, too, you reduce the number of service agents, meaning the customer has to wait longer for a response or a repair. You reduce their qualification (and hence their salary), meaning they may not be able to fix problems on the first try, or even ever. You reduce the tools and spare parts they have to carry along. All of this saves money, but the customer bears the damage. Here, too, the goal of the shady manager is to be promoted to somewhere else before the customer notices the system implodes.

I have witnessed this myself in an (unnamed) company, which once had an outstanding reputation for customer service, both with industrial and private customers. However, the number and qualification of the service personnel has been cut drastically, and now customers actively avoid this company because of the lousy service. It was a shame…

25.2 Research and Development

Figure 191: Theory on Blackboard (Image photosvit with permission)

Research is another expense with only a future benefit. Researching technologies, developing new products, and generally staying competitive with your technology costs money. This can be cut by reducing staff and their qualifications, squeezing even more projects on even less developers. The delay depends on the development cycle. How long do your products take from the idea to the market? That's how long it will take for the problems to appear. Again, the manager in charge tries to be elsewhere when this happens.

Figure 192: Overworked crying businessman (Image Wolfgang Zwanzger with permission)

I have firsthand stories of (again unnamed) development departments that went from three concurrent projects to twelve concurrent projects while reducing manpower. People have quit because of the constant shortage of everything, especially shortages in the availability of people to do the work. On paper it looked like they even did more research (twelve projects instead of three), but only when you looked closely you would find out that all of the projects were VERY delayed, and the quality of the products suffered immensely.

25.3 Kaizen (Improvement)

Figure 193: Up and Down Arrow (Image blackboard with permission)

You not only need to research and develop new products, you also need to research and develop new ways to make these products. Here is one of the core areas of lean manufacturing, improving your system.

From pull to SMED to better standards, there is a lot of potential. However, for all we wish it, these improvements are usually not free but take time and often also money. You need people to decide on a problem, analyze it, develop solution(s), implement them, and then actually verify if they really work (PDCA!). Like maintenance, however, the effect is mostly in the future. The current system works, and without improvement will only gradually get worse.

Hence, it is easy to cut cost at the expense of the future of the plant by reducing available capacity for improvement and loading more work on the same people… except in my experience this has often already be done. Shop floor improvement projects often heavily depend on foremen and shop floor supervisors, but they are already much overworked. A typical foreman in my experience manages 20+ workers on the shop floor, including their schedule, tracks data, is the first responder if something breaks… and then has pretty much no time left for actual improvement and just tries to wiggle through with minimal effort (i.e., time). But maybe you can squeeze them even a bit more (Don't!), telling them to *work smarter not harder* (Don't) or cutting another supervisor out (Don't!).

Figure 194: Shop Floor Discussion (Image pressmaster with permission)

A positive counterexample here is Toyota. Toyota is known for its excellent manufacturing system, giving them quite good quality and one of the best probabilities of any car maker. But you would be surprised to see how many people Toyota has to make this happen. There are many, MANY people on or near the shop floor who completely or partially have time for improvement projects. And, when I say partially, I don't mean another 20% on an 130% workload, but really available time to do things properly. It is quite an expense, but the benefit is very well worth it. Actually, I live in constant worry that one day Toyota will have a weak CEO that cuts these costs, and then ten years later Toyota will be just like GM or Volkswagen.

25.4 Training and Qualification

Figure 195: Child at School (Image Russell Lee in public domain)

Yet another area where you can cut cost now but (your successor) suffers later from it, is training. Keeping your workforce qualified and up to date is an expense that is usually well worth it. Reducing and skipping trainings saves money now, but will lead to a less qualified and less motivated workforce. My best experience regarding training was with McKinsey. During my three years at the firm, I had on average at least two full days of training per month, sometimes even more. For the rest of my career in other companies, however, I considered myself lucky to get even two days of training per year. Overall, my feeling is that expenses for training and qualification are already cut significantly in many companies.

The next post will look at the worst such manipulations, burning the motivation and goodwill of the employees for a quick buck, and also at the one easiest to see (sell the plant and rent it back). It will also look at how this often progresses, not as one drastic elimination but rather death by a thousand cuts over many years and many managers. But now, **go out, improve your plant, and organize your industry!**

26 How to Look Good at the Cost of Your Successor (Please Don't!)–Part 3

Christoph Roser, June 28, 2022 Original at https://www.allaboutlean.com/look-good-at-cost-of-successor-3/

Figure 196: Dog peeing on Concrete block (Image Kapinosova with permission)

This is the last of my three posts on how to benefit at the cost of your successor. And again, please don't. This is more of a warning on how to damage the plant for the benefit of the manager. And again, I hope rather than someone using this as a to-do list, someone uses it to see dangers. This last post looks at the worst "trick" of them all, burning the goodwill of your employees for a quick buck. It also looks at the one easiest to see, selling the plant and renting it back.

26.1 Employee Motivation

Figure 197: Unhappy employee resignation (Image Chatchai.wa with permission)

Possibly the worst way to hurt a plant is to burn the goodwill of your employees for a quick buck. Let's assume an optimistic case where your workforce in general is motivated and is in support of the plant and its management. Note that I said it is an optimistic case, not a realistic one, for most companies. If management asks for some extra effort, some "midnight oil," or similar, employees may be willing to pitch in. However, the longer the manager expects his people to go above and beyond their duty, the less willing they are to do so. Morale goes down, and when a true emergency arises, the willingness of the employees to pitch in may be gone. I personally consider burning the goodwill of your people for a quick buck the worst of these shady practices, as a broken motivation is the one hardest to fix. Or, the manager promises a promotion/raise/perks/bonuses/home-office/etc., but the promise never materializes, and since it was not in writing, the employee has no legal approach to claim the perks. Yet another morale burnt for a quick buck.

Figure 198: Striking Workers (Image Bastian Greshake Tzovaras under the CC-BY-SA 2.0 license)

It seems, the USA as a whole is right now experiencing such a "great resignation" in the workforce, where employees are no longer willing to take the abuse that managers often still take for granted. Hopefully, it will change the USA for the better.

Also, please note that not all broken plant motivation is the result of such shady manipulation; it may also be the result simply of management errors, miscommunication, neglect, or, generally, a lack of respect.

26.2 Sell Your Plant and Rent It

Figure 199: For Sale For Rent Factory (Image Roser)

There may be another big expense, but this one may already be paid: the property your plant sits on and the machines inside. However, there is a (shady) way to get it back. Just sell your plant and your machines. But you need the plant and the machines to produce, you say? No problem, just rent it back from the new owners. You generate a huge incoming cash flow at the expense of a smaller recurring cost.

You hopefully already see the problem. In the long run, renting may be more expensive than owning. It also makes your plant vulnerable. What if the new owner does not want to extend your contract, but instead wants to rent or sell it to the competitor? Or have a housing project built on the property? Any change or improvement is also more difficult. Want to drill a hole here or remove a wall there? You need permission from the owner. Are you now liable if there's contamination of the ground if the new owner wants to build an elementary school on the property? No matter what, there are now at least two legal parties (and their well-paid lawyers) that have to sort things out.

Figure 200: Calculator and Money (Image unknown author in public domain)

As for the "positive cash flow," there is another risk to shady managers. For the other entries in this series (maintenance, quality, service, research and development, and improvement), the savings can be well calculated by cost accounting. The future problems, however, can usually not be determined. What is the cost of unhappy customers? It is there, but it is hard to put a number to it. Yet, if cost accounting can't calculate it, it simply assumes zero. Hence, for maintenance, quality, etc., you have a measurable savings, but an unknown and hence accounting-wise zero future cost.

Not so for selling your plant and renting it back. The future rent is well known, and cost calculation can determine the current cost of future recurring expenses. Hence, if someone does the math, they may actually find out that your "positive cash flow" for selling the plant is actually a negative cash flow if future costs are included. Let's better hope nobody does the math, right?

Because of this – literal – accountability, selling and renting it back is not common. But it has happened. However, you find it more commonly with machines, not so much for selling them and renting them back (although this has also happened), but with renting them outright, forgoing the initial expense at the cost of a regular fee. Properties can also be rented if the company does not have the cash to buy. It may even make sense to rent property and machines instead of buying them if the cash flow is not available.

Figure 201: Forklift with Load (Image Patsy Lynch/FEMA in public domain)

Also very popular is to not rent a machine, but to pay a fee for the availability of a machine. Forklifts especially are often provided by an external service provider, and you pay only for the availability of a working forklift. This may even make sense, as the forklift provider benefits from an economy of scale, and it is easier and cheaper to manage and maintain a large fleet of forklifts than to have a person taking care of three forklifts on the side. Still, you should look at the numbers if renting or a service fee is truly the better option than buying.

26.3 Summary

Figure 202: Insecure Manager (Image STUDIO GRAND OUEST with permission)

There are probably more such areas vulnerable to such shady approaches for managers to benefit at the cost of the future of the plant. Any place where someone can save money at the cost of future performance could be abused for such dirty tactics. Yet, it is often not easy to see for the next level management when it happens. There are many situations where it is quite possible to improve expenses for maintenance, quality, service, research and development, improvements, and training without damaging future performance. In all of these cases, the impact on the future performance is very hard to estimate. The only exception is when someone sells the plant and then rents it back, where you can calculate the future cost impact quite easily.

But for everything else you need a very good understanding of the system to estimate how a reduced service department, for example, will impact customer satisfaction and subsequently sales. Probably the people in the respective departments (maintenance, quality, service, and research and development) know best, but then they are also usually biased toward NOT reducing their department. Even more complicated: The resources of the plant are limited, and not every department can get the resources it wants to have, or maybe not even the ones it needs. This makes it hard to understand how much to allocate where.

Figure 203: Death by a thousand cuts (Image Roser)

Additionally, it is rare for a manager to make drastic cuts to these areas. It is more a death by a thousand cuts, reducing a little bit here, cutting a little bit there, and over multiple years and often multiple generations of managers, you end up with the situation that some of you, unfortunately, already have. The plant is "saved" into the ground. In German we even have a word for it: *Kaputtgespart*!

This happens not only in manufacturing. Just by listening to the news you can find many examples where someone avoids problems now at the cost of the future. For example, politics is a ripe topic for that, from how to finance future pensions (where the problem can be calculated well) to the quality of the school system (where the future impact is anyone's guess).

This concludes the three-post series on a rather odd topic. I was hesitant to write about this, because I usually try to tell you how to do it. But sometimes there is also value in seeing how NOT to do it. Hence, I hope you enjoyed these three posts. Or, more likely, you winced at all the examples because you have seen someone do this. Anyway, **now, go out, do the right thing, and organize your industry!**

27 The 6R Goals of Lean Manufacturing

Christoph Roser, July 5, 2022 Original at
https://www.allaboutlean.com/the-6r-goals-of-lean-manufacturing/

Figure 204: Goals 6R tiles (Image Roser)

Lean manufacturing aims to improve manufacturing. In this post, I would like to look at the 6R goals and clarify them. The 6R are **right product, right place, right time, in the right quantity and quality, and at the right cost**. It has a lot to do with logistics, not only for the final product, but also for the raw materials and intermediate components. Let's have a look:

27.1 Introduction

Figure 205: Taiichi Ohno (Image unknown author in public domain)

The goals of lean are often summarized in a simple sentence: **the right product at the right place, the right time, in the right quantity and quality and at the right cost**. These are also sometimes simply called the 6R. The first four (right product, right place, right time, and right quantity) are all about logistics, highlighting again how important functioning logistics is for an efficient manufacturing process – or really anything related to products.

Taichi Ohno mentions this in similar form multiple times, e.g., *each process receives the exact item needed, when it is needed, and in the quantity needed* (Ohno, Taiichi. 1988. Toyota Production System: Beyond Large-Scale Production. p. 4). Or similarly for logistics in the same book (p. 15): *to procure only what is needed when it is needed and in the amount needed*.

27.2 Right Product

Figure 206: 6R Tiles (Image Roser)

This is the obvious one. You need the right product. Surely you've had the experience in your factory, too, where the incorrect product was delivered. Maybe the label was wrong, and the content of the delivery did not match the description. Maybe the delivery order was incorrect, even though the label of the shipment was good. In any case, the wrong stuff arrived.

This could be either raw materials or semi-processed parts within your factory for further processing or for shipping, or a finished product to the customer. If it is within your factory, you are now unable to produce or transport the desired item, and have to reschedule your production or find the right item – fast. It also does not matter how valuable or expensive the product is. Even if you are missing a simple O-Ring, you cannot complete the car. You also have to find out what item the incorrect item was and bring it back to storage, return it to sender, or scrap it.

It may be even worse if the incorrect item arrives at the customer. The shipping back of the old item and the outbound shipping of the new item probably takes more time than an item moved around within your factory. All the while the customer has to wait for the missing item, which causes additional expenses on the customer side.

27.3 Right Place

Figure 207: Delivery Man With Parcel (Image nruboc with permission)

This is also pretty obvious. You need the items where you need them. Having the right product but at the wrong location is a hassle, as again it causes delays where it is needed, and extra work to reroute the item to the correct location. If you receive parcels at home, you may have gotten the message "Parcel is at a neighbor's." Well, have fun running after your goods.

27.4 Right Time

Figure 208: Time Spiral (Image mipan with permission)

The right time is probably the toughest one. Because the right time means not too late but also not too early! If the item is late, you again cause delays and rescheduling at the receiving side. Earlier is better than late, but earlier increases inventory, which also requires storage space, tied-up capital, and a multitude of other unpleasant side effects. Ideally, the goods arrive neither too early nor too late, but just on time, which in lean, due to a grammar mistake in Japan, is called Just in Time (JIT).

JIT is best achieved in a balanced production line where all processes have similar speeds. The previous process is likely to have a part ready just when it is needed by the next process. It becomes more complicated if there are separate logistic processes involved (e.g., forklifts or trucks) or if you do not have a flow shop but a job shop. In this case, it is better to be early than late, but try to reduce the "earliness." Average Western plants have around two weeks of inventory in the inbound warehouse, excellent Western plants have around two days, but the best Toyota plants have around two hours of inbound inventory. There is also no formal definition of just in time, and I remember a tour at a major German car maker where the guide in the middle of a overflowing warehouse called this their "just in time inventory." Well, in my view piles of warehoused materials are not a Just in Time inventory. Or for another example, a plant that shipped *just in time* within three days from the external warehouse across the street. Three days to cross a road is also not just in time for me!

27.5 Right Quantity

The right quantity is sort of a combination of the above. If you have too many parts, you build up inventory. If it is a customized item, you may not even need it and have to return or scrap it. If it is an item with future use, you have to store it somewhere (including all the data management). But having too much is still better than too little, where again the processes have to stop and cannot make all of the required products.

27.6 Right Quality

Figure 209: Defective Brick (Image Sergey Chuyko with permission)

Quality is an important aspect in lean. Making defective products will cause lots of follow-up problems. At the least, you need to rework or scrap the defective item, and this is if you find the problem right away. The farther a problem goes down the value stream, the more expensive it will be to fix it.

What not everybody knows is that bad quality also influences the problem with the right quantity. If you have an average defect rate of 20%, in average 20 out of 100 parts are defective. If you need 100 parts, how many do you produce? Mathematically this would be 100/80%=125 parts. Unfortunately, your defect rate is not constant but fluctuates. If you make exactly 125 parts, assuming 20% (25 parts) are defect, you may end up with more good parts if the pass rate fluctuates better than 80%, and you will end up with more than 100 good parts, having again all the storage issues for excess material, or you may have to throw them out if they are custom made. If the pass rate fluctuates below 80% and you have less than 100 parts, you are again short on parts. At one point I worked in a plant that printed cardboard packages, and their defect rate was not so hot. They constantly had to overproduce and throw away perfectly good products because the customer did not need more than he ordered.

27.7 Right Cost

Figure 210: Piggy Bank (Image Ken Teegardin under the CC-BY-SA 2.0 license)

The "right cost" is probably hardest to understand. While the requirement is sensible, it quickly becomes fuzzy if you try to define the "right cost." All other *rights* above are usually pretty clear. Right product? Part number! Right place? At the place of consumption. Right time? Exactly when it is needed (although here fluctuations in the demanding process make this also a bit trickier). Right quantity? As much as is needed! Right quality? All within the specifications. But what is the right cost?

If you think about it, the answer is easy in theory: The minimum cost you can get away with while still having a good product in a safe work environment with motivated employees and satisfied suppliers. In practice all of these are fuzzy and hard to determine. This is a bummer. Unfortunately, in lean there are many things that are hard to measure, even though they are important, often putting lean in conflict with accounting, which ignores things that they cannot measure. Nevertheless, this is one aspect you have to work on, especially by reducing the three evils in manufacturing: waste (muda), unevenness (mura), and overburden (muri). In fact, the 6R here also help with reducing waste, unevenness, and overburden.

27.8 Even More Rights!

Figure 211: 3R tiles (Image Roser)

If you want, there are even more *rights*. Logistics sometimes uses eight *rights* (8R). They add the **right source**, right **type of transport**, and the **right contract**. Oops… we had six rights, plus three, now we have nine rights instead of eight. It seems that the 8R fraction has not quite agreed which two of the additional three you need to make eight. Does it matter? It depends on your system. Which of these are important for the performance of the system? I personally often stick with the 6R (or sometimes even the 5R, skipping the right cost). But again, this depends on your needs. Some people in lean want to implement methods, but in my view the goal in lean is to solve problems, and the method does not matter as much as long as it helps you to improve. Now, **go out, follow up on any of the 5, 6, 8, or 9 rights you fancy, and organize your industry!**

28 Drones in Manufacturing

Christoph Roser, July 12, 2022 Original at https://www.allaboutlean.com/drones-in-manufacturing/

Figure 212: Quadcopter camera drone in flight (Image Josh Sorenson in public domain)

A discussion of fancy new technology would be incomplete without mentioning drones. A simple Google search for "drone and manufacturing" returns around 72 million results. There is definitely a lot of buzz on drones and manufacturing. However, you probably have not yet seen a drone in manufacturing. This is because there are indeed very few cases of drones in manufacturing, and most of them are trial runs that never make it into regular production. Let's have a look at what this is all about!

28.1 Introduction

Figure 213: Ingenuity on Mars (Image Kevin M. Gill under the CC-BY 2.0 license)

Drones in general are unmanned aerial vehicles. Nobody is on board, and the pilot is controlling the craft from the ground – if there even is a pilot, as an AI may assist or even control the aircraft. There are fixed-wing aircraft (i.e., planes) and rotary-wing drones (i.e. helicopters, although often with multiple rotors).

Drones have been used for all kinds of purposes. They are used for gathering data as for example forest fire monitoring, aerial photography and videography, agricultural monitoring, archaeology, infrastructure monitoring, and science. The drone Ingenuity has even flown on Mars.

Figure 214: Drone used during an earthquake in Nepal (Image Jessica Lea/DFID under the CC-BY 2.0 license)

Besides gathering data, they can also deliver payloads, as for example smaller parcels to more remote locations, smuggling of drugs or other contraband, or dropping bombs on Russian soldiers invading Ukraine. There are also drones with flame throwers to burn stuff off power lines.

This blog post, however, focuses on the use of drones within a factory – although there is not much of this yet. Factory use rules out pretty much all fixed-wing drones, as they need more space to start and land (i.e., a landing strip), whereas helicopter drones can take off and land on the spot. At least I do not know of any fixed-wing drone use within a factory.

28.2 Problem of Flying in a Factory

Figure 215: Drone falling on Worker (Image Creazilla and unknown author in public domain)

The main problem of flying drones in a factory is drones malfunctioning and crashing. Like every technical device, drones sometimes fail and fall to the ground. This may damage the drone. If it falls on a machine, it may also damage the tool, the machine, and/or the product. The biggest worry is if it falls on a worker. The weight of the drone alone, or with payload, may cause injury, and that is even before dozens of rotating helicopter blades (yes, they are called blades!) injure a person. While small drones may not be strong or heavy enough to cut skin, you definitely don't want their blades hitting your eye.

There are multiple ways around this problem. First, there is the option for the workers to wear personal protection (i.e., safety glasses and hard hats). But this is in all likelihood very unpopular with the workers. It may be okay if they have to do it anyway (e.g., on construction sites), but otherwise it definitely is not a morale booster.

Figure 216: Caged drone by Flyability (Image Roser)

Another option is to create a safety cage for the drone. One maker I know is Flyability. They make a soccer ball–shaped safety cage around the drone. This protects the workers and the machines from the drone, but also protects the drones from the workers, machines, or generally anything it could bump into. Now you can use a drone again even if there are people in the factory. On the downside, it is pretty difficult to attach or remove items for transport. Only very lightweight items could be attached outside of the cage, and anything heavier would need to be inside of the cage. I don't really see how this can be used for transport.

Such caged drones, however, can be used for data gathering. A permanently attached camera within the safety cage is quite easy and safe to do. This seems to be the main use of such drones. The downside here is that you always have a cage in front of your camera, and anything you observe you see through this mesh. But this is doable, at least for humans. It may be an additional twist if you use AI image recognition. The latest model by Flyability, however, keeps a gap in the cage where the camera is, giving an unobstructed view.

The last option for avoiding drones dropping on people in a factory is to simply remove the people. If there is nobody there (except maybe the drone operator), nobody can get hurt. Fly the drones at night or on weekends. I know of at least one example that is doing this (more on this later).

28.3 Piloted or Autonomous

Figure 217: Drone with pilot in Industry (Image kadmy with permission)

Another problem is the cost of running the drone. This is pretty much a question if you need a pilot, or if the drone runs autonomously. If you have a drone pilot, then you add labor cost to the drone when you use it. That makes it quite a bit more expensive. For example, if you use piloted drones for transport, you may just as well have the pilots carry the goods around, and save money by not having drones. If you inspect something hard to reach, you may just as well have the pilot bring a ladder instead. I believe for drones to be more than just a fancy (and temporary) showcase, it would have to be autonomous.

28.4 Transport

Drones may make sense for transporting items over longer distances, where the source and/or the destination is not fixed. Besides the obvious military use of dropping bombs and launching rockets, drones can be used to deliver items like food, medicine, mail, and other items to remote locations or locations that are hard to reach (e.g., the middle of the enemy headquarters in a war).

Figure 218: Drone transporting item in a factory (staged) (Image Audi with permission)

This usually does not apply to manufacturing. Locations within your factory are usually neither remote nor hard to reach, with possible exceptions of inspecting your chimney or similar. On the contrary, especially for mass production you have a large volume of material flowing into and out of the production. Besides the problem of drones dropping onto your workers, you would need a whole fleet of drones to ensure a steady supply.

A car factory produces roughly a car a minute. If you deliver the steering wheel, for example, you need a steering wheel per minute. If the drone takes fifteen minutes for loading, transport, unloading, and return trip, you need at least fifteen drones in the air (or un/loaded) at all times. And this is only for one part. These drones should also not collide with each other. And don't even think about having fifteen pilots (or more if you have multiple shifts) to control the drones. In all likelihood, it will be much cheaper to put the steering wheels in a box and use a forklift to bring them over.

28.5 Information Gathering

Figure 219: Drone with Camera (Image Jon Pauling in public domain)

In my view, pretty much the only use case I see for drones in manufacturing is to gather information. This could be reading of barcodes (see my next post), inspection of hard-to-reach areas, RFID scanning, thermal imaging, and more. The oil and gas industry is at least testing the use of drones to inspect hard-to-reach areas. But even here it is not always easy to use drones for more than just a flashy PR showcase. For a proper use of drones, the benefit should outweigh its cost. However, this is rare. Very rare indeed. Most often, the only buzz you hear is not from the drones but from marketing. While there are plenty of flashy videos, trials, and tests for drones in manufacturing, I know (so far) of only one case at IKEA where the use of drones seems to be worth its cost. But more on the IKEA use case for drones in my next post. **Now, go out, don't fly away with your drone yet, and organize your industry!**

28.6 Source

During my sabbatical at the ETH in Zürich in the summer of 2022 with Torbjørn Netland, I had the pleasure of working with his postdoc and drone-in-manufacturing expert Omid Maghazei, who taught me a lot on drones. Many thanks, Torbjørn and Omid! See also their paper below, which is also the primary source for my next blog post on IKEA.

Maghazei, Omid, Michael A. Lewis, and Torbjørn H. Netland. n.d. "Emerging Technologies and the Use Case: A Multi-Year Study of Drone Adoption." Journal of Operations Management

29 How IKEA Uses Drones for Inventory Management

Christoph Roser, July 19, 2022 Original at https://www.allaboutlean.com/drones-at-ikea/

Figure 220: IKEA store front (Image Kgbo under the CC-BY-SA 4.0 license)

In my last post I went a bit into the theory of where drones in manufacturing *may* be applicable. They are not really for transport, but there is a possibility to use drones to gather data – provided you don't need an expensive pilot and there are preferably no workers around on which a drone could crash. In this post I would like to show you the use of drones at IKEA. This is pretty much the only case I know that is not a mere trial, test, showcase, or example, but an actual beneficial implementation that receives a wide roll-out, with dozens of warehouses and stores either already having drones or planned to receive drones soon. Many thanks to Omid Maghazei for the information and details, see source below.

29.1 IKEA

Figure 221: Ikea Poland Interior (Image Albertyanks in public domain)

IKEA is the world's largest furniture retailer. Their (as of 2022) 461 stores and over 80 warehouses are found all over the world. Their concept of assemble-it-yourself flat packages allows them to keep costs down, making them popular (not only) for people with a limited budget. My home also has a lot of IKEA stuff in it. You probably have been in an IKEA store yourself.

29.2 IKEA Inventory Management

Figure 222: Ikea Warehouse (Image 최광모 in public domain)

The use case for drones at IKEA is in inventory control for their stores and warehouses. Like any other warehouse, they have problems with discrepancies between the digital data and the actual inventory. They may have more than they thought, or less than they thought, or it is not where they thought it is. I'm sure you are familiar with similar problems in your warehouses.

While of course the best way with data discrepancies is to not have any, in reality you always do. The second best way is to take an inventory. If done by humans, this is quite an effort. People have to go through all items and verify what is where. I have taken inventory myself, and the plant pretty much shut down for three days while everybody was going though the inventory. Alternatively, there are also possibilities using RFID chips, where an antenna can automate the taking of inventory.

A typical IKEA store has around 7000 shelf locations, with distribution centers having ten times more. Despite efforts to improve data quality, the accuracy was not satisfactory. A distribution center had ten full-time employees doing nothing else but searching for lost pallets.

So far IKEA used manual running inventory taking, mostly before the store opened and after the store closed. This is a highly repetitive and tedious work, with employees lifting a pallet down, counting and verifying the content, and lifting it back up. Repeat this 7000 times for a store and 70 000 times for a warehouse.

29.3 How Drones Started at IKEA

One of the first use of drones at IKEA was almost unnoticed by IKEA themselves. An employee in Bangkok, Thailand, simply bought a drone and took pictures of the inventory, instead of moving inventory down or himself up. Another trial was in 2018 in Hungary, and yet another in 2019 in Germany.

Figure 223: Close-up of a Verity drone (Image Verity with permission)

IKEA started to centrally organize its experiments with drones in 2019. Working with different drone companies (Verity, whose founder is also one of the founders of Amazon robotics, and EYESEE by Darwin Drones), they created a pilot project. Starting in Switzerland, together with Verity they developed this drone-based inventory management system. This was successful, and the pilot was expanded to one warehouse in 2020. As of December 2021, five warehouses and one distribution center in Sweden, Italy, Germany, and Switzerland use this drone technology to verify their inventory.

This is not much yet, with IKEA having 461 stores worldwide, but it is just the start. In 2021, a handful more warehouses were set up with inventory-taking drones, and for 2022 a whopping 30 additional implementations are planned. For me, such a large roll-out is a good indication that this implementation is not only for show and tell, but actually beneficial. It surely helped that they tried out many different products before settling down on Verity and EYESEE.

29.4 How to Use Drones

Figure 224: A Verity beehive with three drones (Image Verity with permission)

The drone solution by **Verity** is fully autonomous, and does not need a human pilot. All you need to do is press a button to start the drone. It also returns by itself to its charging station. A store with 7000 pallets needs around eight drones to scan all locations during a single day (Sunday when the store is closed). On other days, the drones fly only after hours at night, and check only locations where the data indicated a material movement. After the flights any data discrepancy is corrected either manually or digitally. It seems algorithms can help a lot in finding discrepancies. Altogether this gives IKEA locations with Verity drones a close to 100% data accuracy every day. While not quite a “zero error warehouse,” as claimed by Verity, it is pretty darn good! The eight Verity drones are set up in two beehives (charging stations) of four drones each.

Figure 225: The EYESEE drone in flight (Image EYESEE with permission)

The **EYESEE** drone by Darwin Drones, on the other hand, is only semi-autonomous. It can count only a single aisle at a time, and a markers have to be set up manually beforehand to create virtual boundaries for the drone. This is usually done in the morning. The warehouses where this system was tested had only a single drone, and it did not check the entire inventory. IKEA claims that this works for central warehouses where inventory needs to be checked less frequently. While Verity is fully autonomous, I do not know the cost of the autonomous system to make this happen. In any case, IKEA is proceeding with both Verity and EYESEE.

29.5 Cost-Benefit

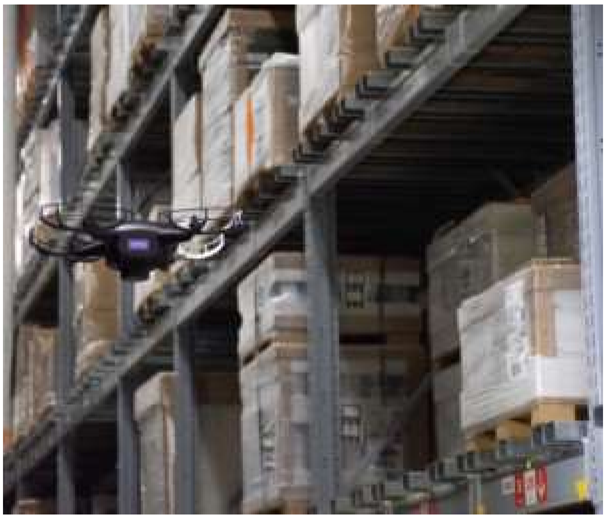

Figure 226: Verity drone scanning inventory (Image Verity with permission)

I do not have hard data on the cost and benefit from IKEA. It is also hard to compare to manual inventory taking, as this was also sometimes flawed, and also less frequently than inventory taking by drone. As is so often in lean, the cost may be easy to measure, but the benefit is hard to determine by cost accounting. What is the benefit of having more accurate data? Surely there is one, but how do you measure this in Euro and dollar?

The lack of hard financials notwithstanding, IKEA is rolling out the use of drones to dozens of warehouses and stores. IKEA management believes that these drones are actually beneficial for the bottom line, even though the benefit is hard to measure. Verity claims that the return on investment is less than one year across all central European and US sites. IKEA is currently using eleven Verity systems in five countries that automatically perform 300,000 inventory checks per month.

29.6 Employee Reaction

The employee reaction was also positive. Taking inventory is considered an unpleasant and potentially dangerous task, and the employees were happy to have this automated. It is also important that there were no employees made redundant. IKEA used the freed-up manpower to improve inventory taking in areas that are less suited to drones. Noise and wind from the drones were not a problem, especially at night when there was not even an employee present.

So, overall, finally a use of drones for internal logistics that actually seems to work and create a benefit beyond flashy PR. Now, **go out, fly your company into the future, and Organize your Industry!**

29.7 Source

During my sabbatical at the ETH in Zürich in the summer of 2022 with Torbjørn Netland, I had the pleasure of working with his postdoc and drone-in-manufacturing expert Omid Maghazei, who taught me a lot on drones. Many thanks, Torbjørn and Omid! See also their paper below, from which much of the information in this blog post originates.

Maghazei, Omid, Michael A. Lewis, and Torbjørn H. Netland. n.d. "Emerging Technologies and the Use Case: A Multi-Year Study of Drone Adoption." Journal of Operations Management. Accessed July 4, 2022. https://onlinelibrary.wiley.com/doi/full/10.1002/joom.1196.

Here are also again the links to Verity and EYESEE by Darwin Drones. There is also an article by IKEA themselves, but this has much less information than the paper by Omid above. There is also a video of the Verity drone at IKEA in action. A similar inventory taking drone inventAIRy XL is also offered by doks.innovation. They also have a highly unusual combination of a wired (!) drone connected to an AGV, allowing for 5 hours of uninterrupted (but tethered) flying.

30 What Is Flow?

Christoph Roser, July 26, 2022 Original at https://www.allaboutlean.com/what-is-flow/

Figure 227: Water flowing over Dam (Image FedBul with permission)

Everybody in lean talks about flow. You have to create flow! In particular you have to create one-piece flow. However, while this is true, I often find a lot of confusion on what *flow* means. Time for a post that goes to the basics and looks at what exactly flow is. My next post takes this up one step by looking at what one piece flow is.

30.1 What Is Flow?

Let's start with the easy part. What is flow? In particular, what is flow in manufacturing? In its most basic form, **flow refers to the movement of parts. The opposite is parts standing still.** Hence, you want to get your parts moving. To be more precise, you don't just want them to move around randomly, but **move in the direction of the value stream**. Otherwise you could just put your entire plant on a ship and drive in circles, but that is not the point.

Figure 228: The part is always moving. (Image Carol M. Highsmith in public domain)

In reality, at any given time, at least some of your parts are standing still. For one, you may need to stop parts for the actual processing. While there are moving assembly lines, you may also have processes that are in one spot, for example a milling machine. Customarily, parts that have stopped for processing are not counted against your flow. If it is a batch process like a heat treatment or a drying process, there may be a lot of parts that are standing still but are being processed for a long time.

Figure 229: Those parts are stopped. (Image Axisadman under the CC-BY-SA 3.0 license)

But you surely also have plenty of parts that are neither moving nor processing. Your warehouse is full of not-moving parts. And, if you are any typical company, these not-moving parts outnumber by far the moving or processed parts. In sum, **flow tries to reduce this share of idle parts and hence also to reduce the lead time**. This is very closely connected to the reduction of inventory. Inventory is usually needed to buffer fluctuations, hence the main lever is to reduce fluctuations to reduce the inventory. Beware. This sounds a lot easier than it is. So overall, flow aims to reduce idle inventory and to increase the share of parts in transport or in processing.

30.2 How Much Flow?

Figure 230: The Iguazu Falls is the largest waterfall in the world. (Image Roser)

So, how much flow do you want? This is also easy only in theory. The true north of flow is 100% in processing or in transport. Just in Time and Ship to Line are common lean methods that improve flow by having less parts idle and more being handled or processed. At the same time, like most true north visions, 100% flow is not possible. You probably always have some products idling.

Figure 231: Faucet with water droplet (Image Nicole-Koehler under the CC-BY-SA 3.0 license)

There is also no agreed on goal for what percentage of the parts should be flowing. In many factories, my guess would be that in excess of 95% or even 99% of the parts are idle at any given time. In this case, even getting it down to 90% would already be an improvement. The goal, simply, is to become better. Whatever your flow rate is, your target should be a higher flow rate.

At the same time, I do not know of any plant that actually measures this flow rate. The closest thing I know is on value streams where the percentage of time a part is processed versus the entire lead time could be plotted. The simple value stream map below has a up/down line at the bottom, where the processing times and the waiting times for a typical part are added. Here, the part waits for around 6 hours in the inbound warehouse, before being milled for 33 seconds, before waiting another hour for 25 seconds of stamping.

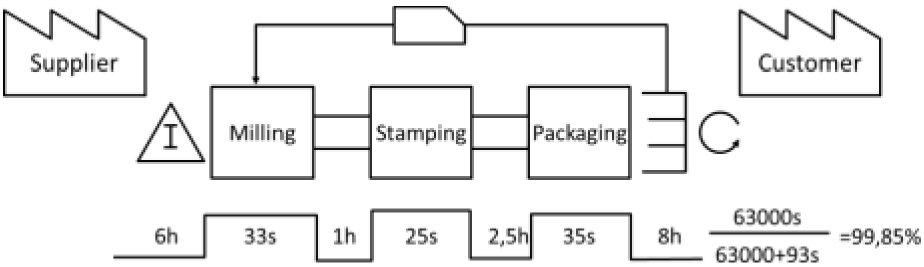

Figure 232: Value Stream Map with Timeline (Image Roser)

Overall, the part is not processed for 99.85%, and only 0.15% of the time there is processing, which is hopefully also adding value. Hence, the percentage of value added time is only 0.15%. Such low numbers of value-added time is typical in many factories, and even 99.99% not value add or more is quite possible. This percentage is a close approximation of the flow, or lack thereof. But do note that these idle times do include transport, which would be part of flow. Yet, for me it makes no sense to also include the transport times, since transport by default is waste.

Hence, improving flow is more of a philosophy than a metric, and if you want a measurable KPI, **the percentage of value-added time is a much better measurement than the percentage of "flow" time.**

30.3 Cheating Flow?

Figure 233: This is NOT improving flow! (Image Anton_Sokolov with permission)

Just for the record, the transport of the parts should also be at normal speeds. If you slow your transports down, your share of goods in progress will increase. This would follow the letter but not the spirit of material flow.

Similarly, if you offshore your factories, a lot of parts would be on the ship moving for months toward the customer. While this numerically would improve the flow, it would also increase the lead time, which is just the opposite of what lean wants you to do.

30.4 What to Flow?

Figure 234: Make me flow 😐 *(Image baicai lin under the CC-BY-SA 2.0 license)*

So, in general, you want to improve flow, or – more precisely – improve the percentage value add. The ultimate but unobtainable vision is 100% value add. It takes a constant effort to merely not become worse, let alone to become better. You simply do not have enough time to improve everything. So, where should you start?

As always, you should start where you get the biggest bang for the buck. Flow reduces inventory and hence also lead time. What parts give you the biggest benefit for reducing inventory? Usually, these are the **expensive** parts due to their tied-up capital, the **large** parts due to their storage cost (and related parts that require **special storage** conditions like refrigeration or climate control), and parts that **expire quickly**. As for the lead time, this is often critical for **make-to-order final products**. Depending on your factory, you may have some additional factors to include. This compares with the effort to reduce inventory, which is probably harder to estimate. Again, start with the part that gives you the best benefit for your effort. Don't optimize your inventory of O rings for 2 cents each while the expensive engine blocks are piling up.

So, in sum, **creating flow is in reality improving the percentage of value added time by reducing inventory, and you should start improving this with your expensive and large end products.** The idea of parts actually moving (flowing) is more of a visual metaphor to highlight your parts idling in your warehouse. In my next post I will move the concept of flow one step further and explain the idea of one-piece flow. You surely have heard of this, but there is still a lot of confusion on the idea. Now, **go out, get your material flowing (or at least less sitting around), and organize your industry!**

31 What is One-Piece Flow?

Christoph Roser, August 2, 2022 Original at https://www.allaboutlean.com/one-piece-flow/

Figure 235: Stream in a Forest (Image Zeynel Cebeci under the CC-BY-SA 4.0 license)

In my last post I went into detail on the concept and philosophy of flow. This post goes deeper and looks at **one-piece flow**. If you are working in manufacturing, you surely must have heard the term *one-piece flow*. However, despite it being ubiquitous, I find that this is still often not very well understood. I also sometimes have the feeling that it is also used as a buzzword merely to impress others. Well, let's have a look.

31.1 A Quick Recap on Flow

Figure 236: Water flowing over Dam (Image FedBul with permission)

Quick Recap: **Flow is the idea that parts are moving or being processed, opposite of them being idle.** The idea behind it is to reduce inventory and to reduce lead time. In reality, however, a **much better measure for this would be the percentage of the value-added time**, since the flow itself (i.e., the transport) is also a waste and should be reduced if possible. You will also never achieve 100% flow, even though this is the true north.

31.2 What is One-Piece Flow?

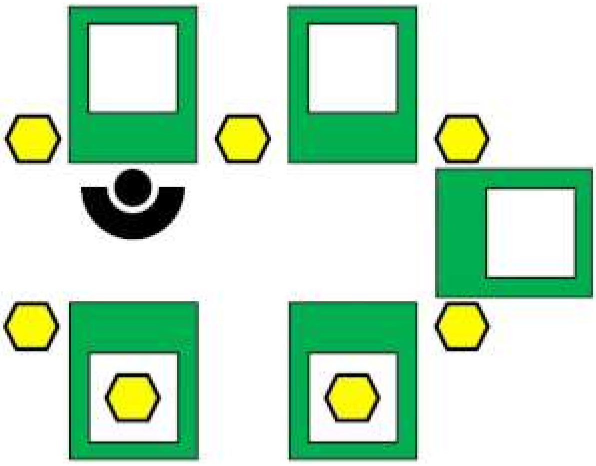

Figure 237: Animated one-piece flow Chaku Chaku (Image Roser)

One-piece flow moves each product to the next stage as soon as it is completed at the previous stage in the value stream. There is no accumulation of larger batches for moving material. The basic idea of one-piece flow is that you do not wait until you have a pallet/box/batch of parts before moving them to the next process, but that you move smaller quantities more frequently. Ideally, the transport quantity is one. The benefit of one-piece flow is also a reduction of fluctuations and hence a reduction of work in progress inventory. You don't get a big box and then nothing, but you get the parts one by one, ideally just in time when you need them.

This helps to reduce transit time of the material through the value stream, and reduces the lead time. The system can react faster, and information can flow quicker. For example, if a subsequent station notices a systematic defect, a faster transit time means that there is less material in between that has to be reworked or scrapped.

31.3 What It Is Not: Lot Size One

Figure 238: Lot size 1 in automotive (Image Brian Snelson under the CC-BY 2.0 license)

I often find that one-piece flow is confused with a lot size of one. A smaller lot size is indeed beneficial to manufacturing, and the true north lot size is one. Different from many other true-north goals, a lot size of one is indeed achievable. Through smaller lot sizes you can also reduce your inventory fluctuations, and hence your buffer inventories.

However, in terms of one-piece flow, you can achieve it even with larger lot sizes. Even larger batches of material can be flowing well, provided that you don't move them as batches but as individual items. In one-piece flow, you can move a larger batch one by one through your value stream, instead of a large pallet/box/batch. Similarly, you have a lot size of one but still no one-piece flow if you move the individual items in larger batches.

Hence, lot size one and one-piece flow can exist independent from each other. On the other hand, it is often easier to do both and there is a mutual benefit. Having smaller lot sizes helps with one-piece flow, and having one-piece flow may be better for smaller lot sizes. But both are also valid goals on its own. Again, one-piece flow refers not to the lot size, but to the transport quantity.

31.4 What It Is Not: Buffer Inventory Reduction

Figure 239: Buffers in assembly line (Image The Light Writer 33 with permission)

Another common confusion is to consider one-piece flow a reduction of the buffer inventories. These, too, are related, but not identical. Buffer inventory is used to decouple fluctuations. Less inventory has many benefits – provided you can get your fluctuations under control. Like the lot size one, one-piece flow and small buffers also create a mutual benefit and are both worthwhile. Besides, it is quite possible to have **zero** buffer inventory between well-balanced processes.

Figure 240: Clueless Manager (Image Gandolfo Cannatella with permission)

There are even more misunderstandings on one-piece flow. The German Wikipedia claims it is group work on a moving conveyor, which is hogwash, besides also claiming a lot size of one. Other books go heavily in the direction of cellular manufacturing (which, admittedly, often use one-piece flow). Overall, there seems to be still much confusion. Or, maybe I am confused? If so, let me know.

31.5 The Benefits of One-Piece Flow

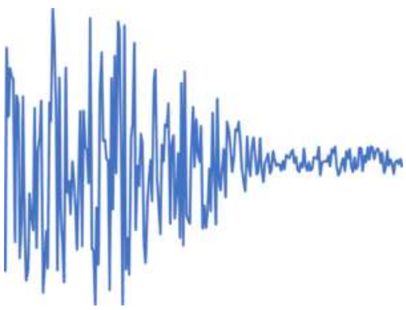

Figure 241: Fluctuation Reduction (Image Roser)

One benefit of one-piece flow is the reduction of fluctuations by having larger quantities stop and go through the value stream. This in turn allows a reduction of (buffer) inventory, which will generate a whole lot of other benefits, from less tied-up cost to faster lead times and information flows. Especially the faster reaction to quality problems is often quite important here.

It also makes it easier to maintain a FIFO (First in first out) sequence. This also has many benefits, like reducing lead time fluctuations, which makes planning the delivery dates much easier. It also helps with the tracing of quality problems.

31.6 The Goal of One-Piece Flow

The goal of one-piece flow is to have the items move one by one through the value stream as soon as they are ready for the next stage. Hence, the true north is a transport size of one item. Within a factory this is often possible. Most assembly lines, or even most manufacturing lines, move an item to the next station as soon as it is possible with a transport quantity of one.

Figure 242: Your supply chain? (Image Uwe Aranas under the CC-BY-SA 4.0 license)

It is often more difficult outside of factories. If you are shipping items between suppliers, factories, and customers, it may often not make sense to send out a truck for a single item. Instead, you send out a truckload.

But even if you cannot reach a true one-piece flow, you still may be able to move in that direction. Instead of one large truck, can you send two smaller ones? Instead of a truck full of one item, could you send smaller quantities of different items? Could an external milk run pick up smaller quantities more frequently from different sources?

Overall, I see one-piece flow as a good visualization of the goal of flow, but to me the concept of flow itself is a bit misleading. Transport is, after all, waste. While not completely avoidable, transport should be reduced to the minimum. But there is definitely benefit in reducing the quantity of transports and increasing the frequency. If I would pick an actual KPI, the percentage value add is more relevant to me. It is easy to have tons of material moving around the world in complete opposition to the visions of lean manufacturing.

I hope this post was made you think more about flow. Now, **go out, don't only think about flow but get your material flowing, and organize your industry!**

32 Manufacturing in a War Zone – Part 1

Christoph Roser, August 9, 2022 Original at https://www.allaboutlean.com/manufacturing-in-a-war-zone-1/

Figure 243: Destroyed Russian tank in Ukraine (Image Ministry of Internal Affairs of Ukraine under the CC-BY 4.0 license)

Running smooth operations is difficult enough in peacetime. But it becomes much trickier if you are located in an area experiencing an active armed conflict. Yet, there are many active armed conflicts on the world, like Ukraine, Myanmar, Afghanistan, and others, many of which have been ongoing for decades. I have put together some of my thoughts in the hope that it may help people and factories in difficult circumstances, with special focus on the current invasion of Ukraine.

32.1 Introduction

In the internal chat of the Lean Global Network (LGN), I came across a question by fellow LGN member Serhii Komberianov from the Lean Institute Ukraine on how to advise a client on running a plant exposed to potential Russian missile attacks. (Side note: The Lean Enterprise Institute of Russia is no longer a member of LGN, as the Russian aggression is not compatible with the ideals of LGN.)

Figure 244: War in Aleppo, Syria (Image Mil.ru under the CC-BY 4.0 license)

A few years ago I also talked with a plant manager of a cement plant in Syria, which is also part of an ongoing conflict. The manager told me that they regularly had flyovers by combat jets, and they have lost employees due to shootings and bombings. He also had to bribe both sides to keep the plant running. He hated giving ISIS money, but the alternative would have been a bullet in the head and a destroyed plant.

Figure 245: Flag of Ukraine (Image UP9 under the CC-BY-SA 3.0 license)

Luckily, I have never been to a war zone, and hence my knowledge is more theoretical. Few people actively want to go to a war zone. The problem is, sometimes the war zone comes to you. The plant in Ukraine would have loved to do normal business, but unfortunately Putin took that option from them by invading Ukraine. And, just to make it absolutely clear, in this conflict I am fully on the side of Ukraine and in opposition to the Russian invasion. So, what can a plant do if an armed conflict threatens the safety of its employees and the integrity of the operations?

32.2 Turn Tail and Run?

Figure 246: Destroyed Building Ukraine (Image Алесь Усцінаў in public domain)

One option is to just run. But this is a hard decision with many factors to consider. **Is your plant an enemy target** that may be actively bombed? Russia did attack factories, but also apartment complexes, hospitals, and shopping malls. It seems these civilian attacks were not only due to really bad Russian aim, but also deliberate terrorization of the population in Ukraine.

If you run, **can you relocate operations or do you have to stop completely?** You may have to (temporarily) abandon equipment. Few companies can relocate easily, exceptions being for example a software company where you merely have to move a few computers.

If you stop operations, **can your employees get to a safer place?** In Ukraine, some may have been able to escape to other European countries. In Syria, they would be just as vulnerable at home, but now jobless and unable to support themselves. Maybe some employees can work off-site from a safer location?

Figure 247: French factory destroyed in WW I (Image Henry Armytage Sanders in public domain)

How important is the plant to you, your employees, and your country? The manager of the Syrian cement plant told me how glad his employees were that the plant was still running. It was one of the few employers left in the region, and their salaries supported not only themselves and their families, but sometimes even extended relatives. The plant manager also actively supported their pride in making cement, hoping to rebuild their beloved Syria again once the conflict ends (as of this writing, unfortunately not yet). Importing cement would have been much more difficult and expensive, and would have increased the outflow of cash from Syria even more.

In sum, the decision to stop or continue operations is a difficult one. You may not be able to guarantee peacetime levels of safety. On the other hand, if everybody just ran away in Ukraine, Putin would win and that is in my opinion not a good outcome either. Individual employees have to decide if they stay or leave depending on their options and opinions. If you are an employee and are leaving, please let management know so that they can plan around this, rather than stop showing up and let management worry about whether you are even still alive. The management of the plant overall also has to decide at what point the risks of continuing operations outweigh the benefits.

Figure 248: Azovstal iron and steel works (Image Chad Nagle under the CC-BY 2.0 license)

It helps for plant management to discuss this with the employees and to get their input in this difficult decision. If the entire plant shuts down, it would be helpful to decide what to take along, what to leave behind, and what to destroy so it does not aid the enemy. In some cases, like the Azovstal iron and steel works in Mariupol, the plant was even turned into a fortress that gave Putin a big headache for a looong time.

But again, this is a very tough decision!

Figure 249: Tank and Toilet Bowl Drawing (Image Dall•E 2 AI in public domain)

It is also not a decision that you make once. It is a decision that has to be continuously updated, depending on how the conflict develops. Is the frontline getting closer or moving away? Did one (or both) sides start to use violence and terror against civilians? What happened to other plants and their employees that are closer to the fighting? Do you still have customers? Can you get your products to the customer, or are you producing washing machines and toilet bowls on inventory for the enemy to steal?

Again, deciding to stay or leave is not an easy question, and also a question that needs to be re-evaluated regularly. If you do stay, there are some steps that can improve the safety of your people and your company. Hence, in my next post, I will look in more detail at how to protect your employees and your company from the actions of war. Now, **go out, stay safe, and organize your industry!**

PS: I wanted to write something in support of Ukraine and fitting the theme of this blog for quite some time now. Many thanks to fellow LGN member Serhii Komberianov from the Lean Institute Ukraine for giving me the inspiration!

33 Manufacturing in a War Zone – Part 2

Christoph Roser, August 16, 2022 Original at https://www.allaboutlean.com/manufacturing-in-a-war-zone-2/

Figure 250: Woman working a Lathe WWII (Image Ministry of Information Photo Division Photographer in public domain)

This post continues to discuss running a plant in a war zone. While the first post focuses on the difficult question of whether you should continue operations, this post looks at what you could do if you decided to continue running your plant despite the armed conflict nearby.

33.1 Stay and Keep Working?

Figure 251: Child Drawing of Truck Traffic Jam (Image Dall•E 2 AI in public domain)

If the decision of the plant is to keep operations running (for now), there are many additional problems to consider. War will disrupt your supply chains, and if you thought you had a bad case of missing parts before, it will look like child's play in comparison with the disruptions you may be facing.

The disruptions in the supply chains are similar to disruptions in peacetime, just larger. You can use similar approaches to deal with them, although due to the size of the disruptions, chances are higher that sometimes it won't work out and operations will stop due to a lack of material.

Like any fluctuation in the material flow, it can be decoupled through inventory, capacity, or time. Plants in a war zone may increase inventory to cover fluctuations. Adjusting or increasing capacity may be difficult. In reality, the most common fallback decoupling will be time, and your customers may have to wait for their goods. Inform them about your situation, and ask them for their understanding.

But overall, the fluctuations in the material flow and its countermeasures are similar to peacetime, except you are playing on hard mode. However, the risk of employees getting hurt and your equipment and property getting damaged by far exceeds peacetime expectations.

33.2 Safety of People

Figure 252: First Aid Kit (Image ~riley under the CC-BY-SA 3.0 license)

Safety should always be a concern for anybody working in industry. During an armed conflict, it may not be possible to guarantee a peacetime level of safety. Nevertheless, steps can be taken to reduce the risk to your people. It should start with a risk assessment. What kind of additional dangers are your employees (and also your equipment) exposed to due to the armed conflict. Is there a risk of a missile attack or an air raid? Could enemy troops cross the area? Is your plant maybe even an special target of interest to the enemy? Is there a risk of nuclear, biological, or chemical attacks? Depending on this assessment you can consider steps before, during, and after an attack.

Before the attack you should prepare your people and your plant. If you expect air raids, do you have bomb shelters nearby? Do you need to prepare shelters? Anything from a sand-bagged location to a sturdy and safe basement could do. If a bomb goes off nearby, glass windows are especially dangerous and could turn into deadly shrapnel. While explosion-resistant windows may not be an option, please consider possibilities. During World War II, duct tape was used across windows, although this may make it even worse with larger shards and may not be advised. Putting plywood over the windows may be a better solution.

Figure 253: Blackout Curtain (Image Ministry of Information Photo Division Photographe in public domain)

Plywood could also help to black out the plant. During WW II entire towns blacked out light, although modern military targeting may not make this necessary. You should also consider fire hazards. Can you reduce these hazards? Can you move the flammable items farther away from the plant?

Also important is to make sure you have enough easy-to-reach first aid equipment, and it is well stocked especially in view of wartime injuries. Similarly for fire extinguishing gear, from buckets of sand to proper extinguishers. Are your people trained in how to use this gear?

During an attack it is important that your people react quickly. An air raid warning may be a few minutes before the actual attack. Make a plan if there are some machines that need to be turned off (quickly), and practice heading for the nearest shelter.

Figure 254: First aid practice during WW I (Image Geoff Charles in public domain)

After the attack you may need to treat the injured and fight fires. Are you lucky and your people escape with only minor injuries? Do you need an ambulance? Are there fires? Your people (and maybe also you) may be at least shaken and disturbed. What can you do for mental health? And, not the most important first part but eventually also necessary, you should resume operations.

33.3 Safety of Your Equipment

Figure 255: Sandbagging at Morda (Image Geoff Charles in public domain)

Besides your people, you also may want to protect critical equipment. You could put sandbags around your important machines to reduce possible damage. Some actions that protect your people (plywood on windows, reducing fire hazards) may also protect your machines.

33.4 Safety of Your Knowledge

Figure 256: Person making backup (Image Dall•E 2 AI in public domain)

Finally, you need to protect the institutional knowledge of your company. The experience of your employees is protected by protecting your employees. But do not forget to make backups of your data! Preferably on a server far away from the war zone, or even in a different county. If you store your backups in the same room as your server, both may be destroyed and you will be left without the data. Actually, this advice applies to anybody everywhere. Backup your important data!

In any case, I hope this post was interesting to you. I hope even more that you don't ever need this post. **Now, go out, backup your data, and organize your industry!**

PS: I wanted to write something in support of Ukraine and fitting the theme of this blog for quite some time now. Many thanks to fellow LGN member Serhii Komberianov from the Lean Institute Ukraine for giving me the inspiration!

34 Examples of Job Shop to Flow Shop Conversions

Christoph Roser, August 23, 2022 Original at
https://www.allaboutlean.com/job-shop-to-flow-shop-examples/

Figure 257: Minsk Tractor Works (Image Homoatrox under the CC-BY-SA 3.0 license)

I am a strong believer in the advantage of flow shops. To me, job shops are an inherently chaotic system. While there are ways to manage job shops, these are merely (more or less) successful attempts to put a Band-Aid on the chaos. To me, only a conversion to a flow shop will bring underlying stability. In this post I would like to give you both historic and current examples of successful conversions from a job shop to a flow shop.

34.1 Introduction

I have written about the change from job shops to flow shops before, for example Why Are Job Shops Always Such a Chaotic Mess?, How to Convert a Job Shop into a Flow Shop, and Performance Comparison of Job Shop and Flow Shop. One of these posts recently led to a heated discussion on LinkedIn, where vocal proponents of job shops accused me of not knowing anything, and even resorted to name calling (at which point I ignored these threads; I don't have time for trolls…). You see, lean can get quite heated too. Many thanks, by the way, to those participants who reported successful transformations from job shops to flow shops and supported my view.

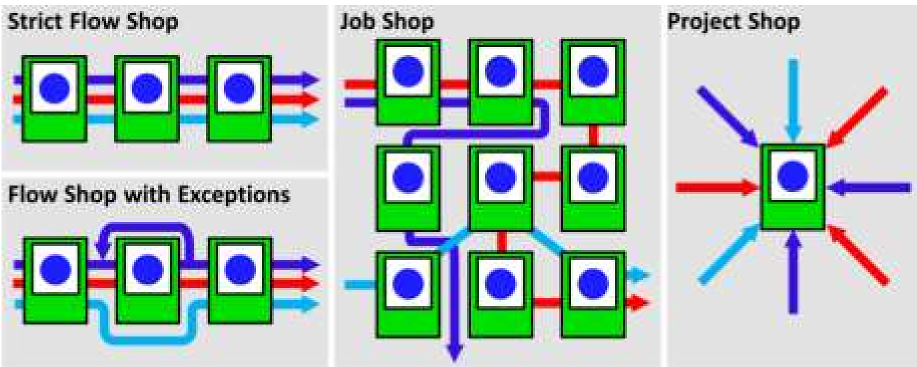

Figure 258: Strict Flow Shop Job Shop Project Shop (Image Roser)

Anyway, one request I got was to name successful transformations from job shop to flow shop. Well, there are plenty. Some I have been involved in but I cannot write about due to nondisclosure agreements. But there are tons of examples in literature, plus a few I know personally and can tell you more about. Hence I would like to write about some examples where high-mix, low-volume production was transformed into a flow shop, despite all the old hands believing it to be impossible. Some are historic, some are current. Some of these examples are plants that transformed from job shop to flow shop; others are examples where a new plant was built as a flow shop from the start for a high-mix, low-volume product.

34.2 Shipbuilding

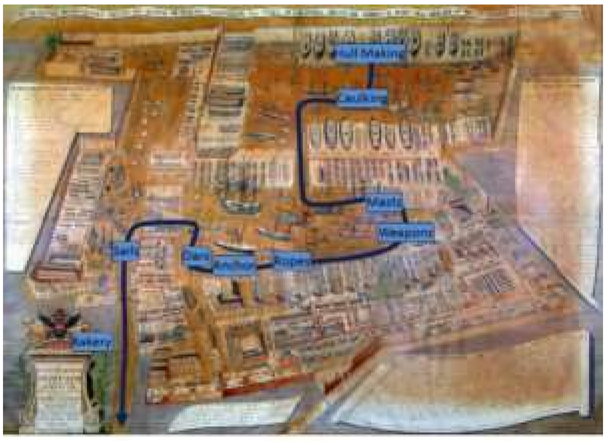

Figure 259: Arsenal of Venice material flow overview (Image Roser)

There are plenty of examples of flow shops or even assembly lines in shipbuilding. The oldest one is probably the Arsenal of Venice (on which I have two posts on the Arsenal of Venice in general and its material flow in particular). Definitely an example of high-mix, low-volume assembly.

Figure 260: Eagle Boat line 1918 (Image unknown author in public domain)

A more modern example would be the Eagle boat assembly line by Ford during World War I. They built three assembly lines on which as many as 21 Eagles could be under construction at once. However, I do not know how much of a mix these products were. Since it was under Henry Ford, he probably tried to make all boats exactly the same. There are other examples of military shipbuilding on an assembly line (e.g., World War II torpedo boats at the Higgins boat assembly line), but these may also have been very identical.

Definitely not identical are modern pleasure boats, which are highly customized to the wishes of the client. For example, Bavaria Yacht has four different production lines, where the hulls are provided with engines, wiring, furniture, lamination, and so on. Similar assembly lines are at the Riva boatyard, and probably many more. All of these are high-mix, low-volume assembly and/or manufacturing lines.

34.3 Aircraft

Figure 261: Junkers JU 87 assembly line (Image Seuffert under the CC-BY-SA 3.0 Germany license)

We can find similar examples for aircraft. Junkers had an assembly line even before World War II, where, by the way, the lean word "Takt" comes from. But again, these planes for the military are rather alike.

Figure 262: Boeing 787 assembly line (Image Jetstar Airways under the CC-BY-SA 2.0 license)

Similar to boats, planes are also more customized for private customers. Almost every larger manufacturer of planes uses assembly lines. I have personally spent time on Airbus assembly lines. Definitely a high-mix (every plane is differently customized) and low-volume environment, as all of Airbus makes only about two planes per day worldwide.

The same applies to Boeing (the picture here shows the Everett factory), Bombardier, Cessna, and many more aircraft makers.

34.4 Automobiles

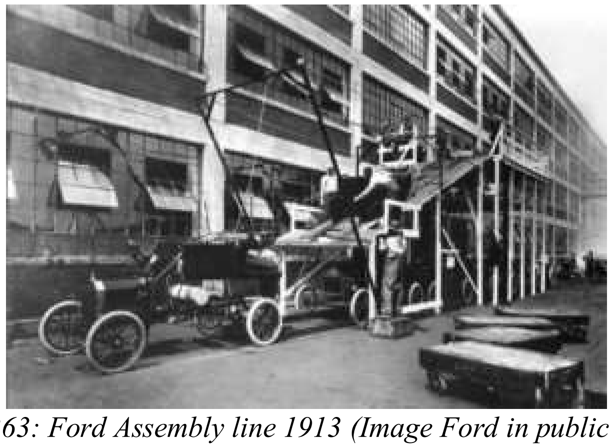

Figure 263: Ford Assembly line 1913 (Image Ford in public domain)

Automobiles is a bit of a special case. They started out as project shops (all material to one location) before different manufacturers used flow lines. The most famous automaker is Henry Ford, whose efficiency gains through the assembly line made the car affordable to almost everybody, and also made Ford incredibly rich. However, he was famous for making identical cars in large numbers, and these are high-volume, low-mix lines, the total opposite of low-volume, high-mix for job shops.

Figure 264: Assembly Line (Image Siyuwj under the CC-BY-SA 3.0 license)

Nowadays, however, pretty much every car maker has a high mix of different customized products, aiming to customize the car for the buyer. For example, an Audi A6 has over 150 variants of the glove compartment alone, and 18 800 variants of the door cover. This is definitely a high-mix scenario. However, with one car per minute it is also still a high-volume production.

Figure 265: Lotus final assembly line (Image Brian Snelson under the CC-BY 2.0 license)

However, there are also low-quantity automobile manufacturers, too, for luxury and sports cars. The picture here is the Lotus final assembly line, which produces around four cars per day. Similar quantities can be found at Lamborghini or Ferrari, where the cars are also produced on assembly lines.

On a side note, every now and then there is an idea to reverse this. For example, Volvo experimented with group work instead of a flow line, first in Kalmar in 1984 and then in the Uddevalla plant in 1990. Volkswagen also tried it once. These ideas are usually abandoned after they find out that a flow line is just so much superior to other concepts.

34.5 Commercial Vehicles

Figure 266: Truck Assembly Line (Image zanskar with permission)

Most commercial vehicles are also produced on assembly lines. Trucks, buses, tractors, excavators, you name it, they probably come from an assembly line. I have seen some of these lines myself. And they are also heavily customized high-mix, low-volume production.

34.6 Machine Tools

Figure 267: Production line at Trumpf (Image Trumpf with permission)

Machine tools also often come from an assembly line. One example I am more familiar with is Trumpf (see my blog posts part 1 and part 2). They have converted their production to a flow shop, and believe me, this was not easy. But nowadays their highly customized and different machines move every eight hours on air cushions from one station to the next. A great example of a high-mix, low-volume production line.

34.7 High-Voltage Breakers

Figure 268: A high voltage breaker (Image Dingy under the CC-BY-SA 3.0 license)

Yet another example where I have spent more time on the production line was high-voltage breakers for power plants. They are also heavily customized and produced in small quantities. The sizes of these range from a large car to a small shed, and they are also heavily customized. Their change from job shop to flow shop was also difficult, and initially many doubted that it would ever work, because their products are “too special” and “too customized.” Well, it worked, much better than the job shop from before.

34.8 Many More Examples

There are many more examples of using flow lines for high-mix, low-volume production, like marine engines for container ships, commercial diesel generators, medical devices, commercial boilers (one example where I was involved), robots, gas turbines and their maintenance, and many more.

For some of the above examples I know the details, and it was always a tough decision with lots of nay-sayers who doubted it. It also was never easy, and many smaller and larger problems had to be solved to make the flow shop come true. In hindsight, it always looks easy and doable. The true grit is to have the foresight and the vision to see the possibilities. Also, while I believe a flow shop to always be easier to manage than a job shop, there may be situations where a flow shop is not economically viable. Yet due to the enormous advantage of flow shops, this economic benefit is huge, but unfortunately hard to calculate beforehand.

I started this post because of a somewhat heated LinkedIn discussion. Will it satisfy these nay-sayers up? Probably not, and I already hear them stating that these examples are n*ot high-mix enough;* or *not low-volume enough;* or *not detailed enough* (to nitpick it apart to their liking); or that *their case is totally different,* or *these are obvious* (in hindsight); or they take parts of the post out of context, or, or…

Whatever. Besides, they are entitled to their opinion, and maybe I am wrong. I am also not saying all job shops must change to flow shops, but there is often a GARGANTUAN benefit that is vastly underestimated, and despite all the doubters, it is often worthwhile to change to a flow shop. In any case, if I get even one of you to wonder if you could change your job shop to a flow shop, then I am happy and it makes my writing worthwhile. Now, **go out, see if you can change your job shop into a flow shop, and organize your industry!**

35 Happy 9th Birthday, AllAboutLean.com

Christoph Roser, September 1, 2022 Original at https://www.allaboutlean.com/happy-9th-birthday/

Figure 269: 9th Birthday Cake (Image Zerbor with permission)

Yet another year has passed. AllAboutLean.com is now nine years old! I never though I would keep it up for so long, but your support and encouragement for my writing keeps me motivated. Many thanks! I am looking forward to writing many more years on the topic of lean. I also have more books planned (but this will take some time). Anyway, let's review the year:

35.1 Books

In April 2021 I finally published my book All About Pull Production. As it turns out, it has been very well received. For example, on Amazon it has 4.9 out of 5 stars with 35 ratings, and 11 highly positive reviews. And that is without me nudging everybody to write me a review, but instead organic feedback merely based on my book 🙂.

Since then, multiple translations have also become available, including German Alles über Verbrauchssteuerung (translated by me), Spanish Todo sobre Producción Pull (translated by Jorge Valle from Lean Transforma), and Brazilian Portuguese Tudo Sobre Produção Puxada (translated by Wellington Batista from DataLEAN). More languages are in preparation, including Chinese 关于拉动生产的一切 by Taojie and Xie Xuan, Italiano by Roberto Ronzani from the Istituto Lean Management, and French by Pierre Jannez from Operae Partners, and more.

Figure 270: All About Pull Production Ebook Cover (Image Roser)

I also published my ninth volume of Collected Blog Posts of AllAboutLean.com 2021, which you can buy on Amazon… or just download it for free on my website. I also created free EPUB eBook versions to download for all nine volumes from 2013 to 2021 in addition to the PDF versions. This is just for fun, and not intended to make money. I plan to publish the next volume for 2022 in spring 2023.

I also needed a timeout while I was pondering which fonts to use in my books, so just for fun I made a book with Font Samples. This has NOTHING to do with lean, and I did this just for myself. Buy this only if you are into fonts.

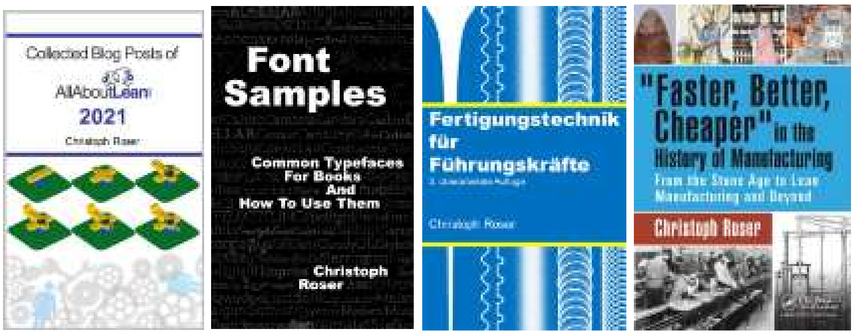

Figure 271: Selected book Covers (Image Roser)

I also updated my German manufacturing fundamentals textbook Fertigungstechnik für Führungskräfte to its third edition. I use this book for my for my university lectures. In the US, it is common to force students to buy overpriced textbooks. I don't want to profit from my students, and hence the price is drastically reduced and the book is available almost at the printing cost.

I am also currently working on a revision of my first book Faster, Better, Cheaper in the History of Manufacturing. Hopefully I can publish an updated version early next year, but first I need to get the rights back from the publisher. I also still have to think about the cover. So, don't buy it yet. :-| On this, also see my post next week on the Cromford cotton mill, which started the industrial revolution 250 years ago.

35.2 Blog Posts

Of course, I also wrote plenty of blog posts. I publish one post per week, usually every Tuesday (unless it is an anniversary post that falls on a different day, like this one). This has made a total of fifty-one blog posts since September 1, 2021.

Figure 272: AllAboutLean WeChat Access (Image Roser)

But wait, there is more. I also translated some of my blog posts into German. As of now, there are eighteen posts and seven pages available also in German. But much more productive was Xie Xuan, who translated many MANY posts into Chinese. As of writing, there are seventy-five blog posts and three pages available in Chinese. Xie Xuan is also working on making them available on Weibo WeChat in China.

35.3 Most Popular Posts

Figure 273: Top 10 (Image Roser)

As every year, here are the top ten posts:

- The Kingman Formula – Variation, Utilization, and Lead Time
- What Exactly Is Jidoka?
- Toyota Standard Work – Part 2: Standard Work Combination Table
- The Inner Workings of Amazon Fulfillment Centers – Part 4
- How Cheap Can You Make it?
- The Inner Workings of Amazon Fulfillment Centers – Part 2
- Line Layout Strategies – Part 2: I-, U-, S-, and L-Lines
- Production Sequences: FCFS, EDD, and Others
- The (True) Difference Between Push and Pull
- The Amazon Robotics Family: Kiva, Pegasus, Xanthus, and more… Usually, the difference between push and pull is the most popular post, but this year the Amazon robotics were more popular.

35.4 Organizational

There's also stuff going on in the background. For example, I used Amazon Affiliate links, giving me a little bit of money if you click on the links of my books. However, I found out that I have to declare these links as adverting. Hence, I removed all Amazon Affiliate tags. The links are still there, and will get you to Amazon, but it is no longer an affiliate link but a normal link, and there is no cash flow involved. I don't want to bugger you with "advertising" just to make a few cents though your click!

Figure 274: AI result for "photo of a business person making backups of a computer" (Image Dall•E 2 AI in public domain)

I also recently got early access to the AI Dall•E 2 by OpenAI. With just a few words the AI will generate quite good pictures. This may help me to illustrate my articles more. I often spend quite a bit of time looking for good images to visualize the concept, and the AI will help me…to spend my time differently looking for images. With a bit of luck, it will bring you more quirky but matching images through my blog.

In any case, **go out, keep on reading, and organize your industry!**

36 250 Years of the Cromford Cotton Mill – Start of the Industrial Revolution

Christoph Roser, September 6, 2022 Original at https://www.allaboutlean.com/250-years-cromford-mill/

Figure 275: Cromford Mill from Parking Lot (Image Roser)

The Industrial Revolution is arguably the most significant change in manufacturing history. Since it was a gradual process over almost a century, the exact start and end dates are hard to pin down. However, for me one of the key dates is the start of the first cotton mill in Britain, the Cromford Cotton Mill by Richard Arkwright. Construction of this mill started in 1771, and production began 1772, which is 250 years ago, hence time for me to write an anniversary post on the Cromford Cotton Mill.

36.1 Preceding Factories

Figure 276: Lombe's silk mill (Image unknown author in public domain)

One of the key parts of the Industrial Revolution is mechanized and centralized large scale mass production (i.e., a factory). There were factories before the Cromford Cotton Mill. I have written about John Lombe and his silk mill, where a curious tale of industrial espionage helped mechanized silk spinning in England. The Arsenal of Venice could also be seen as a factory, as could the pottery workshops of Josiah Wedgwood. There are more examples. However, the Cromford mill had the largest impact, starting a bonanza of cotton mills in England. Hence, this post will look in more detail at the Cromford Cotton Mill.

36.2 Sir Richard Arkwright

Figure 277: Sir Richard Arkwright (Image Mather Brown in public domain)

Sir Richard Arkwright (23 December 1732 – 3 August 1792) was the son of a Taylor from Preston, Lancashire, England. While initially trained as a barber, he started to improve spinning machines, patenting a spinning frame for making threads in 1769. Arkwright built a cotton mill in Nottingham. However, this mill was powered by horses, which turned out to be rather expensive. Hence, he soon looked for other options using water power.

36.3 Establishing the Cromford Cotton Mill

Arkwright found a good spot in Cromford. An old Roman lead mine drainage channel provided water year round, even in the coldest of winter. The village was also isolated and hence away from trouble and spies. Still a major trade route passed through the village, which would help with sending and receiving materials.

Figure 278: Arkwright Cromford Mill-Photoshop (Image Roser)

First mill (right) from 1772, Warehouse from 1785. The upper two floors of the first mill burned down, the image is photo-shopped to show these floors again as well as the water wheel. Fundaments of the burned second mill are in the foreground.

Arkwright leased the property on August 1, 1771, and started construction immediately. He even bought a house and had it pulled down to get raw materials for building his mill. The mill started producing cotton yarn in 1772, making this year the 250th anniversary of the Cromford Cotton Mill.

36.4 Second Mill

The mill was a huge success. Arkwright was able to produce cotton yarn much cheaper and faster than anybody before. Thus he built a second mill in 1775. This mill was even larger than the first one, with seven floors of 325 square meters each.

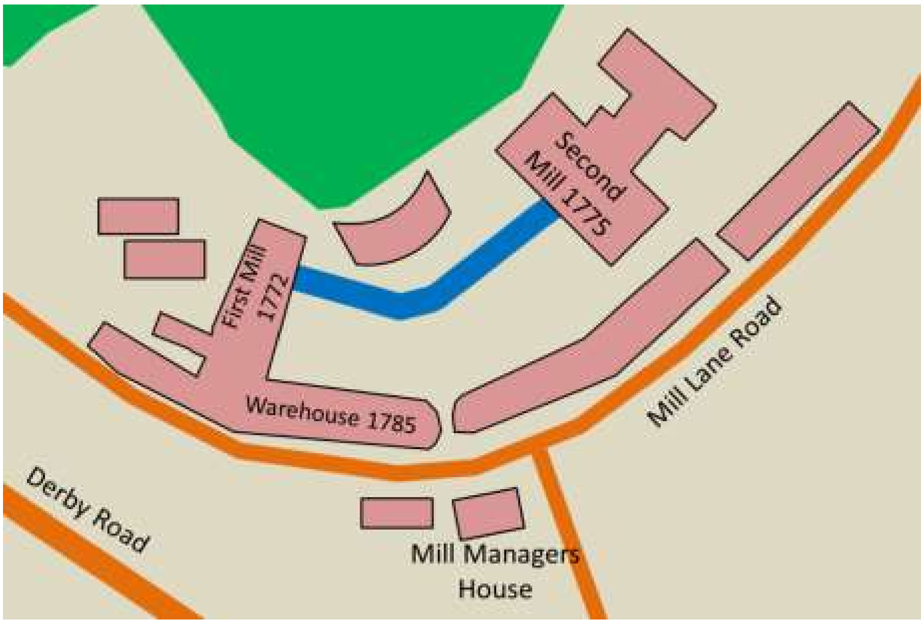

Figure 279: Rough layout of the Cromford Cotton Mill. Altogether, twenty buildings belong to the mill. (Image Roser)

36.5 Managing the Workforce

Like all larger employers at his time, Arkwright had difficulties managing his workforce. However, he was considered a good employer, providing schooling and housing. His salaries were somewhat larger than average, and he tried to avoid violence in managing his workforce.

Highly uncommon for the time, the mill was heated and each floor had a toilet. However, this may have been more in consideration for the cotton, which is easier to process at warmer temperatures, and toilets on each floor reduced the absence of the workers when they needed to go.

Nevertheless, the workers were not always truly motivated, and were often more interested in their ale rather than their work. This was somewhat understandable, as the twelve-hour shifts were quite long (although, again, not uncommon for its time).

36.6 Influence of the Mill

The mill was an enormous success, and hence was hugely influential. While his water-frame spinning machine was still protected by his patents, Arkwright himself built a flurry of mills nearby, including Birkacre Mill at Chorley, Haarlem Mill in Wirksworth, and Masson Mill in Matlock Bath.

Figure 280: Masson mill by Arkwright (Image Justinc under the CC-BY-SA 2.0 license)

Once his copyright expired, many others in England started to build their own mills. Samuel Slater brought the technology to the USA, and Gottfried Brügelmann to Germany—both of course in violation of British intellectual property protection.

36.7 Backlash

The weavers in Britain were very much against the mechanized competition, which was able to produce yarn (and later cloth) both cheaper and better. The Luddite movement destroyed multiple mills, including Arkwright's Birkacre mill in 1779. In response, Arkwright armed up, and even had a cannon installed at the Cromford mill. The mill from the outside also looks more like a fortress than a factory. However, the mill breakers never even got close to Cromford, and the mill escaped unharmed.

Figure 281: The outside of the mill (seen from the mill manager's house) looks more like a fortress. (Image Roser)

36.8 Decline and End

Richard Arkwright died very wealthy in 1792. His son Richard Arkwright Jr. took over the business, and became the richest man in Europe. Unfortunately, the lead mines from which the water came to the mills were deepened, and the water flow was reduced. The mills were never running at full capacity again. In 1850 the Cromford mill was closed. The second mill burned down to the ground in 1890. The first mill burned in 1930, and lost its top two floors. The mill is now a UNESCO world heritage location, but when I visited it it felt somewhat underwhelming for the significance of the mill. Much of the mill is still empty, and other parts have an assortment of random businesses from a software developer to a stop-smoking center.

Figure 282: Ruins of the second mill in the foreground, with the remaining (non-photoshopped) three floors of the five floor first mill in the background. (Image Roser)

Still, I am very impressed with the mill and its historic significance. If you ever happen to be in the area (between Sheffield and Birmingham), check it out, and maybe even some of the other mills from this bonanza of cotton mills. For me, this is one of the first milestones of the Industrial Revolution. It is also an important part of my book in the history of manufacturing – for which I am preparing a revised version to be published next year (however, I have to get the rights back from my publisher first). In any case, I will definitely let you know once it is out. Now, **go out, make whatever you are producing even more efficient, and organize your industry!**

37 This is NOT Lean: Lean Staffing

Christoph Roser, September 13, 2022 Original at https://www.allaboutlean.com/lean-staffing/

Figure 283: Unhappy service employees" (Image Dall•E 2 AI in public domain)

In this post I would like to talk about another term that claims to be lean: **lean staffing**. It is NOT lean! It is an abomination. It is pretty much the opposite of what, in my opinion, lean stands for. It is a complete **lack of respect for humanity**. Let me explain you what it is, why it is terrible, and how to prevent this. Note that this post may include a rant here and there.

37.1 What Is Lean Staffing?

Figure 284: Overworked restaurant waiters (Image Dall•E 2 AI in public domain)

Lean staffing is a buzzword that is making its way around America. It is basically a **deliberate and drastic under-staffing** of whatever you want to do. You intentionally provide not enough manpower for the work, and let the employees scramble to make up for it. Or even if you provide (barely) enough manpower for the average work, it is insufficient to cover the fluctuations. Often it is combined with paying the lowest wage the company can get away with. The reason for this is simple: the owners want to save money and reduce labor cost. But this is very short sighted, as we will see.

Sometimes lean staffing is also used to properly link the tasks with the people (i.e., which person does what when). That may be of use, but the abuse to simply cut labor to the bone is bad. Really bad!

37.2 Where Does It Come From?

Lean staffing comes from the USA. It seems labor relations in the USA are on a very different level than in Europe. Europe sees a company as a social construct, and the company needs to care for its employees (and this is often required by law). In the USA, a hire-and-fire approach is common, and employees are often seen more as biological machines… and treated as such. There is a lack of compassion for workers of middle class and below.

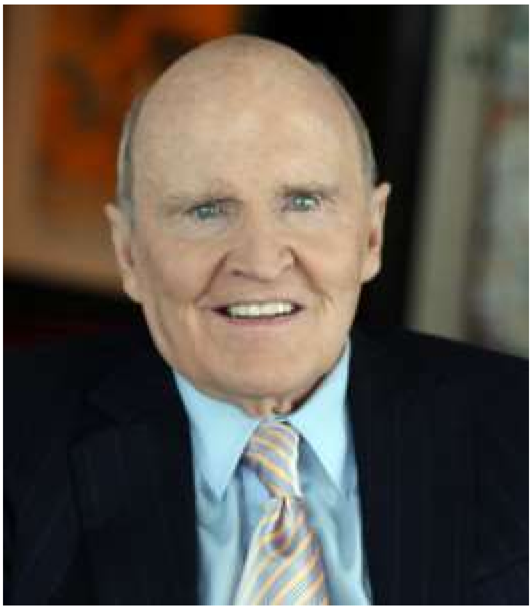

Figure 285: "Neutron Jack" (Image Hamilton83 under the CC-BY-SA 3.0 license)

One early driver of this was "Neutron Jack" Jack Welch, the CEO of General Electrics. He was probably the most prominent top manager who put profit before the happiness of his people. He popularized the "rank and yank" policy (nowadays euphemistically called the "vitality curve"), where the bottom 10% performing employees would be fired each year. This led to a decline in morale and motivation, as well as increased discrimination, and may not even have saved any cost since all managers now spent a lot of time on looking good. The evaluations also cost a pretty penny. Jack Welch increased the valuation of GE, but this may be mostly due to mergers and acquisitions, while the overall value of the company suffered. Overall, it is uncertain whether he was a good manager or was merely looking good.

37.3 Where Is It Used?

Figure 286: Waitress re-stocking Buffet (Image kadmy with permission)

Lean staffing is most commonly found in the service industry and in development. It is more difficult (but not impossible) in manufacturing. An assembly line provides regular work, and having not enough people may stop the entire line. Additionally, technical job workers, even low-skilled ones, do need some training to do the job correctly, which has problems with high turnovers. The workload in service jobs often fluctuates much more, and an under-staffing may be followed by an over-staffing if the current demand goes down.

37.4 Why Is It Terrible?

Figure 287: Burned out Waiters (Image Dall•E 2 AI in public domain)

Lean staffing is terrible. First, it creates an incredible hardship for the employees. Due to the under-staffing, there is always more work than reasonable. Good work is a mixture of busy and not-so-busy times. Being required to always give 130% burns out the workforce. This is often combined with excessively long hours to still get the work done. Lots of pressure and guilt trips ("*Do you want to let your coworkers down?*", "*We all need to give our best,*"…). I read one credible Reddit post (since deleted) where a nurse claimed she was assigned to work 144 hours in a row, or six days straight around the clock. This would be humanly impossible.

People are forced to come in when sick, do two jobs, or do jobs they are not properly trained for. Even if the staff is not exhausted already, safety measures may be neglected. Overall, the employee may get burnout, and both mental and physical health may decline. Once they can no longer do it, they are discarded by the company (i.e., fired) and the next sucker is hired.

37.5 What Are the Effects?

The effects are terrible on the employee. Mental health may decline, physical health may diminish, and the paid wages are often at poverty level. There is no time for friends and leisure, and life is simply no longer fun. If you are curious, for the US you can calculate the poverty level and the living wage for your location here livingwage.mit.edu. After looking up some data, I increased the wage of my copyeditor by 20% to make it (hopefully) a decent wage. I'd rather have a happy service provider than save a few bucks.

Figure 288: Angry Waiters leaving Work (Image Dall•E 2 AI in public domain)

The effects are also bad for the company. The company discards a burned-out employee like a broken tool and gets the next one, and the employees are not stupid. They quickly notice if the company is abusive, and the morale of the employees drop. If the company does not treat them well, they quickly—and rightfully—no longer give a sh*t about the company either. The quality of work declines. Workers may be looking for a better job, and quit at short notice, increasing the under-staffing even more. There are multiple anecdotal examples where the entire staff just walked out, and the business had to close temporarily or permanently. The word gets around, too, and staffing may become more difficult. There is an internal memo at Amazon where they worry "If we continue business as usual, Amazon will deplete the available labor supply in the US network by 2024." In other words, they may run out of people to hire by 2024 due to their eye-watering 150% annual turnover rate.

Overall, this is not a sustainable business. Demotivated and burned-out employees that do not care about the company. High turnover with frequent hiring and firing, including the associated expenses for onboarding, training of new employees, and severance pay or unemployment benefits for dumped workers, not to mention possible legal costs. The customer will notice, too, if the quality of the service is shitty, and may take his money elsewhere. Overall, the entire company will fall short of its potential earnings.

37.6 How to Prevent This

Figure 289: Happy Claymation Waiters (Image Dall•E 2 AI in public domain)

The whole problem of lean staffing seems to be mostly a US problem. While in Europe some employers would like to do this too, European labor laws protect employees from abuse. In Germany we get at least 25 days (usually 30) vacation every year. Additionally we get almost unlimited paid sick days. I have heard of employees that were finally let go after 2.5 years of uninterrupted paid sick leave. Firing is difficult and requires a very good cause. If the company messes this up, the courts will breathe down their necks. Except for gross misconduct, there is a termination period of at least 1 month before an employee gets fired and actually leaves the company. Depending on your stay with the company, this can increase up to seven months.

Figure 290: Happy Waiter and Manager (Image Rido81 with permission)

Since companies in Europe are forced to stick with the employees they have, they must treat them not as expendable but as a fixed asset, and take care of them and maintain good relations. The USA often sees workers as commodities to be disposed of if they no longer work. Europe usually sees them as investments, and they have to work on maintaining relations. Partially responsible for this are labor unions that represent the interests of the workers. Not all unions are good, but no unions would be quite bad. Unions in Germany are, in general, also seen as cooperative and working with the company to its overall success. The unions of one plant I worked at had a strike every year out of principle, but they scheduled it two weeks in advance for a Friday afternoon one hour before closing time. Hence, while they proved that they can strike, the actual impact on the plant was negligible. Overall, unions can also influence the government to improve labor relations. But in the USA, many companies are fighting against unions ("union-busting") with legal and not-so-legal means (Starbucks, Amazon, Apple, and many more).

Overall, work life in Europe is much more benign than in the USA. A worker in the USA, even in middle class, has the constant threat of losing everything. You got cancer? Here's your multimillion-dollar medical bill. Now you are homeless too, and still have cancer. Europe provides many safety nets like unemployment insurance, health insurance, pension insurance, and more. While you still can fall, it is unlikely to end in homeless, broken, sick ruin. This lack of safety in the USA makes many people literally sick. Crime increases, mental health overall declines, and the entire nation pays the price for a questionable profit of some companies. I have worked in both the USA and in Europe, and while Europe also has its flaws, I much MUCH rather prefer to work in Europe.

I hope this was not too much of a rant. I love lean, and it hurts me to see the total opposite of lean labeled as lean. Now, **go out, respect your employees, and organize your industry!**

38 Should You Split Your Production System into Two?

Christoph Roser, September 20, 2022 Original at https://www.allaboutlean.com/split-your-production-system/

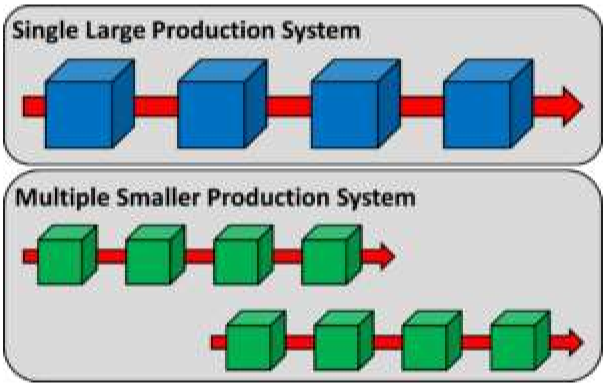

Figure 291: Single Large or Multiple Smaller Production Systems (Image Roser)

In a recent discussion on setting up a new line, a question came up: Should we make a single line (or generally a production system), or should we establish two (or even more) separate independent production lines? There are usually a handful of arguments for either side, and cost is only one of them. Sometimes the issue is clear, but sometimes you have to judge the different factors to decide. This post will give you an overview of the different factors that are relevant. Let's dig a little bit deeper on how to approach this issue.

38.1 The Initial Situation

Figure 292: Valve Assembly Line (Image The Light Writer 33 with permission)

Assume you have to make more of a product or a product type. This could be a completely new type of products (i.e., a new production system), or a larger production volume for an existing type of products (i.e., you are producing them already). In any case, you need more capacity. If you already have a line, maybe you could expand the existing line or build another line. If it is a completely new product, you could establish one or two lines (or even more).

This is influenced if you make multiple (similar) products: Do you make one large line that can produce all, or do you make dedicated lines that can produce only one product (or a subset of your product group), with multiple lines dedicated to different product subgroups?

38.2 Cost of a Second System

Figure 293: Assembly line workers (Image bibiphoto with permission)

Probably one key factor is cost. But this is a multi-faceted aspect. If you have two lines, you need **twice the equipment**, **twice the tools**, and **twice the floor space**. However, depending on the situation, this is probably not double the price tag, as the different machines could be smaller and may not be as expensive. For example, if you need an oven, two smaller ovens are not twice as expensive as one big oven. At the minimum, you could get a discount from the tool maker for buying two ore more of the same tools. Overall, a single larger system can usually produce items cheaper than two smaller systems.

38.3 Fluctuations

One big advantage of one larger system is the economy of scale, especially **reduced fluctuations**. While the absolute fluctuations of a larger system will be bigger than that of a single system, the relative fluctuations are reduced. Let's take, for example, an inventory that is managed using a reorder point method. The image below on the left shows a single large system, where the inventory fluctuates between the reorder point (the safety buffer) and the inventory limit. Using the same material at different locations makes the absolute fluctuations at each location smaller, but the combined fluctuations at both locations are larger. You need, in total, more safety buffer, and more inventory between the reorder point and the inventory limit. Altogether the combined average inventory of two separate systems will be more than the average inventory of a single system with twice the production volume.

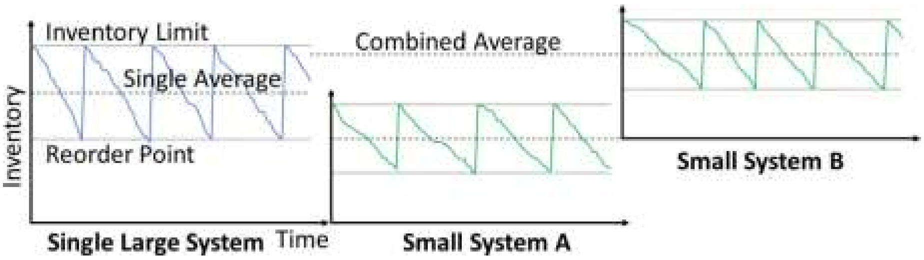

Figure 294: Large Small System Fluctuations (Image Roser)

This applies to many different fluctuations related to your production system. You need to **establish two logistic chains**. If it is in the same plant, the logistics only differ inside of the plant. If it is in different locations or on different continents, you need to create two separate logistic systems. This will **increase your overall work in progress**, as you now have material fluctuations on two (or more) different locations. This may not be twice the inventory, but providing material at two locations needs more material than providing at one location. Similarly, you may need slightly more workers to cover the fluctuations of absences. You may also need slightly more maintenance personnel. Overall, the management of fluctuations is usually a big reason for having one system instead of two systems.

This is also the primary reason that Toyota pushes for flexible assembly lines that can produce multiple models, as this allows them to merge multiple products in one line and reduce fluctuations proportionally. If product A is popular and B not so much, then the line can handle it. If a little bit later B is now popular and A not, then the line adjusts and can also handle this. Usually a larger system provides more flexibility, but please note that there are **exceptions for batch processes**. A larger oven (or similar batch process) can process more products, but this may require larger lot sizes. And lean manufacturing does not like larger lot sizes. It may be better to install two (or more) smaller ovens that allow you to process in smaller batches and hence **smaller lot sizes**. This reduces your inventory and has many benefits that are hard to measure but are still substantial.

38.4 Management Effort

Figure 295: Smiling Manager in a Warehouse (Image mavoimages with permission)

You definitely need more **management effort** and attention, as someone now needs to manage and maintain two production systems. Please do not underestimate this, both for the initial set up (e.g., calculating the number of kanban) and the effort in running the line. If the lines are in different locations, two managers/supervisors need to learn how to manage the line. If they are in the same plant, the same manager can handle both lines, which eases the learning curve, even though it is still more effort than a single larger line.

38.5 Benefit of Different Locations

Figure 296: World Map made of Felt (Image Dall•E 2 AI in public domain)

One factor is the location. Do you have one production system in one plant, or do you have production systems in different locations? A common reason for having a second production system elsewhere is to be **closer to the customer**. This **reduces delivery time** and **delivery cost**. It may also make your production system **more robust** against human and natural disruptions. Having a second independent location elsewhere may make your production **more resilient** against natural disasters (earthquake, tsunami, …), plant disruptions (fire, strike, …) political upheaval (war, closure of borders, …). It may also give you brownie points with the political caste for producing “made in [a country],”, both internationally but sometimes also within the same country (Made in Alabama?).

38.6 Capacity

Figure 297: One empty green wine bottle (Image Roser)

Another major constraint is capacity. Can you fit all your products through a single production system? Or does the capacity of a single line no longer suffice to satisfy the customer demand? Often there are some workarounds like a capacity improvement, bottleneck detection, or simply additional shifts. But night shifts are more expensive, and it may be not economically sensible to improve capacity.

38.7 Summary

Usually, I try to **go for larger systems to benefit from the economies of scale, unless there are reasons not to**. Reasons for making separate production systems are if it is important to be close to the customer, or if the (reasonable) capacity is maxed out, or for political reasons, or a demand on robustness requires additional locations. I may also choose multiple smaller systems for batch processes if it allows me to process smaller batches and hence reduce the lot size. Now **go out, build one (or two?) production systems, and organize your industry!**

PS: Phil Ledbetter on LinkedIn added that different quality levels (e.g. Lexus vs. Toyota) may benefit from different lines, since the attitude towards the product needs to be different. Thanks, Phil!

PS2: Marco Dannerhill on Linkedin also added the very valid point of robustness. if one line breaks down, it is easier if you have a second one.

39 What Should Be Your Target OEE?

Christoph Roser, September 27, 2022 Original at https://www.allaboutlean.com/target-oee/

Figure 298: Smiley Frowney Percent (Image Roser)

It is common in industry to measure the utilization or the closely related OEE. It is a bit more difficult, however, to set targets for these KPI. Often you hear people wanting or demanding an OEE as high as possible, with a long-term target of ideally 100%. That is often problematic. The utilization or OEE is unfortunately not a clear cut target that you can simply maximize. Let me explain…

39.1 Introduction

OEE is short for Overall Equipment Effectiveness (or sometimes Overall Equipment *Efficiency*), and is a measure closely related to utilization. It tells you **how much you produced compared to how much you could have produced at most, theoretically, in the same time**. In other words, if you have an OEE of 80%, you produced 80% of what your system could have produced if everything went perfectly. The OEE can be calculated in two ways, giving identical results:

$$OEE = \frac{Minimum\ Time\ to\ make\ Parts\ under\ ideal\ Conditions}{Actual\ Time\ needed\ to\ make\ Parts}$$

$$OEE = \frac{Number\ of\ Parts\ produced}{Parts\ that\ could\ have\ beenproduced\ in\ the\ same\ Time\ under\ ideal\ Conditions}$$

In both cases you compare the actual time or output with the time or output that would have been possible under ideal conditions (i.e., nothing goes wrong, no breakdowns, defects, etc.). The OEE should be a number between 0 and 100% – although with number fudging you sometimes see values over 100%.

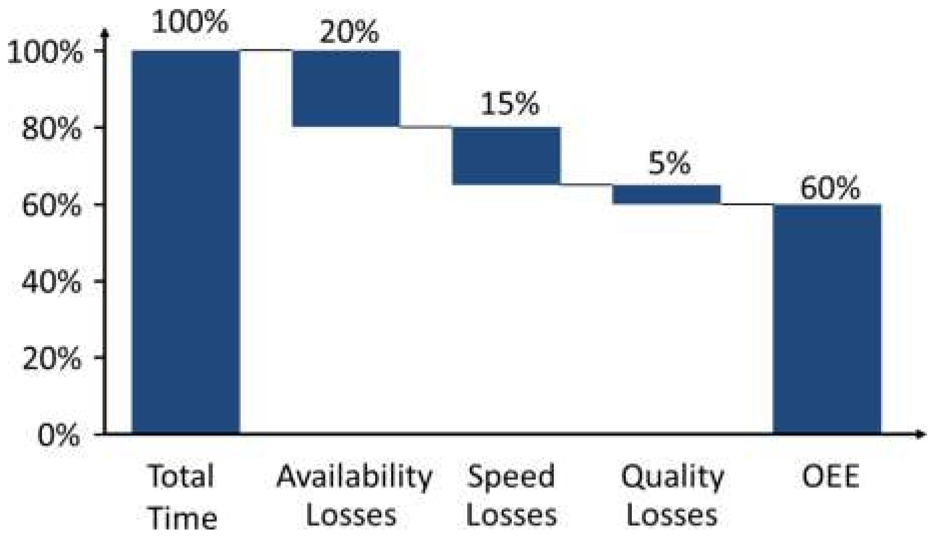

Figure 299: OEE waterfall chart (Image Roser)

I have written a lot about OEE before, including what it is, what OEE is good for, how to measure it, and also some alternative ways to calculate it and many measures similar to OEE.

39.2 OEE above 100% – Your OEE Is Wrong

Figure 300: Arrow going through the roof (Image monsitj with permission)

First, let's get one thing out of the way: an OEE above 100% is bogus. An OEE is a percentage of what is possible under ideal, perfect circumstances (i.e., the maximum speed). If your OEE exceeds that, then you are either working faster than physically possible, or you are fudging the numbers. Pardon me, but I don't believe that you can break the laws of physics, hence I won't believe any OEE above 100% – although I have seen quite a few claims to OEEs above 100%.

39.3 Target OEE at 100% – No, You Don't Want That

So, if above 100% is not possible, what about 100%? This should be the maximum possible speed, and we should aim for that, right? Sorry, no. For this I actually have to dig a bit deeper. OEE, and in relation the utilization, has an inverse relationship with inventory. If your inventory goes down, so will the utilization. If your utilization goes up, so will your inventory. The graph below is derived from the Kingman equation. For a simple single-arrival single-process system, it shows the waiting time in relation to the utilization. The waiting time represents the number of items waiting. The higher the utilization, the higher the waiting time. Unfortunately, it is not a linear relation, but an exponential one, and the waiting time for a 100% utilization is infinite.

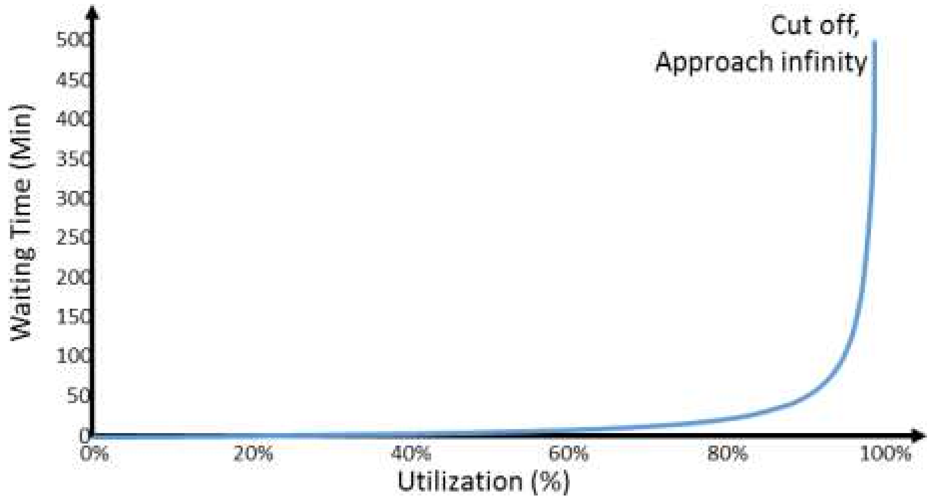

Figure 301: Utilization and waiting time according to Kingman (Image Roser)

This means that if you want a utilization of 100%, you are willing to have an infinite inventory. In lean, large inventories are bad, and infinite inventories are as bad as it gets. Luckily, infinite inventories are not possible, and hence 100% utilization is not possible either.

The Kingman equation is a simplified system, but you will find similar behavior in all production systems. For example, if you make products on order (make-to-order), then your utilization usually goes up with the number of orders you have. However, the more orders you have, the longer each order has to wait. For a 100% utilization, you would need an infinite number of customers waiting.

39.4 Fluctuations

Naturally, there are ways to reduce inventory despite high utilization, and that is by reducing fluctuations. The second important input to the Kingman equations are the fluctuations. The higher the fluctuations, the higher the inventory or waiting time in your system for the same utilization (or the lower the utilization for the same inventory). The relationship is shown below again for different exemplary levels of fluctuation. I added this, since I feel that managing fluctuations is often ignored or neglected on the shop floor.

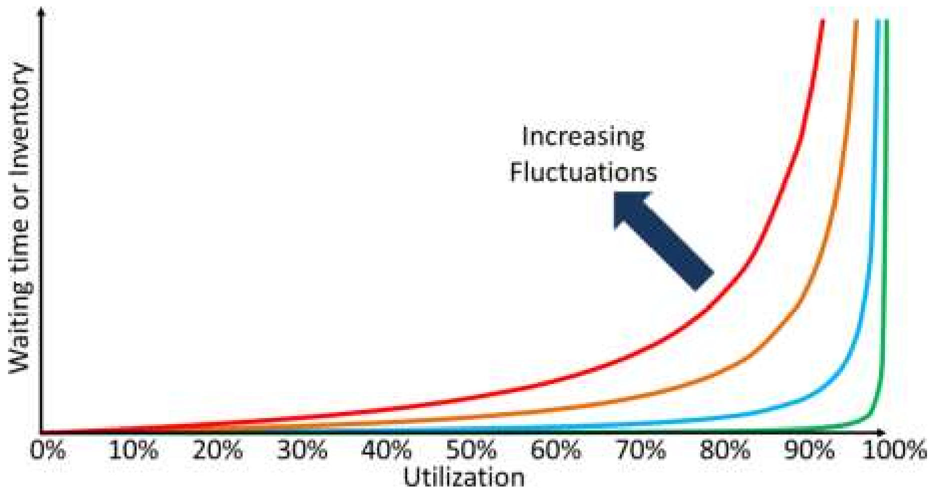

Figure 302: Kingman Multi-Line (Image Roser)

In any case, regardless of the level of fluctuations, they all approach infinity as the utilization approaches 100%. Hence, again, 100% utilization is not possible.

39.5 Make-to-Order vs. Make-to-Stock

Figure 303: 100% utilization means long waiting times (Image Markburger83 and Lauro Sirgado under the CC-BY-SA 3.0 license)

Before we will look at what a good OEE is, we should make one important distinction. Are you producing on order (make-to-order) or is the product on stock (make-to-stock)? With make-to-order, the lead time is usually critical for the customer, and the number of open or worked-on jobs should not get out of hand. Make-to-stock, however, can not only have larger inventories, but actually needs larger inventories to have items for the customers when they need them. Hence, very generally, you can have higher OEEs for make-to-stock production than for make-to-order production.

39.6 Common OEEs in Industry

Figure 304: What is the OEE? (Image olly2 with permission)

When in the industry, I am often presented with OEEs of 70–90% in mass production of make-to-stock items. However, whenever I dig deeper, I find lots of ~~funny things~~ unusual ways to calculate the OEE, like taking out maintenance time and other things that make the OEE look better but less stringent. For details, see my sarcastic article on fudging the OEE. If I would have done a more stringent calculation, I would get OEEs of 60–70% for not-outstanding-but-also-not-bad companies. The lowest OEE I have actually measured in mass production was around 30%, meaning 70% of the machine capacity was wasted. That was a not-so-good company.

39.7 Bottleneck or Not?

Figure 305: One empty green wine bottle (Image Roser)

Before I finally go to the different ranges of OEE, one more comment: The OEE is usually only relevant for processes that are bottlenecks or, more generally, limit your output. If you want more parts, you should improve the bottlenecks (and this may be more than one machine at different times). For more on bottlenecks and their detection, see my series on bottleneck detection.

If a process is NOT the bottleneck, then its utilization does not matter, and usually the OEE does not either. (Small caveat: if it is highly inefficient, you may still improve it to reduce the time of the workers, but this is not a measure to get more parts out of your system). But overall, focus with your OEE on your bottlenecks.

One anecdote: I know the story of one smaller company that bought an expensive primary machine. Since it was expensive, the thought was that the machine should run as much as possible. Yet, the customer did not buy enough product, and the machine was just filling up warehouses with products that got old and tied up cash. If your customer is not buying enough, then the OEE should not be used to justify more production, but could be used to produce more efficiently.

39.8 What Are Good OEEs?

Figure 306: Good Range of OEE (Image Roser)

So, let’s have a look at what I consider a good range of OEEs. This is only my personal opinion, and (unfortunately) not based on a lot of data, the problem being heavy number fudging of OEEs all over industry. Also note that these are for OEEs that are calculated stringently, and not the generous "*I need goo numbers*" type of OEEs that are unfortunately all too common. I believe for make-to-stock production, having an OEE of 80–90% is outstanding. If the OEE is above 90%, then you are getting too much toward the danger zone of infinite inventory. For make-to-order production, I would go a notch lower and consider 70–80% OEE (stringently calculated) an excellent value. This (and ballparks for good, average, and bad OEEs) is shown in the table and graph here. Again, this is only my opinion.

Ranking	Make-to-Stock	Make-to-Order
Too Much!	>90%	>80%
Benchmark	80-90%	70-80%
Good	60-80%	50-70%
Average	40-60%	30-50%
Bad	<40%	<30%

So, this concludes the post on what I consider a good OEE. I hope this was useful, and I hope that your (stringently calculated) OEEs are not too far away from where you want them to be (again, not 100%!). Now **go out, get your OEE to a good range, and organize your industry!**

40 Why FIFO: The Benefits of First In, First Out

Christoph Roser, October 4, 2022 Original at https://www.allaboutlean.com/fifo-benefits/

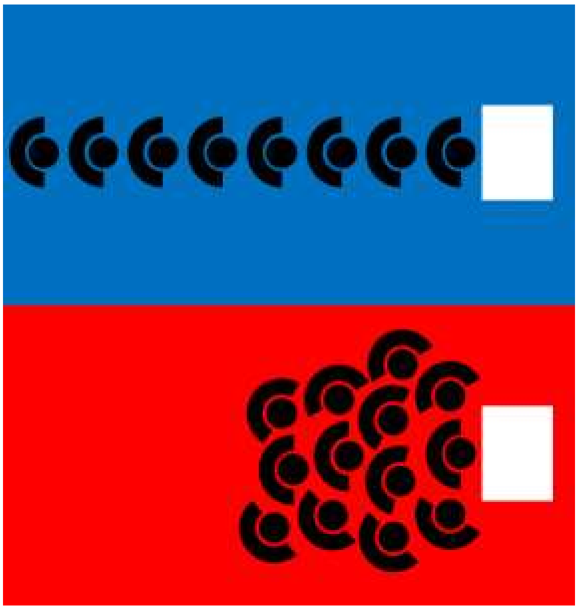

Figure 307: Waiting for service – FiFo or not (Image Roser)

FIFO (first in, first out) is one of the simplest and most basic ideas in manufacturing, and yields significant benefits. It is so simple that I don't even want to call it a tool, since it is one of the fundamentals in manufacturing (and many other areas). In this post I want to take a closer look at the power of this most fundamental approach to material flow.

40.1 Introduction

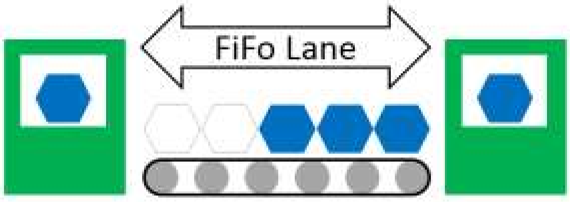

Figure 308: FiFo Lane (Image Roser)

FIFO simply means that the first part going into a system is also the first part going out of the system. There are some alternatives (see my blog posts on delivery sequences and production sequences for more), but unless you have a specific reason for not doing FIFO, you should stick with FIFO.

If the FIFO is part of a pull system, it is also helpful if the FIFO has a clearly defined limited capacity. But the big advantage is the sequence of parts.

40.2 Reduces Fluctuations, Especially Lead Time

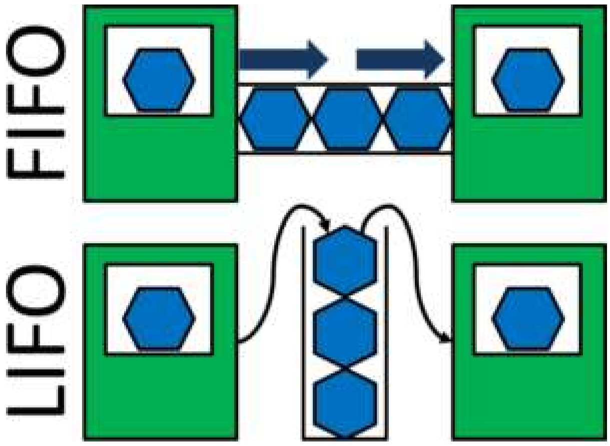

Figure 309: FIFO vs LIFO (Image Roser)

The main reason for FIFO is that it reduces fluctuations in the material flow, especially on lead time. To understand this, let's compare FIFO with its opposite, LIFO (last in, first out). While in FIFO all parts have to wait similar times, in LIFO the last part get serviced first, and the first part has to wait excessively long. On average, the waiting times will be the same. However, the fluctuations (or the width of the distribution of the waiting times) will be much MUCH larger in LIFO than in FIFO.

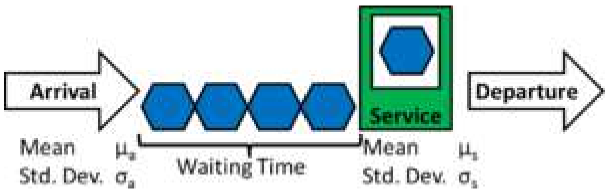

Figure 310: Kingman Equation Example System (Image Roser)

This point is so important that I made a small simulation of a single-arrival single-server process. A part arrives every 10 time units, with a random exponential distribution. The process can handle a part every 9 minutes, also exponentially distributed, giving overall an utilization of 90%. Parts wait in a queue with infinite capacity. Simulation time is 100 000 time units after a 100-time-units warm-up. I measure the time a part spends in the system. The only difference is that in one simulation, the queue or buffer is using FIFO. In a second simulation, the queue is using LIFO. Everything else is the same, even the pseudo-random number generator created exactly the same random numbers for each simulation.

Below is the histogram showing the waiting times of up to 100 time units. The average waiting time was identical for both simulations, 49.7 time units. However, the distribution differed quite a bit. The median (i.e., half of the parts were faster than this) was 36.1 time units for FIFO, and only 15.1 time units for LIFO. Most parts were much faster through the system in LIFO than in FIFO. You can also see this on the bars, where the blue LIFO bars are much more toward the left than the green FIFO bars. What is happening? I tell you that FIFO is so much better than LIFO, and yet this graph seems to indicate that LIFO is actually faster. Well, there is a crux.

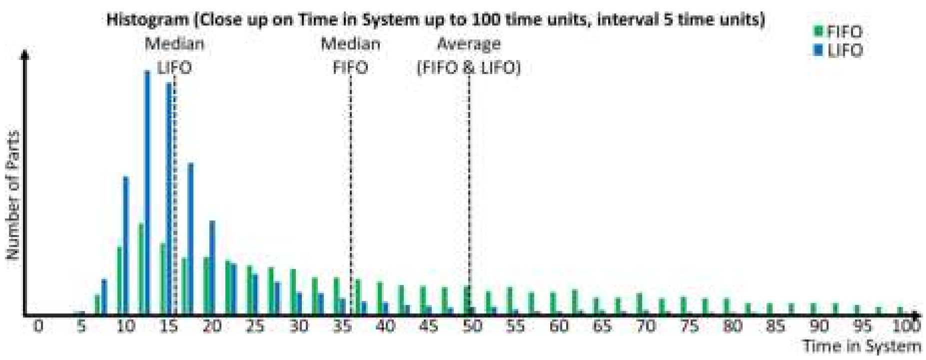

Figure 311: FIFO LIFO Time in System Closeup (Image Roser)

The chart above is cut off at 100 time units. The full histogram is shown below. In average, FIFO and LIFO have the same mean waiting time. But if a lot of LIFO parts are much farther to the left than the FIFO parts, it means that some LIFO parts are far, FAR out on the right end of the scale. These are not many, but they have a much MUCH larger waiting time. In my simulation, the FIFO part with the worst waiting time was 268 time units in the system. The worst LIFO part was 3170 time units in the system, almost 12 times longer! The standard deviation of FIFO was 42.5 time units, but for LIFO it was 168.8 time units, a fourfold increase. In the graph below it is a bit hard to see, but there are quite a few LIFO instances of waiting times all the way out to 3170 time units. In academic terms, this LIFO histogram is a heavy-tailed distribution.

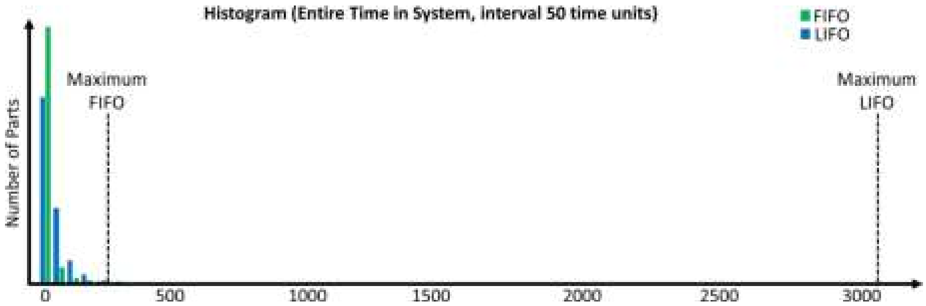

Figure 312: FIFO LIFO Time in System Entire System (Image Roser)

This is the real problem of LIFO. While on average it makes no difference between FIFO and LIFO, the worst parts of LIFO wait magnitudes longer than with FIFO. And, with a LIFO system, you cannot control this. It is really hard to plan lead times and buffer inventories if some parts arrive quickly, but others take forever to arrive.

Note this is different with prioritization. If you properly prioritize, then you do the same thing and your urgent parts arrive faster at the cost of your less urgent parts. However, with prioritization you control which part gets handled first. With LIFO it is pretty much random. Hence, use FIFO if you can. Avoid other sequences if possible, and stay away from LIFO!

40.3 Reduces Management Overhead

A second, smaller but also significant benefit is that FIFO reduced management overhead. If you have any sequence out of FIFO, someone needs to decide which part to make/ship next. That is effort, and also a potential for mistakes. If nobody does that, then the workers will merely pick the part that they like most (because it is the closest, the easiest to work with, the one with the largest bonus payment, …). With FIFO, the organization is easy. Simply take the next in line.

40.4 Traceability


Figure 313: Connected dots (Image Your_photo with permission)

FIFO also helps with traceability. Full traceability requires giving every part its own serial number, and tracking it in a database across its way along the value stream is most stringent—but also requires the most effort. A FIFO is sort of a traceability light. Within a few processes, if there is FIFO it can be reconstructed which part was where if you find, e.g., a defect. Following up on that defect and trying to narrow down the root cause is much easier if you have the original sequence of parts. It is still work, but it is possible. If the sequence is out of order, tracing back the error to its cause will be much harder.

Note that it helps you in detecting the cause of the defects, but it does NOT help in detecting the defects earlier. This depends solely on how much work in progress you have, where less is better. FIFO and other sequences have the same mean waiting time, and only different fluctuations. If you have LIFO, you may detect some defects earlier, and some defects later, but in average it will be the same. As for how large this FIFO inventory should be, it depends on how many of your fluctuations you want to decouple. You can calculate this, but this is messy. You use my online calculator, or you can just use your best guess.

40.5 Even More Advantages

There are even more advantages of FIFO. If set up correctly, it is a clearly defined material flow. This makes the material flow easier and more efficient. As any material flow is also simultaneously an information flow, FIFO is also an information flow. Different from other sequences, it is an easier information flow. While other sequences need additional information on the sequence (i.e., “Which part is next?”), FIFO automatically includes this information. The next part is always the first in line! It is also easier to see, and can hence be part of visual management.

40.6 Further Reading

I have written a lot about FIFO already. Some of the links are already mentioned above. I, of course, have some basic theory on FIFO. Other posts are on strong and weak FIFO, or when NOT to use a FIFO. Overall, FIFO is a great approach, and unless there are strong reasons not to do FIFO, I would always use FIFO wherever possible. I hope this article motivated you to (continue to) use FIFO. Now, **go out, get the FIFO flowing, and organize your industry!**

41 How to Reduce Your Lot Size Part 1—Introduction

Christoph Roser, October 11, 2022 Original at https://www.allaboutlean.com/reduce-lot-size-3/

Figure 314: Large Pile of Screws (Image BearVision with permission)

In lean, the perfect lot size is one. Ideally, you should be able to make your products in a lot size of one. However, especially in mass production, larger lot sizes are common. Getting down to smaller lot sizes, or ideally to a lot size of one, is not always easy, and sometimes may not even be economically feasible (yet!). Let me discuss ways to reduce lot sizes.

41.1 Introduction

Figure 315: Different Piles of Screws (Image BearVision, firehell, and PavelMuravev with permission)

Smaller lot sizes have lots of benefits. For make-to-stock, the biggest benefit is a reduction in inventory, as you need less material to cover the time until you make the product again. For details on the math behind that, read this post. Both for make-to-stock and for make-to-order, a smaller lot size reduces fluctuations (mura). I have written a three-post series on How to Determine Your Lot Size, and also on Toyota's and Denso's Relentless Quest for Lot Size One.

On a side note, batch size and lot size are used interchangeably here. In industry a batch refers to a production size, and a lot can refer to either the quantity in production, or in purchasing, or in a customer order.

41.2 Why Lot Sizes?

Figure 316: Stack of Euro Boxes (Image Nino Barbieri under the CC-BY-SA 3.0 license)

There are different reasons to use lot sizes larger than one. These are often one or a combination of the causes listed below.

- **Changeover Time**: Changeovers that take more time often require larger lot sizes.
- **Container Size**: Often, a lot size is set to how much goods you fit in one (or multiple) transport unit(s) (a container, a box, etc.).
- **Shipment Size**: Similarly, a lot size is often set to the size of a shipment.
- **Customer Order Size**: Somewhat overlapping with the shipment size, a lot is also often simply set to the order size of the customer.
- **Machine Batch Size**: Some processes can produce multiple products at once (e.g., an oven for annealing, or a injection mold making multiple parts of one product). A lot size is often set to one or multiple batch size quantities of the largest machine batch size in this part of the value chain.
- **Leveling Pattern**: Some leveling approaches try to make a multi-week pattern, with daily quantities pooled together in lots. I really do not like this type of leveling at all, as it usually does not work. See here for a rant on this. But the lot size would here be the long-term average daily demand.
- **Tradition**: The lot size has always been this way at the company…
- **Accounting**: Accounting simply determined the economic order quantity. Unfortunately, there are lots of assumptions in this equation, and the benefits of smaller lot sizes are especially hard to calculate and hence usually ignored.

41.3 Where to Start?

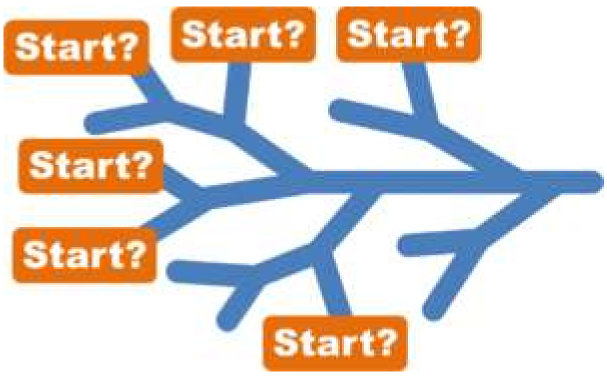

Figure 317: Where to Start? (Image Roser)

As you see, there are many causes for the symptom of larger lot sizes. Simply reducing the lot size will often cause subsequent problems. You need to address the cause of the lot size, before you can reduce the lot size itself. Depending on why you have a larger lot size, the approach may differ. Note that if you have a larger lot size due to multiple reasons, then you may have to address multiple causes. However, not all of these reasons have the same priority. For example, assume that you make some metal bolts, of which 10 fit in a box. The box then indicates a lot size of 10. At the same time, the changeover time at your machine is significant, suggesting lot size of 100 bolts (or 10 boxes). If you would start to use smaller boxes that fit 5 bolts each, you still would have a lot size of 100 due to the changeover time. In this example you must start addressing the changeover that causes the larger lot size, before any improvement in the box size would have an impact. **Always start with the biggest cause (i.e., the largest constraint on your lot size).**

41.4 How to Proceed?

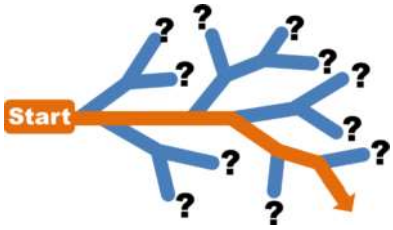

Figure 318: Too many options (Image Roser)

You have identified the reasons that cause your lot size to be not one. But I strongly caution you not to make one big step to lot size one and eliminate all reasons at the same time. Lean is usually most successful as a series of many small steps. Start with the biggest cause. Once this is stable (and you have time again), address the next cause, and so on. It may take a long time and multiple steps to get even close to lot size one. On a side note, multiple small steps also often looks better for your career, as many bosses subconsciously put more weight on the number of improvements rather than the quantity of improvement. If you improve your lot time ten times a bit, it may give you more credits for promotion than reducing it once to a lot size of one.

Also, if other problems pop up that are more serious than the lot size (e.g., your quality takes a nosedive), address these before continuing with reducing the lot size. Always focus on the most relevant problems on hand, and if your lot size is not a high priority, let it wait until you have time again to improve the lot size. Now, let me go through these causes for larger lot sizes one by one.

41.5 Reducing Lot Sizes Caused by Accounting

Figure 319: But the cost!!! (Image Minerva Studio with permission)

This one is the last on my list above, but let me discuss it here first, since it is a major part of most of the other reasons for larger lot sizes. One of the recurring problems we will find when reducing lot sizes is that the cost of this reduction is easy to calculate. If you reduce your lots size to half, you need twice the changeovers, or twice the number of shipments, or twice the number of boxes, etc. All of this can be measured monetary by accounting.

Unfortunately, the benefits are hard to calculate even though they are definitely there. You can capture part of it by measuring the cost of inventory…or at least the tied up capital and the storage cost. However, the benefit of reduced fluctuations is nearly impossible to pin down. Hence, here, too, you have a conflict between measurable cost and unmeasurable benefits. This will be a recurring theme in this series of posts, and many levers are affected by this.

Accounting likes to determine lot sizes using the economic order quantity formula. This gives the—supposedly—optimal lot size. Unfortunately, this equation neglects many costs or benefits, and completely ignores fluctuations. Hence, the lot sizes tend to be much larger than sensible. Personally, if I use this formula, I like to divide the result by three for a better target lot size. In any case, be prepared for some tough discussions with accounting.

In my next two posts I will go into more details on the different causes for larger lot sizes, and the different ways how you can reduce thee lot size accordingly. Now, **go out, try to reduce your lot size, and organize your industry!**

42 How to Reduce Your Lot Size Part 2—Changeover, Container, and Shipments

Christoph Roser, October 18, 2022 Original at https://www.allaboutlean.com/reduce-lot-size-2/

Figure 320: Small Pile of Screws (Image firehell with permission)

In my last post I gave some basics on how to reduce the lot size in order to reduce both inventory and fluctuations (mura). There are many different reasons why you may have larger lot sizes in the first place. Depending on the root cause, the possible solution may differ. In this and the next post I will look at these different root causes and possible solutions in more detail.

42.1 Reducing Lot Sizes Caused by Changeover Time

Figure 321: A lot of work to change the tool… (Image Roser)

If you want to improve the lot size due to the changeover time, then your first guess would probably be improving the changeover time through SMED (Single Minute Exchange of Die). Yes… but hold on a minute before starting a SMED workshop.

If the lot size is primarily due to the changeover time, then indeed SMED can help. But often, the lot size based on the changeover is set generously, because manufacturing often just loves large lot sizes.

Before you embark on a SMED workshop (which takes a bit of effort and time), first look at the numbers to see if you can reduce the lot size to something less generous but still compatible with the current changeover time. If so, this would improve your lot size with a mere stroke of the pen (and a bit of convincing on the shop floor), and save you a lot of time and effort. If this is enough for a first step, then it would be the easier approach.

However, for a larger improvement, of course, you need SMED to reduce your changeover time. Get your people together, including some that actually do the changeover. Analyze the changeover(s) that cause your large lot size, and improve them. Create a new and improved standard for the changeover. This may be more work, but will yield larger benefits. I have described SMED in a small series of blog posts starting here. As always, do the PDCA and verify that the new changeover sequence actually works and is also still used even a few weeks later.

42.2 Reducing Lot Sizes Caused by Container Size

Figure 322: Not filled to the brim… (Image Roser)

If your lot size is primarily due to your container size, the first thought would be, too, to reduce the size of the container. This is possible, but also more effort and cost to use smaller containers. An interim solution would be simply to fill containers only partially. This is less effort on the hardware, but may need more convincing and working with your people to have them actually fill the container only partially. If it is always the same container, it can help to use a visual indicator on how high the container is to be filled. For example, you could mark the target fill level in a plastic box using a permanent marker. This works especially well if the lot size does not need to be ultra precise (e.g., a box with approximately 100 screws).

Figure 323: Stack of Euro Boxes (Image Nino Barbieri under the CC-BY-SA 3.0 license)

If you decide to use smaller containers, you have a bit more work. You need to obtain smaller containers. Maybe you have them already as part of your storage system, or you may have to buy some. Next you need to look at how the container is used and where it is stored. Do you have to adjust the shelves, supermarkets, or general storage locations to the smaller container size? Do you need to train the workers and update the standard for the smaller container sizes? How are the containers transported? Do you need to update the standards for transport? Do you need to adjust or update the transport equipment? As always, include at least some people in the process that work with these containers, as this will help you with the acceptance of your improvement. As always, do the PDCA and verify that the new container size actually works and is still used properly even a few weeks later.

42.3 Reducing Lot Sizes Caused by Shipment Size

Figure 324: Your logistic chain? (Image Uwe Aranas under the CC-BY-SA 4.0 license)

If your lot size is primarily due to the size of the shipment (either from your supplier or to your customer), then the solution is to reduce the sizes of the shipment. However, be prepared that this will raise the blood pressure of your colleagues in accounting, because more shipments for the same volume usually means more shipping cost, which accounting can calculate you down to the cent. Unfortunately, the benefits are hard to calculate even though they are there. Hence, again you have a conflict between measurable cost and immeasurable benefits.

Figure 325: Gullwing Truck in Japan (Image Roser)

Here, too, are—depending on the circumstances—some different ways to address this issue. If your shipment is a truckload, then smaller shipments mean more trucks. Alternatively, you can consider an external milk run, or generally try to fill your truck with different shipments. Toyota does this very successfully at their main plants in Toyota City, using smaller "gullwing" trucks that are also quick to open from the side. (Note: I have been told that there may be some EU regulations that do not permit this in the EU).

If your shipment is merely a parcel with many other parcels, then less and more frequent parcels have only an additional ordering and handling cost, which is hopefully not too big and won't be opposed by accounting. Also, to remind you from my last post, while a lot size of one is the ultimate true north, it is not necessarily a sensible next step in many cases.

The next post will conclude these approaches for reducing lot sizes by looking at customer orders, machine batch size, leveling patterns, and tradition. Now, **go out, reduce your lot size by reducing changeover time, or container size, or shipment size, and Organize your Industry!**

43 How to Reduce Your Lot Size Part 3—Customer, Machine, Leveling, and Tradition

Christoph Roser, October 25, 2022 Original at https://www.allaboutlean.com/reduce-lot-size-1/

Figure 326: Five Screws (Image PavelMuravev with permission)

This is the third and last post in my series on how to reduce the lot size. The first post gave some introduction and how to approach the problem of reducing lot sizes. The second post looked in more detail at how to reduce lot sizes due to changeovers, container size, and shipment size. This final post will look at the remaining causes of customer order size, machine batch size, the abominable leveling pattern, and tradition.

43.1 Reduce Lot Sizes Caused by Customer Order Size

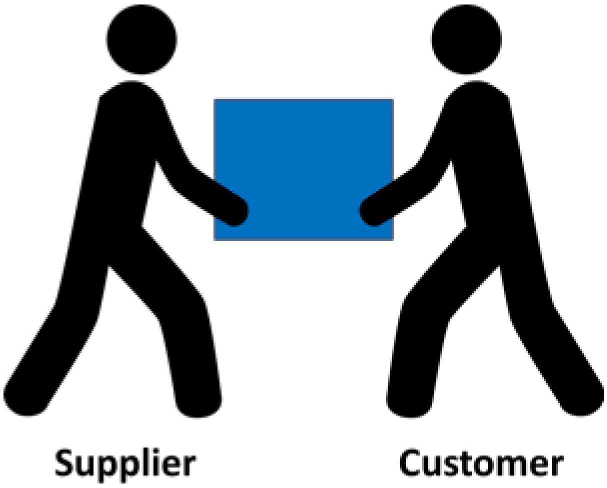

Figure 327: Supplier and Customer (Image Roser)

Another possible reason for your lot size is your customer order. If the customer orders 300 pieces, then of course he will get 300 pieces. Yet, you still can make smaller lot sizes. There are two basic directions in which you can reduce lot sizes. You can do this independently from the customer order. If the customer orders 300 pieces, then you can make once 300 pieces, or three times 100 pieces. At this point, accounting will get high blood pressure again, since 300 pieces once is more efficient than three times 100 pieces…or at least that is what their numbers tell them. However, it is again a case where the cost can be measured but the benefit is hard to put in numbers. Please do consider smaller lot sizes even if there is a larger customer order.

Just reducing the lot size internally despite a larger customer order does give you the benefit of less inventory and reduced fluctuations. Unfortunately, to the customer side you still have the large order, and hence lose out on these benefits. However, this can be changed too, but now you have to work with your customer. Can you convince the customer that three shipments of 100 pieces each is better for him too, rather than one shipment for 300 pieces? You may run into the same arguments from accounting (again), arguing the cost and ignoring the hard to measure benefits. I know examples, however, where the customer was open for such suggestions, and also benefited from the reduced lot size.

43.2 Reduce Lot Size Caused by Machine Batch Size

Figure 328: Industrial autoclave (Image mulderphoto with permission)

Many machines process parts one by one. However, some processes can treat multiple parts at once. For example, an oven can harden multiple parts at the same time. A flash freezer freezes multiple products. In the processing industry, the batch size (i.e., lot size) is pretty much how much you can fit in the pot. The solution to smaller lot size initially also sounds obvious, just put less parts in the oven/freezer/pot/whatever.

Unfortunately, here we may often find issues with the process parameters. The number of items in the process can influence the process parameters and/or the quality of the product. If the oven has many parts, it may need different temperature and time settings than if an oven has only a few parts. It can be done, but make sure that quality does not suffer.

Figure 329: Chemical process (Image PEO, Assembled Chemical Weapons Alternatives under the CC-BY-SA 2.0 license)

This approach also has a comparatively large impact on capacity. If you, for example, half the lot size due to changeovers, you double the changeovers. However, changeovers are only a small part of the overall time, and if you initially lose 5% due to changeovers, you now lose 10% of the time. This is unfortunately different with an oven. If you fill the oven only to half capacity, you use only half of the capacity (or maybe a smidgen less due to faster heating times). hence, halving your lot size also halves your capacity, and this is not always a feasible way. Additionally, if you need slightly more capacity due to more frequent change overs, a SMED workshop can help to reduce the changeover times again. For your oven, however, it is usually not possible to significantly reduce the time needed for a batch. If you roast two chickens in an oven at 180°C for 1 hour, then one chicken will still take about 1 hour. Doubling the temperature to 360°C while reducing the time to 30 minutes will NOT give you the desired results. Hence, unlike SMED, it is really hard to reduce the processing times for such batch processes.

Figure 330: Good luck trying to cook two sauces in the same pot… (Image Dall•E 2 AI in public domain)

It is also not always possible to mix and match different products in the same batch. If you roast a chicken and a turkey in the same oven at the same time, you may be disappointed by the overcooked chicken and raw turkey. Similarly, in the processing industry you cannot whip up half a batch of sauce Bolognese and half a batch of Alfredo sauce in the same pot.

Overall, if your lot size is due to the machine batch size, your options are limited. The only feasible way requires significant investment by replacing one large batch process by two smaller batch processes. Or, even better, when a new system is set up, two smaller batch processes are installed from the start instead of two larger ones. But this, again, will raise the blood pressure of accounting when they calculate the cost. However, it can be done, and has been done. It just may not be cheap.

43.3 Reduce Lot Size Caused by Leveling Pattern

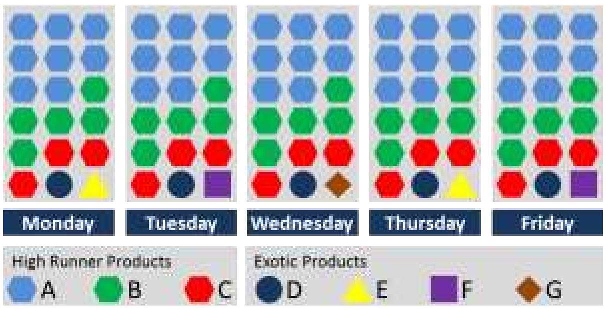

Figure 331: Example of an EPEI leveling pattern (Image Roser)

Another reason for lot size is a leveling pattern. Leveling, in general, aims to reduce fluctuations. However, there is one type of leveling that does this not very well, and which in my experience in general does not even work. This is a multi-week leveling pattern, where there is a single batch for every product every day (or every shift) based on the average demand for the next few weeks (often 1 to 4 weeks). Hence, your lot size is your expected average daily demand, at least for the high runners.

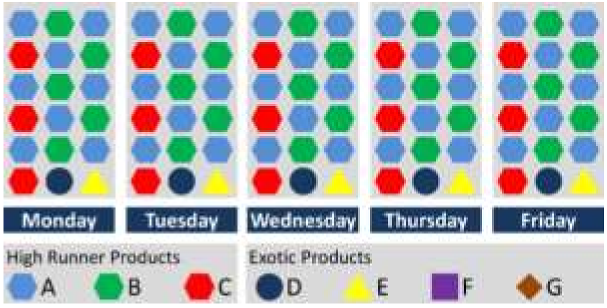

Figure 332: EPEI Leveling pattern with reduced lot size (Image Roser)

One possible solution is to make the batches smaller. You can take the average demand for half a day, or the average demand for two hours. Or, possibly better, you define a smallest feasible lot size, and break the demand down to chunks of this lot size. Compare for example the improved pattern here with the previous pattern.

I have written on The Folly of EPEI Leveling in more detail, because it almost never works. Most companies cannot reliably produce tomorrow what they decided yesterday. A multi-week pattern is bound to fail and to increase chaos. Hence, my most preferred solution to reduce your lot size due to your leveling pattern is **don't use a multi-week leveling pattern!**

43.4 Reduce Lot Size Caused by Tradition


Figure 333: … because of tradition … (Image Dall•E 2 AI in public domain)

A lot size that is based on tradition may be simultaneously the easiest and the hardest lot size to change. It may be the easiest, since there is no real reason for this lot size, and reducing the lot size can be done with the stroke of a pen.

At the same time it may be the hardest, because it is tradition, and the people may oppose the change because of tradition. Depending on which situation you find in your plant, you may have to do a lot of talking and convincing to get your people on board.

This concludes this small three post series on how to reduce lot sizes. Now, **go out, fight tradition (or whatever restricts your lot size), reduce your lot size, and organize your industry!**

44 How to Reduce Product Variants

Christoph Roser, November 1, 2022 Original at
https://www.allaboutlean.com/reduce-product-variants/

Figure 334: Steering wheels (Image Chris 73 under the CC-BY-SA 3.0 license)

Product variants drive up cost. The more variants you have for the same quantity sold, the higher your production cost. Inversely, if you can reduce your number of variants, you can reduce your cost. In this post I will give you some general suggestions on how to reduce your number of variants. Hopefully these inspire and help you to become more efficient.

44.1 Why Variants Are Bad

Figure 335: Array of cars (Image Roser)

Variants increase complexity. The more product variants you have, the more parts you need to obtain or make, track, and keep on stock. Overall, this increases your inventory. It also increases your fluctuations. The sales of two products at half the quantity will fluctuate proportionally more than one product with full quantity. Ten products at one-tenth the quantity will fluctuate even more. The impact of these fluctuations are often not well understood in industry, but they cause a lot of trouble, most significantly the risk of running out of parts, but also the risk of excess stock. Also, making a part very seldom requires more effort by the workers to remember how to make it, more effort to set up the tools, etc. It is an economy of scale, where a low-volume product is much more expensive than a high-volume product. Hence, **the number of variants are a major cost driver for manufacturing and logistics.**

44.2 Why Variants Are Necessary

Figure 336: Trabant (Image Lothar Spurzem under the CC-BY-SA 2.0 Germany license)

On the other hand, variants are necessary. It is rare that a company has only a single product and all customers will be happy with the same product you provide. One example would be tap water. You get one type of water, and the the water supply company does not give you an option of low-chalk or sparkling tap water. Another example would be if the supplier has immense power over the customer, and for example in former East Germany the Trabant car had very few options, yet people were still waiting on average for seventeen years to get one.

But most companies have variants simply because the customer wants them. Having slightly different products attracts more customers and/or more market segments, and overall provides more sales. Hence, **the number of variants are a major driver for sales.**

44.3 A Trade-Off?

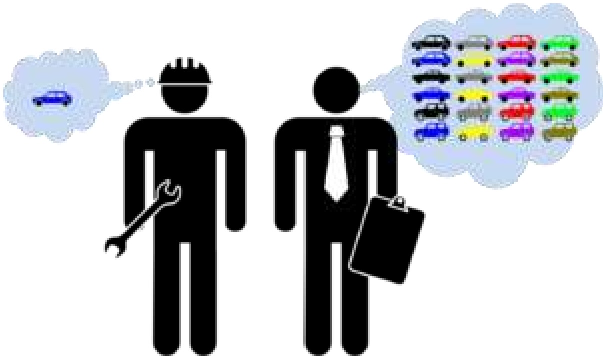

Figure 337: Sales and Manufacturing Dream (Image Roser)

The first obvious direction is a trade-off. Is the cost of producing a variant worth the sales? Or, more generally, does the sale cover the cost, is there a profit? It sounds like an easy solution to do the math for every product, and keep those that make a buck. Unfortunately, we run into a common problem again with lean manufacturing. It is very easy to calculate the revenue from a sale. It is much harder to calculate the cost of making the product. Especially the impact of fluctuations are nearly impossible to pin down financially. Thus, cost accounting often ends up with a revenue that exceeds the (far-underestimated) costs. It does not help that the cost data may be outdated and from times when the product was selling well and had significant economies of scale. Overall, manufacturing is often losing the trade-off with sales due to the inability to measure fluctuation costs.

44.4 How to Reduce Variants

Reducing variants requires you to look at every product you sell and determine whether making it is still worth the effort. This is a slow process and requires time and determination. Don't start this analysis with the high runners—these you are likely to keep. Instead start with the products that sell the least—those have the best chances of being eliminated. Below you see a bar plot of 100 (fictions) products with their sales quantity, sorted from the best selling to the slowest selling product. The line is the cumulative number of sales (different scale). You probably have seen similar plots before, these Pareto diagrams are famous, and you will probably find that 80% of your sales are from roughly 20% of your products.

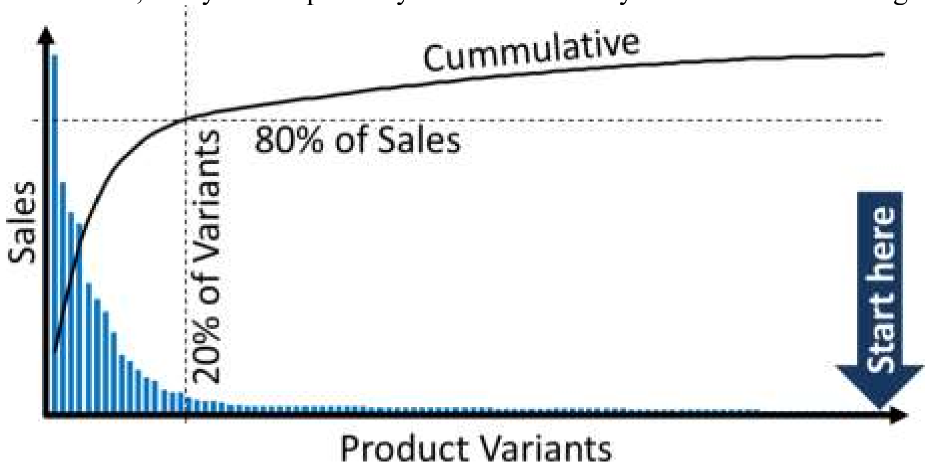

Figure 338: Sales Pareto Diagram Arrow End (Image Roser)

Hence, start looking at the least-selling products first. Can you eliminate these? Such low-selling products are often either failed products, products at the end of their life cycle, or the result of previous bad product decisions.

This will in all likelihood always be a battle with sales, which is measured on how much they sell. As mentioned above, they have the advantage that the revenue can be measured much easier than the cost. But, assuming there is a neutral discussion (yes, I know, I am an optimist), then the revenue generated should be compared to the cost, including an estimation of the additional cost from fluctuations and a lack of economy of scale. This gives you an idea **whether the product is viable on its own**.

Figure 339: Strawberries Small Medium Large (Image AnRo0002 in public domain and Dllu under the CC-BY-SA 4.0 license)

However, you rarely sell only independent products. You probably have a family of similar products. The question is, what will the customer do if the product is no longer available? **Is it a lost sale, or will the customer switch to an alternative similar product** from your product line-up? Unfortunately, here you have even less reliable data than for the standalone cost-benefit analysis. Nobody really knows what the customer will do until after the fact. You may end up with manufacturing arguing that there are plenty of good alternatives, while sales argues equally enthusiastically that the customer will never ever come back. It is a tough, gut-based decision.

Figure 340: Shopping Cart (Image Ivonne Wierink with permission)

Additionally there may be other considerations. Do you have a major **customer who insists on this product?** I once had such a case where a major customer infrequently also wanted to buy a very exotic product. In fact, he was the only one who occasionally bought this exotic product. Yet, the customer insisted on having this product and threatened to switch to a competitor if it was no longer available. In this case, it makes sense to keep on producing. Or, more generally, are there external factors that require this product? Besides a customer, having this product may also be required due to **government regulations, contractual obligations, or simply as a way to annoy your competitor**.

Overall, deciding on which product to ax and which one to keep is a tough question. In my next post I will also look at the related question of how to reduce the part variants that go into products. Now, **go out, ax your most inefficient and slow-selling products, and organize your industry!**

45 How to Reduce Part Variants

Christoph Roser, November 8, 2022 Original at https://www.allaboutlean.com/reduce-part-variants/

Figure 341: Bicycle hub Parts All (Image Keithonearth under the CC-BY-SA 3.0 license)

In my last post I looked at how to reduce product variants, and the inevitable conflict with sales. In this post I will look at how to reduce not the number of final products, but the number of part types that go into the final product… and here you often have a conflict with product development. However, like the reduction of the number of final products, this reduction in fluctuation has significant benefits for the company.

45.1 Introduction

Figure 342: Product Component Part Tree labeled (Image Gerry Goertzen and Knightrider1uk under the CC-BY-SA 4.0 license. Markus Schweiss, Ralf Roletschek, Niabot, and Keithonearth under the CC-BY-SA 3.0 license)

Reducing the number of product variants reduces fluctuations, and makes the entire logistics more efficient. As a second lever, you could go one level down in the bill of materials and reduce the number of components you need to build your products. Below that are sub-components, and eventually you get to the different parts.

Reducing variants on different levels has different effects on the overall fluctuations. Eliminating a product variant can be done anytime, and the effect on the fluctuation is immediately after eliminating the variant.

Reducing the components is more tricky, as you may have to change the design of all products that use this component. This takes more time and effort (i.e., expense) until all designs are changed and the old product designs are phased out… and you may even have to provide spare parts anyway. Similarly for parts. Eliminating a part type requires a design change of all products that use this part type.

The higher up you are in the bill of materials, the easier and more effective a variant reduction usually is. Eliminating a product cuts out all the unique components and parts needed for this product in one go.

Eliminating a single type of screw merely eliminates this screw. The higher up you are in the bill of materials, the larger the impact.

45.2 Modular Strategy

Figure 343: Computer and Components (Image Mimistok under the CC-BY-SA 3.0 license)

Many car makers and other manufacturers use a modular strategy. They create standard modules, and try to limit the number of new modules. For example, Toyota as a general rule allows only 20% new modules for a new car model; everything else needs to be re-utilized from older models and existing modules. For example, the air conditioner unit is very similar across many models, with sometimes only cosmetic changes on the interface to the user. Please do not confuse this with the similar platform strategy, where the same platform in different variations is used across different models. The goal of a platform strategy is more to reduce the development effort for new products, and reducing the number of parts and components is often only a secondary effect.

45.3 Reactive

Figure 344: Firefighters fighting a house fire (Image Helitak430 under the CC-BY-SA 4.0 license)

One possible approach to reduce the number of component and part variants is to do it reactively. You try to eliminate parts and components from existing products. This is usually the hard way, as you have to put in additional effort to redesign existing products. Few companies do this, as it is a large additional workload on the development and design department. If you decide to do this, I recommend starting with the parts that are used for the least number of products or components. A part that goes into only one product is easier to eliminate than a part that goes into ten products, as you need to change only one design instead of ten. If you have multiple possible parts under consideration, eliminate the largest or most expensive parts, as this will make your inventory easier and cheaper to manage. But again, eliminating a component or part afterwards is difficult.

45.4 Proactive

Figure 345: Fire Extinguisher on a Wall (Image Santeri Viinamäki under the CC-BY-SA 4.0 license)

It is much easier to reduce the number of parts or components BEFORE you start producing the product. You don't need to change the designs afterwards, but rather to do it during the initial design. On the downside, this is usually a slow process, and the benefits will show up only months or years afterwards, depending on your product release cycles.

However, you need to manage your development department well for that. If unchecked, developers will pick parts or components while ignoring if the part is new or already in use. Just recently I visited an (unnamed) company, where the purchasing manager sighed that he has to order all standard screws from the screw supplier, and then also some non-standard ones since the development department just picked whatever suited them, ignoring any pre-existing parts. And indeed, when I looked at their screw inventory, they had, for example, M6 hex screws in lengths of 8mm, 10mm, 12mm, 14mm, 16mm.., the same again for M5, M8, M10…, and all again for Pozidriv heads. You name the screw, and they had to use it for at least one product.

45.5 Conflict with Development

Figure 346: Developer and Production Engineer arguing (Image Dall•E 2 in public domain)

All of this reduction in part or component variants will reduce your fluctuations. But all of these are extra work for development, either beforehand or afterwards, whereas the benefit is usually for logistics or production. Hence, the motivation of development to participate is often not quite there. Be prepared for lots of arguments why the developer needs exactly this screw for this product, and any other screw will be inferior/more expensive/dissatisfy the customer/etc. The problem is, sometimes development is correct with this assessment, and sometimes it is merely ignorance or a power play, and for an outsider it is really hard to distinguish which one is what.

45.6 The Many Colors of LEGO

Figure 347: 100 colors of LEGO bricks (Image Roser)

One example of a successful reduction is (or was) LEGO. In the 1950s, LEGO started out with 10 colors, slowly increasing to 49 colors by 1995. But in the 2000s, the number of brick colors exploded. This coincided with a dramatic decrease in profitability, although this was not only due to the colors, but due to a general shift in management and also a change in the design teams. In 2004, there were 117 different colors, and LEGO made a staggering loss and was almost bankrupt.

The turnaround came with a new CEO, Jørgen Vig Knudstorp, an ex-McKinsey consultant. Among other measures, he drastically reduced the number of brick and color variants. In the graph below, you can see a significant reduction in the number of colors between 2004 and 2008. In 2009 there were only 71 colors. LEGO became profitable again. The reduction in variants was not the only reason, but it definitely helped. Since then, LEGO held the number of colors almost constant between 72 and 78. (Source: Rebrickable)

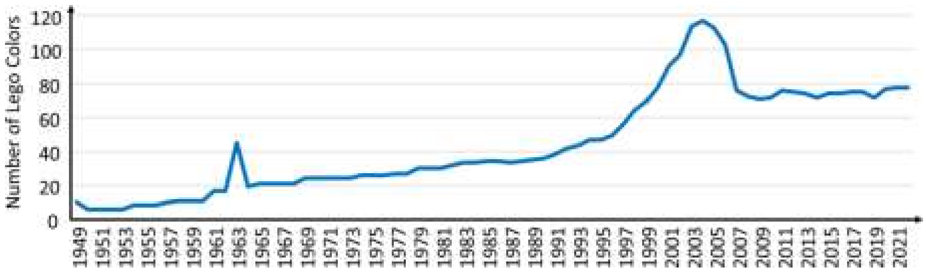

Figure 348: Number of Lego Colors over Time (Image Roser)

Overall, the number of product, component, and part variants has a significant influence on your business success, both positive and negative. Finding the right balance is difficult, and my gut feeling tells me that many companies have too many variants for their own good. Now, **go out, reduce the number of part and component variants, and organize your industry!**

46 What Is Ikigai?

Christoph Roser, November 15, 2022 Original at [*https://www.allaboutlean.com/ikigai/*](https://www.allaboutlean.com/ikigai/)

Figure 349: Ikigai (Image Roser)

Recently, the Japanese word *ikigai* has been popping up as a way to find happiness. While not quite a manufacturing theme, it is related to industry and to Japanese culture, and hence I decided to write a blog post about it. It is a lot of hubbub around a few good (but not new) ideas, wrapped in a out-of-context Japanese word.

46.1 The Idea of Ikigai

The idea behind Ikigai is simple, and explained easiest by the Venn diagram below. You find happiness if you manage to do a) what you are good at; b) what you can be paid for; c) what the world needs, and d) what you love.

Figure 350: Ikigai (Image Roser)

It is supposed to help you find inner happiness, peace, and your purpose for living. And, just looking at the Venn diagram above, if you manage to live at the intersection of all four circles, your chances at being happy are probably better, albeit happiness is by no means guaranteed.

46.2 The (Supposed) Japanese Philosophy

This Venn diagram was initially created by Marc Vinn from Britain. Then two Spanish writers wrote a best-selling self-help book *Ikigai: The Japanese Secret to a Long and Happy Life*, translated already into sixty-three languages. It created a cottage industry of coaches and mentors, and even an *ikigai weight loss pill* (not sure if this one works…). Studies supposedly show the benefit of ikigai on your health, although my guess would be that simply being happier is good for your health. These *secrets of the Japanese centenarians* are supposedly the reason why Japanese, especially from Okinawa, have very long lives.

Figure 351: Old Couple in Japan (Image Stephen Kelly under the CC-BY 2.0 license)

The philosophy of ikigai talks a lot about reducing stress, and gives suggestions similar to many other self-help books, like focusing on what you are doing. It mentions *takumi* (匠), which means artisan or craftsman, and is also used at Toyota for their manufacturing specialists. The book jumps from Steve Jobs to the anime studio *Ghibli*, a splatter of Okinawan gods, and interviews of really old people. This results in five conclusions:

1. Don’t worry.
2. Cultivate good habits.
3. Nurture your friendships every day.
4. Live an unhurried life.
5. Be optimistic.

I’m not sure if you agree, but I think the hippies in the 1960s and 1970s already figured these out, without any Japanese help.

Figure 352: Rajio taisō radio exercise, Japan (Image t.kunikuni under the CC-BY-SA 2.0 license)

The book also talks about *Okinawa’s miracle diet*: don’t stuff yourself, eat different foods, and drink lots of green tea and s*hikuwasa* juice (a type of lemon). It even includes the *rajio taisō* (ラジオ体操, an exercise that is on the Japanese radio and done by many Japanese regularly), Yoka, Tai Chi, shiatsu, and many more. It closes with the *ten rules of ikigai*, which is another laundry list of good but general suggestions.

46.3 What It Actually Means in Japanese

Figure 353: Confused Asian Woman (Image Mix and Match Studio with permission)

The Japanese word for ikigai (生き甲斐) consists of the characters 生き for *living* or *being alive* and 甲斐 for *effect, result, worth, use, or avail*. In combination it means the *reason for living, something one lives for,* or *the purpose in life*. But the whole idea of this being an ancient Japanese philosophy and culture baffles native Japanese… because it is not. In fact, the word has a different meaning in Japan. It is a term for the small joys in life, like a hobby or quality time with friends or family. In fact, Japanese writers on the web are amused and baffled by the hubbub around this obscure word. It is a successful creation of an industry around a non-existent Japanese philosophy.

Maybe I am too critical, but it looks to me like the authors merely took a big swing and hit every fad, trend, and popular thing in Japan, plus some from outside it (e.g., Steve Jobs). Granted, many of these are actually good for your health, as the book basically recommends that you eat healthy and exercise using many different styles. I just don’t see the need for the mystic (nonexistent) philosophy of ikigai—albeit it is a great marketing strategy.

46.4 Using Foreign Words Out of Context Is Popular…

Figure 354: Karate kata (Image Jonathan Fowler in public domain)

Ikigai is by no means the only example where a foreign word is taken over and twisted out of context to give something a mythical aura. Another example is kata. The method behind it is mostly sound, and using it can help you with your business. However, the Japanese word *kata* (型 or 形) means form, model, pattern, type, style, or mold. It is most often used in the context of Japanese martial arts (judo, kendo, aikido, and karate), but also in Japanese theater and tea ceremony. Most Japanese are surprised about the additional meaning it has in Western manufacturing.

Figure 355: Asian Hiker in Forest (Image Boonkung with permission)

Another buzzword is *shinrin yoku* (森林浴), or forest bathing, where supposedly the Japanese spiritually relax in nature. In reality, it is merely a nice walk through a forest, and you don't need any *shinrin yoku guide* to help you enjoy your time.

Figure 356: The deep meaning of Aufheben… (Image olesiabilkei with permission)

It also works the other way round. In Japan, there is the German word *Aufheben* (アウフヘーベン). This is supposedly a concept proposed by the German philosopher Hegel on "developing unifying contradictory elements through the process of confrontation and struggle" and "deriving a higher-dimensional answer from conflicting ideas and things." It was recently used extensively by the governor of Tokyo, Yuriko Koike (who is controversial, as she supposedly graduated from the University of Cairo despite not speaking Arabic, among other things). I am German, and I can tell you that there is no such deep meaning connected with the word *Aufheben*. It simply means to *pick something up*, or also to *cancel something*. Like you pick up a pen from the floor (*den Stift aufheben*), or you cancel the curfew (*die Ausgangssperre aufheben*).

So, why am I writing about self-help, or more generally about out-of-context use of foreign words to make a business out of it? Well, this also happens often in lean. Lean manufacturing is full with Japanese words, many of which describe methods that are indeed used in Japanese manufacturing, but are exaggerated in the Western world to make them sound more mysterious and give them a mythical aura. Don't just do something because someone describes it as the latest hot sh*t from Japan. Use a method if it helps you, not because it sounds fancy. On this blog I also use a lot of Japanese terms, but I try my best to describe what actually works and try to stick to the facts without all the pathos and glory. Now, **go out, find your inner peace (no matter what it is called), and organize your industry.**

46.5 Selected Sources

- What Japan makes of ikigai, The Economist, October 27, 2022.
- "*Ikigai: The Japanese secret to a long and happy life*" Héctor García, Francesc Miralles, Cornerstone Digital, 2017 (**Note**: this is not a recommended reading)

47 Toyota’s Master Craftsmen: Takumi

Christoph Roser, November 22, 2022 Original at https://www.allaboutlean.com/toyotas-takumi/

Figure 357: Japanese master brush maker Yoshiyuki Hata (Image Yuriizu under the CC-BY-SA 4.0 license)

You may have heard of Takumi at Toyota. Takumi in general are highly skilled artisans that excel in their craft. Despite Toyota mass-producing cars using lots of machines, they also employ hundreds of Takumi. This blog post takes a deeper look at what a Takumi is, and why they are so important for Toyota and other Japanese companies.

47.1 What Is a Takumi?

Figure 358: Japanese paper making (Image TR15336300101 under the CC-BY-SA 4.0 license)

A Takumi is, in Japanese, a craftsman. artisan, workman, or carpenter (匠). At Toyota, they are highly skilled artisan-experts focused on one area. This may be leather-working for seats, plastics for injection molding, sheet metal working, spray painting, welding, test driving, and many more. They also have Takumi that specialize in quality control of sheet metal, able to feel even the slightest dents with their hands. At some Toyota plants you can give this dent detection a try, and it is really tough, even when they point out the dent to you. Most importantly, these Takumi still frequently work the material with their own hands instead of machines. They use all their senses—sight, hearing, touch, smell, taste, and more—to create a masterpiece.

47.2 How to Become a Takumi

Figure 359: Expert cutting tuna at the Tsukiji Fish market (Image Roser)

Becoming a Takumi takes skill and time. A LOT of time. A person who puts his life's work into one specific field can eventually become a Takumi.

In the West, it is often (and somewhat arbitrarily) said that you need 10 000 hours of practice to become an expert. For example, you would need to practice the piano for 10 000 hours to become really good at it. Hence, I proudly announce that I am a master of eating, sleeping, and sitting on a chair. Sadly, based on a back-of-the-envelope calculation, I have not yet mastered the use of toilets. But you are probably happy to hear that I will be fully potty trained within the next twenty years or so.

In Japan, the demands on a Takumi are more rigorous. It is (also somewhat arbitrarily) said that you need 60 000 hours to become a Takumi. This is roughly the working time of a thirty-year career. But the time alone is not enough. Surely you know a colleague who has worked for thirty years in the field but still does not know what they are doing. But with skill and intelligence, thirty years of experience is enormous! A colleague with thirty years of experience is a respected authority, and his word carries a lot of weight. A Takumi is basically the highest level of skill in its respective field.

Also note that the time is for a task that requires skill, talent, and practice. A career at checkout at the supermarket would probably not be considered a Takumi, since it requires much less skill than, for example, making wooden joints or cooking a sophisticated meal. Takumi are masters in their craft, and it would be odd to call an experienced supermarket checker a master in their craft.

47.3 Why Toyota Uses Takumis

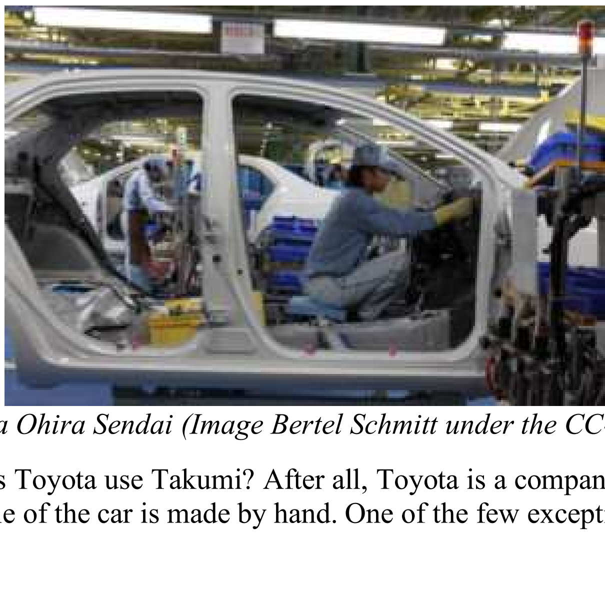

Figure 360: Toyota Ohira Sendai (Image Bertel Schmitt under the CC-BY-SA 3.0 license)

The question is, why does Toyota use Takumi? After all, Toyota is a company that mass-produces cars using machines. Very little of the car is made by hand. One of the few exceptions may be the sewing of leather seats for Lexus, the luxury-brand of Toyota. Most parts are made by machines, and the skill of the worker has little influence on an automated and highly standardized process. Where at Toyota does the Takumi master artisan fit in?

The skills of a Takumi would be wasted if they merely produce cars or car parts. And they (usually) don't. Instead, they try to infuse their skills on the system. They train workers. They help with designing parts and setting up machines. They are the ultimate authority on any questions related to their expertise, and are regularly consulted on this.

Toyota believes (and I agree) that you need humans to improve. A machine by itself will never become better. You need human ingenuity and creativity to improve. If you want to improve to become world class, you need world-class experts to help you with that. And that is where the Takumi come in at Toyota. Their expertise gives Toyota the edge to make parts, machines, and works standards even better than they are now. They push the envelope of the possible. They travel all around the world to train, help, and mentor others, as well as fix problems, develop new techniques, or generally improve Toyota.

Figure 361: Robot spray painting a car (not Toyota) (Image BMW Werk Leipzig under the CC-BY-SA 2.0 Germany license)

For example, in painting, a Takumi helped in programming the painting robots. Toyota says the Takumi "trained" the robot. As a result, the robots now move very smoothly without jerking around, producing better quality while at the same time using less paint. Due to the improved quality, Toyota was able to reduce the number of human workers on the line from sixteen to six. Similar improvements in car door seals saved Toyota 39 cents per car—which does not sound like much, but in automotive with millions of cars that is huge! (Source)

Toyota employs around 500 Takumi in all kinds of specialties. Roughly one of every thousand employees at Toyota is a Takumi. Due to the level of expertise, most Takumi are near retirement age. The next generation of Takumi is selected from the most skilled younger workers. They then get a three-year course, including at least one year in a Toyota Global Production Center in addition to stays at multiple plants.

Figure 362: Feel the metal! (Image Roger and Renate Rössing under the CC-BY-SA 3.0 Germany license)

Despite all the machines, these Takumi often still work by hand, as only the actual working by hand gives you the experience and feeling for the product and the process. For similar reasons, apprentices in metal working spend considerable time filing metal in different exercises. While the file is, from an industrial point of view, outdated, the feeling for the metal is invaluable for later metalworking with machines. Hands-on experience truly can’t be replaced.

47.4 Are Takumi Only at Toyota?

Figure 363: Living National Treasure Shimura Fukumi (textiles) (Image 小松菜もぐもぐ under the CC-BY-SA 3.0 license)

Takumis are found all over Japan, in all kinds of fields. This may range from the seventy-year-old sushi chef to the eighty-year-old carpenter. They have in common that they spend a long career in one profession, and are among the best in their field. Takumi is simply the Japanese word for a master artisan.

Nissan also has Takumi. They have only a few of these experts. But different from Toyota they do not “train” the robots, but instead build high end V6 engines for the GT-R.Each engine gets a label with the name of the Takumi that built it. Nissan believes that this gives better quality for their flagship engine.

They may even have different names. For example, at Nippon Steel, a steel foundry, the Takumi are called *Steel Meister*, where the Japanese mix the English word *Steel* with the German word *Meister* for master craftsman. These are truly experienced old hands that are in charge of mixing the steel, a skill that requires a lot of intangible knowledge.

Figure 364: Living National Treasure Shoji Hamada (Pottery) (Image unknown author in public domain)

Japan's oldest company, Kongo Gumi, is a fortieth-generation carpenter's workshop that builds temples. Their master carpenters are called Miya Daiku (宮大工, for shrine carpenter). Interestingly, they specialize in a single tool. They have a miyadaiku for saws, another one for chisels, and another one for planers, for example.

Even the Japanese government officially recognizes such masters in performing arts and Japanese crafts and calls them Living National Treasures (人間国宝, ningengokuho, for human and national treasure). These Living National Treasures are truly exceptional, as (due to budget limitations), there are at most 116 of them in Japan. South Korea has a similar system (인간 문화재; ingan munhwajae)

Even other countries have this. German craft still often uses the apprentice-journeyman-master (*Lehrling, Geselle, Meister*) system, and a certified *Meister* is expected to know his craft well. However, the average age of a freshly branded Meister is only twenty-five, hence some of them are still a bit green behind the ears. It is seen as comparable to a bachelor degree. However, an older and more experienced Meister can easily be compared to a Takumi.

47.5 Video

There is a well-known one-hour video "Takumi – a 60,000-hour story on the survival of human craft," available on YouTube. However, it is rather thin on actual content. Instead, it has plenty of flowery words with little actual meaning. Nevertheless, the pictures are stunning. Watch only if you are bored.

The Video by Lexus UK is available on YouTube as "Takumi – a 60,000-hour story on the survival of human craft" at https://youtu.be/9EI3aEFANBo

So, overall, Takumi can help a company to improve their processes. But real Takumi are rare. I have been doing lean for twenty-five years now, and some people started to call me a lean sensei, but I am probably not (yet?) a Takumi. At Toyota, there are experts in lean that know oh-so-much-more than me…except that they don't write a blog. Anyway, now **go out, get the help of a Takumi, or if unavailable at least sometimes work the material by hand to learn its behavior, and organize your industry.**

48 The Van of Nerds in France—Overview and Aircrafts

Christoph Roser, November 29, 2022 Original at https://www.allaboutlean.com/van-of-nerds-france-1/

Figure 365: The nerds and the van (Image Roser)

In 2019 I organized an Industry 4.0 tour through southern Germany for a few friends. We called this the "Van of Nerds," and you can read all about it in a series of blog posts starting here. The participants liked the van trip so much that we wanted to repeat this experience… and then came COVID. We held two online Van of Nerds mini-conferences (organized by our Nerd Torbjörn Netland), and finally, on September 5–9, 2022, we were able to take another real-world tour with our van of nerds, this time in France. The tour was organized thanks to nerds Franck Vermet and Michel Baudin.

48.1 The Nerds

Figure 366: En route in the van (Image Roser)

The group consisted of seven people from all over the world coming together for one week of studying Industry 4.0 in France and having fun. If you work in lean, you surely will recognize some of these names. The group also included multiple recipients of Shingo Awards. We are (in alphabetical order):

- Michel Baudin (Lean Expert and Consultant; USA)
- Prof. Dr. Peter Hines (Director, Enterprise Excellence Network; Wales)
- Prof. Torbjörn Netland (Production Professor at ETH Zürich; Switzerland)
- Prof. Dr. Ralph Richter (Retired Plant Manager of Bosch, Production Researcher; Germany)
- Cécile Roche (Director for Industrial Performance, Thales group, but soon an independent consultant, France)
- Prof. Christoph Roser (Lean Professor, Author of this blog; Germany)
- Franck Vermet (Production Systems Mentor, France)

48.2 The Locations

Figure 367: We also had time for fun 😐 (Image Roser)

We visited quite a few locations, many of them in Paris, but some all over France, as shown on the map below, including a lot of aerospace companies. Of course, we also had plenty of time for fun stuff and lengthy discussions in the van. I will write briefly about all locations in this Van of Nerds series (not necessarily in sequence), but a few locations revealed interesting things that justify a larger article. These will follow later. **Many thanks to all hosts for letting us see their locations!**

- Campus Fab, Bondoufle: An innovative demonstration lab with lots of fancy technology to showcase industry 4.0.
- Centre innovation Évry, University of Évry Val d'Essonne/Université Paris-Saclay, Evry: A full assembly line for scooters for students, researchers, and companies to experiment with industry 4.0 on an assembly line.
- SNCF Warehouse / Repair, Saint Dizier: Maintenance for the French railway SNCF, with lots of good kaizen activity.
- LISI aerospace, Saint Ouen l'Aumone: Making high-quality screws for aerospace, and a forerunner on Industry 4.0. I was especially excited that they used CONWIP.
- Safran Innovation Aerogarage, Saclay: Research and Innovation Center of the world's second-largest aircraft equipment manufacturer.
- Renault, Douai: A plant of the maker of famous French cars, including body welding, painting, and assembly.
- Safran Nacelles, Le Havre: Maker of engine nacelles (Structure that cover the engine, attached to the aircraft).
- SLB (formerly Schlumberger), Clamart: Maker of sensors for mining and drilling, where the sensor is down a mineshaft five kilometers below ground.
- JPB, Montereau: Highly innovative maker of self-locking screws and other parts for aircraft; excellent use of industry 4.0.
- Thales, Elancourt: Maker of military sensors, from small night vision goggles to large aircraft sensor pods.
- AFI KLM E&M, Orly: Maintenance facility for aircraft engines at Orly airport.

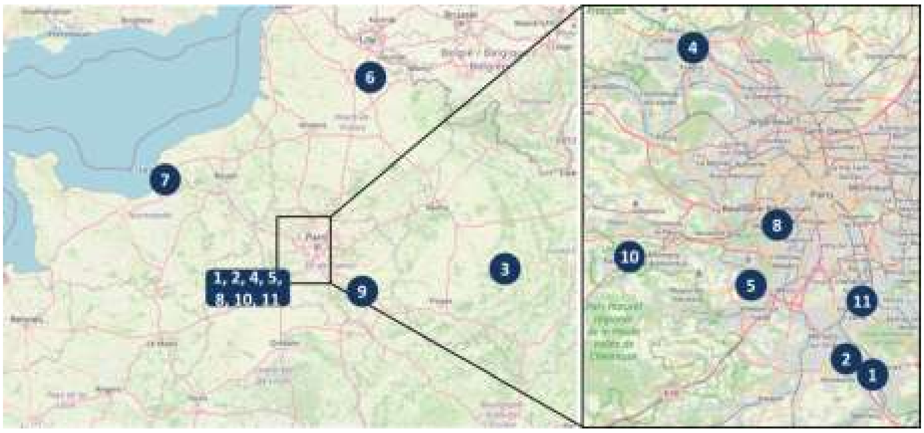

Figure 368: Van of Nerd France map (Image OpenStreetMap Foundation (OSMF) Open Data Commons Open Database License (ODbL)

48.3 Safran Innovation Aerogarage

Figure 369: We Can Do It! (Image J. Howard Miller in public domain)

The Safran Innovation Aerogarage in Paris Saclay is an innovation center of Safran, the world's second-largest aircraft equipment manufacturer. It doesn't do manufacturing, but it does do research. It also provides a safe haven for startups. This is actually the workplace of fellow nerd Franck Vermet. We visited the 3D printing lab and tried out 3D glasses set up for training of employees. I did like that they used the approach of Training Within Industry (TWI) for their training. I am a big fan of TWI. The program is old but still very valid, and it was refreshing to see TWI updates with modern technologies.

48.4 AFI KLM E&M

AFI KLM E&M is a major player in aircraft maintenance, with repair facilities all over the world. We visited the repair and maintenance facility at Orly airport. Taking apart an engine and putting it back together is a major effort, and around 6000 parts for one engine have to be disassembled and reassembled again. There are usually six to seven levels of disassembly (i.e., from the engine to a sub-component, a sub-sub component, and so on) until you end up with a single screw or turbine blade to be inspected and cleaned. The example for components are the fan blades, the LPC modules, the fan frames, the fan case, the core engine, the high-pressure turbine (HPT), the low-pressure turbine (LPT), and the fan shaft.

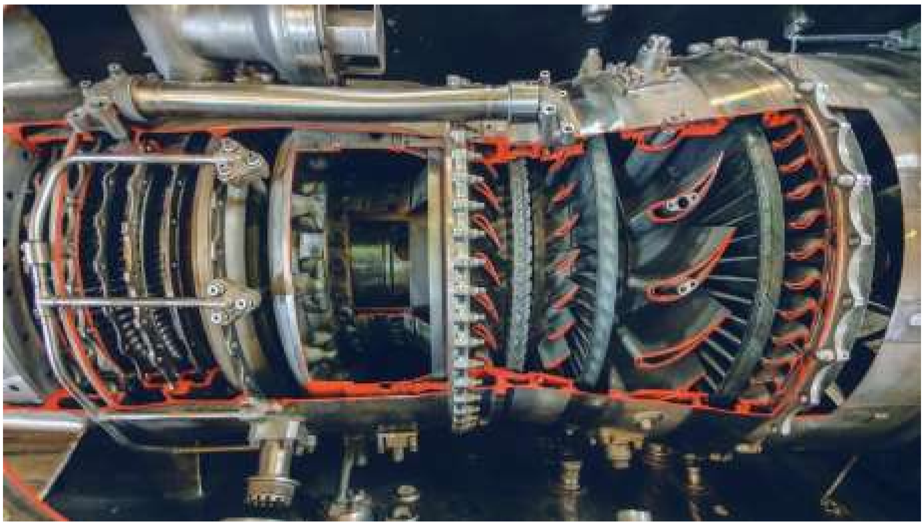

Figure 370: Not from AFI KLM E&M (no photos allowed), but a stock picture. (Image Petr Kratochvil in public domain)

There are different types of engines and different types of inspection levels, and it is a make (or service)-to-order approach. This makes planning a bit difficult, and during our visit there were still the COVID aftereffects on the airline industry, and the facility was running at half capacity. I have actually been in quite a few aircraft maintenance facilities from different service providers in Haneda (Tokyo), Frankfurt, Zürich, and now Orly (Paris), and it is always a bit chaotic.

They mark all parts with a tag including the serial number of the engine and the reference number of the next higher assembly (i.e., which component the part goes in). Most parts also had a RFID tag with the same information. Only, if there was a box or container with multiple parts for the same engine component, only one part had the RFID chip. There were dozens of customized containers and transports, from boxes with slots for the turbine blades to rolling shelves, rolling drawers, and rolling carts with hangers. For the inspection of larger parts they had some ergonomic aids. For instance, the turbine unit was put upright either in a hole with a lift or in a hole around a large platform that can be raised. This allows the ergonomic inspection of the blades.

The location actually will have a major reorganization coming up, and much of the shop floor will look quite different in the near future. This is of course a great opportunity to improve operations.

In my next post I will look at some more locations, and even have some posts that go into much more detail on some of the most juicy bits of what we saw and learned. **Now, go out, keep on reading, and organize your industry!**

PS: Fellow Nerd Michel Baudin (and Cécile Roche) has also written about the trip. Here are his blog posts, check ’em out for a different view of the same tour 😐.

- Automation and People
- Processes and Products | Cécile Roche
- About Digital Twins

49 The Van of Nerds in France—Research Laboratories

Christoph Roser, December 6, 2022 Original at https://www.allaboutlean.com/van-of-nerds-france-2/

Figure 371: Evry Group Photo (Image Roser)

As part of our Van of Nerds tour through France, we also visited two research laboratories. While not shop floors, these are the places to experiment with new technologies.

49.1 Campus Fab, Bondoufle

The Campus Fab in Bondoufle near Paris is an innovative demonstration lab with lots of fancy technology to showcase Industry 4.0, including advanced machining, additive manufacturing, assembly, equipment maintenance, and process data analysis/control. It is financed through a mix of private- and public-sector companies, including Dassault, Safran, ABB, Kuka, DMG Mori, and more to enable a “digital continuity” across the value chain. The concept originated in 2016, and it started operating in 2019… and then came the COVID pandemic. But they recovered and are now operating as planned. They have three main goals of 1) training technicians for Industry 4.0; 2) onboarding new employees of the partner companies; and 3) providing specific training in focus technologies. They also aim to get young people interested in a career in manufacturing by showing them what is possible nowadays in manufacturing. They have regular buses of high school students arriving and spending a day in the campus fab, and have shown the technologies to over 1000 students so far.

Figure 372: CampusFab Overview (Image Roser)

The site contains a nice assortment of technologies, including 3D printing (laser sintering of plastics), AGVs, different milling machines, digital twins, Cobots, and more. There are a few pictures below.

Figure 373: CampusFab ABB Two Arm Cobot (Image Roser)

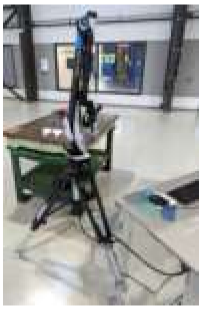
Figure 374: CampusFab Absolute Arm Measuring Unit (Image Roser)


Figure 375: CampusFab Two AGV (Image Roser)

A few of these technologies I would like to talk about a bit more since I found them interesting. For example, I liked the AbsoluteArm (photo above) for measuring parts, which I found easy to use.


Figure 376: Clear view screen on a boat (Image Bin im Garten under the CC-BY-SA 3.0 license)


Figure 377: Clear view screen on a milling machine (Image Roser)

Another thing I had not yet seen was a special window in a milling machine. With most milling machines, you cannot see anything during use since the window is splattered with coolant and chips. Here they used an idea common on ships: a clear view screen. This is a rotating window, where the centrifugal force forces water and snow off the window on a ship, or coolant fluid and chips off the window in the milling machine.

One of the most impressive things for me was their usage of augmented reality. Below you see a monitor with a disassembled aircraft engine. Overlapping are the instruction steps for assembling the engine. The operators need to go through these steps one by one, and acknowledge the completion of each step. This helps them to not only not forget a step, but it also creates traceability, which is very important in aircraft building and maintenance. At first glance, this monitor looks just like a fancy PowerPoint. However, it is not.

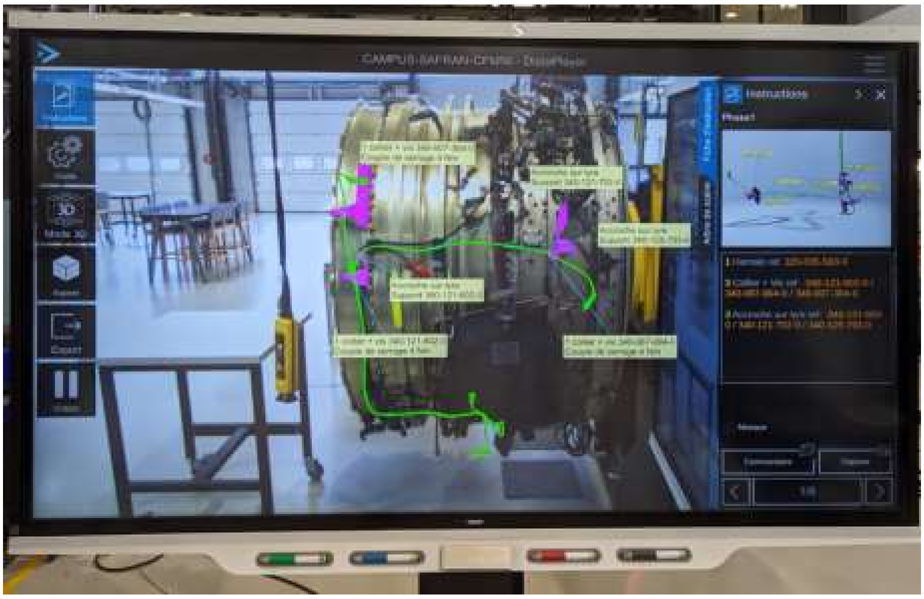

Figure 378: CampusFab Augmented Reality Screen of Engine (Image Roser)

It is indeed an augmented reality or, as they called it, a *mixed reality*. The picture is a live camera feed, and the computer recognizes the parts and overlays the instruction steps. Below you see the setup in its entirety. At the upper right edge you see the camera pointed at the aircraft engine. If you rotate the engine, the overlay of the instruction steps moves with the engine. When I tried this out, I found the movement rather smooth, and the overlay was moving along with the engine without any noticeable lag or jarring. The display can be on a monitor or also in augmented reality goggles. The latter are easier to use but can cause some stress on the eyes for some users.

Figure 379: CampusFab Augmented Reality Engine and Screen (Image Roser)

With Industry 4.0–related topics, it is often hard to distinguish what is just a demo and what it actual use. Hence I was thrilled when we saw this again later in actual use at Safran for the assembly of their nacelles.

Another technology that was demonstrated was a vibration sensor in milling tools. While the concept is not new, I liked the implementation by Schunk. The sensor measures vibration in three directions, and transmits the data wireless through Bluetooth. From this they calculate a *chatter index.* Like similar vibration sensors, they measure the vibration to detect problems, ideally before they happen but at the latest when the tool is broken. The internal battery lasts for eight hours before it needs to be recharged. The picture below shows one of the tools including the charger cable and the display. The display was also on a larger monitor.

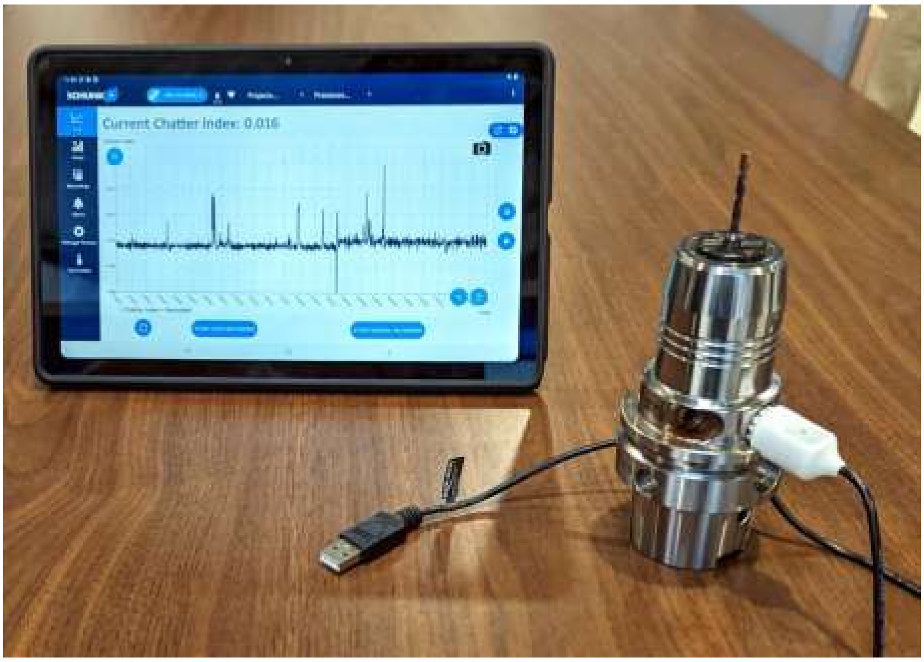

Figure 380: CampusFab Vibration Sensor on Drill (Image Roser)

49.2 Centre Innovation Évry, Université Evry

The Centre Innovation Évry, from the University of Évry Val d'Essonne/Université Paris-Saclay, in Evry and funded by a consortium of different engineering schools as well as Dassault, Fanuc, Schunk, Cisco, and the startups Datategy and Cosmyx, is a training factory including a full-sized assembly line for scooters for students, researchers, and companies to experiment with Industry 4.0. As a lean guy, I always find the problem with such model factories is that they rarely run at full capacity, and hence it is not possible to do typical lean optimization like reducing waste or fluctuations. It was also clearly visible on the scooters that they have been assembled and disassembled quite a few times already. However, the goal here is not efficiency or flawless scooters, but instead to research Industry 4.0 solutions, and for that purpose the factory is well designed.

Figure 381: Evry Assembly Line (Image Roser)

Figure 382: An AMR at Evry (Image Roser)

What I found particularly interesting was the management of the AMR (autonomous mobile robots), a highly autonomous type of AGV. The AMR knows where it needs to go and decides the route itself. I tried this out a few times and intentionally blocked an AMR. If necessary, the AMR even took the long way around the complete assembly line, as illustrated by the sketch below.

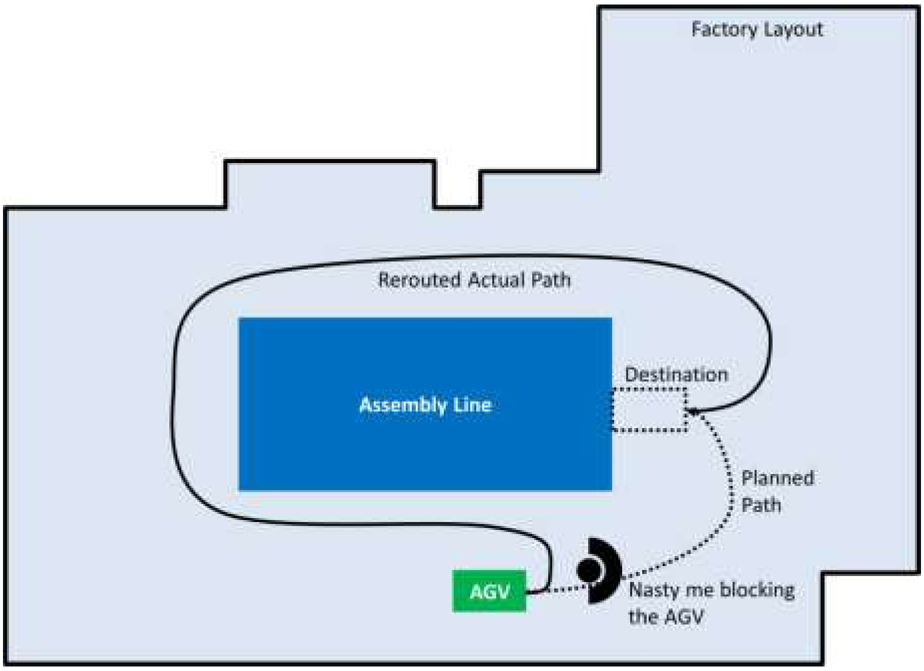

Figure 383: Evry AGV reroutig Map (Image Roser)

The AMR navigated using LIDAR (sort of 3D laser scanning). Below is the screenshot of the LIDAR of one AMR. Black are permanent structures, but what I found amazing were all the red dots—these are our feet. This navigation works very well. When I was trying to block another AMR (not for fun, it is science, of course), it went around me through a very narrow gap but at quite high speed. There was less than 30cm between the AMR and my feet. It felt quite fast, and I was happy to wear safety shoes, just in case. During our visit, a few other members even got touched by an AMR, but only at slow speed. For example, the handle of a scooter on an AMR gently touched the arm of a team member.

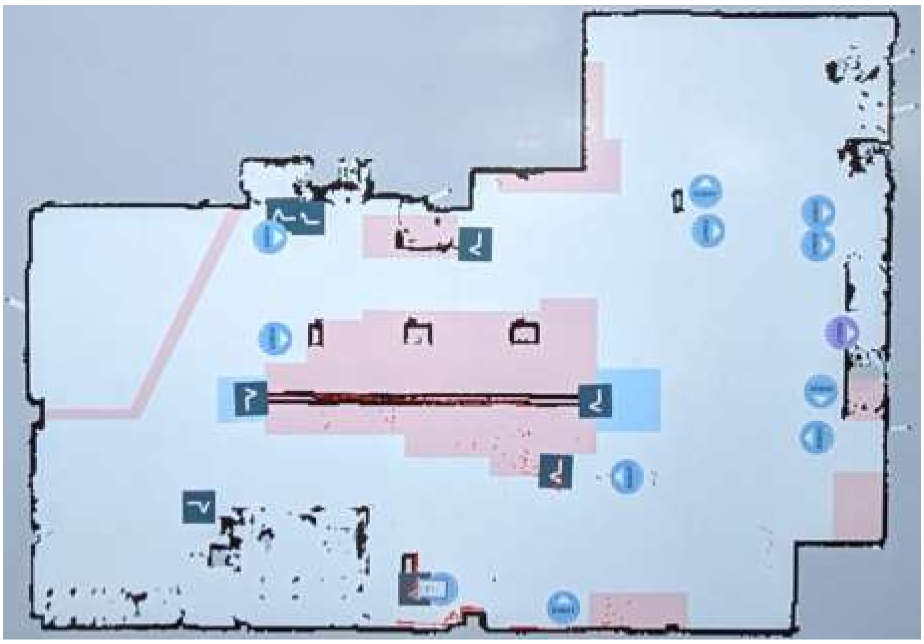

Figure 384: Evry Sensor Map2 (Image Roser)

Overall, these two research labs were quite a nice visit, and a good start to our van of nerds in France tour. Now, **go out, keep on reading for more visits of the Van of Nerds, and organize your industry!**

50 The Van of Nerds in France—Aircraft Engines and Parts

Christoph Roser, December 13, 2022 Original at https://www.allaboutlean.com/van-of-nerds-france-3/

Figure 385: The Nerds at LISI (Image Roser)

This post looks at more plants we visited on our Van of Nerds tour in France in 2022. The focus this time is the aircraft industry, in particularly the engines. We visited a major maker of aircraft engines, or their nacelles and thrust reversers to be more precise, Safran in Le Havre. But we also visited two suppliers for engine components. LISI specializes in high-performance bolts and screws for aircraft, but also has some highly advanced digital displays on their shop floor. JPB makes well-designed inspection ports for aircraft engines, for which they developed some really clever digital solutions, which they now also provide to others. It was definitely a set of highly interesting visits. Let me show you!

50.1 Safran Nacelles in Le Havre

Figure 386: SafranNacelles Tool kits (Image Cecile Roche with permission)

Safran is a French company with 77 000 employees that design and produce aircraft engines, rocket engines, and other equipment that can fly. One of their subdivisions is Safran Nacelles. The nacelle is the structure that cover the engine, attached to the aircraft. It channels the engine's airflow, brakes the aircraft during landings, through its built-in thrust reverser, and reduces noise of the engine. The factory goes back to a workshop from 1896, but became Safran only in 2005 after a merger of two other companies (SNECMA and SAGEM).

Like most aircraft plants, I was struck by the cleanliness of the location. We looked in detail at the building of nacelles, their carbon-fiber composite operations, and their thrust reverser assembly line. The assembly line was particularly interesting. They build the two halves of a thrust reverser in parallel on an assembly line with seven stations. A robotic arm lifted the huge half thrust reverser, and was able to position it exactly where the operator wanted it. These robotic arms were on wheels, and could move to the next station when completed. In fact, it was a continuously moving assembly line, although at 5 millimeter per minute the movement was not really visible.

Figure 387: CampusFab Augmented Reality Screen of Engine (Image Roser)

Like many low-volume flow lines, the time at one station is roughly one shift, as this makes the assignment of workers much easier (see also Trumpf). At Safran, the takt was seven hours. They also matched supply with demand by having idle stations for one shift. It is hard to remember seven hours' worth of tasks, and a good work standard including the documentation of all completed tasks was necessary. Hence, particularly interesting was that they used augmented reality for the operator instructions. This was exactly the system we saw earlier at the CampusFab (photo shown here). It was really cool to see this actually used in action, although it was at the time of our visit only the final test before full implementation. Overall an impressive plant.

50.2 LISI Aerospace in Saint-Ouen-l'Aumône

Figure 388: LISI Screws (Image Roser)

LISI Aerospace with 5500 employees dates back to a clock factory in 1777, which turned into a screw factory, and now into a company specializing in fasteners for the aircraft industry. You could call them screws, but these are anything but your ordinary hardware store bolts. These are high-end, ultra-lightweight marvels of material science and engineering. A typical aircraft has over 10 000 types of fasteners.

Figure 389: LISI Shop Floor (Image Roser)

Compared to other companies I visited, the material flow was much less complex. Instead of assembling complex parts, they merely cut a piece off a titanium rod and machine it into a screw. Each part went through only a few steps before completion. Despite all the machining, it was an extremely clean plant. They have on average one week worth of material inbound, and one week worth in production.

Figure 390: LISI Digital Shop floor Boards (Image Roser)

But what impressed me the most was their digital integration. They had highly advanced digital shop floor boards that were well integrated with the machine data, and used by the operators. This was for me such an important topic that I plan to write a separate article on shop floor boards. LISI uses the software from a startup called FABRIQ, although I found it surprising that the data is also hosted at the software vendor.

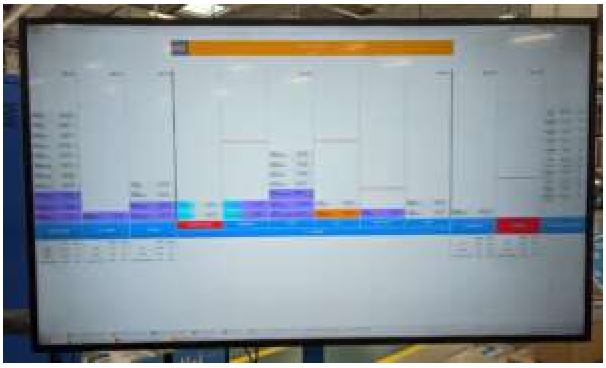

Figure 391: Digital CONWIP board (Image Roser)

Another personal highlight for me was their use of CONWIP. CONWIP is a way to do pull production for make-to-order products. Even though LISI makes screws, these are high-end screws often make-to-order instead make-to-stock. Hence, since 2017 they decided to use CONWIP. As the author of the bible on pull, "All About Pull Production," I was very happy to see this type of pull system so well implemented.

50.3 JPB Système in Montereau

Figure 392: JPB Nerds Group Photo (Image JPB with permission)

JPB Système is a small, family-owned company with around 150 employees, that started in 1995. They make self-locking for-access ports for borescopes to inspect aircraft engines. It is basically a screw that closes the hole for the borescope without the need for any extra anti-vibration locks. After the founder passed away in 2006, the son took over, bringing a very interesting set of qualifications along. He studied programming, but had to get familiar with the mechanical engineering side of the business. Hence, he is comfortable both in the mechanical and the digital world, which was clearly visible on the shop floor.

Figure 393: JPB KeyProd Dashboard (Image JPB with permission)

For one thing, he was able to bring the different data structures of the different machine makers under control (no easy task, I tell you) and integrate them all into a digital shop floor display. I will talk more about this in an upcoming posts on digital display boards.

Figure 394: JPB KeyProd Green (Image Roser)

Another very neat feature was the use of vibration sensors. They developed a small computer that is simply attached to the side of the machine using magnets. This KeyProd system has a vibration sensor and simply measures the vibration of the machine. With two learning cycles, algorithms can understand the proper operations of the machine, and from then onward track the machine status. It can count the pieces, analyze an OEE, and even detect micro stops—which are usually very tough to analyze. By simply sticking this digital brick to the side of a machine **they can bring an old machine into the digital world**. They can also bypass complicated different machine databases and integrate the machine status on the same data platform. I found this so impressive that I plan to write a longer blog post on this too, as a simple paragraph won't do justice to the possibilities from this gadget.

They also set up their plant to run two shifts. A third night shift is fully automated, and no workers are present. After the workers refill the material at the end of the second shift, they leave, and the system runs on its own till morning (with the occasional shut down due to a problem). Overall a highly impressive and dynamic company.

Altogether, the van of nerds in France was a huge success. Special thanks to nerds Franck Vermet and Michel Baudin for organizing the sites. I will definitely write a few more blog posts in the future on some details we learned from this tour (e.g., on dashboards and vibration technology). Now, **go out, keep on reading, and organize your industry!**

51 The Van of Nerds in France—Internal Logistics in Well Exploration and Military Products

Christoph Roser, December 20, 2022 Original at https://www.allaboutlean.com/van-of-nerds-france-4/

Figure 395: Schlumberger Group of Nerds (Image Roser)

This post looks at two plants we visited during our Van of Nerds tour in France in 2022. Both plants are in areas in which I have little experience. The first one was SLB, specializing in sensors for oil field exploration. The second one was the Thales Group, where we visited the location manufacturing military sensors. In both locations we had a deeper look at **internal logistics**. This is (from the point of view of car manufacturing) a low-volume but definitely not a low-cost business. Let’s have a look.

51.1 SLB in Clamart

SLB (formerly Schlumberger) is an oilfield services company founded in 1926. They build sensors for wells. I find it amazing that they have sensors in a hole I could not fit in but that go down for five kilometers. There they measure flow rates, electric resistance, temperatures, and many other parameters. They also provide specialized well cement and many other products. These products are technically not for sale, but SLB provides the service of using them. In effect, they sell data. Out of their 90 000 employees, more than 10 000 are field engineers that run these sensors on site.

We were at the SLB Riboud Product Center (SRPC) in Clamart, France, where these products are developed and produced. The center employs around 1000 people. The company overall has a very open-minded “work together” culture. Their equipment is a low-volume high-mix both in production and in sending it out to field engineers. They are in the middle of a transformation toward an advanced (meaning agile) manufacturing system. We liked their roadmap quite a lot, although it had a rather ambitious schedule. Use cases and projects are derived from the needs of shop floor people and embody clever tricks for dealing with product complexity.

We had a quick look at actual manufacturing. Compared to the buzz in an automotive factory it is a low volume production. The focus of our visit, however, was on the internal logistics. They work on managing their inventory digitally, trying to organize their material. One challenge they face is that the different data structures of different systems are not quite compatible. Sorting these out is a lot of work. Most of the information can be accessed using a mobile phone app. Overall, they are on the right path with a motivated workforce, but there is still quite a bit of work left.

51.2 Thales in Elancourt

Figure 396: Thales Targeting Pod (Image Thales with permission)

The Thales Group is a French multinational company that designs, develops, and manufactures all kinds of electrical systems. We visited their LAS (Land-Air-System) location in Elancourt, where 2000 people manufacture all kinds of military sensors, from night-vision and thermal goggles to missile guidance to electronic rifle sights to jammers to laser warning detectors to aircraft sensor pods. Much of this is of course quite confidential, and we did not visit manufacturing. Even in the showroom we were not allowed to take photos. The images here are from free sources, but are slightly outdated. A big part of their products is the software that runs the analysis and detection, and especially allows interaction between products. If the sensor pod detects a target, it needs to let the missile know where to go. Their takt time depends on the product but ranges from three days to two months.

Figure 397: Thales thermal binoculars, older model from 2010. (Image Thales with permission)

Instead we focused on internal logistics, which we were able to visit after a background check. Like SLB, they are a low-volume, high-mix company. But unlike SLB, they sell the actual products instead of only the services. Like SLB, their logistics is on a path of improvement, and they managed to get their logistics well organized. They had a significant (-70%) reduction in their lead time and their pick rates (-60%), improved the picking quality, reduced the injuries, and drastically improved overall customer satisfaction. They also established a kanban-based pull system for most consumables, with more kanban loops to be implemented soon. They also established tracking for nearly all parcels, which they also called kanban, although it is not quite a pull-kanban like for their consumables.

What was a mindset change for their thirty logistic people was the use of a takt time. For the different stages in their inbound and outbound logistics like inspection, scanning, packing, shipping preparation, quality check etc., they determined the takt time and also communicated this to their people. Knowing that they need to pack a parcel in average every 16 minutes helped with the **mindset change** toward a better performance.

We dug a little bit deeper on how they prepare their shipments, and especially how they merge different products for the same shipment. This is shown below (partially blurred for confidentiality). Each of these stands represent one shipment, and the paper indicates what products go into these shipments, which ones are already there, and which ones are still to come. For a low-volume shipment area it looks very organized.

Figure 398: Thales setting up shipments in Outbound Logistics, details blurred for security reasons. (Image Cecile Roche with permission)

Figure 399: Thales logistics office andon (Image Cecile Roche with permission)

Another nice feature was their andon board. While this is common in automotive, it was the first time I have seen such an andon board in a logistics office. Each clerk has a button, and pressing the button updates the andon board to yellow, which requires the team leader support. Besides the andon board, there is also an SMS to the team leader and sound signal. If the problem is not resolved in time, the andon board switches to red, and a wider group including the manager is alerted by SMS. They get around two to three alerts per day.

Figure 400: Another Thales Andon (Image Thales with permission)

Through this and other measures like strict focus on FIFO (First In, First Out), work standards, and improvement of the layout, they were able to drastically reduce the lead time for their shipments. What I really liked was that they also not only looked at the average, but also at the fluctuations. Fluctuations (mura) are one of the major but usually overlooked sources of problems on the shop floor and in logistics, and Thales did a good job analyzing AND improving these fluctuations. Upping the frequency of the internal milk run from four per day to ten per day also helped both the lead time and the fluctuations. They also experimented with a leveling box, but this turned out to be difficult for customer shipments.

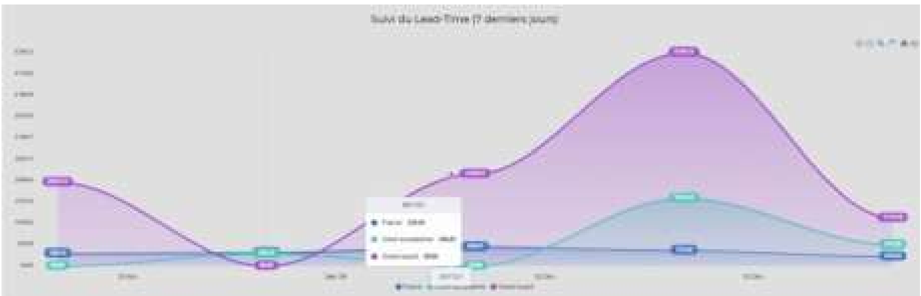

Figure 401: Thales tracking lead time (Image Thales with permission)

Granted, not everything works perfectly yet, but in which company does it? It was overall very interesting to see these two companies SLB and Thales making quite different but low-quantity, high-mix products, and to have a look at their solutions for their logistic systems. Now, **go out, get your logistics under control, and organize your industry!**

52 The Van of Nerds in France—Trains and Cars

Christoph Roser, December 27, 2022 Original at https://www.allaboutlean.com/van-of-nerds-france-5/

Figure 402: SNCF Nerd Group Photo (Image Roser)

In this post I would like to talk about two other plants that we visited as part of the Van of Nerds in France. One is a railway repair and maintenance plant by SNCF, and the other is a body shop and final assembly by the well-known French car maker Renault. Both offered interesting insights. I am personally quite familiar with automotive assembly. The railroad repair facility, however, was something quite new to me. Let me show you.

52.1 SNCF Warehouse Repair in Saint Dizier

Figure 403: SNCF Repair Workshop (Image Roser)

SNCF stands for *Société nationale des chemins de fer français* and is the *National Society of French Railroads*. This state-owned railroad company was founded in 1938. The company transports both passengers and freight, and includes the iconic TGV high-speed service. It has around 275 000 employees.

Figure 404: Electric switch ca. 1960 (Image Roser)

We visited the lean pilot area of their maintenance and repair facilities in Saint Dizier, where they service and maintain all kinds of railroad-related equipment, from switches and signals to locks and keys.

SNCR is a state-owned monopoly, although due to EU regulations this will end in December 2023. Usually, competition helps a lot with kaizen simply because they force you to improve or else they will take over your business. A monopoly often has less urge to improve. However, we were pleasantly surprised by the improvement activities at their lean pilot area in Saint Dizier. There were lots of creative improvements and good work standards.

Figure 405: SNCF Railroad locks in service (Image Roser)

Railroad technology is made to last, and some of the products that are being serviced are older than the employees, with sixty-year-old or older technology still being used. Some tools used in the repair shop match the technology. For example, we have not seen the use of gauges in regular manufacturing for a long time. The workshop builds and repairs keys and locks for railroad equipment using gauges extensively.

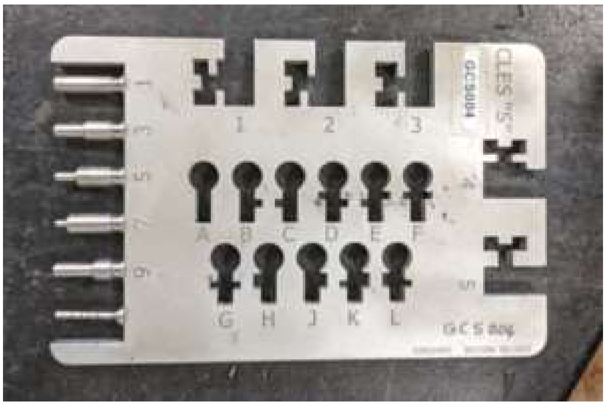

Figure 406: Go & No-Go gauge for railroad keys (Image Roser)

This is all done by hand using a file. The accuracy of about twenty dimensions are checked using go and no-go gauges for both for the upper and the lower tolerance limit. This feels more artisanal than manufacturing, and I was wondering if a milling machine and modern measurement equipment could be more efficient. However, I don't know the quantity of keys produced or serviced, so I can't say anything on the financial feasibility.


Figure 407: Jigs for assembling switch boxes (Image Roser)

However, a lot of other lean implementations were done nicely. Most of the material flow was organized by kanban and supermarkets. Floor markings were not only frequently applied but also followed consistently. A milk run was providing material. Plenty of team boards hung throughout the workshop. One of the nicest examples was their use of setups to make electric switch boxes. The employees themselves developed and set up different tools and jigs to make the assembly of such housings much easier.

Overall, they see five areas for improvement: 1) the use of andons; 2) the use of near field communication (NFC), where every part gets a small chip to identify it later if needed; 3) Gemba walks, 4) 5S; and 5) standards. Overall, the people seem to be motivated and the workshop is actively improving. Granted, as a (soon former) monopoly, they still have a long way to go, but at least in the lean pilot area, the process has started.

52.2 Renault in Douai

Figure 408: Renault Nerds Group Photo (Image Roser)

Renault, also known as the Renault Group, is a French car maker. Established in 1899, it is as of 2021 the ninth-largest car maker worldwide. Their plant in Douai was founded in 1970, and they have produced 10.6 million cars since then. Currently they produce the all electric Renault Megane E Tech as well as the Espace 5, with a body shop, a paint shop, and a final assembly line. The plant itself is running below capacity. At their peak in 2008, the plant had 7000 people, but currently has 2300 employees, at least partially due to the drop in demand caused by COVID. Most material transport in the entire plant is by AGV.

Figure 409: The Renault Megane E Tech (Image Alexander Migl under the CC-BY-SA 4.0 license)

The automated body shop had 200 robots and 300 workers, and was for me the highlight of the plant. Due to the automation, the size of the workforce has been reduced over the years. On two floors they produce the body (lower floor) and the doors, hoods, and fittings (upper floor). This line produces the Megane. The takt time is 30 bodies per hour, although with a possible ramp-up to 60 cars per hour. This ramp-up will be implemented if there is increasing demand. Some equipment exists already at double capacity, and other equipment at current capacity but with the space to put another machine/robot in there to increase capacity again. The line is flexible to produce up to eight models in up to four platforms. Similar standardized lines can be found in many Renault and Nissan plants.

They assemble these metal parts with a precision of+/- 1 millimeter, which is verified by a 100% 3D measuring robot at the end. A monitor showed the timeline of the precision, making it easier to see if there was a drift. The data is also stored for traceability.

Figure 410: The body line andon looked somewhat like this. (Image Roser)

The robots had a nice andon showing the status of all robots at all stations. Each station had one column, and the number of fields represents the number of welding robots. If the pressure needed to weld was increasing, the field turned orange. This indicated that the contacts needed to be replaced soon. If the pressure was too high, the field turned red. This and many more data were also available in a large war room near the shop floor.

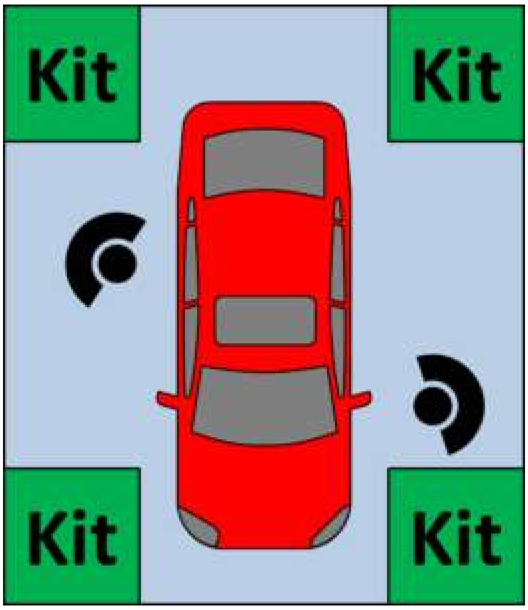

Figure 411: Renault Kits on Assembly line (Image Roser)

The final assembly was also interesting, as I find automotive assemblies always interesting. Compared to Toyota, there was more material on the shop floor, with quite a bit of AGV and forklift traffic going on. They said that they had more than one thousand AGVs in the plant. If they plan to double the capacity, the material and traffic may increase. Since all cars are different, they rely quite a bit on kitting, with four carts with the kits in each corner of the moving assembly line platform.

Overall, some quite interesting locations. Thanks to both SNCF and Renault for showing us their shop floor! Now, **go out, keep on reading, and organize your industry!**

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Figure 412: 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 and his second book “All About Pull Production” on implementing pull production as well as this series of collected blog posts. This book was awarded the **Shingo Publication Award** in 2022.